DOE/OR/22343--1-Vol. 1

Reuse of Concrete from Contaminated Structures

Prepared for:

The Office of Science and Technology (EM-50)
Department of Energy

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Under:

Grant Number DE-FG05-94OR22343

January 29, 1999

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EXECUTIVE SUMMARY

The end of the Cold War has drastically changed one of the missions of the Department of Energy (DOE). Instead of focusing on the production of weapons grade material, DOE is now maintaining the allowable nuclear stockpile and downsizing and remediating environmental contamination at facilities no longer needed. This has resulted in a number of DOE facilities being scheduled for decommissioning. These facilities consist of a large number of contaminated and non-contaminated production, storage, and office buildings which have concrete foundations, floors, and in some instances, walls. Additionally, there are concrete pads, basins and channels that must be addressed. Table EE-1 lists the major DOE facilities and their estimated volumes of concrete.

Table EE-1. DOE Complex Area and Volume Estimates (Cubic Feet)

Facility	Contaminated Volume	Clean Volume	Total Volume
ANLE	5,000	430,000	440,000
ANLW	35,000	2,800,000	2,800,000
BNL	2,000	130,000	130,000
ETEC	36,000	2,800,000	2,900,000
HANFORD	1,400,000	108,000,000	110,000,000
INEL	1,100,000	83,000,000	84,000,000
LANL	61,000	4,800,000	4,900,000
LBL	18,000	1,400,000	1,500,000
LLNL	25,000	2,000,000	2,000,000
METC	1,000	48,000	49,000
NTS	110,000	8,500,000	8,600,000
ORR	110,000	8,300,000	8,410,000
PP	47,000	3,700,000	3,700,000
RFP	66,000	5,200,000	5,300,000
RESL	19,000	1,500,000	1,500,000
SNL	760,000	60,000,000	61,000,000
SRS	700,000	55,000,000	55,000,000
K-25	140,000	11,000,000	11,000,000
PADUCAH	80,000	6,300,000	6,400,000
PORTSMOUTH	100,000	8,100,000	8,200,000
TOTAL	4,800,000	375,000,000	380,000,000

* List of abbreviations given on page 14

One of the primary challenges facing DOE's decontamination and decommissioning (D&D) program is to find an ecologically and economically sound method to deal with the large volume of concrete (380,000,000 cubic feet) that will be generated. The decommissioning and environmental restoration process for concrete structures include: characterization and treatment of the contamination, and either dismantlement and disposition of the structure or reuse of the facility. The current baseline technology is expensive and would result in the need to bury, at great cost, very large quantities of low level, slightly, or not contaminated waste.

One possible alternative is to characterize the structure, decontaminate the concrete when possible, separate the concrete and rebar, recycle the rebar, crush, screen, and recycle the "clean" concrete as aggregate. Several options exist for recycling the contaminated concrete within the DOE complex. Uncontaminated and decontaminated concrete can be crushed and used as aggregate in new concrete; used as base and sub-base material for roads and foundations; used as fill material; and, used as riprap to stabilize slopes and stream channels.

There are various options for decommissioning of the DOE facilities. Based on the decision tree used to depict potential concrete processing paths for DOE D&D activities, six distinct scenarios were developed. The scenarios are:

- **Scenario 1** – Decontaminate by Surface Removal, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate
- **Scenario 2** – Decontaminate by Surface Treatment, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate
- **Scenario 3** -Decontaminate, Dispose of all LLW, Demolish the Structure In-Place (Rubblize), and Cap the Site
- **Scenario 4** - Demolish the Structure In-Place (Rubblize) and Cap the Site
- **Scenario 5** – Demolish the Structure, Crush the Concrete Rubble, Dispose of all LLW in an On-Site LLW Facility
- **Scenario 6** – Decontaminate the Structure, Dispose of all LLW, Demolish the Structure, and Dispose of Clean Rubble as Construction Debris (Baseline Case)

Decontamination technologies can be divided into two broad classes: surface removal and surface treatment, although the distinction between the two is not always sharp. Surface removal technologies, such as spalling, milling, and grinding, are those that remove the initial two to five centimeter surface layer of the concrete matrix (and contaminants). Surface treatment technologies are those that extract the contamination from the matrix, that is, decontamination achieved without the actual removal of concrete. Tables EE-2 and EE-3 summarize the decontamination technologies examined during this study.

A probabilistic spreadsheet model was developed to estimate the risk for each recycle/disposal scenario. Based on the surface area of concrete to be recycled or disposed, the model calculates the man-hours required to perform site preparation, decontamination, demolition, crushing, material separation, disposal, site clean-up, and demobilization as appropriate for each scenario. Risk coefficients are applied to the man-hour estimates to determine the non-radiation, non-transportation risks. Radiation exposures for decontamination, demolition, and disposal operations are estimated using the RESRAD and RESRAD-Build codes. Transportation risks are estimated for both radiation and non-radiation exposures.

Table EE-2. Surface Removal Technologies and Process Rates

Surface Removal Technology	Process Rate (ft^2/hr)	Technology Costs ($/ft^2)
Abrasive Jetting with Ice	100	1
Abrasive Jetting with Plastic Pellets	140	2.15
Abrasive Jetting with Sand	47	10
Abrasive Jetting with Soft Media	80	12
Carbon Dioxide Compressed Air	60	2
Carbon Dioxide Nitrogen Blasting	50	2
Centrifugal CO_2	60	2.50
Drill and Spall	6	3
Electro-hydraulic Scabbling	30	2
Explosive	100	5
High Pressure Water	40	2
Ultra-High Pressure Water	60	2
Laser Heating	150	1
Grinding	100	2
Microwave Scabbling	40	2
Milling	25	0.75
Mechanical Scabbling	30	10
Shot Blasting	150	5
Soda Blasting	180	7
Strippable Coating	100	1.40

Table EE-3. Surface Treatment Technologies and Process Rates

Surface Treatment Technologies	Process Rate (ft^2/hr)	Single Application Efficiency (%)	Adjusted Process Rate (ft^2/hr)	Technology Cost ($/$ft^2$)
Chelation	100	90	50	2
Chemical Extraction	100	90	50	2
Chemical Foam	100	82.5	33	3
Chemical Gel	100	82.5	33	3
Electrokinetic	100	77.5	33	1.30
Flashlamp Cleaning	120	90	60	2.50
Laser Ablation	85	90	48	2
Sponge Blasting	85	90	48	2

A second probabilistic spreadsheet model was developed to estimate the costs for each of the recycle/disposal scenarios. The model utilized unit costs developed for each unit operation. These unit operation estimates were combined to develop estimates for each scenario. Unit costs for treatment and removal technologies were extracted from DOE, IAEA, Means and vendor data. The Remedial Action Cost Engineering and Requirements System model v3.2 (RACER 1996), developed by the US Air Force, was used as the basis for developing the non-technology unit costs. Costs for the technologies and RACER costs were supplemented with other cost data from Dickerson (1995), the DOE (1994), and Means (1992) to fully develop the unit costs.

The calculated fatalities, lost workdays, and costs were determined for each scenario. Tables EE-4, EE-5, EE-6, EE-7, EE-8, and EE-9 summarize the results of the model runs for the three facility size categories: < 10^6 ft^2 of floor area; 10^6 to 10^7 ft^2 of floor area; and, >10^7 ft^2 of floor area. The average floor areas were 197,000 ft^2 for small facilities; 4,300,000 ft^2 for intermediate facilities; and 64,500,000 ft^2 for large facilities. As the Tables show, the recycling scenarios are lower in risk and cost than any of the other options analyzed, including the current baseline case (Scenario 6 – Decon and C&D Disposal).

Table EE-4. Risks for Average Small Facilities

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.050	0.021	0.12	0.095	0.11	0.12
	56%	51%	74%	90%	86%	76%
Construction	0.015	0.008	0.018	0.010	0.017	0.014
	17%	20%	12%	10%	13%	9%
Delayed	0.024	0.012	0.024	0.00044	0.00056	0.023
	26%	29%	15%	0%	0%	15%
Total	0.089	0.042	0.16	0.11	0.13	0.15
Lost Workdays						
Transportation	3	3	15	16	19	15
	5%	8%	17%	27%	20%	20%
Construction	63	36	73	44	74	59
	95%	92%	83%	73%	80%	80%
Total	66	39	88	61	93	74

Table EE-5. Risks for Average Intermediate Facilities

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.070	0.038	0.20	0.17	0.20	0.20
	49%	50%	71%	90%	86%	72%
Construction	0.028	0.016	0.035	0.019	0.031	0.030
	20%	21%	13%	10%	13%	11%
Delayed	0.044	0.022	0.045	0.00082	0.0010	0.047
	31%	28%	16%	0%	0%	17%
Total	0.14	0.08	0.28	0.19	0.24	0.27
Lost Workdays						
Transportation	6	6	28	29	35	28
	8%	14%	26%	49%	36%	30%
Construction	118	69	148	81	137	126
	95%	92%	84%	73%	80%	82%
Total	124	76	177	111	172	154

Table EE-6. Risks for Average Large Facilities

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.97	0.56	2.85	2.40	2.85	2.82
	43%	47%	68%	90%	86%	69%
Construction	0.43	0.23	0.53	0.26	0.45	0.43
	19%	20%	13%	10%	13%	10%
Delayed	0.85	0.40	0.84	0.013	0.016	0.86
	38%	34%	20%	0%	0%	21%
Total	2.24	1.20	4.22	2.67	3.31	4.11
Lost Workdays						
Transportation	90	90	410	410	490	410
	5%	8%	15%	27%	20%	18%
Construction	1800	1020	2250	1130	1970	1820
	95%	92%	85%	73%	80%	82%
Total	1890	1110	2660	1540	2460	2230

Table EE-7. Costs for Average Small Facilities

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	1.29	1.14	2.24	1.68	1.77	1.43
Project Management @ 10%	0.13	0.11	0.22	0.17	0.18	0.14
Contingencies @10%	0.13	0.11	0.22	0.17	0.18	0.14
Engineering @6%	0.08	0.07	0.13	0.10	0.11	0.09
Overhead And Profit @14%	0.23	0.20	0.39	0.30	0.31	0.25
Credit for Recycling	-0.30	-0.30	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	1.55	1.33	3.21	2.42	2.54	2.06
Cost /Square ft.	8.45	8.14	19.83	16.56	17.12	11.63

Table EE-8. Costs for Average Intermediate Facilities

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	19.7	17.0	31.7	20.2	21.6	22.2
Project Management @ 10%	2.0	1.7	3.2	2.0	2.2	2.2
Contingencies @10%	2.0	1.7	3.2	2.0	2.2	2.2
Engineering @6%	1.2	1.0	1.9	1.2	1.3	1.3
Overhead And Profit @14%	2.8	2.4	4.4	2.8	3.0	3.1
Credit for Recycling	-5.6	-5.6	0.0	0.0	0.0	0.0
TOTAL PROJECT COST	22.0	18.2	44.4	28.3	30.3	31.1
Cost /Square ft.	5.12	4.24	10.33	6.59	7.04	7.23

Table EE-9. Costs for Average Large Facilities

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	198	171	320	201	215	223
Project Management @ 10%	20	17	32	20	22	22
Contingencies @10%	20	17	32	20	22	22
Engineering @6%	12	10	19	12	13	13
Overhead And Profit @14%	35	30	56	35	38	39
Credit for Recycling	-57	-57	0	0	0	0
TOTAL PROJECT COST	227	189	459	289	309	321
Cost /Square ft.	5.37	4.91	11.92	7.50	8.03	8.31

Legal impediments and existing case law relative to recycling were also investigated. The review found no major legal or regulatory restrictions for recycling concrete from the DOE complex.

The social and political concerns with recycling were explored through a survey of selected stakeholders familiar with the DOE complex. The results of the survey indicated that stakeholder wanted to be involved with the decision process at its earliest stages and that their major concern was that no concrete should leave the DOE complex without meeting free release standards.

Based on the analyses performed, two goals for DOE D&D concrete recycling were recommended. The goals, based on the rubbles ultimate end use are:

1. general fill material: recycle at least 70% of the concrete rubble;
2. aggregate in roadway and other new construction: recycle at least 55% of the concrete rubble.

Using the total volume of concrete available for recycling throughout the DOE complex (380,000,000 ft^3) and the scenario costs developed by the economic model, potential complex-wide scenario costs were developed. The costs for large facilities were used to compute the complex-wide costs since they represent the estimated costs for approximately 85% of the complex.

Table EE-10. Complex – Wide Costs

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Cost ($ /ft^2)	5.37	4.91	11.92	7.50	8.03	8.31
Complex-Wide Cost ($)	2.04E+09	1.87E+09	4.53E+09	2.85E+09	3.05E+09	3.16E+09

The baseline case, Scenario 6 – Decon & C&D Disposal is estimated to cost $3.16 billion dollars complex-wide. Scenario 1 – Remove & Recycle is estimated to cost $2.04 billion offering potential savings of $1.1 billion over the baseline case. Scenario 2 – Treat & Recycle is estimated to cost $1.87 billion offering potential. savings of nearly $1.3 billion over the baseline case, complex-wide. Scenarios 4 – Rubblize & Cap and 5 – Crush & On-Site Disposal offer savings of $310 million and $110 million, respectively, over the baseline case. Scenario 3 – Decon, Rubblize, and Cap at $4.53 billion is more expensive than the baseline case.

CHAPTER 1 – INTRODUCTION

The end of the Cold War has drastically changed one of the missions of the Department of Energy (DOE). Instead of focusing on the production of weapons grade material, DOE is now maintaining the allowable nuclear stockpile and downsizing and remediating environmental contamination at facilities no longer needed. This has resulted in a number of DOE facilities being scheduled for decommissioning. These facilities consist of a large number of contaminated and non-contaminated production, storage, and office buildings which have concrete foundations, floors and, in some instances, walls. Additionally, there are concrete pads, basins and channels that must be addressed. Figure 1-1 depicts the major locations and their relative volumes of concrete within the DOE complex.

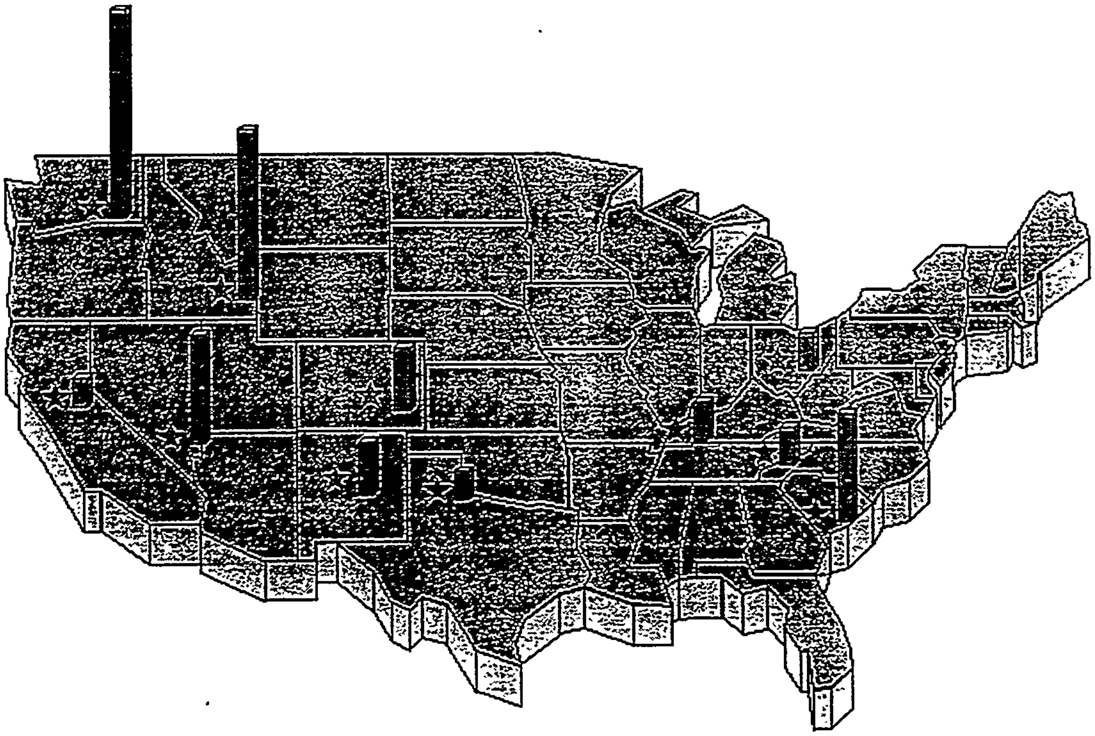

Figure 1-1. Locations of Major DOE Facilities and Relative Volumes of Concrete

One of the primary challenges facing DOE's decontamination and decommissioning (D&D) program is to find an ecologically and economically sound method to deal with the large volume of concrete that will be generated. The decommissioning and environmental restoration process for concrete structures includes: characterization, treatment, and disposal of any contamination; and either dismantlement or reuse of the structure. The current baseline approach (remove contaminated concrete and send to low level waste (LLW) facility and send remainder to construction and demolition (C&D) landfill) is expensive and will result in the need to bury, at great cost, very large quantities of low level, slightly, or not contaminated waste. One possible alternative is to characterize the structure, decontaminate the concrete when possible, separate the concrete and rebar, recycle the rebar, crush and screen the "clean" concrete, and recycle the "clean" concrete as aggregate.

Section 2 Recycling Options explores the potential uses of recycled concrete. **Section 3 – Aggregates** examines the costs and availability of natural aggregate material. **Section 4 – Concrete Volumes and Levels of Contamination** develops an estimate of the volumes of both contaminated and non-contaminated concrete within the DOE complex. Various decontamination/disposal/ recycle scenarios that may be employed are developed in **Section 5 – Scenarios**. The technologies available for decontaminating concrete are illustrated in **Section 6 – Concrete Decontamination Technologies**. The risks associated with recycling contaminated concrete are modeled in **Section 7 – Risk Model**. **Section 8 – Cost Model** develops a model to estimate the costs of the various scenarios. The results of the risk and cost model runs are presented in **Section 9 – Risk Results** and **Section 10 – Estimated Costs**, respectfully. **Section 11 - Regulatory Overview** briefly examines the laws and regulations applicable to recycling decontaminated concrete. Social Considerations are addressed in **Section 12 – Social Considerations.** **Section 13 – Recycling Goals** proposes concrete recycling goals for DOE. **Section 14 – Conclusions** summarizes the findings of this study. Finally, **Section 15 – Recommendations for Further Study** presents areas for future study.

CHAPTER 2 - RECYCLING OPTIONS

Background

Current DOE practice is to dispose of concrete rubble either at a construction and demolition (C&D) debris landfill, or, if contaminated, in low-level radioactive waste landfills. Landfilling of concrete rubble has become increasingly expensive and has motivated the examination of recycling and reuse alternatives. Concrete rubble was first successfully recycled during the reconstruction of Europe following the end of World War II. However, once the rebuilding was completed, the recycling ended. Recycling of broken concrete pavements as base material and concrete and asphalt binder courses appeared in the US during the early 1970s. The initial success of recycling concrete rubble led to the use of crushed concrete as aggregate in new concrete and to the recycling of airport runways (Collins, 1994).

These positive concrete recycling experiences prompted research into the use of crushed concrete as aggregate in new concrete mixes. Some of the results of this research were:

- Coarse aggregate from particles produced from crushed concrete has good particle shape, high absorption, and lower specific gravity compared to conventional mineral aggregates.
- Changes in gradation due to shearing of crushed concrete are not significant.
- Use of crushed-concrete as coarse aggregate had no significant effect on the mix proportions or workability of the mixtures.
- Use of crushed-concrete as fine aggregate resulted in less workable mixtures, requiring more cement.
- The high absorption of recycled aggregate may require more water in the mix.
- Use of recycled concrete aggregate did not have any significant effect on the volume response of specimens to temperature and moisture.
- Concrete made from recycled aggregates has increased freeze-thaw resistance.
- Aggregate recycled from low strength concrete is not detrimental to the compressive strength of concrete mixtures containing this material.
- Durability of concrete made with aggregate produced from concrete subject to D-cracking can be substantially improved by recycling. (D-cracking is deterioration of poor quality aggregates through freeze-thaw action.)
- Use of admixtures requiring less water content increased the strength of concrete mixtures containing recycled crushed-concrete.
- Recycled concrete makes an excellent base course due to secondary cementation as the material is compacted.
- Fine particles from the screening process contain approximately four- percent calcium hydroxide that improves plasticity and grain size distribution when

used as an additive to clay soils. (Haas, 1985; Yrjanson, 1989; Hansen, 1992; Negussey, 1993; Mack, 1993; Tavakoli, 1996; Zakaria, 1996; Anderson, 1996; Wood, 1997; Ali, 1998)

Uses of Recycled Concrete

Several options exist for recycling the contaminated concrete within the DOE complex. Uncontaminated and decontaminated concrete can be crushed and used as aggregate in new concrete; used as base and sub-base material for roads and foundations; used as fill material; and, left in large pieces and used as riprap to stabilize slopes and stream channels (Yrjanson, 1989; Hendrickson, 1996; Miller, 1976).

Portland cement concrete pavements (PCCP) and asphaltic cement pavements (ACP) containing crushed recycled concrete aggregate have been used and have been found to be of satisfactory quality and economical by the federal and state highway administrations. These agencies have been actively promoting demonstration projects on the recycling of PCCPs since the early 1970's (Collins, 1994). Table 2-1 illustrates the reuse of paving and building debris by various state highway departments.

Table 2-1. Reuse of Paving and Building Debris in Highway Construction

Material ⇒ State⇓	Recycled Asphaltic Pavement (RAP)	Recycled Concrete Pavement (RCP)	Broken Concrete	C&D Debris
Alabama	AGG	AGG		
Alaska	SUB			
Arizona	AGG, ABC	CON, ABC		
Arkansas	AGG			
California	AGG, SB		CON, ABC	
Colorado	AGG		ABC, RR	
Connecticut	AGG	AGG	CON	ABC, CON
Delaware	AGG		EMB	EMB
Florida	AGG	ABC		
Georgia	REC			
Hawaii	AGG			
Idaho				
Illinois	AGG, ABC	CON	EMB	
Indiana	AGG, SHL	ABC, SB		AAG, ABC
Iowa	AGG, CON	AGG, ABC		
Kansas	REC	CON, SB	EMB, RR	
Kentucky	AGG			
Louisiana	AGG, ABC	CON, ABC		
Maine	AGG, ABC			

Material ⇒ State⇓	Recycled Asphaltic Pavement (RAP)	Recycled Concrete Pavement (RCP)	Broken Concrete	C&D Debris
Maryland	AGG	SUB		
Massachusetts	AGG		SUB	
Michigan	REC	REC		
Minnesota	REC	ABC		
Mississippi	AGG			
Missouri	AGG	ABC, RR	RR	EMB
Montana	REC	REC		
Nebraska	AGG, ABC	CS		
Nevada	REC			
New Hampshire	AGG, ABC			
New Jersey	AGG		ABC	
New Mexico	AGG			
New York	REC, SUB	SUB	RR	EMB
North Carolina	REC			
North Dakota	AGG, ABC	AGG, SUB		
Ohio	AGG, SUB			
Oklahoma	AGG			
Oregon	REC, SUB			
Pennsylvania	AGG, REC	CON, SUB		
Rhode Island	AGG, ABC	SUB		
South Carolina	AGG		ABC	
South Dakota	ABC, REC	REC	EMB	
Tennessee	AGG			
Texas	AGG, ABC		ABC	
Utah	REC, SUB			
Vermont	SB, SHL			
Virginia	AGG, ABC			
Washington	AGG			
West Virginia	AGG			
Wisconsin	ABC			
Wyoming	AGG	CON		

Legend:
ABC - Aggregate base course
CON - Concrete aggregate
RR - Riprap
SHL- Shoulder aggregate
AGG - Asphalt aggregate
EMB - Embankment barrow
SB - Stabilized base
CS- Chip seal
CEM - Cement replacement
REC - Recycled pavement
SUB - Subbase
C&D - Construction and Demolition

The information described above indicates that there are a number of possible uses for concrete rubble generated during D&D activities. It also indicates that a potential market exists for recycled concrete aggregate provided the costs and risks associated with recycling concrete rubble are within acceptable ranges.

Problems with Recycled Concrete

While the recycling of concrete has many advantages, there are a few problems. The first and potentially the most damaging is the problem of alkali-silica reactivity (ASR). ASR is the swelling and/or dissolution of soluble silica and the formation of alkali silicate gels by their reactions with calcium ions from the cement hydration reactions (Helmuth, 1993). Abnormal expansion and cracking of concrete structures due to ASR has been observed across the US. Figure 2-1 depicts the occurrence of ASR across the US in 1988 as reported by Stark (1993).

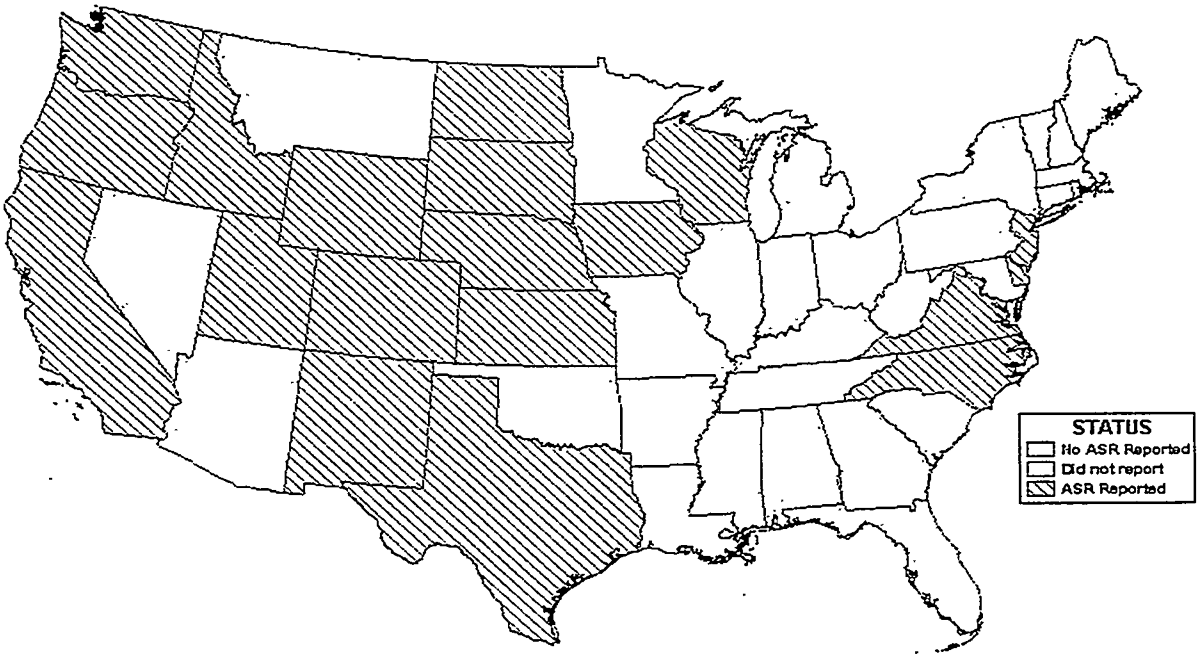

Figure 2-1. Occurrence of Alkali-silica Reactivity (ASR) in the US

Stark (1993) identified three basic requirements that are necessary for ASR to occur:

1. Reactive silica or siliceous components in the aggregate,
2. Sufficiently high hydroxyl ion concentration in the pore solution, and
3. Sufficient moisture available in the concrete.

Although deleterious rock exists in all parts of the US, ASR manifestations do not appear in all states. This is due to the use of cements with low alkalinity and the use of pozzolans that suppress ASR. If concrete that exhibits ASR is recycled to produce aggregate, new concrete made with that aggregate may manifest ASR dependent on the amount of ASR material in the recycled aggregate.

A second problem encountered when recycling concrete is the production of tufta. Tufta is the porous calcium carbonate precipitant that forms as water percolates through aggregate containing free lime. This problem has appeared when crushed-concrete has been used as base material. The calcium carbonate precipitant has clogged underdrain systems (Hurd, 1996).

The final problem encountered is the use of crushed-concrete as fine aggregate. This has resulted in less workable mixtures that required additional cement due to the increased water demand. Most states do not allow the use of crushed-concrete as fine aggregate in the production of new concrete. Those that do, limit the portion of crushed-concrete fines to less than 30 percent of the fine aggregate (Yrjanson, 1989; Collins, 1994).

CHAPTER 3 – AGGREGATES

Of the various uses for concrete rubble, replacement of virgin aggregate is the most common. Nearly twenty-five years ago (1974), the National Stone Association recognized the need for long-range resource planning and the need to conserve accessible aggregate reserves to maintain a viable infrastructure base in the US. Unfortunately, little has been done to address this problem. Continued growth in many urban areas has depleted aggregate resources or rendered existing supplies inaccessible. This phenomenon – known as "aggregate sterilization" – has been identified in Anne Arundel County, MD, Chicago, Connecticut, Denver, Los Angeles, and New York City. This has resulted in the importation of aggregates from outside the US (predominately Canada and Mexico) (Hayden, 1997). Figure 3-1 shows the quantities of aggregate imported into the US.

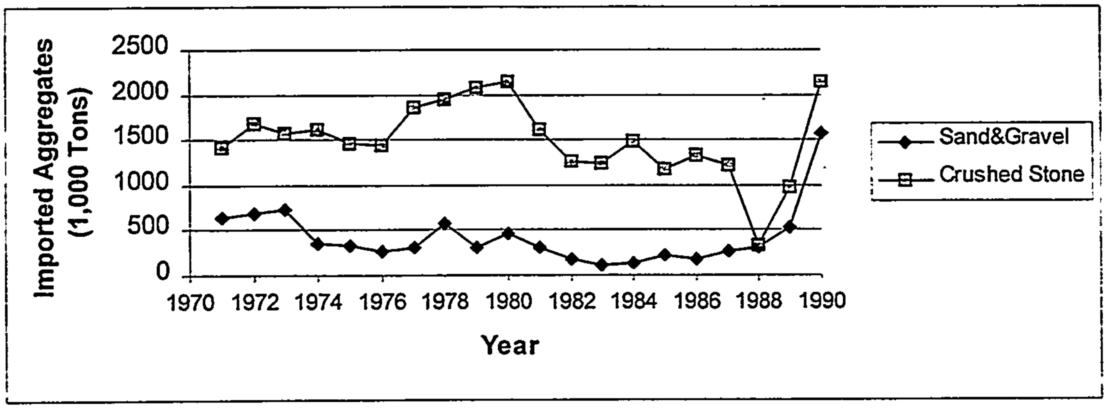

Figure 3-1. Aggregates Imported into the US.

Mineral Industry Surveys indicate that in 1996 1.3 billion tons of crushed stone were produced by 3,700 quarries operating within the US. An additional 970 million tons of sand and gravel were produced by over 6,000 operations. Of the over 1.3 billion tons of aggregate produced approximately 40 percent of the total production was used to produce Portland cement concrete, asphaltic concrete, and base and sub-base material (USGS, 1997). Figure 3-2 illustrates the quantities of aggregate produced in the US since 1960.

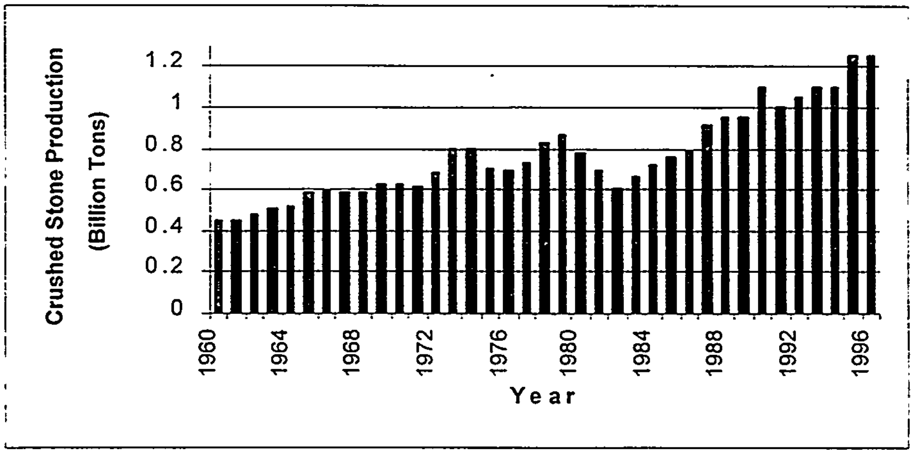

Figure 3-2. Aggregate Production in the US

The US Geologic Survey (USGS) also tracks the prices of mineral commodities in the US, based on use. In 1994, the average price per ton of crushed stone in the US was $5.39. This ranged from a high of $11.47 per ton for roofing granules to a low of $4.41 per ton for road base material. Sand and gravel averaged $4.19 per ton in 1994. The most expensive use was again roofing granules at $8.02 per ton and the least expensive use was road stabilization at $3.49 per ton.

Demand and price are the key components of the aggregate usage equation. These are driven by the availability of quality aggregates. As part of their study on recycling concrete in highway construction, the Highway Research Board conducted a nation-wide survey (excluding Alaska and Hawaii) to determine if shortages of acceptable aggregate existed within any state. A shortage was defined as an inadequate supply of high quality material within a 50 mile haul radius (Witczak, 1971). The results of this survey are shown in Figure 3-2. Figure 3-3 indicates a shortage within a given state, that shortage may be isolated and may not apply to the entire state. This study indicates that a potential market exists for recycled concrete aggregate provided the costs associated with recycling concrete are within acceptable ranges.

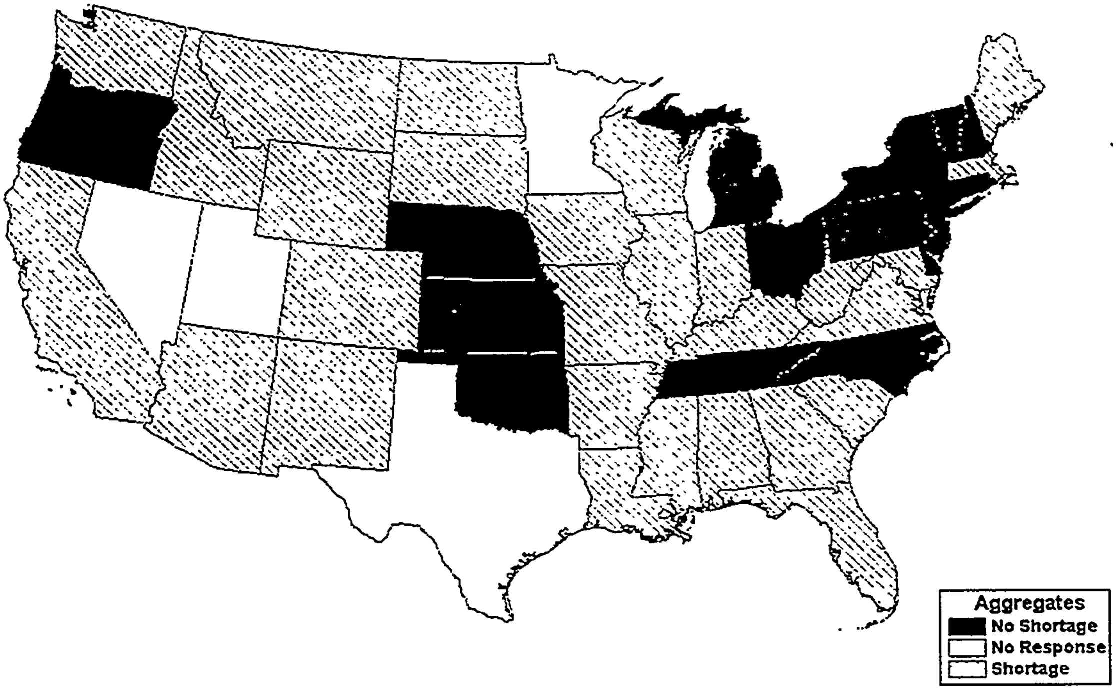

Figure 3-3. Shortage of Aggregates

CHAPTER 4 – CONCRETE VOLUMES AND LEVELS OF CONTAMINATION

Volume of Concrete

To estimate the costs and risks associated with recycling radioactively contaminated concrete, both the quantity of concrete involved and its level of the contamination are needed. Since data on the actual volume of concrete at each facility was not available, floor area data was used as a proxy to estimate the total volume of concrete potentially available for recycling.

The first step was to develop an inventory of existing structures. The basis of this inventory was the listing of DOE "surplus facilities" in the Surplus Facilities Inventory and Assessment (SFIA) database (DOE, 1994a), which includes facilities that:

1. Have been officially designated as "surplus" by the cognizant Secretarial Officer,
2. Have no mission projected beyond FY 98,
3. Have a budget reduction greater than 50% over a 5-year period,
4. Are orphaned, have not been formally accepted by the site landlord,
5. Are abandoned, i.e. have an owner but are left unattended with essentially no surveillance and maintenance activities,
6. Currently have funding solely dedicated to surveillance and maintenance activities, and
7. Are on a "watch list" of contaminated facilities that have the potential to be designated surplus (Dickerson, 1995).

To estimate the volume of contaminated and uncontaminated concrete from the SFIA floor area (SFIAFA) data, a "scale-up" factor for the SFIA data was developed. The scale-up factor (SUF) – a weighted average multiplier which, when applied to the SFIAFA data, estimates the total volume of concrete at each facility – was determined to be 10.11. The SUF was determined by computing the ratio of verified floor areas (VFA) to SFIAFA for four facilities (ORNL, RFP, SRS, and LLNL). The four ratios were weighted, based on reporting facility size, and averaged. The SUF was determined as follows:

$$\mathrm{SUF} = \sum w_i \frac{\mathrm{VFA}\ \left(\mathrm{ft}^2\right)}{\mathrm{SFIA}_i \left(\mathrm{ft}^2\right)}$$

Facility floor areas were determined as follows:

$$FFA\left(ft^{2}\right)=\left(SUF_{i}\right)\left(SFIAFA_{i}\left(ft^{2}\right)\right)$$

In addition to the scale-up factor, several other values are necessary to estimate the volume of concrete. The thickness of foundations and floors may vary widely from building to building and facility to facility. Based upon review of several specification drawings, consultation with a structural concrete expert, and other sources, it was determined that an average concrete thickness of 12-inches should be used. The 12-inch thickness also incorporates any concrete beams and columns associated with the structures.

Final concrete volumes were then computed as follows:

$$FCV_{i}\left(ft^{3}\right)=\frac{FFA_{i}}{12(in)\Big/12\left(\frac{in}{ft}\right)}$$

Percentage of Contaminated Concrete

Once an estimate of the total floor area for a facility was developed, the portion of the area expected to be contaminated was estimated. Current literature on characterization of contamination of nuclear facilities indicates that the percentage of floor area contaminated may range from 100% in decontamination buildings and areas where there have been major spills to almost zero in some office buildings. The US Nuclear Regulatory Commission (USNRC) (1994) estimated that 10% of R&D facility floor areas are contaminated to some degree. The National Research Council (1996) estimated that 15% of the floor area in process support buildings for DOE's gaseous diffusion plants is contaminated. Based on the available data, a lognormal distribution was used to represent the percent of contaminated floor area (log mean (λ) = 15, log standard deviation (ζ) = 5).

Contamination of concrete usually results from spills, contaminated dust, or other surficial deposition. In some instances, the contaminants may migrate into the concrete matrix, particularly over time and under environmental stresses. Cracks and crevices may also provide routes for contaminants to spread deeper into the concrete matrix. A one-inch depth of contamination – based on an agreement between the Fernald Environmental Management Project (FEMP) and the Ohio Environmental Protection Agency (Longenbach, 1996) – and current literature (Bechtel, 1994; Dickerson, 1995; USNRC, 1994) was used throughout the study. The volume estimates for the major DOE facilities are presented in Table 4-1.

Level of Contamination

The most common radioactive contaminants found at DOE facilities, excluding gaseous diffusion plants (GDP), are ^{137}Cs, ^{238}U, ^{60}Co, ^{90}Sr, and tritium, in order of frequency (Dickerson, 1995). A typical R&D facility might have activities of approximately 100,000 dpm/100 cm^2 of ^{60}Co and approximately 34,000 dpm/100 cm^2 of ^{137}Cs (USNRC, 1994). The most common contaminant at a GDP is ^{238}U. The isotopes ^{235}U, ^{234}U, and ^{99}Tc are also present, but in smaller concentrations. Surface contamination in the GDPs range from 5,000 dpm/100 cm^2 to greater than 1,000,000 dpm/100 cm^2 (NRC, 1996).

For the purposes of this risk analysis, it was assumed that ^{60}CO, ^{137}Cs, and ^{238}U provided a good representation of the radionuclides of concern at DOE facilities. These were used as surrogates for all other β-γ and α emitters throughout the analysis. The following lognormal distributions[1] were used for each contaminant (USNRC, 1994):

- ^{60}Co λ = 100,000 dpm/100 cm^2, ζ = 59,700 dpm/100 cm^2
- ^{137}Cs λ = 34,000 dpm/100 cm^2, ζ = 19,500 dpm/100 cm^2
- ^{238}U λ = 19,000 dpm/100 cm^2, ζ = 11,400 dpm/100 cm^2

Table 4-1. DOE Volume Estimates (Cubic Feet)*

Facility	Contaminated Volume	Clean Volume	Total Volume
ANLE	5,000	430,000	440,000
ANLW	35,000	2,800,000	2,800,000
BNL	2,000	130,000	130,000
ETEC	36,000	2,800,000	2,900,000
HANFORD	1,400,000	108,000,000	110,000,000
INEEL	1,100,000	83,000,000	84,000,000
LANL	61,000	4,800,000	4,900,000
LBL	18,000	1,400,000	1,500,000
LLNL	25,000	2,000,000	2,000,000
METC	1,000	48,000	49,000
NTS	110,000	8,500,000	8,600,000
ORR	120,000	9,900,000	10,000,000
PP	47,000	3,700,000	3,700,000
RFP	66,000	5,200,000	5,300,000
RESL	19,000	1,500,000	1,500,000
SNL	760,000	60,000,000	61,000,000
SRS	700,000	55,000,000	55,000,000
K-25	140,000	11,000,000	11,000,000
PADUCAH	80,000	6,300,000	6,400,000
PORTSMOUTH	100,000	8,100,000	8,200,000
TOTAL	4,800,000	375,000,000	380,000,000

*Totals may not add due to rounding

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[1] Distributions were determined by evaluating contamination level data with the BESTFIT Program from Palisade Corporation, Newfield, NY.

Table 4-2. Site Abbreviations Used in Report

ANLE	Argonne National Laboratory – East
ANLW	Argonne National Laboratory – West
BNL	Brookhaven National Laboratory
ETEC	Energy Technology Engineering Center
FETC	Federal Energy Technology Center
Hanford	Hanford Site
INEEL	Idaho National Engineering and Environmental Laboratory
K-25	K-25 Gaseous Diffusion Plant
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
METC	Morgantown Energy Technology Center
NTS	Nevada Test Site
ORR	Oak Ridge Reservation (Except K-25 Site)
Paducah	Paducah Gaseous Diffusion Plant
PP	Pantex Plant
Portsmouth	Portsmouth Gaseous Diffusion Plant
RESL	Radiological and Environment Sciences Laboratory
RFS	Rocky Flats Site
SNL	Sandia National Laboratories
SRS	Savannah River Site

Facility Size Assignments

Due to the large number of facilities and model outputs, the facilities were grouped into bins of similar size, which represent smaller, intermediate, and larger facilities, to facilitate data presentation. Three bins were used: $< 10^6$ ft^2 of floor area; 10^6 to 10^7 ft^2 of floor area; and, $>10^7$ ft^2 of floor area. Table 4-3 depicts the facilities and the assigned bins. The average floor areas were 197,000 ft^2 for small facilities; 4,300,000 ft^2 for intermediate facilities; and 64,500,000 ft^2 for large facilities.

Table 4-3. Bin Assignments

Bin 1 - Small Facilities (less than 10^6 sq. ft)	
Facility	**Area**
ANLE	440,000
BNL	130,000
METC	49,000
Average	***197,000***
Bin 2 - Intermediate Facilities (10^6 sq. ft. to 10^7 sq. ft.)	
ANLW	2,800,000
ETEC	2,900,000
K25	11,000,000
LANL	4,900,000
LBL	1,500,000
LLNL	2,000,000
NTS	8,600,000
ORR	10,000,000
PADUCAH	6,400,000
PP	3,700,000
PORTSMOUTH	8,200,000
RFP	5,300,000
RESL	1,500,000
Average	***4,300,000***
Bin 3 – Large Facilities (greater than 10^7 sq. ft.)	
HANFORD	110,000,000
INEL	84,000,000
SNL	61,000,000
SRS	55,000,000
Average	***64,500,000***

CHAPTER 5 – SCENARIOS

Decision Tree Analysis

There are various options that can be exercised in dealing with the decommissioning of the DOE facilities. Figure 5-1 depicts the decision tree used to determine the various options available. D&D at all facilities begins with characterization. The information gathered during characterization is necessary to determine whether or not the level of contamination is below free release limits. If it is below the limits, then the facility can be retained or it can be demolished. There are two options for facilities that are demolished. The first is rubblizing in-place that requires the site to be capped and monitored after demolition. Transporting the concrete rubble off-site is the second option. In this case, the rebar is removed from the concrete after demolition. The rebar is either shipped to a scrap dealer for recycle or it is shipped to a C&D landfill for disposal. The concrete that remains is crushed and either shipped to a C&D landfill for disposal or recycled. Before the concrete can be recycled, it must again be tested to ensure that it is below free release levels. Concrete that is above free release levels is transported to a low-level radiological waste disposal site. All material that is below free release levels can be recycled. The two recycling options use the concrete rubble for on-site work or sell it on the open market.

When initial characterization reveals contamination above free release levels, a decision must be made to decontaminate the concrete or not. If the decision is to leave the concrete untreated, the structure may be demolished and the rubble transported to a LLW disposal site, it may be rubblized in-place and capped, or the concrete rubble may be crushed, the contaminated portion removed and disposed either on-site or off-site, and the clean material recycled.

There are two principal methods of decontaminating contaminated concrete surfaces: surface removal and surface treatment. Surface removal is simply the mechanical removal of the top one-half to one-inch layer of the concrete that contains the contamination. The alternative to surface removal is surface treatment, applying a technology that removes the contaminants from the concrete with minimal concrete removal. Once the surface has been decontaminated, the resulting wastes are collected, and transported to a LLW disposal site. The remaining facility is then treated as if it is below free release levels.

Scenarios

Overview

Based on the decision tree, six (6) distinct scenarios were developed. The scenarios, shown in Figures 5-2 through 5-8, are:

- **Scenario 1** – Decontaminate by Surface Removal, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate
- **Scenario 2** – Decontaminate by Surface Treatment, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate
- **Scenario 3** -Decontaminate, Dispose of all LLW, Demolish the Structure In-Place (Rubblize), and Cap the Site
- **Scenario 4** - Demolish the Structure In-Place (Rubblize) and Cap the Site
- **Scenario 5** – Demolish the Structure, Crush the Concrete Rubble, Dispose of all LLW in an On-Site LLW Facility
- **Scenario 6** – Decontaminate the Structure, Dispose of all LLW, Demolish the Structure, and Dispose of Clean Rubble as Construction Debris (Baseline Case)

These scenarios represent possible paths through the decision tree. Because there are several different types of facilities (buildings, pits, channels, pads, etc) that will be decommissioned, scenarios were developed that will apply to the entire range of decommissioning activities. Concrete contamination generally does not penetrate far below the surface (<1 inch), even in areas of high contamination (USNRC 1994). There are, however, areas — cracked or porous, unsealed concrete — where contamination may penetrate deeper than the one-inch assumed for this study, but these areas are, in most cases, few in number and are assumed to be negligible for this generic estimate.

Scenarios 1 and 2 are identical except for the decontamination technology employed. The distinction was drawn between removal and treatment technologies for two reasons. First, removal technologies completely separate the first one-inch layer of concrete from the remaining mass thereby generating a greater volume of LLW for disposal. Second, removal technologies have been proven in the field and their costs and effectiveness are well characterized. Many treatment technologies, while promising, have only been tested at the bench or pilot scale level and are lacking full scale cost data. The two are treated as separate scenarios to remove any bias resulting from untested technologies, yet provide data on possible savings from the application of not fully tested decontamination methods.

The current practice or base case, drawn from DOE's Formerly Utilized

Sites Remedial Action Program (FUSRAP) experience, is presented in Scenario 5-6 Decontaminate the Structure, Dispose of All LLW, Demolish the Structure, and Dispose of Clean Rubble as Construction Debris (Baseline Case).

Description of Scenarios

Scenario 1 - Decontaminate by Surface Removal, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate — In Scenario 1, shown in Figure 5-2, the concrete is characterized and then decontaminated by removal of the concrete's upper (one-inch depth) surface. The contaminated concrete surface layer and any other secondary waste streams resulting from the removal technology are collected and transported to a LLW disposal facility. The structure is then demolished. Concrete from the demolition is crushed, screened, stockpiled, and finally delivered to the job site and the rebar is removed and recycled.

Scenario 2 - Decontaminate by Surface Treatment, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate — Scenario 2, shown in Figure 5-3, is similar to Scenario 1. The only difference is the use of surface treatment technologies rather than surface removal technologies to decontaminate the concrete.

Scenario 3 - Decontaminate, Dispose of all LLW, Demolish the Structure In-Place (Rubblize), and Cap the Site — The initial steps in Scenario 3, shown in Figure 5-4, also include characterization and decontamination by either surface removal or treatment. The wastes are disposed in the same manner as in Scenarios 1 and 2. After decontamination, the structure is demolished, rubblized, and capped in-place. The cap is monitored and maintained for a period of 30 years.

Scenario 4 – Demolish the Structure In-Place (Rubblize) and Cap the Site — Scenario 4, shown in Figure 5-5, is similar to Scenario 3 except the facility is not decontaminated prior to demolition. The structure is simply demolished and capped in-place. Since the concrete rubble has not been decontaminated, extensive, long-term (100 years) monitoring of the site is required.

Scenario 5 - Demolish the Structure, Crush the Concrete Rubble, Dispose of all (contaminated and clean) Rubble in an On-site LLW Facility — Scenario 5, shown in Figure 5-6, begins with characterization and demolition of the facility. Following demolition, the concrete rubble and rebar are crushed and disposed in an on-site LLW facility. Since the concrete rubble has not been decontaminated, extensive, long term (100 years) monitoring of the LLW disposal facility is required.

Scenario 6 - Decontaminate the Structure, Dispose of all LLW, Demolish the Structure, and Dispose of Clean Rubble as Construction Debris (Baseline Case) — Scenario 6, shown in Figure 5-7, is the current practice based on DOE's FUSRAP experience. As in the Scenarios 1, 2, and 3, characterization is followed by decontamination of the concrete and disposal of the resulting wastes in a LLW facility. The structure is then demolished. Unlike Scenarios 1, 2, and 3, however, the concrete rubble and rebar are then transported to a C & D landfill for disposal rather than recycling.

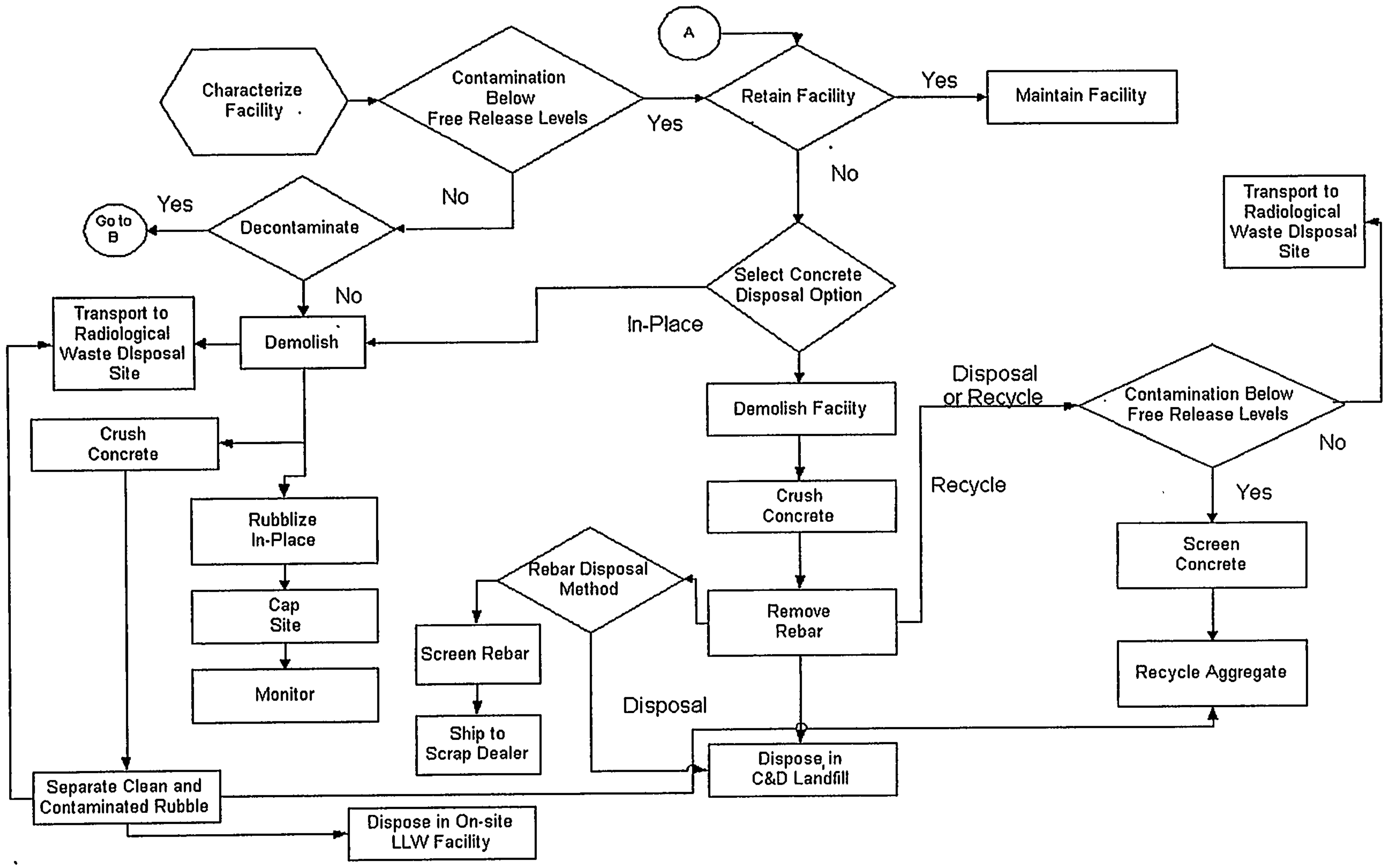

Figure 5-1. Decision Tree (Part A)

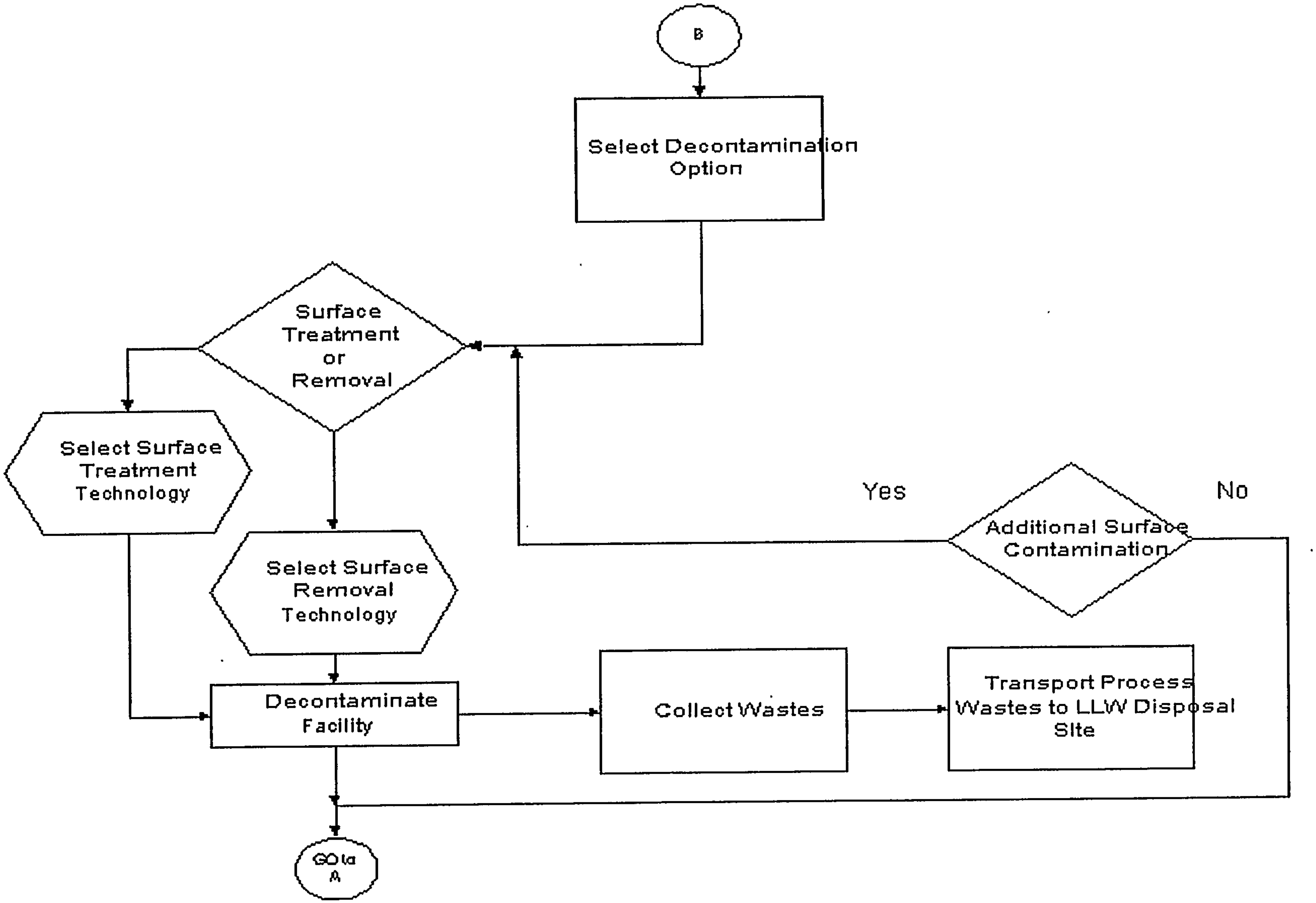

Figure 5-1. Decision Tree (Part B)

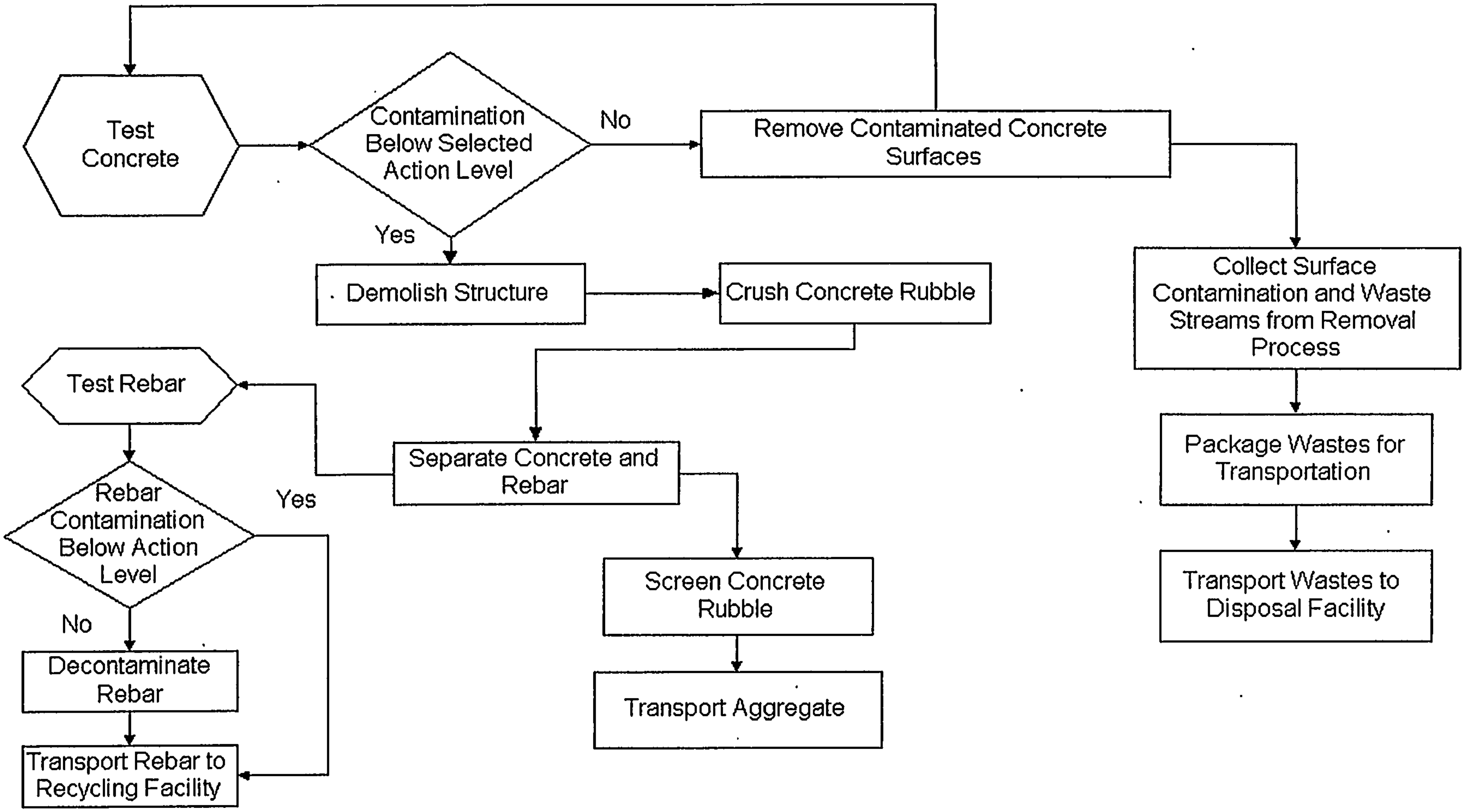

Figure 5-2. Scenario 1 - Decontaminate by Surface Removal, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate

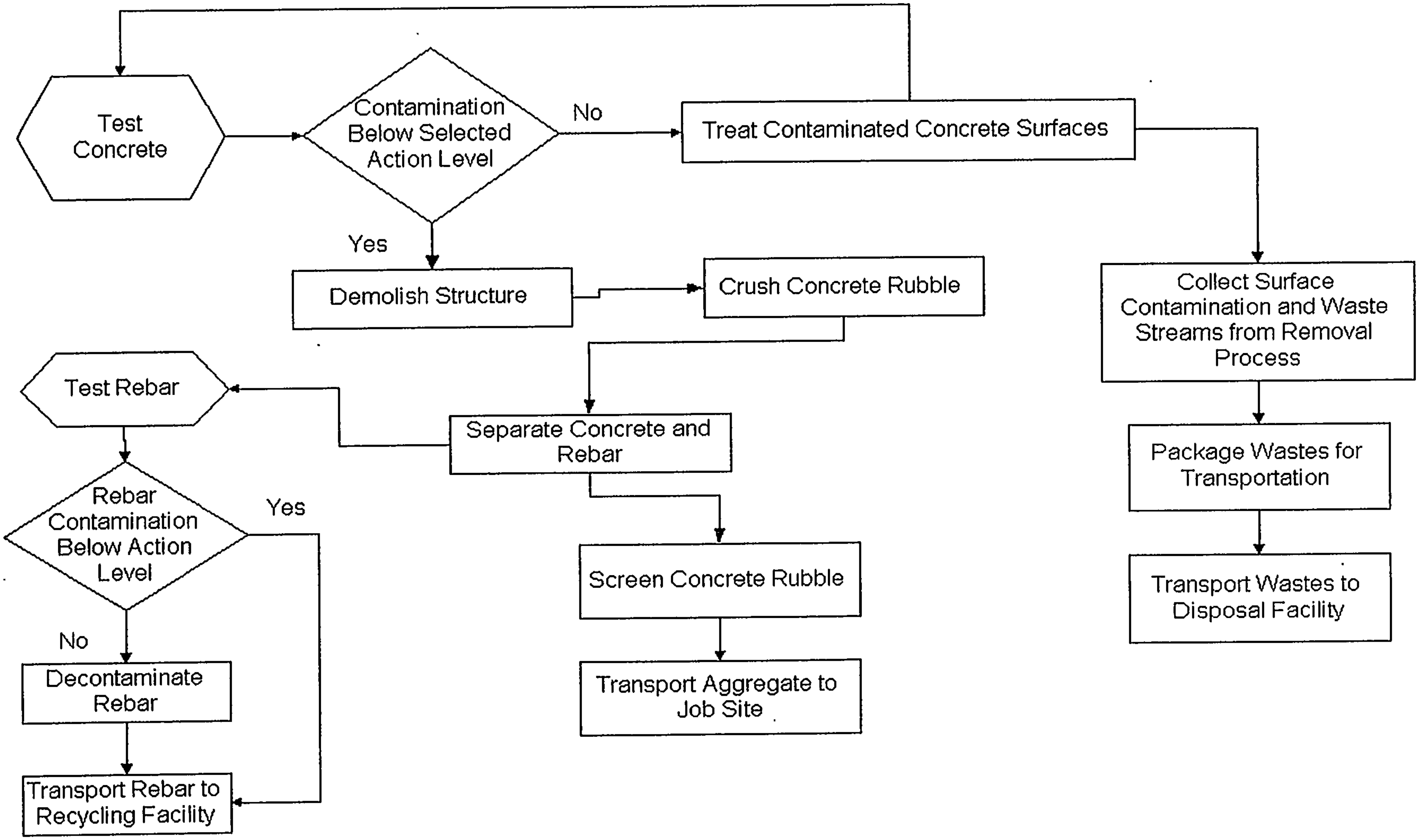

Figure 5-3. Scenario 2 -Decontaminate by Surface Treatment, Dispose of all LLW, Demolish the Structure, and Recycle the Clean Aggregate

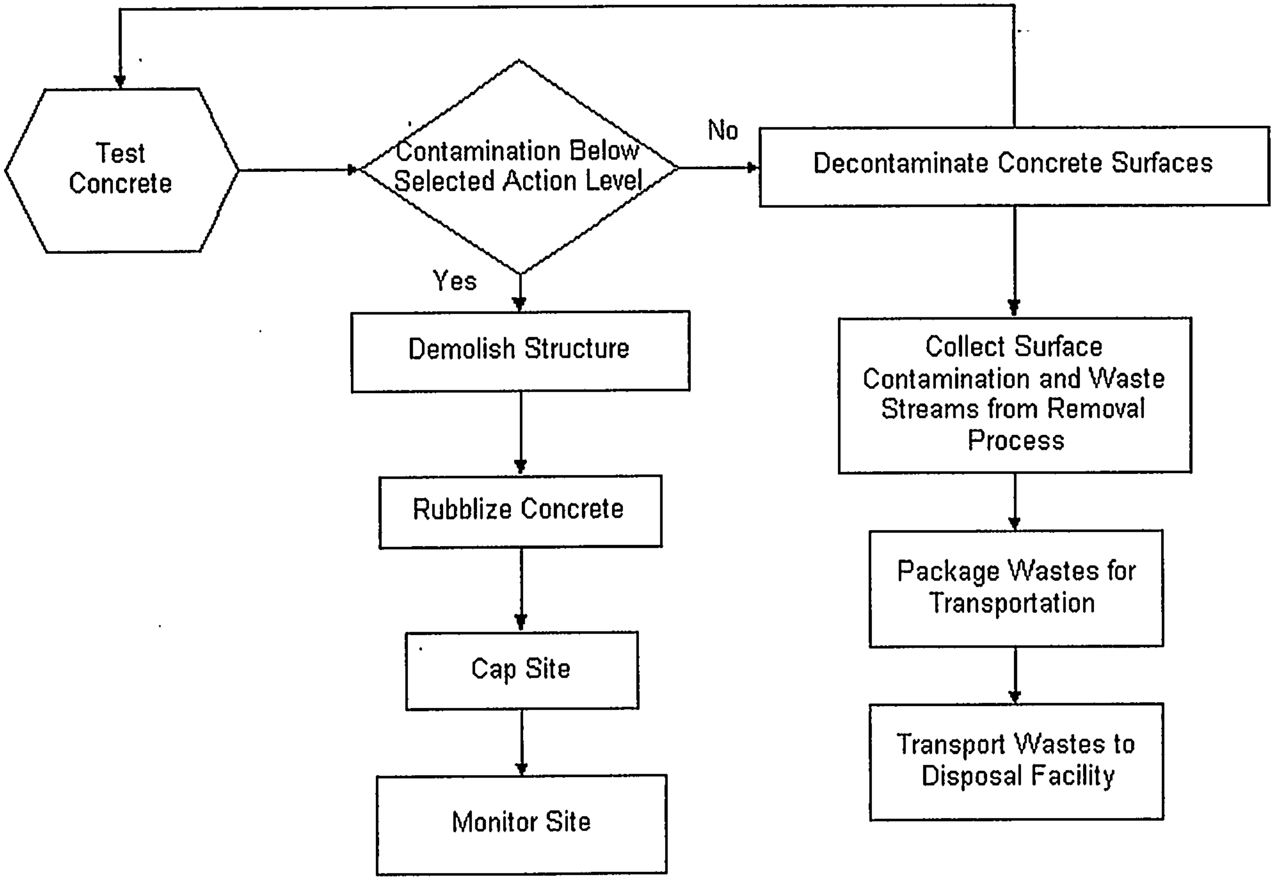

Figure 5-4. Scenario 3 - Decontaminate, Dispose of all LLW, Demolish the Structure In-Place (Rubblize), and Cap the Site

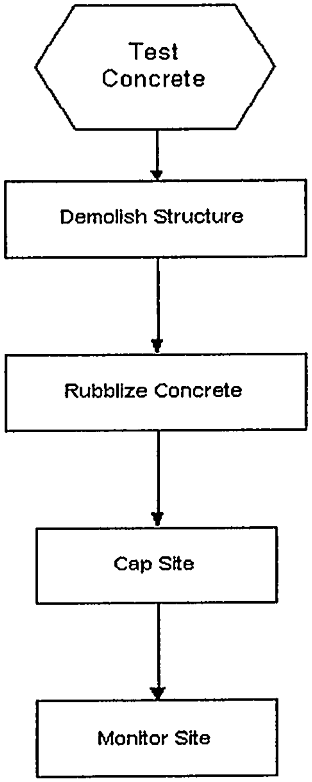

Figure 5-5. Scenario 4 - Demolish the Structure In-Place (Rubblize) and Cap the Site

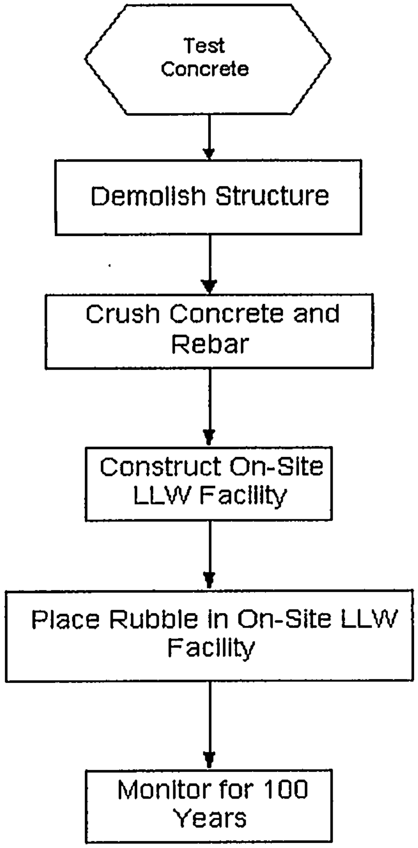

Figure 5-6. Scenario 5 - Demolish the Structure, Crush the Concrete Rubble, Dispose of all LLW in an On-Site LLW Facility

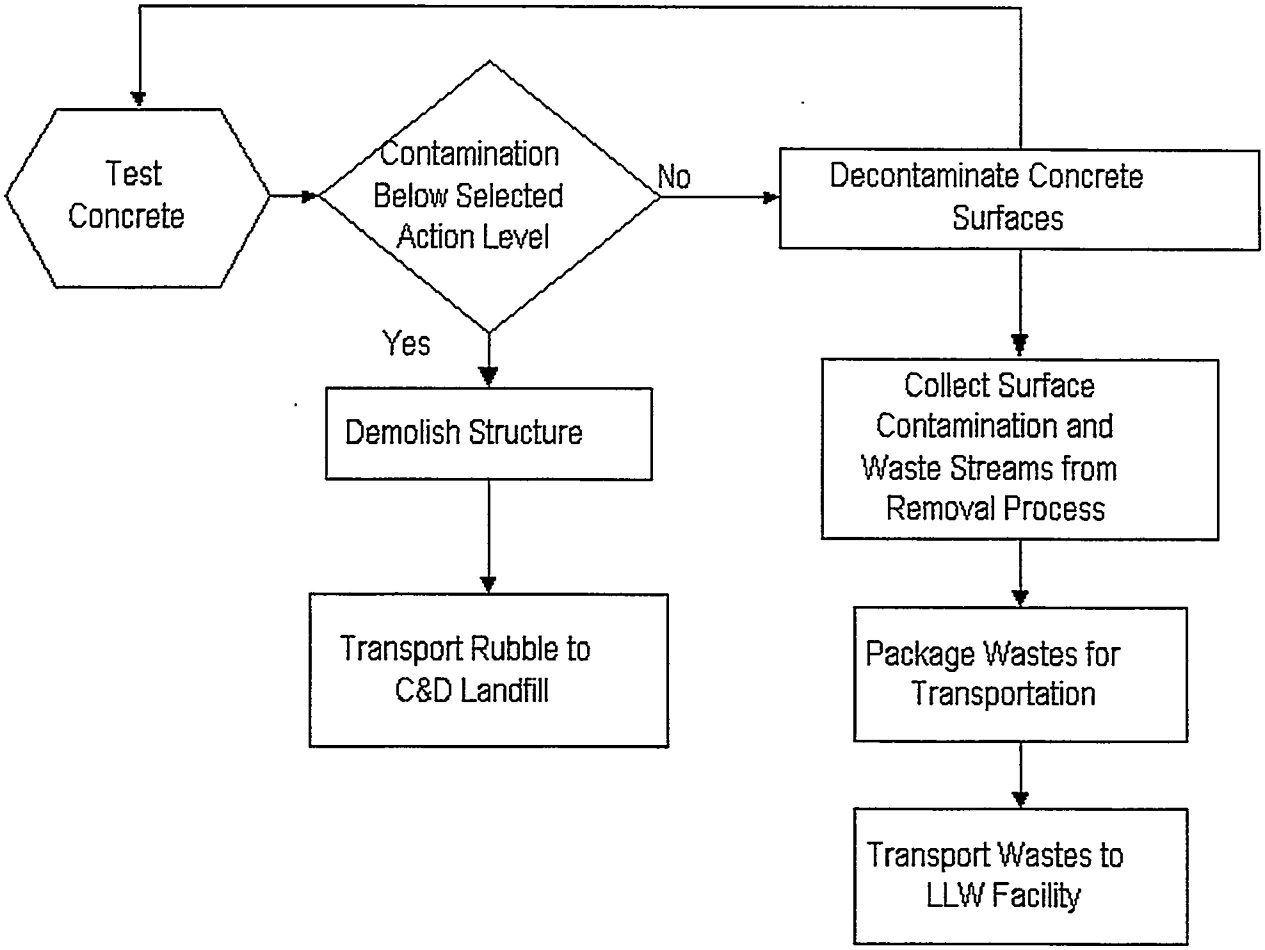

Figure 5-7. Scenario 6 - Decontaminate the Structure, Dispose of all LLW, Demolish the Structure, and Dispose of Clean Rubble as Construction Debris (Baseline Case)

CHAPTER 6 – PROCESS AND TRANSPORTATION RATES AND UNIT COSTS

Process Rates

Key to each scenario was the determination of the process rates for each unit operation. The process rates, excluding those for decontamination addressed in Chapter 8, used in the economic and risk models are summarized in Table 6-1.

These process rates were developed from Means Construction Costs (1992). For example, consolidation of rubble is accomplished by passing a bulldozer over the rubble to achieve compaction. Since only one source of data was available, all process rates were assumed to be deterministic.

Table 6-1. Demolition and Construction Process Rates

Process	Rate	Units
Site Preparation		
Set up of job trailer	23	mh/each
Construct access road	0.067	mh/yd^2
Install chain link fence	0.16	mh/ft
Grading of the site	8	mh/acre
Characterization		
Characterization of the building	0.0022	mh/ft^2
Surface Removal		
Removal technology	Varies	hr/ft^2
Collect waste from technology	0.16	mh/ft^3
Collect & load debris	0.012	mh/yd^3
Surface Treatment		
Treatment technology	Varies	hr/ft^2
Collect waste from technology	0.16	mh/ft^3
Collect & load debris	0.012	mh/yd^3
LLW Disposal		
Unload at Envirocare	2.9	bulk/drum
Demolition		
Demolition of structure	0.035	mh/yd^2
Crush concrete	200	tons/hr
Load rubble	0.012	mh/yd^3
Rebar		
Separate rebar	100	tons/day

Process	Rate	Units
Test rebar	6.86×10^{-6}	mh/lb
Concrete		
Crush and screen concrete	200	tons/hr
Store aggregate	0.01	mh/yd^3
Construct and Operate LLW Disposal Facility		
Liner installation	5000	ft^2/day
Placement of waste and cover material	0.025	mh/yd^3
Capping		
Consolidate rubble	0.0006	mh/yd^3
Phase 1a (First Layer)	260	mh/acre
Phase 1b (Second Layer)	260	mh/acre
Phase 2 (Final Layer)	520	mh/acre
Monitoring		
Install water wells	0.43	mh/ft
Operation of monitoring equipment	0.5	md/well
Cap Maintenance		
Annual mowing	5	acre/day
Fertilization/reseeding	5	acre/day
Clean-up		
Site cleanup	0.008	mh/yd^2
Remove job trailer & fence	23	mh/each
Fines Handling		
Loading	0.012	mh/yd^3

mh = man-hours
md = man-days

Transportation Rates

Two modes of transportation were incorporated into the models: truck and rail. Truck transportation was used to estimate costs and risks for mobilization/demobilization, hauling liner and cap material, transporting samples, hauling rebar, hauling waste to C&D landfills, sampling monitoring wells, and performing O&M activities. All low-level radioactive waste not disposed on-site was assumed to be transported by rail to Envirocare's LLW Disposal facility in

Clive, Utah for final disposal. Sufficient data on transportation distances were available to allow the distributions shown in Table 6-2 to be developed.

Table 6-2. Transportation Distances

Transportation Activity	Mode	Distance (Miles or Distribution)
Mobilization/Demobilization	truck	Triangular (25,50,100), Most Likely 50 miles
Transport samples	truck	Triangular (25,50,100), Most Likely 50 miles
Transport rebar	truck	Triangular (5,25,125), Most Likely 25 miles
Haul aggregate	truck	Triangular (5,25,75), Most Likely 25 miles
Transport to C&D facility	truck	Triangular (5,25,75), Most Likely 25 miles
Transport to railhead	truck	Triangular (0.1, 0.5, 5) Most likely 0.5 miles
Transport LLW to Envirocare	rail	Site Specific
Haul liner material	truck	Triangular (25,50,75), Most Likely 25 miles
Haul lift material	truck	Triangular (5,25,75), Most Likely 25 miles
Haul cap material	truck	Triangular (5,25,75), Most Likely 25 miles
Monitoring activities	truck	Triangular (25,50,100), Most Likely 50 miles
Operation & Maintenance Activities	truck	Triangular (25,50,100), Most Likely 50 miles

Non-Technology Process Unit Costs

In addition to determining the process rates for each unit operation, the estimated cost for each unit operation was determined. The estimated unit costs, excluding those for decontamination addressed in Chapter 8, used in the economic model are summarized in Table 6-3.

The process unit costs were developed from Means Construction Costs (1992) and the RACER[2] Cost Estimating Model. Table 6-3 has some values listed as distributions and some values as determinants. Where sufficient data was available to determine a cost distribution, that distribution is given. In the cases where costs were taken from a cost book or developed by the RACER model, a deterministic (single point) cost is shown.

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[2] Remedial Action Cost Engineering and Requirements System (RACER) Model v3.2 was developed by the US Air Force in conjunction with the US EPA to assist in developing cost estimates for environmental restoration projects.

Table 6-3. Demolition and Construction Process Costs

Process	Cost
Site Preparation	
Mobilize job trailer	\$2,000/trailer
Construct access road	\$4.04/ft^2
Install site fence	\$2.75/ft
Site grading	\$1.13/yd^2
Construct decontamination pad	\$13,000/pad
Utilities	
Construct water service	\$6.00/ft
Construct electrical service	\$10.00/ft
Provide water service	\$300/month
Provide electrical service	\$200/month
Provide telephone service	\$225/month
Provide sanitation service	\$80/month/toilet
Characterization	
Initial characterization	\$370/sample
Specific sampling	\$250/sample
Aggregate and rebar screening	\$25/load
Decontamination	
Technology application	Varies
Load wastes	\$1.39/yd^3
Demolition	
Demolish structure	\$1/ft^2
Crush and screen rubble	Lognormal (λ=3.12,ζ=1.06) \$/ton
Crush concrete rubble	Lognormal (λ=2.10,ζ=1.00) \$/ton
Haul Material	
Waste to railhead	\$0.15/ton/mile
Waste to LLW disposal site	\$0.04/ton/mile
Rebar to recycler	\$0.078/ton/mile
Aggregate to recycling site	\$0.15/ton/mile
Cap and liner material	\$0.15/ton/mile
Disposal Fees	
LLW disposal fee	\$60/ft^3
C&D waste disposal fee	Normal (x = 25,σ=17) \$/yd^3
Construct and Operate LLW Disposal Facility	
Excavate disposal site	\$0.60/yd^3
Excavate liner, fill, and cap material	\$0.60/yd^3
Place soil liner	\$14.77/yd^3

Process	Cost
Install synthetic liner	\$5/ft^2
Place waste and cover material	\$14.77/yd^3
Capping	
Consolidate rubble	\$1.40/yd^3
Cap	Varies by cap size
Monitoring	
Install water wells	\$10/ft
Monitor Site	Varies by site
Cap Maintenance	
Cap O&M	\$9,400/acre
Clean-up and Decontamination	
Landscape and cleanup	\$871/acre
Decontaminate equipment	\$180/piece

CHAPTER 7 – CONCRETE DECONTAMINATION TECHNOLOGIES INTRODUCTION

This chapter provides a brief summary of various technologies for the decontamination of radioactively contaminated concrete. These technologies vary widely in their effectiveness and processing rates. Since many emerging technologies are still under development or in the early pilot-scale tests, there is a dearth of knowledge about their effectiveness. (Technologies considered to still be in the development stage are noted with *). Much of the data is qualitative and derived from professional judgment and limited experience. Furthermore, it may be reasonably anticipated that commercialization of technologies will result in improved performance for some processes while some may prove to be infeasible.

Decontamination technologies can be divided into two broad classes: surface removal and surface treatment, although the distinction between the two is not always sharp. Surface removal technologies, such as spalling, milling, and grinding, are those that remove the initial one-inch (two to three centimeters) surface layer of the concrete matrix that contains the majority of the contaminants. Surface treatment technologies extract the contamination from the concrete matrix while removing much less of the matrix than surface removal technologies.

As stated in Chapter 1, virtually all of the radioactive contamination is confined to the first one-inch of the concrete matrix. The models described in this study assume that surface removal technologies remove the top one-inch of the concrete matrix and that surface treatment technologies remove the equivalent of the top one-fourth inch of the matrix.

Surface Removal Technologies

Abrasive Jetting

Abrasive jetting involves propelling an insoluble abrasive (sand, alumina, metals, metal oxides, and sawdust) by a jet of air or water to remove a thin layer of the surface (paint, concrete, rust). Depending on the specific configuration used, processing rates vary from 80 to 240 ft^2/hr (Dickerson, 1995).

CO_2 Blasting

Dry ice (CO_2) pellets are propelled by nitrogen gas or compressed air and impinge on a contaminated surface. The pellets shatter upon impact and, in turn, shatter the target material. The CO_2 sublimes immediately and returns to the atmosphere. An advantage of CO_2 blasting is that the cleaning medium (CO_2)

does not become radioactive. The only waste stream is shattered concrete. Processing rates range from 10 to 90 ft²/hr (Dickerson, 1995).

Drilling and Spalling

Holes are drilled to a depth of approximately 2.5 inches in uniform patterns; the spalling tool is inserted and then is expanded. Fugitive dust control is accomplished by filter or water spray. In addition to dust and possibly small amounts of contaminated wastewater, contaminated concrete chips are also generated for collection and treatment. Production rates range from 2 to 10 ft²/hr (DOE, 1994).

*Electro-Hydraulic Scabbling**

The concrete surface is removed (scabbled) by powerful hydraulic shock waves induced by electric discharges between two electrodes. A hydraulic shock wave propagates through the water between the electrical discharge channel and the concrete causing the concrete to crack and peel. The high impulse pressure developed at the liquid-solid interface creates stresses that crack or break the surface layer. Depth of scabbling is controlled by pulse energy, shape, and electrode placement. Processing rates vary between 20 to 40 ft²/hr (Dickerson, 1995).

Grinding

A coarse grained abrasive, such as a diamond grinding wheel or tungsten carbide disc, is rotated in direct contact with the floor to remove a thin layer of the concrete surface or protective coating. Grinding rates average 100 ft²/hr. Although effective for removing thin surface layers (up to one-half inch), grinding is not effective for cracks, crevices, or complex irregular shapes (Davis, 1996).

High-pressure Water/Steam Lance

High-pressure lances employ a water jet with an exit velocity of up to 3,000 ft/sec. Surface contaminants are first eroded and then removed by the water jet. Deeper penetration is possible by adding abrasives. Typical processing rates for high-pressure water range from 370 to 400 ft²/hr (Dickerson, 1995; DOE, 1994).

*Microwave Scabbling**

Microwave energy is used to heat the structural (residual) water in concrete, causing it to turn to steam. The high-pressure steam, along with the thermal stress from the cold concrete, results in the surface layer of concrete breaking into small chips. At a rate of 40 ft²/hr, microwave scabbling has been demonstrated to be quite effective at removing up to 2-inch layers of concrete (Dickerson, 1995).

Milling

Milling is the process of shaving concrete from the floor that is similar to highway asphalt strippers. Milling rates are usually slow, in the range of 25 ft²/hr. Milling is most effective on large, open, horizontal surfaces (floors) (Dickerson, 1995).

Mechanical Scabbling

This technology uses mechanical impact methods to physically remove the contaminated surface. Many commercial units use high-speed, reciprocating, tungsten carbide-tipped pistons to attack the surface. Processing rates range from 20 to 40 ft²/hr (Dickerson, 1995).

Shot Blasting

Shot blasting strips, cleans, and etches the surface simultaneously. Abrasive is fed into the center of a completely enclosed centrifugal blast wheel; as the wheel spins, the abrasives are hurled from the blades, to strike and clean the surface. Commercial units with design rates of 150 ft²/hr are available (Dickerson, 1995).

Soda Blasting

Contaminated surfaces are blasted with sodium bicarbonate grit. Soda blasting process rates approach 200 ft²/hr. Soda blasting has been shown to effectively remove concrete and metal equipment surface contamination (Dickerson, 1995).

Strippable Coatings

A polymer mixture is applied (brush, roller, spray) to a contaminated surface and allowed to react. As the coating reacts, the contaminants are stabilized and become entrained in the polymer. The coating can be pulled off, containerized, and disposed of (or left in place as a protective, fixative coating. Coating and removal rates up to 100 ft²/hr are possible (Dickerson, 1995; DOE, 1994).

Surface Treatment Technologies

Chelation

Chelators can be applied to contaminated surfaces to break the chemical bond between the contaminant and the concrete matrix. By dissolving the bond, the contaminant is mobilized for removal. Processing rates range between 60 and 90 ft²/hr (Means 1994). Chelating technology has been employed at several sites (Dickerson, 1995).

Chemical Decontamination

The main objective of chemical decontamination is to remove the radioactive contaminants by partial or complete dissolution of the concrete layers containing the contaminants. Foam is one example of chemical decontamination. The foam (produced by detergents and wetting agents) acts as a carrier of chemical decontamination agents and is applied by mixing compressed air with the foam/reagent mixture. Removal efficiencies of 75 to 90% are common (Dickerson, 1995).

Gels can also be used to apply chemicals to horizontal or vertical surfaces. The liquid waste volume can be reduced by application of a chemical reagent to dissolve the contaminated layer mixed with a gel. Processing rates are unknown, although several coatings may be required. Gels are well suited for surface contamination, but are not considered effective for crack and crevice contamination (Dickerson, 1995).

*Electrokinetic**

An electric field induces migration of ionic contaminants from the porous concrete to the decontamination unit. All contaminants are captured in the aqueous electrolyte solution and/or in the polymeric matrix. An advanced "gel-cell" is being developed that will permit the process to occur with a carpet-like device that will eliminate any aqueous liquids. Removal efficiencies >90% have been reported. Decontamination rates are estimated to be 100 ft^2/hr (DOE, 1994).

Flashlamp Cleaning

Energy from a high-energy xenon flashlamp is used to rapidly heat the surface of the concrete matrix. The rapid rise in temperature vaporizes or decomposes the material to a particulate residue. Flashlamp cleaning is expected to have processing rates of up to 120 ft^2/hr (Dickerson, 1995).

*Laser Ablation**

Laser ablation utilizes high-power, high repetition-rate lasers for ablation of coatings from metal and concrete surfaces. Laser ablation efficiency is controlled primarily by wavelength, pulse width, energy, power densities on target, pulse repetition rate, scan rate, and light sources (xenon, pinch plasma). Rates of up to 85 ft^2/hr have been demonstrated (Frewald, 1996).

Sponge Blasting

Surfaces are pneumatically blasted (>100 psig) with various grades of foam-cleaning media (i.e., sponges). During contact, sponges contract and expand, creating a scrubbing action. Application and treatment rates average approximately 1 ft^2/min (Dickerson, 1995; DOE, 1994).

TechXtract™[3]

TechXtract™ is a patented chemical technology which, has been successfully demonstrated to be effective for the extraction of radionuclides, heavy metals, PCBs, and hazardous organics from construction materials such as metals and concrete. It uses specifically designed chemical formulas to penetrate below the surface and remove the contaminants. Depending on the type and level of contamination a tailored sequence of different chemicals are applied and extracted to achieve the final level of contamination. Decontamination rates of 90-99% per cycle (depending on the type of surface) have been demonstrated. Field results of TechXtract™ have shown effective removal of contaminants at depths of 1 to 3 inches below the surface (TechXtract, 1998).

Technology Process Rates and Costs

Tables 7-1 and 7-2 summarize the 27 decontamination technologies and their processing rates incorporated into the models. Surface removal technologies shown in Table 7-1 were assumed to remove the required depth of concrete with one pass of the equipment. Surface treatment technologies listed in Table 7-2 have both single application process rates and adjusted process rates that incorporate multiple applications of the technology to meet desired decontamination levels (assumed to be 99% removal). As with actual process rates, surface treatment technology costs presented have been adjusted to reflect the need for multiple applications to meet decontamination requirements.

Table 7-1. Surface Removal Technologies and Process Rates

Surface Removal Technology	Process Rate (ft^2/hr)	Technology Costs ($/$ft^2$)
Abrasive Jetting with Ice	100	1
Abrasive Jetting with Plastic Pellets	140	2.15
Abrasive Jetting with Sand	47	10
Abrasive Jetting with Soft Media	80	12
Carbon Dioxide Compressed Air	60	2
Carbon Dioxide Nitrogen Blasting	50	2
Drill and Spall	6	3
Electro-hydraulic Scabbling	30	2

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[3] This technology is not used in the model, as complete details were not available during the construction of the model. At the time of writing this report, enough details were available to acknowledge its potential use as a treatment technology in decontamination operations.

Surface Removal Technology	Process Rate (ft^2/hr)	Technology Costs ($\$/ft^2$)
Explosive	100	5
High Pressure Water	40	2
Ultra-High Pressure Water	60	2
Laser Heating	150	1
Grinding	100	2
Microwave Scabbling	40	2
Milling	25	0.75
Mechanical Scabbling	30	10
Shot Blasting	150	5
Soda Blasting	180	7
Strippable Coating	100	1.40

Table 7-2. Surface Treatment Technologies and Process Rates

Surface Treatment Technologies	Process Rate (ft^2/hr)	Single Application Efficiency (%)	Adjusted Process Rate (ft^2/hr)	Technology Cost ($\$/ft^2$)
Chelation	100	90	50	2
Chemical Extraction	100	90	50	2
Chemical Foam	100	82.5	33	3
Chemical Gel	100	82.5	33	3
Electrokinetic	100	77.5	33	1.30
Flashlamp Cleaning	120	90	60	2.50
Laser Ablation	85	90	48	2
Sponge Blasting	85	90	48	2

Table 7-3. Probability Distributions

Variable	Cell Reference	Distribution	Source
% Contaminated	Parms, D7	Truncated Lognormal λ=15 ζ = 5 min = 0.1 max = 100	USNRC, 1994 NRC, 1996
Surface Activity of ^{60}Co (dpm/100cm^2)	Parms, I22	Truncated Lognormal λ =105000 ζ = 59700 min = 0 max = 7500000	USNRC, 1994
Surface Activity of ^{137}Cs (dpm/100cm^2)	Parms, J22	Truncated Lognormal m =34300 ζ = 19500 min = 0 max = 2400000	USNRC, 1994
Surface Activity of ^{235}U (dpm/100cm^2)	Parms, K22	Truncated Lognormal λ =19100 ζ = 11400 min = 0 max = 1100000	USNRC, 1994
Wind Speed at 10m (m/s)	Air Dispersion, C2	Truncated Normal x =3.98 s = 1.06 min = 0 max = 10	NOAA, 1997
Emergency Response Time (hr)	Air Dispersion, C5	Triangular Most Likely = 1 min = 0.1 max = 4	HAZTRANS, 1996
Sand Deposition Velocity (m/s)	Air Dispersion, E12	Truncated Normal x =7.65 σ = 3.01 min = 0 max = 15	Ledbetter, 1972
Cement Dust Deposition Velocity (m/s)	Air Dispersion, E13	Truncated Normal x =0.25 σ = 0.1 min = 0 max = 0.5	Ledbetter, 1972
Dust Deposition Velocity (m/s)	Air Dispersion, E14	Truncated Normal x =0.0004 σ = 0.000164 min = 0 max = 0.0008	Ledbetter, 1972

Variable	**Cell Reference**	**Distribution**	**Source**
Plume Stability, wind<2m/s	Air Dispersion, I2	Discrete Unstable = 60% Neutral = 20% Stable = 20%	Turner, 1967
Plume Stability, 2m/s<wind<3m/s	Air Dispersion, I3	Discrete Unstable = 60% Stable = 40%	Turner, 1967
Plume Stability, 3m/s<wind<5m/s	Air Dispersion, I4	Discrete Unstable = 60% Neutral = 20% Stable = 20%	Turner, 1967
Plume Stability, 5m/s<wind<6m/s	Air Dispersion, I5	Discrete Unstable = 30% Neutral = 70%	Turner, 1967
Plume Stability, wind > 6m/s	Air Dispersion, I6	Discrete Unstable = 20% neutral = 80%	Turner, 1967
Fatal Non-rad. Accident Rate (Construction) (fatalities/man-day)	Risk Factors, C39	Truncated Normal x = 0.0000011 σ = 0 min = 0 max = 0.0008	BLS, 1994 BLS, 1996 OSHA, 1990 CDC, 1990
Fatal Mining Accident Rate (fatalities/man-day)	Risk Factors, C41	Uniform min = 0.00000053 max = 0.00000227	MSHA, 1996
Non-fatal, non-rad Accident Rate (Construction) (lost days/man-day)	Risk Factors, C42	Truncated Normal x = 0.00461 σ = 0.00127 min = 0 max = 1	BLS, 1992a BLS, 1992b OSHA, 1993
Non-fatal Truck Accident Rate (lost days/accident)	Risk Factors, C43	Lognormal λ = 25.33 ζ = 5.07	Raj, et al, 1996
Non-fatal Rail Accident Rate (lost days/accident)	Risk Factors, C44	Lognormal λ = 48.53 ζ = 9.71	Raj, et al, 1996

X = mean, σ = standard deviation, λ = Lognormal mean, ζ= lognormal standard deviation

CHAPTER 8 – RISK MODEL

Overview

As stated in earlier discussions, the ultimate decision to recycle will be based on the economic feasibility of the proposal, the risks associated with recycling activities, the ability of the recycling process to meet legal and regulatory requirements, and the social acceptance of the concept. This section details the model used to estimate the risks associated with the six scenarios.

Estimation of Risk

Traditionally, risk is defined as the probability of suffering harm. This is often computed as the product of the probability of an event occurring times the severity of the consequence.

Risk = Probability of the Event x Severity of the Consequence

The National Research Council has further defined risk assessment as "...the characterization of the potential adverse health effects of human exposure to environmental hazards" (NRC, 1983). The total risk from any operation is a combination of the background risk - risk from exposure to hazards in the absence of the specific source being studied- and incremental risk - risk attributable to the specific source being studied (LaGrega, 1994). In the following discussion, all risks are incremental risks.

Our approach to assessing the incremental risks for each of the scenarios was to follow the systematic risk assessment methodology of:

Hazard identification
Exposure assessment
Hazard assessment
Risk characterization

Hazard Identification

Two types of hazards are addressed in this report: (1) injuries and (2) fatalities due to construction, demolition, and, transportation activities, and radiation. Radiation hazards were approximated by varying the levels of ^{60}Co, ^{137}Cs, and ^{238}U, which were used as surrogates for all α and β-γ emitters in the concrete.

Exposure Assessment

Exposures were determined by evaluating the individual operations in the process trains for each scenario. The man-hours required to perform each operation for a given volume of concrete were estimated. The man-hour estimates for construction and demolition activities were taken from Means (1992). Man-hours for decontamination technology application were developed from vendor literature. Transportation exposures were a function of the number of miles driven by truck or traveled by railcar and the levels of contamination. Population data for transportation-related exposures was extracted from US Census data (Census, 1994).

Hazard Assessment

Numerical risk indices for hazards from radiation were based upon the linear non-threshold hypothesis. Construction, demolition, and transportation risk indices were based upon fatalities and lost workdays experience for the occupational codes most similar to D&D activities. Radiation exposures were determined in rems and then converted to fatalities by applying a risk value of 5×10^{-4} calculated deaths per rem (5×10^{-2} deaths per sievert) (NCRP, 1993). Worker fatalities and lost workdays risk values were taken from Bureau of Labor Statistics (BLS) (1992) data for SIC code 179 - Miscellaneous trades which include construction.

Risk Characterization

The magnitudes of the various types of risk examined were estimated by determining the man-hours of exposure for each operation and then applying the appropriate risk indices. Three types of risk were addressed as part of this study: fatalities due to exposure to radiation, fatalities resulting from construction, demolition, and transportation activities; and, injuries and illnesses from non-radiation accidents. It was assumed that radiation levels were below the threshold to cause acute injuries or illnesses; therefore, illnesses or injuries from radiation were not included in the study.

Risk Model Overview

A probabilistic spreadsheet model was developed to estimate the risk for each recycle/disposal scenario. The model incorporates the process train for each scenario, process rates, release rates, exposure pathways, and physical parameters. Based on the surface area of concrete to be recycled or disposed, the model calculates the man-hours required to perform site preparation, decontamination, demolition, crushing, material separation, disposal, site clean-up, and demobilization as appropriate for each scenario. Risk indices are applied to the man-hour estimates to determine the non-radiation, non-transportation risks. Radiation exposures for decontamination, demolition, and disposal operations are estimated using the RESRAD and RESRAD-Build codes

(Yu, et al, 1993; Yu, et al, 1994). Groundwater contamination from D&D activities was deemed too small to be considered.

Transportation risks are estimated for both radiation and non-radiation exposures. For non-radiation risks, the distance in miles to both hazardous and construction and demolition (C&D) disposal facilities, borrow sites for cover material, and the contractor's equipment yard for mobilization/demobilization were estimated.

For transportation risks associated with incident free radiation exposures are estimated for distances to Envirocare using relationships developed by Raj, et al (1996). The risks associated with accidental releases of radionuclides are estimated by assuming the derailment of a railcar and the release of a particulate plume. The particulate plume is modeled as a Gaussian puff. Population densities are taken from US Census Data.

Modeling Approach for Non-Radiation Risks

To estimate the risk for each scenario, relationships were developed for each unit operation. For demolition, construction, and transportation, the risk is a simply the duration of the activity (time or length of haul) multiplied by a risk indices (fatalities/man-hour or fatalities/mile).

The first risk indices to be considered were for construction and demolition. After initially attempting to match individual unit operations with accident rates associated with specific activities defined by the Department of Labor SIC codes, it was decided to use the accident rate for "General Construction" as an adequate measure of accident occurrence. This assumption was necessary due to the number of discrepancies between individual activities and SIC. The mean fatality rate was $1.11\text{x}10^{-6}$ fatalities per man-day for SIC code 179. A mean value of $4.61\text{x}10^{-3}$ lost-days per man-day worked for SIC code 179 was used to represent the non-fatal risk (BLS, 1996; BLS, 1994; BLS, 1992a; BLS, 1992b: CDC, 1990; OSHA, 1993; OSHA, 1990).

For non-radiological transportation risks, fatal accident rates for both rail and truck transport were chosen. A rate of $3.1\text{x}10^{-7}$ fatalities per kilometer for truck transport and a rate of $6.8\text{x}10^{-8}$ fatalities per kilometer for rail transport were used in the model. These values were taken from Raj, et al (1996) and are of the same order of magnitude as those cited in other sources (Saricks and Kvitek, 1994; and Rao, 1992).

A nominal distance was assumed for truck transportation to move the material from the crushing site to the railhead. In recycling scenarios, it was assumed that trucks would be used to haul the clean rebar to scrap yards and decontaminated concrete rubble material to C & D landfills in the baseline case, Scenario 6.

Rail transport was used to transport the low-level waste from the railhead to Envirocare Inc. in Utah. An estimate of the rail haul distance from each DOE facility to Envirocare was calculated using the computer program HazTrans®[4]. HazTrans® was used to calculate the most direct route rail route available and to provide the average population density along the rail corridor.

Modeling Approach for Radiation Risks

Radiological risk is a function of not only the duration of work, but also the source strength, the receptor's relationship to the source, and the pathway of exposure (inhalation, direct radiation, etc.). Due to the complexity of the radiation exposure, several models were used to estimate the risks. Worker exposure during construction, demolition, and placement of wastes in an on-site disposal facility was calculated using the RESRAD and RESRAD-BUILD computer codes (Yu, et al, 1993; Yu, et al, 1994). Non-worker exposure during construction activities was estimated by developing a Gaussian puff model for dust migration off-site. A similar Gaussian puff model was used to estimate public exposure from a transportation accident resulting in the release of contaminated dust. Finally, exposure to the public and the workers incident free transportation of contaminated concrete rubble and wastes was modeled using relationships developed by Raj, et al (1996). The formulas derived by Raj, et al, are for transport of high level waste in casks. Low level concrete rubble in rail cars represents lower source strength and far less radioactive material. Multiple simulations using RESRAD-BUILD confirmed that the exposure varied linearly with the source strength. Therefore, a ratio of the user-specified source strength to the source strength used by Raj, et al, is incorporated into the model developed.

The RESRAD and RESRAD-BUILD codes were used to quantify the exposure to workers during characterization, sampling, decontamination, demolition, and construction activities. Multiple simulations with variable spatial relationships between the receptor (person) and source (contaminated concrete), source strength, and area of contamination were run. In all cases, any protection from shielding and personal protective equipment was discounted. The BestFit[5] computer program was used to fit distributions to the simulation results. Table 8-1 summarizes the relationships between the source and the receptor exposure.

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[4] HAZTRANS is a proprietary code for transportation routing developed by Abkowitz and Associates, Inc. of Nashville, TN.

[5] BestFit Version 1.2 is a proprietary code for fitting data to distribution functions developed by the Palisade Corporation, Newfield, NY.

The risk of cancer deaths was estimated by applying a risk value of 5×10^{-4} calculated deaths per rem (NCRP, 1993).

Table 8-1. Radiation Source and Receptor Relationships

Exposure	**Dose Relationship (in mrem/yr)[1,2] (10^{-2} mSv/yr)**
Rubble consolidation	$Dose = 2.67\,(1-e^{-(0.016*Area)}) + 0.38(1-e^{-(4.2x10\text{-}6*Area)})$
Decon waste collection	$Dose = 11.14(1-e^{-(0.07472*Area)}) + 1.77/(1+e^{(2.22-0.0033*Area)})$
Rubble collection	$Dose = 38.93*Area^{-.15}$
Demolition	$Dose = (4507*Area^{-1.16})Area + 1658*Area^{-0.48}$
Characterization	$Dose = (7139*Area^{-1.001})Area - 180.6 + 15.02*\ln(Area)$
Decontamination	$Dose = -0.12 + 0.20*\ln(Area)$
Capping - Phase 1a (First Layer) (< 5 acres) (> 5 acres)	 $Dose = 11.35 + 0.43*\ln(Area)$ $Dose = 15.43$
Capping - Phase 1b (Second Layer)	$Dose = 2.46$
Capping - Phase 2 (Final Layer)	$Dose = 0.011$
Aggregate Storage	$Dose = 5.07/(1+e^{(0.46 - 0.04*Area)})$

[1] Dose per unit source strength (pCi/g) (3.7×10^{-2} Bq/g)
[2] Area in square meters

Risk Spreadsheet Model

After defining the unit operations, process rates, exposure pathways, accident rates, and the relationship between risk and exposure for each scenario, a probabilistic, spreadsheet model was created. The model was created on an Excel[6] spreadsheet with the @Risk[7] add-on used for Monte Carlo simulations. The model consists of the following six major components:

1. Parameter Input Sheet
2. Scenario Simulation Sheets
3. Risk Factor Sheet
4. Transportation Accident Sheet
5. Off-site Public Exposure Sheet

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[6] Excel is a product of Microsoft Corporation.

[7] @Risk is a spreadsheet add-on risk analysis and simulation tool developed by Palisade Corporation, Newfield, NY.

6. Risk Summary Sheet

The following is a brief overview of the model's major components. A detailed description of the spreadsheet model is in Appendix A.

Parameter Input Sheet - Parms

The Parameter Input Sheet (or Parms) of the model defines the physical quantities and site locations used to model the risks. The sheet allows site specific selection of model parameters and the case specific entry of data. Table 8-2 lists the parameters that can be entered on the Parms sheet.

Various other derived model parameters are computed in other cells on the Parms sheet (and should not be manually entered). Other model worksheets obtain data from the Parms sheet as necessary.

Table 8-2. Spreadsheet Parameters

Parameter	Units	Comment
Total Area	ft^2	Total concrete area being evaluated.
% Contaminated	%	Percent of total area that is contaminated.
Thickness	inches	Thickness of concrete slab.
Depth of Contamination	inches	Maximum depth of contamination.
Density	lbs/ft^3	Density of concrete.
Rubble Expansion Factor	%	Used to compute expanded volume of concrete rubble.
C&D Facility	miles	Distance to C&D landfill.
On-site Facility	miles	Distance to FOB point.
Rebar Scrap Yard	miles	Distance to rebar delivery point.
LLW Disposal Facility	miles	Distance to LLW disposal facility.
Prior to Release	$test/yd^3$	Number of characterization tests to be conducted on recycled aggregate.
Facility	N/A	User marks the facility to be used in the analysis.
Surface Contamination	$dpm/100cm^2$	Surface contamination levels for four different isotopes: ^{60}Co, ^{137}Cs, ^{235}U, ^{238}U

Scenario Simulation Sheets

The Scenario simulation sheets are all very similar in structure. Each contains a separate row for each activity in the process train. Within each row, the duration of each activity is calculated and risks associated with the activity are either calculated or imported from other sheets. For example, non-radiological risks for construction activities are calculated based solely on a duration and accident rate. This calculation takes place directly in the simulation sheet. However, the radiological risk for the population living near the site is calculated on a separate sheet and then imported into the proper simulation sheet cell. Scenarios 1 & 2 also include calculations regarding the surface removal and surface treatment processes.

Scenario 1

The risks associated with processing concrete according to the Scenario 1 methodology are estimated on this sheet. Any of the twenty technologies available for physically removing the surface layer of concrete may be selected for analysis as would be done for a specific application, or, in the default mode, the model will randomly vary the technology as part of the simulation process.

The discrete processes used to estimate Scenario 1 risks are listed in the third column (Column C) of the spreadsheet. These processes have been grouped and are summarized below.

Site Preparation
Travel of workers to the site
Set up of job trailer
Construction of an access road
Installation of a chain link fence
Grading of the site

Characterization
Characterization of the building for action
Transport of samples to the lab

Surface Removal
Remove contaminated concrete
Collect waste (from removal technology), load it into drums, and load the drums onto a truck
Collect debris & load into dump trucks

LLW Disposal
Haul LLW to Envirocare
Unload at Envirocare

Demolition
Demolition of facility
Crush concrete

Transport to point of sale

Rebar
Separate rebar
Test rebar to verify that rebar meets free-release criteria
Load and haul rebar to metals recycling facility

Population
Suspension of radionuclides into the air during D&D activities and deposition around non-workers in the surrounding area

Clean-up
Site cleanup
Remove job trailer & fence
Demobilization of workers

Fines Handling
Loading of fines (from concrete crushing) for sale or disposal
Accidents to vehicle hauling fines

Scenario 2

The Scenario 2 simulation sheet is identical to the Scenario 1 simulation sheet, except concrete surfaces are treated instead of removed. The discrete processes used to estimate Scenario 2 risks are listed in the third column (Column C) of the spreadsheet. These processes have been grouped and are summarized below.

Site Preparation
Travel of workers to the site
Set up of job trailer
Construction of an access road
Installation of a chain link fence
Grading of the site

Characterization
Characterization of the building for action
Transport of samples to the lab

Surface Treatment
Remove the contamination from concrete surface.
Collect waste (from treatment technology), load it into drums, and load the drums onto a truck.
Collect debris & load into dump trucks

LLW Disposal
Haul LLW to Envirocare
Unload at Envirocare

Demolition
Demolition of facility
Crush concrete
Transport to point of sale

Rebar
Separate rebar
Test rebar to verify that rebar meets free-release criteria
Load and haul rebar to metals recycling facility

Population
Suspension of radionuclides into the air during D&D activities and deposition around non-workers in the surrounding area

Clean-up
Site cleanup
Remove job trailer & fence
Demobilization of workers

Fines Handling
Loading of fines (from concrete crushing) for sale or disposal
Accidents to vehicle hauling fines

Scenario 3

Scenario 3 differs from the first two scenarios in that the structures are rubblized in-place after decontamination. The rubble is then capped.

Site Preparation
Travel of workers to the site
Set up of job trailer
Construction of an access road
Installation of a chain link fence
Grading of the site

Characterization
Characterization of the building for action
Transport of samples to the lab

Decontamination

Decontaminate the concrete surface
Collect waste (from treatment technology), load it into drums, and load the drums onto a truck.
Collect debris & load into dump trucks

LLW Disposal
Haul LLW to Envirocare
Unload at Envirocare

Demolition
Demolition of facility

Capping
Consolidate rubble with bulldozer
Placing & spreading cap material
Monitoring
Install groundwater wells
Monitoring groundwater wells for 30 years

Cap Maintenance
Annual mowing of the cap for 30 years.
Fertilization/reseeding associated with maintaining grass.

Population
Suspension of radionuclides into the air during D&D activities and deposition around non-workers in the surrounding area

Clean-up
Site cleanup
Remove job trailer & fence
Demobilization of workers

Scenario 4

Scenario 4 is similar to the previous scenario, except the facility is not decontaminated. No final characterization is necessary, since no reduction in contamination is expected prior to capping. The monitoring duration for this scenario is longer than for Scenario 3 due to more stringent monitoring requirements.

Site Preparation
Travel of workers to the site
Set up of job trailer
Construction of an access road
Installation of a chain link fence

Grading of the site

Characterization
Characterization of the building for action
Transport of samples to the lab

Demolition
Demolition of facility

Capping
Consolidate rubble with a bulldozer.
Phase 1a: placing & spreading first layer of cap material.
Phase 1b: placing & spreading second layer of cap material.
Phase 2: placing geomembrane & final cover for cap.

Monitoring
Install groundwater wells
Monitoring groundwater wells for 100 years

Cap Maintenance
Annual mowing of the cap for 100 years.
Fertilization/reseeding associated with maintaining grass.

Population
Suspension of radionuclides into the air during D&D activities and deposition around non-workers in the surrounding area

Clean-up
Site cleanup
Remove job trailer & fence
Demobilization of workers

Scenario 5

In Scenario 5, the facility is demolished, all concrete rubble is crushed, the rebar removed, and the crushed concrete placed in an on-site, LLW landfill. The concrete is not decontaminated but is crushed to reduce its volume and to ease placement in the LLW landfill. Initial characterization is conducted so that appropriate precautions to protect workers can be taken. This scenario includes the risks associated with the construction, operation, and capping of an on-site LLW disposal facility.

Site Preparation
Travel of workers to the site
Set up of job trailer

Construction of an access road
Installation of a chain link fence
Grading of the site

Characterization
Characterization of the building for action
Transport of samples to the lab

Demolition
Demolition of facility

Concrete
Crush concrete
Stockpile contaminated, crushed, concrete rubble

Construct LLW Disposal Facility
Excavate site for disposal facility
Haul material for liner and intermediate lifts
Place clay liner that meets RCRA requirements
Place synthetic liner
Place crushed concrete in disposal cell
Phase 1a: placing & spreading first layer of cap material.
Phase 1b: placing & spreading second layer of cap material.
Phase 2: placing geomembrane & final cap cover.

Monitoring
Install groundwater wells
Monitoring groundwater wells for 100 years

Cap Maintenance
Annual mowing of the cap for 100 years.
Fertilization/reseeding associated with maintaining grass.

Population
Suspension of radionuclides into the air during D&D activities and deposition around non-workers in the surrounding area

Clean-up
Site cleanup
Remove job trailer & fence
Demobilization of workers

Scenario 6

The sheet for Scenario 6 estimates the risk for the "baseline" case. Contaminated surface areas are removed or treated and disposed at an off-site LLW facility, the structure is demolished, and the concrete is disposed at a C&D landfill. No concrete is recycled.

Site Preparation
Travel of workers to the site
Set up of job trailer
Construction of an access road
Installation of a chain link fence
Grading of the site

Characterization
Characterization of the building for action
Transport of samples to the lab

Surface Removal
Remove contaminated concrete
Collect waste (from removal technology), load it into drums, and load the drums onto a truck
Collect debris & load into dump trucks

LLW Disposal
Haul LLW to Envirocare
Unload at Envirocare

Demolition
Demolition of facility
Load rubble into trucks.
Transport rubble to C&D landfill

Population
Suspension of radionuclides into the air during D&D activities and deposition around non-workers in the surrounding area

Clean-up
Site cleanup
Remove job trailer & fence
Demobilization of workers

Risk Factors

The Risk Factors sheet has two main functions. The first is the definition of accident and hazard rates which include both transportation and construction accident rates. Secondly, the Risk Factors sheet calculates transportation. The transportation risks are divided into three categories:

1. **Incident Free Radiological Risk:** This risk is associated with the exposure to the driver, train crew, and public along the transportation corridor from direct radiation.

2. **Non-radiological Accident Risk:** This risk is associated with vehicular accidents that do not result in a breach of containment.

3. **Radiological Accident Risk:** This risk assumes that the low-level waste is released from any containment as a result of a vehicular accident. An air dispersion model is used to estimate the exposure to the surrounding public.

To calculate each of the categories of risk, it was necessary to incorporate corridor-specific transportation information that includes: the population density along the corridor and the length of the corridor. It was assumed that rail cars would be used to transport all contaminated material (concrete rubble, process wastes, and personal protective equipment) to the Envirocare LLW disposal facility.

Air Dispersion

The Transportation Accident Model sheet contains an air dispersion model used to estimate the exposure to the public in the event that a transportation accident occurs resulting in the release of radioactively contaminated concrete. It was assumed that the concrete would be dumped into a pile and that a portion of the rubble would be released into the air. The portion of the contaminated rubble released was calculated by using the EPA's air emissions model for dumping activities at Superfund sites (EPA, 1989).

The air dispersion model is a Gaussian Plume model adapted from Schnelle (1992) that considers deposition velocities, radioactive decay, particle size, and atmospheric conditions. The accident was assumed to take place on level ground. The model includes direct exposure from the dust cloud, inhalation of radioactive particles, and groundshine from the deposited material. The area through which the cloud passes resembles a wedge with a central angle that depends upon atmospheric stability and wind speed.

The population exposed is estimated by dividing the wedge into sectors every 10 meters along the centerline of the plume. The population within each sector is exposed to the average concentration of radionuclides within each sector. The sum of the three types of exposures – dust cloud, inhalation, and groundshine – from all of the sectors provides the total exposure in rems. This result is then utilized in the Risk Factors sheet to calculate the overall radiological risk per shipment for each facility

Off-Site Population Exposure

The Off-Site Public Exposure sheet estimates the exposure to the public residing near the remediation site. As remediation activities progress, it is assumed that some radioisotopes, in the form of fine particles, will be routinely suspended in the air. The Off-site Exposure sheet uses a Gaussian air dispersion model (Lamarsh, 1982) to estimate the risk imposed upon the public by the suspended particles. The model calculates the particulate concentrations at different distances from the perimeter of the site in a similar manner as the Transportation Accident Model. The population surrounding the site is imported from the risk factors sheet, and the same sector by sector approach as the Transportation Accident Model is utilized.

Risk Summary

The final sheet is the Risk Summary sheet. The Risk Summary sheet compiles the information produced by the simulation sheets and organizes it into tables that report risks for each scenario according to the following criteria:

1. Radiological Fatalities
2. Transportation Fatalities (Non-radiological)
3. Construction Fatalities (Non-radiological)
4. Total Fatalities
5. Transportation Lost Workdays
6. Construction Lost Workdays
7. Total Lost Workdays

Probabilistic Simulations

Monte Carlo simulation was employed to better account for the uncertainty within the model's parameters. The computer code @RISK was used as the engine for the simulations. @RISK is a plug-in addition for Microsoft Excel that allows probability distributions to be defined within Excel. By using @RISK to perform Monte-Carlo type simulations, the Risk Spreadsheet Model produces probability ranges rather than point estimates. Table 7-3 lists the distributions and sources for each of the input variables.

Model Operation

The risks associated with recycling and/or disposing of contaminated concrete were modeled using Monte Carlo simulation. All six scenarios were modeled for each of the major DOE facilities. Model default parameters were used except for the area of concrete and the facility's distance from Envirocare, which were entered for each run.

At the completion of each model run, the mean and 95 percentile values were recorded for the following output parameters:

1. Total fatalities
2. Construction fatalities
3. Transportation fatalities
4. Delayed (Radiation) fatalities
5. Total lost days
6. Construction lost days
7. Transportation lost days

Appendix B provides a sample model output.

CHAPTER 9 – COST MODEL

Unit Costs

Unit costs were developed for each unit operation. These unit operation estimates were combined to develop estimates for each scenario. Unit costs for treatment and removal technologies were extracted from DOE, IAEA, Means and vendor data. The Remedial Action Cost Engineering and Requirements System model v3.2 (RACER[8], 1996), developed by the US Air Force, was used as the basis for developing the non-technology unit costs. Costs for the technologies and RACER costs were supplemented with other cost data from Dickerson (1995), the DOE (1994), and Means (1992 and 1994) to fully develop the unit costs.

Unit processes have been grouped into related categories to ease the understanding of the estimation process. These categories are: Mobilization/Demobilization, Site Preparation and Support, Utilities, Characterization, Decontamination, Demolition, Package and Load, Haul, Disposal, Capping, Monitoring, Site Clean-up and Decontamination, Operation and Maintenance, Project Management, Engineering, Overhead and Profit, Contingencies, and Credit for Recycled Material.

Mobilization and Demobilization

Mobilization includes the costs for transport of required heavy equipment and transport of job and decontamination trailers to the site. The mobilization cost for each piece of heavy equipment is estimated at $300. The costs for job and decontamination trailers are also included in mobilization. They are estimated at $2,000 per trailer per year (Racer, 1996).

Site Preparation and Support

Site preparation includes:

1. rough grading and graveling a 3-acre job-yard area for the trailers, decontamination pad, equipment storage, and parking at $1.13/yd^2 (Means, 1992) and $4.50/ ton (USGS, 1996) for grading and gravel, respectively;
2. fencing the perimeter of the yard area at $2.75/ft (Racer, 1996);

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[8] RACER is a PC-based environmental cost estimating system developed by the US Air Force. Racer estimates are based on generic engineering solutions to environmental remediation projects. The generic solutions are derived from historic project information, government laboratories, construction management agencies, vendors, contractors, and engineering analyses. The generic solutions are tailored to the site.during development of the estimate. The tailored design is specific work assemblies. The work assemblies are priced using data from the Corps of Engineers' Unit Price Book.

3. constructing the decontamination pad for $13,000 (Racer, 1996);
4. constructing a fourteen-foot wide access road to the site at $\$4.04/ft^2$ (Means, 1992)
5. providing water service to the site at $6/linear foot of service line (Racer, 1996); and
6. providing electrical service to the site at $10/linear foot of electrical line (Racer, 1996);.

Utilities

The monthly costs to provide water and sanitation facilities, electrical service, and telephone service are estimated under this category. These costs are estimated at $300/month, $80/month/port-a-john, $200/month, and $225/month, respectively (Means 1992).

Characterization

Initial characterization of the facility is required to determine the extent and type of contamination present. Assumptions regarding sampling and target analytes were derived from past D&D experience (Bechtel 1994; Bechtel 1995), while costs were estimated from the *Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-Licensed Nuclear Facilities* (USNRC 1994), unless otherwise noted. The initial characterization of the entire structure was assumed to consist of the following measurements/tests per 1,000 ft^2 of facility floor area:

1. general area testing including an exposure rate survey ($50/sample);
2. directional gamma measurements ($200/sample);
3. thermoluminescent dosimetry (TLD) ($20/sample); and
4. gamma spectroscopy ($100/sample).

The total cost of these tests is $370/sample event.

Additional **specific testing** for contaminated areas identified during initial characterization was assumed to consist of:

1. alpha, beta, and gamma counts, and
2. a smear sample for a total of $250/sample site (RACER, 1996).

These latter measurements/samples are taken once every 100 ft^2.

Final characterization establishes that the structure meets free release criteria and is assumed for Scenario 1, 2, 3, and 6, since the facility is intended to be "clean" prior to demolition. The same assumptions (and costs) made for specific testing apply to final characterization.

Material screening is performed on all rebar and recycled rubble prior to shipment from the site. Testing consists of scanning each truck with a portable meter. The model assumes a cost of $25/vehicle for this testing (Racer, 1996).

Decontamination

Surface Removal Technologies

The cost data discussed in Chapter 7 for surface removal technologies were used to estimate the unit cost to remove a 1-inch thick surface layer from the concrete.

Surface Treatment Technologies

The cost data for surface treatment technologies discussed in Chapter 7 were used to estimate the cost to decontaminate the concrete surfaces to a depth of 1-inch.

Demolition

After decontamination, the facility is demolished. Costs to demolish the structure are estimated to be $1/SF of floor area (Racer, 1996). For Scenarios 1 and 2, the concrete rubble is crushed, the rebar removed, and the crushed rubble screened to separate coarse aggregate from fill material (fines). The model uses a lognormal distribution for crushing, screening and separating costs based on work by Deal (1997).

In Scenarios 3 and 4 the concrete is rubblized by passing a bulldozer over the rubble prior to capping. The model uses a cost of $1.40/yd^3 for rubblizing and consolidation (Means, 1992).

Collect and Load

LLW wastes generated during decontamination activities are collected and loaded on a truck for transport to the nearest railhead at a cost of $1.39/yd^3 (Racer, 1996).

Haul

This category provides estimates of the costs to transport LLW wastes to the railhead truck, "clean" wastes to the C&D landfill by truck, recycled aggregate and fill by truck to reuse sites, rebar to recycling facilities by truck, and low-level wastes from the railhead to Envirocare by rail. Costs to transport wastes and recycled material by truck are estimated to be $0.15/CY/mile (Racer, 1996). Rail transport costs are estimated at $0.04/ton/mile based on current DOE contract prices (Powell, 1996). Rebar transportation costs were taken from Warren (1995) and estimated to be $0.08/ton/mile.

Miles for each of these distances were estimated for each of the DOE facilities and approximating the distance to a possible reuse site. The distances, except the distance to Envirocare, used in the probabilistic model were assumed to be triangular distributions. The most likely haul distances for each site are (also see Table 8-4):

1.	Aggregate reuse sites	20 miles
2.	Railhead	0.5 miles
3.	C&D disposal facilites	20 miles
4.	Rebar recycling facility	25 miles
5.	Envirocare varies by site	(see Table 9-1)

Disposal

Disposal of LLW at Envirocare was estimated to be $60/ft^3 (Gresalfi, 1995). The cost for disposal of concrete rubble at a C&D landfill was assumed to approximate a normal distribution with a mean of $25/yd^3 (Deal, 1997).

Capping

For Scenarios 3, 4, and 5 the cost to cap the rubblized structure or LLW landfill was estimated using RACER v3.2 (1996). The size of the cap for Scenarios 3 and 4 was determined by assuming the rubble from the collapsed building was consolidated to a depth of six feet. The cap occupied an area 1.5 times the volume of material from the collapsed building divided by six (area of cap = 1.5*Volume of concrete/6). Since the concrete was decontaminated, it was also assumed that a cap consisting of three feet of clay soil cover would be sufficient.

Table 9-1. Estimated Distances to Envirocare

Facility	Distance to Envirocare (miles)
ANLE	1540
ANLW	1540
BNL	2466
ETEC	793
HANFORD	811
INEEL	327
LANL	941
LBL	743
LLNL	751
METC	2047
NTS	469
ORR	2024
PP	974
RFP	600
RESL	1196
SNL	994
SRS	2204
K-25	2024
PADUCAH	1689
PORTSMOUTH	1897

The area of the cap for Scenario 5 was estimated by assuming the LLW disposal site would have waste placed to a depth of eight feet and that the cap would occupy an area 1.5 times the total volume of concrete divided by the depth of the waste (area of cap = 1.5*Volume of concrete/8). Scenarios 4 and 5 were assumed to require a six-foot thick clay RCRA cap.

The model assumes that the material excavated from the site will not be siutable fro capping. The cost to excavate the necessary cap material was estimated to be $0.60/CY (Racer, 1996). This value was also used for excavation of the LLW landfill. Hauling costs for capping material were estimated to be $.015/CY/mile.

Monitoring

Monitoring for Scenarios 3,4, and 5 includes the construction of groundwater monitoring wells around the perimeter of the cap and continuous environmental monitoring of the area. Groundwater wells were estimated to cost $10/foot to construct and develop. The monitoring encompasses collecting groundwater samples, air monitoring stations, and checking soil gas in wells. The sampling activities for Scenario 3 are assumed to continue for 30 years and monitoring for Scenarios 4 and 5 was assumed to last 100 years. The RACER v3.2 (1996) monitoring model was used to determine the cost of sampling for each scenario. The present value of the monitoring activities was estimated to be $80,600/well and $92,600/well for 30 years and 100 years, respectively.

Site Clean-up and Decontamination

Site clean-up costs were assumed to include final site grading, removal of the fence, and restoration of grass. These costs were estimated to be $870/acre (Racer, 1996). Equipment decontamination costs were assumed to be $180/piece of equipment and performed only at the completion of the project (Racer, 1996).

Cap Maintenance

Routine cap maintenance was assumed to include annual reseeding, fertilizing, and twelve mowings per year. The present value of cap maintenance was estimated to be $26,965/acre for 30 years and $31,000/acre for 100 years (Racer, 1996).

Credit for Recycled Material

These items account for the benefits of recycling the concrete rubble and rebar in Scenarios 1 and 2. Sale of the recycled rubble and rebar reduces the total cost of the D&D projects. Credit for the coarse aggregate and fill material produced is estimated to be 75% of the price of virgin products across the US.

The prices for both materials fit a triangular distributions with a most likely values of $7/ton and $5.25/ton for coarse aggregate and fill, respectively (Deal, 1997).

The rebar that is separated from the rubble during crushing also has salvage value. Prices for rebar fit a triangular distribution with $55/ton as the most likely value (Gresalfi, 1995).

Cost Model

A computer spreadsheet model was developed to assist in the estimation and presentation of costs for each scenario. The spreadsheet was developed for Microsoft Excel®. The spreadsheet model consists of one workbook with 8 worksheets.

Each scenario cost estimate is presented on separate sheets titled Scenario 1, Scenario 2, Scenario 3,..., Scenario 6. Data common to each scenario are entered into the "Parms" (parameters) sheet. A summary sheet is included to display results.

Detailed documentation for the model can be found in Appendix E and sample printouts are provided in Appendix F. The model is briefly described in the following paragraphs.

Parameter Input Sheet

The "Parameter Input Sheet (Parms) is used for case-specific data entry. The following list of parameters is entered in the appropriate location on the Parms sheet. The scenario sheets obtain data from the Parms sheet as necessary.

Table 9-2. Spreadsheet Parameters

Parameter	Units	Comment
Total Area	SF	Total concrete area being evaluated
Facility		Name of facility
% Contaminated	%	Percent of total area that is contaminated
Contaminated Area	SF	Total contaminated area
Thickness	inches	Thickness of concrete slab
Depth of Contamination	inches	Maximum depth of contamination
Fines	%	Percent of fines after screening

Parameter	Units	Comment
Concrete Density	lbs/CF	Density of concrete
Rubble Expansion Factor	%	Used to compute volume of rubblized concrete
Demolition	$/SF	Cost to demolish the structure
Crushing	$/ton	Cost to crush and screen concrete rubble
Rebar Sale Value	$/ton	Value of scrap rebar
Coarse Aggregate Sale Value	$/ton	Value of recycled coarse aggregate
Fill Sale Value	$/ton	Value of recycled fill material
C&D Disposal	$/CY	Construction and demolition debris disposal cost
LLW Disposal	$/CF	LLW disposal cost
Mobilization	miles	Distance to job site
Railhead	miles	Distance from job site to railhead
LLW Disposal Facility	miles	Distance to LLW disposal facility
Coarse Aggregate Reuse Site	miles	Distance to coarse aggregate reuse site
Fill Reuse Site	mile	Distance to fill reuse site
Rebar Scrap Yard	miles	Distance to rebar recycling facility
C&D Landfill	miles	Distance to C&D landfill
Cap Material	miles	Distance to source of capping material

Scenario Simulation Sheets

The Scenario simulation sheets are all similar in structure. Each contains a separate row for each activity in the process train. Within each row, the duration and costs associated with the activity are calculated.

Scenario 1

The costs associated with processing concrete according to Scenario 1 – Surface Removal, Demolish and Disposal of LLW, and Recycle Clean Aggregate are estimated on this sheet. One of nineteen (19) technologies capable of physically removing the surface layer of concrete (and contamination) and its associated cost are randomly selected by the model. For a specific facility, the most appropriate technology would be chosen. Process and decontamination wastes are assumed to have a volume equal to the contaminated floor area times the depth of contamination (typically 1-inch).

Mobilization & Demobilization
- Cost to transport required trailers and equipment

Site Preparation & Support
- Rough grade 3 acres of land
- Install chain link fence around perimeter of 3 acres
- Construct decontamination pad
- Construct access road – 100 ft x 14 ft

Utilities
- Construct water service and provide monthly water service
- Provide monthly telephone service
- Construct electrical service and provide monthly electrical service
- Provide sanitation facilities (Port-a-johns)

Characterization
- Initial characterization of the site with one sample collected and analyzed for every 1000 ft^2 for floor space
- Specific sampling of the facility's contaminated areas identified during initial characterization with one sample collected and analyzed for every 100 ft^2 of floor space
- Final characterization provides confirmation that the decontamination activities were successful. The sampling requirements are the same as for specific sampling
- Final rebar screening provides a final check of the rebar by handheld instruments prior to release for recycling
- Final recycled material screening provides a final check of the recycled concrete rubble by handheld instruments prior to release

Decontamination
- Decontamination of the concrete by a surface removal technology

Demolition
- Demolish the concrete structure
- Crush rubble and screen the concrete rubble
- Separate the rebar

Collect and Load
- Collect all technology waste streams and load them on a truck for transport to the railhead

Haul
- Transport LLW wastes to railhead by truck
- Transport LLW wastes to ENVIROCARE by rail

- Transport rebar to recycling facility by truck
- Transport coarse aggregate to reuse site by truck
- Transport fill to reuse site by truck

Disposal Fees
- LLW at Envirocare

Site Clean-up & Decontamination
- Final site clean-up and necessary landscaping
- The costs to decontaminate equipment used during the project

Credit for resale
- Value of recycled rebar
- Value of recycled coarse aggregate
- Value or recycled fill material

Project Management
- DOE and contractor management costs estimated to be 10% of direct costs

Engineering
- Engineering costs estimated at 6% of direct costs.

Overhead and Profit
- Overhead and profit estimated at 14% of direct costs

Contingencies
- Contingencies estimated at 10% of direct costs

Scenario 2

The “Scenario 2” estimate sheet is very similar to the previous sheet, except that concrete surfaces are treated instead of removed. Decontamination wastes are assumed to equal a volume equal to the total contaminated floor area times a depth of ¼-inch. Each unit process is summarized below.

Mobilization & Demobilization
- Cost to transport required trailers and equipment

Site Preparation & Support
- Rough grade 3 acres of land
- Install chain link fence around perimeter of 3 acres
- Construct decontamination Pad
- Construct access road – 100 ft x 14 ft

Utilities

- Construct water service and provide monthly water service
- Provide monthly telephone service
- Construct electrical service and provide monthly electrical service
- Provide sanitation facilities (Port-a-johns)

Characterization

- Initial characterization of the site with one sample collected and analyzed for every 1000 ft^2 for floor space
- Specific sampling of the facility's contaminated areas identified during initial characterization with one sample collected and analyzed for every 100 ft^2 of floor space
- Final characterization provides confirmation that the decontamination activities were successful; The sampling requirements are the same as specific sampling
- Final rebar screening provides a final check of the rebar by handheld instruments prior to release for recycling
- Final recycled material screening provides a final check of the recycled concrete rubble by handheld instruments prior to release

Decontamination

- Decontamination of the concrete by a surface treatment technology

Demolition

- Demolish the concrete structure
- Crush rubble and screen the concrete rubble
- Separate the rebar from the rest of the rubble

Collect and Load

- Collect all technology waste streams and load them on a truck for transport to the railhead

Haul

- Transport LLW wastes to railhead by truck
- Transport LLW wastes to ENVIROCARE by rail
- Transport rebar to recycling facility by truck
- Transport coarse aggregate to reuse site by truck
- Transport fill to reuse site by truck

Disposal Fees

- For LLW at Envirocare

Site Clean-up & Decontamination

- Final site clean-up and necessary landscaping

- The costs to decontaminate equipment used during the project

Credit for resale

- Value of the recycled Rebar
- Value of the recycled concrete coarse aggregate
- Value of recycled fill material

Project Management

- DOE and contractor management costs estimated to be 10% of direct costs

Engineering

- Engineering costs estimated at 6% of direct costs

Overhead and Profit

- Overhead and profit estimated at 14% of direct costs

Contingencies

- Contingencies estimated at 10% of direct costs

Scenario 3

Scenario 3 considers either surface treatment or removal to decontaminate the concrete prior to demolition, rubblizing, and capping. Since the site is being capped, there are two new costs introduced into this scenario: 1) monitoring; and 2) capping. No recycling is included in this scenario.

Mobilization & Demobilization

- Cost to transport required trailers and equipment

Site Preparation & Support

- Rough grade 3 acres of land
- Install chain link fence around perimeter of 3 acres
- Construct decontamination Pad
- Construct access road – 100 ft x 14 ft

Utilities

- Construct water service and provide monthly water service
- Provide monthly telephone service
- Construct electrical service and provide monthly electrical service
- Provide sanitation facilities (Port-a-johns)

Characterization

- Initial characterization of the site with one sample collected and analyzed for every 1000 ft^2 for floor space

- Specific sampling of the facility's contaminated areas identified during initial characterization with one sample collected and analyzed for every 100 ft^2 of floor space
- Final characterization provides confirmation that the decontamination activities were successful; The sampling requirements are the same as specific sampling

Decontamination

- Decontamination of the concrete

Demolition

- Demolish the concrete structure
- Consolidate the concrete rubble prior to capping

Collect and Load

- Collect all technology waste streams and load them on a truck for transport to the railhead

Haul

- Transport wastes to railhead by truck
- Transport wastes to ENVIROCARE by rail

Disposal Fees

- For LLW at Envirocare

Capping Activities

- Excavate the material for the cap; the model assumes that the material is available at no cost except for labor and equipment
- Haul the cap material to the site by truck
- Construct the cap; since the material being capped is clean, the cap is a simple three foot layer of compacted soil
- Install groundwater monitoring wells
- Monitor the groundwater for a period of 30 years

Site Clean-up & Decontamination

- Final site clean-up and necessary landscaping
- The costs to decontaminate equipment used during the project

Cap Maintenance

- Annual mowing and reseeding for 30 years

Project Management

- DOE and contractor management costs estimated to be 10% of direct costs

Engineering

- Engineering costs estimated at 6% of direct costs

Overhead and Profit

- Overhead and profit estimated at 14% of direct costs

Contingencies

- Contingencies estimated at 10% of direct costs

Scenario 4

Scenario is similar to the previous cost estimate, except no decontamination activities are performed. No final characterization is necessary, since no reduction in contamination is expected prior to capping. Monitoring costs are higher than for the Scenario 3 since more intensive monitoring is included and the monitoring period is extended to 100 years. No recycling is included in this scenario.

Mobilization & Demobilization

- Cost to transport required trailers and equipment

Site Preparation & Support

- Rough grade 3 acres of land
- Install chain link fence around perimeter of 3 acres
- Construct decontamination Pad
- Construct access road – 100 ft x 14 ft

Utilities

- Construct water service and provide monthly water service
- Provide monthly telephone service
- Construct electrical service and provide monthly electrical service
- Provide sanitation facilities (Port-a-johns)

Characterization

- Initial characterization of the site with one sample collected and analyzed for every 1000 ft^2 for floor space
- Specific sampling of the facility's contaminated areas identified during initial characterization with one sample collected and analyzed for every 100 ft^2 of floor space

Demolition

- Demolish the concrete structure
- Consolidate the concrete rubble prior to capping

Capping Activities

- Excavate the material for the cap; the model assumes that the material is available at no cost except for labor and equipment
- Haul the cap material to the site by truck
- Construct a RCRA cap; since the material being capped is still contaminated, the cap must meet RCRA and NRC requirements
- Install groundwater monitoring wells
- Monitor the groundwater for a period of 100 years

Site Clean-up & Decontamination

- Final site clean-up and necessary landscaping
- The costs to decontaminate equipment used during the project

Cap Maintenance

- Annual mowing and reseeding for 100 years

Project Management

- DOE and contractor management costs estimated to be 10% of direct costs

Engineering

- Engineering costs estimated at 6% of direct costs

Overhead and Profit

- Overhead and profit estimated at 14% of direct costs

Contingencies

- Contingencies estimated at 10% of direct costs

Scenario 5

The Scenario 5 estimates the costs for characterizing and demolishing the structure. The concrete rubble and rebar are crushed and placed into an on-site LLW landfill. The scenario estimate includes the cost to construct, operate, close, and monitor the LLW landfill. The LLW landfill is provided with a RCRA or NRC cap and liner. No recycling is included in this scenario.

Mobilization & Demobilization

- Cost to transport required trailers and equipment

Site Preparation & Support

- Rough grade 3 acres of land
- Install chain link fence around perimeter of 3 acres
- Construct decontamination Pad

- Construct access road – 100 ft x 14 ft

Utilities
- Construct water service and provide monthly water service
- Provide monthly telephone service
- Construct electrical service and provide monthly electrical service
- Provide sanitation facilities (Port-a-johns)

Characterization
- Initial characterization of the site with one sample collected and analyzed for every 1000 ft^2 for floor space
- Specific sampling of the facility's contaminated areas identified during initial characterization with one sample collected and analyzed for every 100 ft^2 of floor space

Demolition
- Demolish the concrete structure
- Crush the concrete rubble and rebar

Capping Activities
- Excavate the site for the LLW facility
- Haul the excavated material from the site
- Excavate the material for the liner, intermediate lifts, and cap; the model assumes that the material is available at no cost except for labor and equipment
- Haul the liner, lift, and cap material to the site by truck
- Place the clay liner material
- Place a synthetic liner
- Place the crushed concrete rubble and intermediate clay lifts
- Construct a RCRA cap; since the material being capped is still contaminated, the cap must meet RCRA and NRC requirements
- Install monitoring wells around the site
- Monitor the groundwater for a period of 100 years

Site Clean-up & Decontamination
- Final site clean-up and necessary landscaping
- The costs to decontaminate equipment used during the project

Cap Maintenance
- Annual mowing and reseeding for 100 years

Project Management
- DOE and contractor management costs estimated to be 10% of direct costs

Engineering

- Engineering costs estimated at 6% of direct costs

Overhead and Profit

- Overhead and profit estimated at 14% of direct costs

Contingencies

- Contingencies estimated at 10% of direct costs

Scenario 6

The sheet for Scenario 6 estimates the costs associated with the current DOE D&D practice. This scenario serves as the base-line case for the study. The concrete is decontaminated by surface removal, rubblized, and the rubble disposed at a C&D landfill. No credits are given for recycling.

Mobilization & Demobilization

- Cost to transport required trailers and equipment

Site Preparation & Support

- Rough grade 3 acres of land
- Install chain link fence around perimeter of 3 acres
- Construct decontamination Pad
- Construct access road – 100 ft x 14 ft

Utilities

- Construct water service and provide monthly water service
- Provide monthly telephone service
- Construct electrical service and provide monthly electrical service

Characterization

- Initial characterization of the site with one sample collected and analyzed for every 1000 ft^2 for floor space
- Specific sampling of the facility's contaminated areas identified during initial characterization with one sample collected and analyzed for every 100 ft^2 of floor space
- Final characterization provides confirmation that the decontamination activities were successful; The sampling requirements are the same as specific sampling
- Final rubble screening provides a final check of the concrete rubble by handheld instruments prior to release to a C&D landfill

Decontamination

- Decontamination of the concrete by a surface removal technology

Demolition
- Demolish the concrete structure

Package and Load
- Collect all technology waste streams and load them on a truck for transport to the railhead

Haul
- Transport wastes to railhead by truck
- Transport wastes to ENVIROCARE by rail
- Transport concrete rubble to a C&D landfill by truck

Disposal Fees
- LLW at Envirocare
- C&D wastes at a C & D Landfill

Site Clean-up & Decontamination
- Final site clean-up and necessary landscaping
- The costs to decontaminate equipment used during the project

Project Management
- DOE and contractor management costs estimated to be 10% of direct costs

Engineering
- Engineering costs estimated at 6% of direct costs

Overhead and Profit
- Overhead and profit estimated at 14% of direct costs

Contingencies
- Contingencies estimated at 10% of direct costs

Summary

The “Summary” sheet consolidates the cost estimates into a single table for comparison and presentation.

CHAPTER 10 – ESTIMATED RISKS

Findings

The calculated fatalities and lost workdays were determined for each scenario. To simplify the presentation and discussion of the data, the following section presents the average mortality risks followed by the average lost workdays due to injuries for each average size facility. Complete data for sites are presented in Appendix E.

Small Facilities

Small facilities floor areas ranged from 49,000 ft^2 to 440,000 ft^2 for Morgantown Energy Technology Center and Argonne National Laboratory-East, respectively. The average floor area for small facilities is 197,000 ft^2. Table 10-1 depicts the average calculated risks for each of the six scenarios for the average small facilities. Figures 10-1 and 10-2 depict these risks for average small facilities.

Table 10-1. Risks for Average Small Facilities (% of Total Risk)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.050	0.021	0.12	0.095	0.11	0.12
	56%	51%	74%	90%	86%	76%
Construction	0.015	0.008	0.018	0.010	0.017	0.014
	17%	20%	12%	10%	13%	9%
Delayed	0.024	0.012	0.024	0.00044	0.00056	0.023
	26%	29%	15%	0%	0%	15%
Total	0.089	0.042	0.16	0.11	0.13	0.15
Lost Workdays						
Transportation	3	3	15	16	19	15
	5%	8%	17%	27%	20%	20%
Construction	63	36	73	44	74	59
	95%	92%	83%	73%	80%	80%
Total	66	39	88	61	93	74

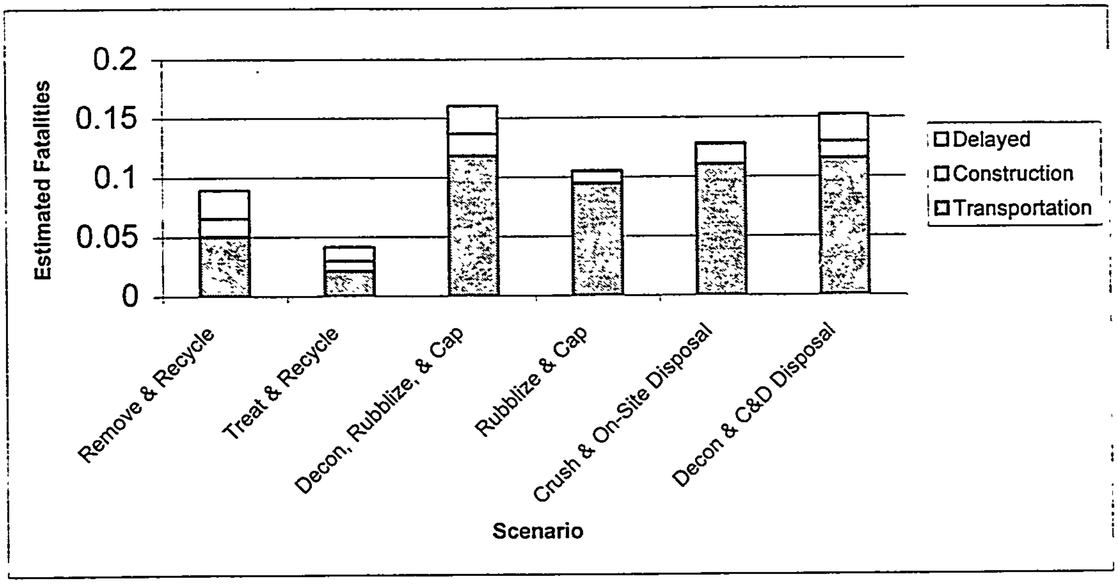

Figure 10-1. Average Small Facility Fatality Risks

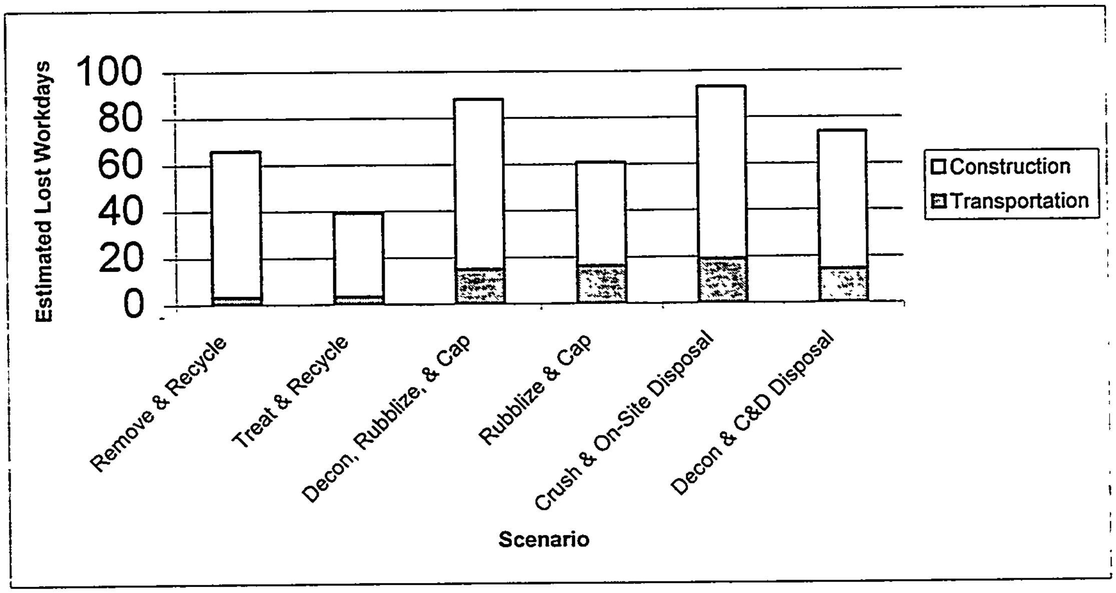

Figure 10-2. Average Small Facility Lost Workdays Risks

Intermediate Facilities

Intermediate facilities floor areas range from 1,500,000 ft^2 at Lawrence Berkeley Laboratory to 11,000,000 ft^2 at the K-25 Site. The average floor area for intermediate facilities is 4,300,000 ft^2. Table 10-2 depicts the calculated risks for each of the six scenarios for average intermediate facilities. Figures 10-3 and 10-4 graphically depict these risks for intermediate facilities.

Table 10-2. Average Risks for Intermediate Facilities (% Total Risk)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.070	0.038	0.20	0.17	0.20	0.20
	49%	50%	71%	90%	86%	72%
Construction	0.028	0.016	0.035	0.019	0.031	0.030
	20%	21%	13%	10%	13%	11%
Delayed	0.044	0.022	0.045	0.00082	0.0010	0.047
	31%	28%	16%	0%	0%	17%
Total	0.14	0.08	0.28	0.19	0.24	0.27
Lost Workdays						
Transportation	6	6	28	29	35	28
	8%	14%	26%	49%	36%	30%
Construction	118	69	148	81	137	126
	95%	92%	84%	73%	80%	82%
Total	124	76	177	111	172	154

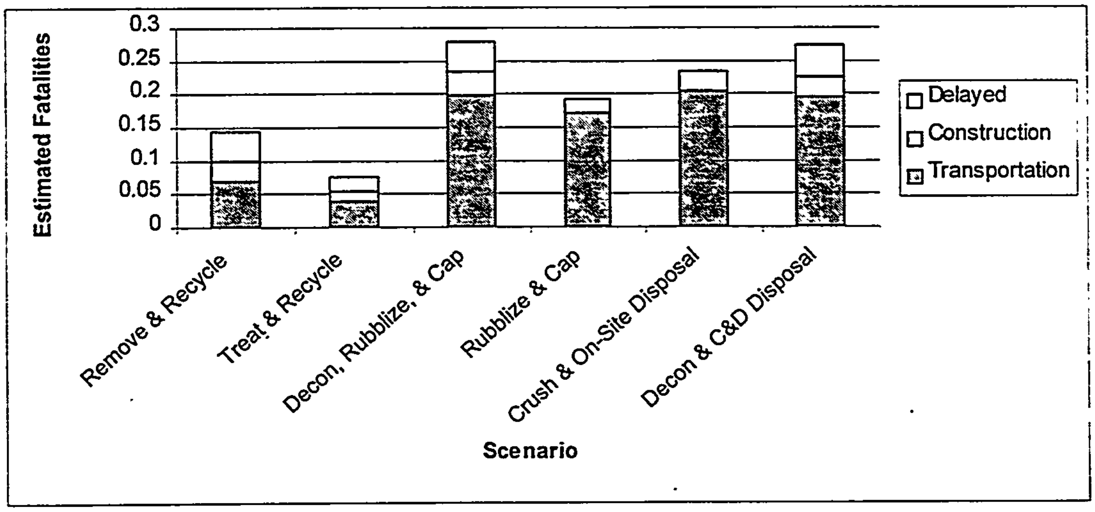

Figure 10-3. Average Intermediate Facility Fatality Risks

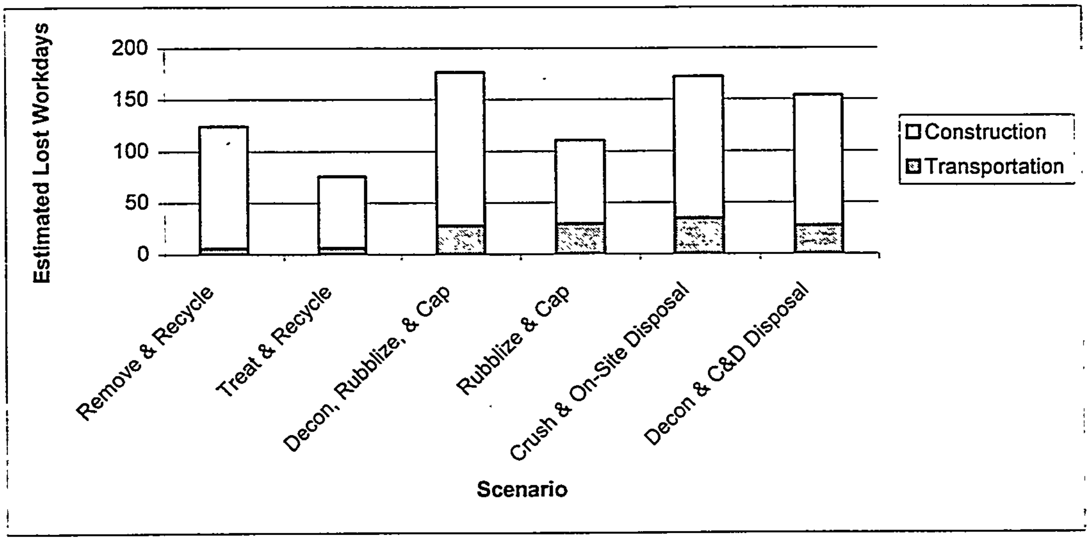

Figure 10-4. Average Intermediate Facility Lost Workdays Risks

Large Facilities

Large facilities floor areas range from 55,000,000 ft^2 at the Savannah River Site to 110,000,000 ft^2 at Hanford. The average floor area for large facilities is 64,500,000 ft^2. Table 10-3 depicts the calculated risks for each of the six scenarios at large facilities. Figures 10-5 and 10-6 graphically depict the risks for large facilities.

Table 10-3. Average Risks for Large Facilities (% Total Risk)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.97	0.56	2.85	2.40	2.85	2.82
	43%	47%	68%	90%	86%	69%
Construction	0.43	0.23	0.53	0.26	0.45	0.43
	19%	20%	13%	10%	13%	10%
Delayed	0.85	0.40	0.84	0.013	0.016	0.86
	38%	34%	20%	0%	0%	21%
Total	2.24	1.20	4.22	2.67	3.31	4.11
Lost Workdays						
Transportation	90	90	410	410	490	410
	5%	8%	15%	27%	20%	18%
Construction	1800	1020	2250	1130	1970	1820
	95%	92%	85%	73%	80%	82%
Total	1890	1110	2660	1540	2460	2230

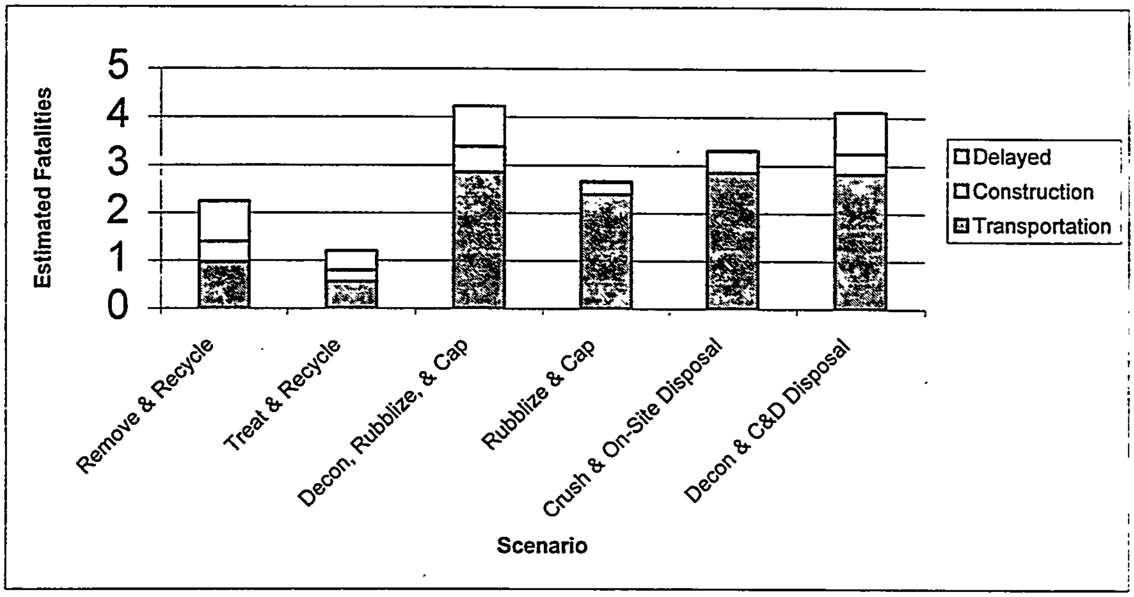

Figure 10-5. Average Large Facility Fatality Risks

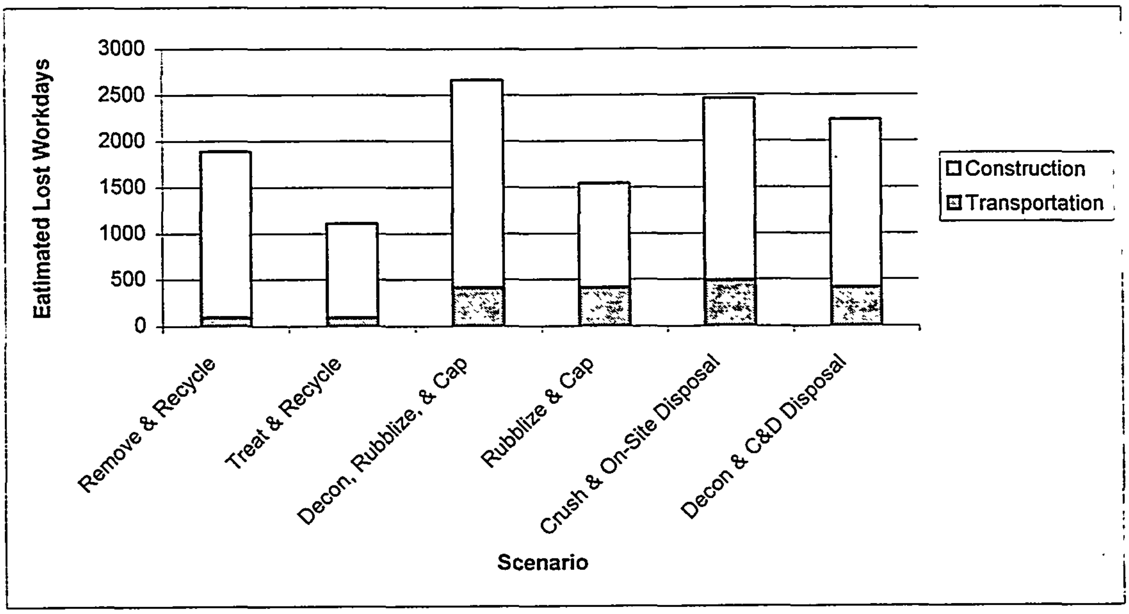

Figure 10-6. Average Large Facility Lost Workdays Risks

Discussion

Fatalities

Small Facilities

The average number of calculated fatalities from processing (recycling and/or disposal) all surplus concrete at the site for small facilities (< 10^6 ft^2 of floor area with an average size of 197,000 ft^2) ranged from 4.2×10^{-2} to 1.6×10^{-1} fatalities per project. The number of fatalities for both the recycle options (Scenario 2 - Treat & Recycle and Scenario 1 - Remove & Recycle) were the lowest at 4.2×10^{-2} and 8.9×10^{-2}, respectively. The largest number of calculated fatalities was for Scenario 3 – Decon, Rubblize & Cap at 1.6×10^{-1}. At 1.5×10^{-1} calculated fatalities, the current practice of decontamination and disposal at a C&D landfill (Scenario 6) ranked fifth. Table 10-4 lists the scenarios in rank order based on calculated fatalities.

Table 10-4. Rank Ordered Fatality Risks for Average Small Facilities

Scenario	Average Total Fatalities per Site	Fatalities per ft^2
Scenario 2 - Treat & Recycle	4.2E-02	2.1E-07
Scenario 1 - Remove & Recycle	8.9E-02	4.6E-07
Scenario 4 - Rubblize & Cap	1.1E-01	5.3E-07
Scenario 5 - Crush & On-Site Disposal	1.3E-01	6.5E-07
Scenario 6 - Decon & C&D Disposal	1.5E-01	7.7E-07
Scenario 3 - Decon, Rubblize, & Cap	1.6E-01	8.2E-07

As shown in Table 10-1, the total number of calculated fatalities is composed of transportation, construction, and delayed (radiation) fatalities. The transportation fatalities dominated the total for all scenarios ranging from 2.1 x 10^{-2} fatalities (56% of the total) for Scenario 2 - Treat & Recycle to 1.2 x 10^{-1} fatalities (74% of the total) for Scenario 3 – Decon, Rubblize & Cap. Estimated transportation fatalities were the largest for the three capping Scenarios (3 – Decon, Rubblize, & Cap; 4 - Rubblize & Cap; and 5 - Crush & On-site disposal) and the baseline scenario (Scenario 6 – Decon & C&D Disposal) due to volume of material transported.

Construction related fatalities for small sites were essentially constant for all six scenarios ranging from 8 x 10^{-3} to 1.8 x 10^{-2} fatalities per site. Scenario 2 - Treat & Recycle was lowest at 8 x 10^{-2} (20% of total fatalities) with Scenario 3 – Decon, Rubblize & Cap being the highest at 1.8 x 10^{-2} fatalities (12% of total fatalities). The minor differences in construction fatalities are attributable to capping and/or constructing on-site disposal facilities.

Delayed or radiation related fatalities ranged from 4.4 x 10^{-4} for Scenario 4 - Rubblize & Cap (< 1%) to 2.4 x 10^{-2} for Scenarios 1 - Remove & Recycle (26%), and 3 - Decon & Cap (15%) and d2.3 x 10-2 for Scenario 6 – Decon & C&D Disposal (15%). The last three scenarios presented the greatest risk for delayed fatalities due to the longer, direct exposures of workers to radiation during decontamination activities.

Intermediate Facilities

Intermediate size facilities ($10^6 < x < 10^7$ ft^2 of floor area with an average size of 4,300,000 ft^2) demonstrated average calculated fatalities ranging from 8.0 x 10^{-2} for Scenario 2 - Remove & Recycle to 2.8 x 10^{-1} for Scenario 3 – Decon & Cap. As with the small facilities, the number of fatalities for both the recycle options (Scenario 2 - Treat & Recycle and Scenario 1 - Remove & Recycle) were the lowest at 8.0 x 10^{-2} and 1.4 x 10^{-1}, respectively. At 2.7 x 10^{-1} calculated fatalities, the current practice of decontamination and disposal at a C&D landfill (Scenario 6) ranked fifth. Table 10-5 lists the scenarios in rank order based on calculated fatalities.

Table 10-5. Rank Ordered Fatality Risks for Average Intermediate Facilities

Scenario	Average Total Fatalities per Site	Fatalities per ft^2
Scenario 2 - Treat & Recycle	7.6E-02	1.8E-08
Scenario 1 - Remove & Recycle	1.4E-01	3.3E-08
Scenario 4 - Rubblize & Cap	1.9E-01	4.5E-08
Scenario 5 - Crush & On-Site Disposal	2.4E-01	5.5E-08
Scenario 6 - Decon & C&D Disposal	2.7E-01	6.3E-08
Scenario 3 - Decon, Rubblize, & Cap	2.8E-01	6.5E-08

Transportation fatalities dominated the total for all scenarios ranging from 3.8 x 10^{-2} fatalities (50% of the total) for Scenario 2 - Treat and Recycle to 2.0 x 10^{-1} fatalities for Scenario 5 - Crush & On-site Disposal, Scenario 3 – Decon & Cap, and Scenario 6 – Decon & C&D Disposal, 86%, 71%, and 72% of the total respectively. Estimated transportation fatalities were the greatest for two of the capping Scenarios (3 - Decon & Cap, and 5 - Crush and On-site Disposal) due to volume of material hauled for construction of the cap and liner. However, the transportation fatalities for Scenario 6 - Decon & C&D Disposal were equal to those for the capping scenarios. This was due to the large amount of rubble that had to be hauled by truck to the local C&D landfills.

Construction related fatalities mirrored the trend for the small sites and were essentially constant for all six scenarios ranging from 1.6 x 10^{-2} to 3.5 x 10^{-2} fatalities per site. Scenario 2 -Treat & Recycle was again lowest at 1.6 x 10^{-2} (21% of total fatalities) with Scenario 3 - Decon & Cap being the highest at 3.5 x 10^{-2} fatalities (13%).

Delayed or radiation related fatalities ranged from 8.2 x 10^{-4} for Scenarios 4 - Rubblize & Cap (0.4%) to 4.7 x 10^{-2} for Scenario 6 - Decon & C&D Disposal (17%). Scenarios 1 - Remove & Recycle, 2 - Treat & Recycle, 3 - Decon & Cap, and 6 - Decon & C&D Disposal followed the trend for small facilities and presented the greatest risk for delayed fatalities due to the longer, direct exposures of workers to radiation during decontamination activities.

Large Facilities

Large facilities (> 10^7 ft^2 of floor area with an average size of 64,500,000 ft^2) demonstrated average estimated total fatalities ranging from 1.20 for Scenario 2 - Treat & Recycle to 4.22 for Scenario 3 – Decon & Cap. Scenario 2 - Treat & Recycle again presented the lowest risk for fatalities of all the scenarios. Scenario 1 - Remove & Recycle at 2.24 remained number two followed closely by Scenario 4 - Rubblize & Cap with 2.67 fatalities. The highest estimated number of fatalities was for Scenario 3 - Decon & Cap at 4.22. The current practice of decontamination and disposal at a C&D landfill (Scenario 6) ranked fifth at 4.11 fatalities. Table 10-6 lists the scenarios in rank order based on calculated fatalities.

Table 10-6. Rank Ordered Fatality Risks for Average Large Facilities

Scenario	Average Total Fatalities per Site	Fatalities per ft^2
Scenario 2 - Treat & Recycle	1.2	1.9E-08
Scenario 1 - Remove & Recycle	2.2	3.5E-08
Scenario 4 - Rubblize & Cap	2.7	4.2E-08
Scenario 5 - Crush & On-Site Disposal	3.3	5.2E-08
Scenario 6 - Decon & C&D Disposal	4.1	6.4E-08
Scenario 3 - Decon, Rubblize, & Cap	4.2	6.6E-08

Transportation fatalities again dominated the total for all scenarios. Scenarios 2, Treat & Recycle, and 1, Remove & Recycle, presented the lowest number of estimated transportation fatalities with 0.97 (43%) and 0.56 (47%), respectively. Scenarios 3 - Decon & Cap and 5 - Crush & On-site Disposal were the highest with an estimated 2.85 fatalities (68% and 86% of the total fatalities, respectively). Scenario 4 - Rubblize & Cap had an estimated 2.4 (84%) transportation fatalities. Scenario 4 was lower than Scenario 3 - Decon & Cap due to the increased volume of contaminated material hauled to LLW disposal facilities from Scenario 3.

Construction related fatalities mirrored the trend for the small and intermediate sites with the six scenarios ranging from 0.25 to 0.53 fatalities per site. Scenario 2 -Treat and Recycle was again lowest at 0.23 (20% of total fatalities) with Scenario 5 - Crush & On-site Disposal the highest at 0.53 fatalities (13%).

Delayed or radiation related fatalities ranged from 1.3 x 10^{-2} for Scenario 4 - Rubblize and Cap (< 1%) to 0.86 for Scenario 6 - Decon & C&D Disposal (21%). Scenarios 1 - Remove & Recycle, 3 - Decon & Cap, and 6 - Decon & C&D Disposal followed the trend for small and intermediate facilities presenting the greatest risk for delayed fatalities due to the longer, direct exposures of workers to radiation during decontamination activities.

Lost Work Days

Small Facilities

The average number of estimated lost days from processing (recycling and/or disposal) all surplus concrete at the site for small facilities (< 10^6 ft^2 of floor area with an average size of 197,000 ft^2) ranged from 39 to 93 days per project. The number of lost days for Scenario 2 - Treat & Recycle was the lowest at 39 days. The largest number of estimated lost workdays was Scenario 5 - Crush & On-site Disposal at 93 days. Both recycle scenarios (1 – Remove & Recycle and 2 – Treat & Recycle) were lower than the baseline case (Scenario 6 – Decon & C&D Disposal). Table 10-7 lists the scenarios in rank order based on estimated number of lost workdays.

As opposed to the risk of fatalities, construction activities were the largest contributor to lost workdays for all scenarios. The distribution of construction and transportation lost workdays for small facilities is shown in Table 10-1.

Table 10-7. Rank Ordered Estimated Lost Days for Average Small Facilities

Scenario	Average Total Lost Days per Site	Lost Days per
Scenario 2 - Treat & Recycle	39	2.0E-04
Scenario 4 - Rubblize & Cap	61	3.1E-04
Scenario 1 - Remove & Recycle	66	3.4E-04
Scenario 6 - Decon & C&D Disposal	74	3.7E-04
Scenario 3 - Decon, Rubblize, & Cap	88	4.5E-04
Scenario 5 - Crush & On-Site Disposal	93	4.7E-04

Intermediate Facilities

The average estimated lost work days ranged from 76 days for Scenario 2 - Treat & Recycle to 177 days for Scenario 3 - Decon & Cap for intermediate size facilities ($10^6 < x < 10^7$ ft^2 of floor area with an average size of 4,300,000 ft^2). As with the small facilities, the number of lost workdays for Scenarios 2 - Treat & Recycle (76) and 1 – Remove & Recycle (124) were lower than the baseline scenario (6 – Decon & C&D Disposal [154]). At 154 lost work days, the current practice of decontamination and disposal at a C&D landfill (Scenario 6) ranked fourth. Table 10-8 lists the scenarios in rank order based on calculated fatalities.

Table 10-8. Rank Ordered Estimated Lost Days for Average Intermediate Facilities

Scenario	Average Total Lost Days per Site	Lost Days per ft^2
Scenario 2 - Treat & Recycle	75	1.8E-05
Scenario 4 - Rubblize & Cap	110	2.6E-05
Scenario 1 - Remove & Recycle	124	2.9E-05
Scenario 6 - Decon & C&D Disposal	154	3.6E-05
Scenario 5 - Crush & On-Site Disposal	172	4.0E-05
Scenario 3 - Decon, Rubblize, & Cap	176	4.1E-05

Following the trends for small facilities, lost workdays attributable to construction activities greatly outweighed the number of lost workdays due to transportation accidents for all scenarios. Table 10-2 illustrates the distribution of lost workdays between transportation and construction activities for intermediate size facilities.

Large Facilities

Large facilities (> 10^7 ft^2 of floor area with an average size of 64,500,000 ft^2) demonstrated average estimated lost work days ranging from 1110 for Scenario 2 - Remove & Recycle to 2660 for Scenario 3 - Decon & Cap. Scenario 4 - Rubblize & Cap was in the number two position with an estimated 1540 lost workdays. Scenario 1 - Remove & Recycle at 1890 was third. The current practice of decontamination and disposal at a C&D landfill (Scenario 6) ranked fourth. Table 10-9 lists the scenarios in rank order based on calculated fatalities.

Table 10-9. Rank Ordered Estimated Lost Days for Average Large Facilities

Scenario	Average Total Lost Days per Site	Lost Days per ft^2
Scenario 2 - Treat & Recycle	1110	1.7E-05
Scenario 4 - Rubblize & Cap	1540	2.4E-05
Scenario 1 - Remove & Recycle	1890	3.0E-05
Scenario 6 - Decon & C&D Disposal	2230	3.5E-05
Scenario 5 - Crush & On-Site Disposal	2460	3.8E-05
Scenario 3 - Decon, Rubblize, & Cap	2660	4.2E-05

As with intermediate facilities, lost workdays attributable to construction activities greatly outweighed the number of lost workdays due to transportation accidents. Table 10-3 illustrates the distribution of lost workdays between transportation and construction activities for each scenario.

Chapter 11 - ESTIMATED COSTS

The costs for each of the six scenarios for each of the major DOE facilities and for the three average bin sizes were determined by our model. The model first estimated the direct costs (characterization, decontamination, demolition, crushing, disposal, transportation, etc.) for each scenario. To these direct costs, the model then added engineering costs (at 10%), overhead and profit (at 14%), and a contingency factor (at 10%) to reach the total estimated cost. Complete cost data for all sites is presented in Appendix F.

Findings

Estimated Costs for Small Facilities

Small facilities floor areas range from 49,000 ft^2 to 440,000 ft^2 for Morgantown Energy Technology Center and Argonne National Laboratory-East, respectively. The average floor area for small facilities is 197,000 ft^2. Table 11-1 presents the estimated costs for each of the six scenarios for the average small facilities as represented by Bin 1. Figure 11-1 depicts the estimated costs for average small facilities.

Table 11-1. Estimated Costs for Average Small Facilities

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	1.29	1.14	2.24	1.68	1.77	1.43
Project Management @ 10%	0.13	0.11	0.22	0.17	0.18	0.14
Contingencies @10%	0.13	0.11	0.22	0.17	0.18	0.14
Engineering @6%	0.08	0.07	0.13	0.10	0.11	0.09
Overhead And Profit @14%	0.23	0.20	0.39	0.30	0.31	0.25
Credit for Recycling	-0.30	-0.30	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	1.55	1.33	3.21	2.42	2.54	2.06
Cost /Square ft.	8.45	8.14	19.83	16.56	17.12	11.63

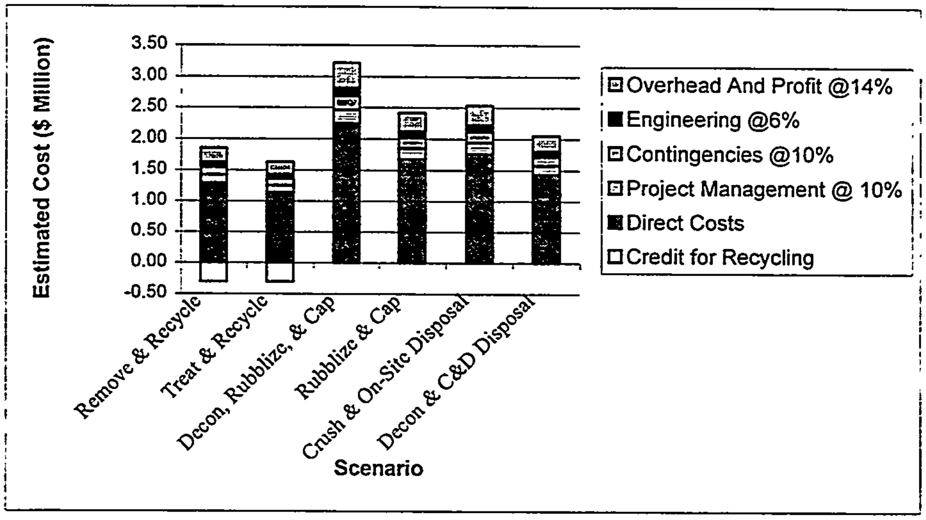

Figure 11-1. Estimated Costs for Average Small Facilities

Estimated Costs for Intermediate Facilities

Intermediate facilities represent floor areas from 1,500,000 ft^2 at Lawrence Berkeley Laboratory to 8,600,000 ft^2 at the Nevada Test Site. The average floor area for intermediate facilities is 4,300,000 ft^2. Table 11-2 presents the estimated costs for each of the six scenarios at intermediate facilities (Bin 2). Figure 11-2 depicts the estimated costs for intermediate facilities.

Table 11-2. Estimated Costs for Average Intermediate Facilities

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	19.7	17.0	31.7	20.2	21.6	22.2
Project Management @ 10%	2.0	1.7	3.2	2.0	2.2	2.2
Contingencies @10%	2.0	1.7	3.2	2.0	2.2	2.2
Engineering @6%	1.2	1.0	1.9	1.2	1.3	1.3
Overhead And Profit @14%	2.8	2.4	4.4	2.8	3.0	3.1
Credit for Recycling	-5.6	-5.6	0.0	0.0	0.0	0.0
TOTAL PROJECT COST	22.0	18.2	44.4	28.3	30.3	31.1
Cost /Square ft.	5.12	4.24	10.33	6.59	7.04	7.23

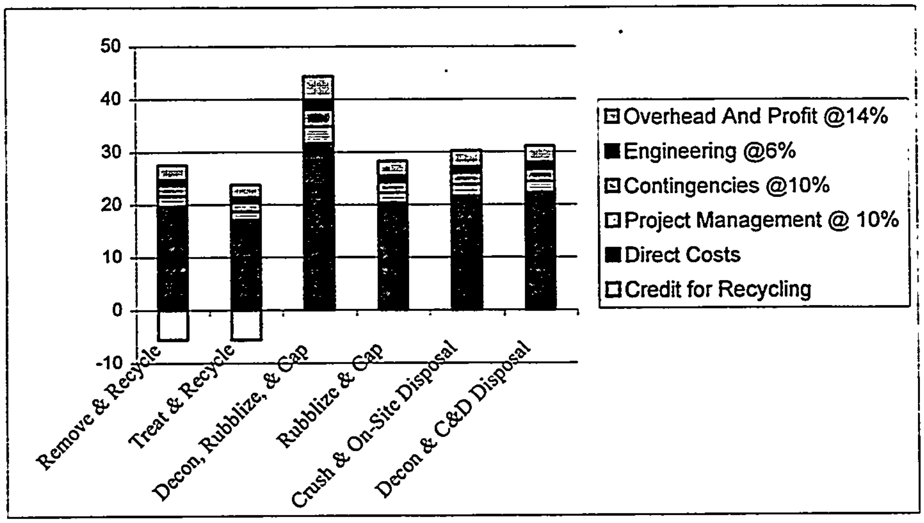

Figure 11-2. Estimated Costs for Average Intermediate Facilities

Estimated Costs for Large Facilities

Intermediate facilities represent floor areas from 11,000,000 ft^2 at the K-25 site to 110,000,000 ft^2 at Hanford. The average floor area for large facilities is 64,500,000 ft^2. Table 11-3 presents the estimated costs for each of the six scenarios at average large facilities (Bin 3). Figure 11-3 depicts the estimated costs for average large facilities.

Table 11-3. Estimated Costs for Average Large Facilities

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	331	285	532	335	358	373
Project Management @ 10%	33	29	53	33	36	37
Contingencies @10%	33	29	53	33	36	37
Engineering @6%	20	17	32	20	21	22
Overhead And Profit @14%	58	50	94	59	63	66
Credit for Recycling	-95	-95	0	0	0	0
TOTAL PROJECT COST	380	315	765	481	514	536
Cost /Square ft.	5.39	4.90	11.90	7.49	8.01	8.33

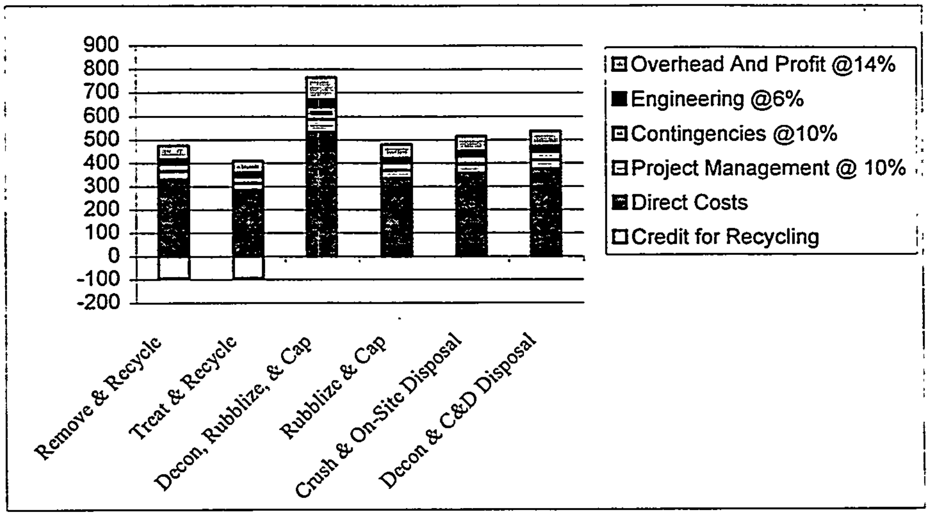

Figure 11-3. Estimated Costs for Average Large Facilities

Discussion

Small Facilities

The average cost for processing (recycling and/or disposal) concrete from a small facility (< 10^6 ft^2 of floor area with an average size of 197,000 ft^2) ranged from \$1.33 million to \$3.21 million per facility. The costs for both the recycle options (Scenario 2 - Treat & Recycle and Scenario 1 - Remove & Recycle) were the lowest at \$1.33 and \$1.55, respectively. The highest estimated cost was for Scenario 3 – Decon, Rubblize & Cap at \$3.21 million. At \$2.06 million, the current practice of decontamination and disposal at a C&D landfill (Scenario 6) ranked third behind the two recycle options. Table 11-4 lists the scenarios in rank order based on estimated costs.

Table 11-4. Rank Ordered Costs for Average Small Facilities

Scenario	Average Total Cost per Site ($ Million)	Average Cost per ft^2
Scenario 2 - Treat & Recycle	1.33	8.14
Scenario 1 - Remove & Recycle	1.55	8.45
Scenario 6 - Decon & C&D Disposal	2.06	11.63
Scenario 4 - Rubblize & Cap	2.42	16.56
Scenario 5 - Crush & On-Site Disposal	2.54	17.12
Scenario 3 - Decon, Rubblize, & Cap	3.21	19.83

Table 11-5 presents the contributions of the various components to the total direct costs for small facilities. Characterization is a major cost for all scenarios. Capping costs overwhelm all other costs for Scenarios 3 (Decon & Cap), 4 (Rubblize & Cap), and 5 (Crush & On-site Disposal). The difference between the capping costs for Scenario 3 (Decon & Cap) and Scenarios 4 (Rubblize & Cap) and 5 (Crush & On-site Disposal) is due to the 30-year monitoring period for Scenario 3 and the 100-year monitoring period for the other two. Figure 11-4 depicts the cost of each major component as a percentage of the total direct costs for the scenario.

Table 11-5. Component Cost Contributions for Average Small Facilities

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
MOB and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	0.37	0.38	0.18	0.18	0.18	0.36
Decontamination and Demolition	0.46	0.31	0.25	0.24	0.23	0.40
Load, Haul and Disposal	0.23	0.22	0.03	0.00	0.00	0.44
Site Clean-up & Decontamination	0.01	0.01	0.01	0.04	0.01	0.01
Capping	0.00	0.00	1.55	0.99	1.13	0.00

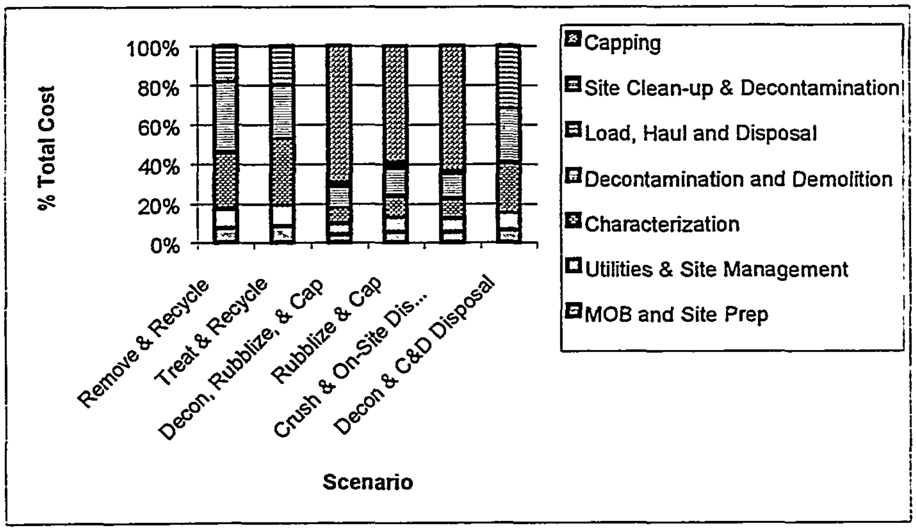

Figure 11-4. Component Cost Contributions for Average Small Facilities

Intermediate Facilities

The average estimated costs ranged from $18.2 million for Scenario 2 - Remove & Recycle to $44.4 million for Scenario 3 – Decon, Rubblize & Cap for intermediate size facilities ($10^6 < x < 10^7$ ft^2 of floor area with an average size of

4,300,000 ft^2). As with the small facilities, the estimated costs for both the recycle options (Scenario 2 - Treat & Recycle and Scenario 1 - Remove & Recycle) were both lower at \$18.2 million and \$22.0 million, respectively, than the baseline scenario (6 – Decon & C&D Disposal) at \$31.1 million. The current practice of decontamination and disposal at a C&D landfill (Scenario 6) ranked fifth. Table 11-6 lists the scenarios in rank order based on calculated fatalities.

Table 11-6. Rank Ordered Costs for Average Intermediate Facilities

Scenario	Average Total Cost per Site ($ Million)	Average Cost per ft^2
Scenario 2 - Treat & Recycle	18.2	4.24
Scenario 1 - Remove & Recycle	22.0	5.12
Scenario 4 - Rubblize & Cap	28.3	6.59
Scenario 5 - Crush & On-Site Disposal	30.3	7.04
Scenario 6 - Decon & C&D Disposal	31.1	7.23
Scenario 3 - Decon, Rubblize, & Cap	44.4	10.33

The intermediate facilities followed the same trends as the small facilities with characterization being a major cost for all scenarios. Capping costs overwhelm all other costs for Scenarios 3 (Decon & Cap), 4 (Rubblize & Cap), and 5 (Crush & On-site Disposal). As with the small facilities, the difference between capping costs for Scenario 3 (Decon & Cap) and Scenarios 4 (Rubblize & Cap) and 5 (Crush & On-site Disposal) is due to the 30-year monitoring period for Scenario 3 and the 100-year monitoring period for the other two. Table 11–7 displays the component costs for each scenario while Figure 11-5 depicts the cost of each major component as a percentage of the total direct costs for the scenario.

Table 11-7. Component Cost Contributions for Average Intermediate Facilities

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Managemen	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	6.9	7.0	3.3	3.3	3.3	6.7
Decontamination and Demoliti	8.4	5.7	4.5	4.5	4.2	7.3
Load, Haul and Disposal	4.1	4.0	0.4	0.0	0.0	7.9
Site Clean-up & Decontaminati	0.09	0.09	0.23	0.76	0.12	0.09
Capping	0.00	0.00	23.0	11.5	13.7	0.00

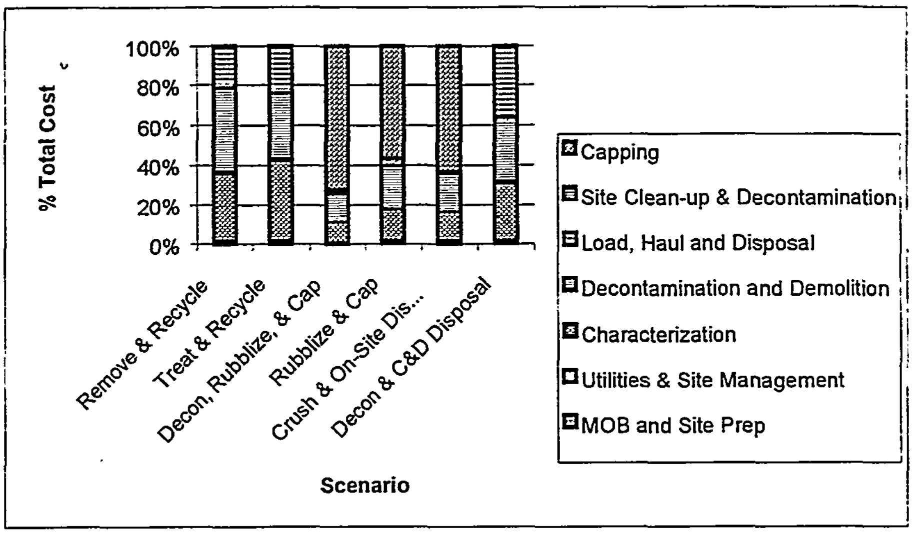

Figure 11-5. Component Cost Contributions for Average Intermediate Facilities

Large Facilities

Large facilities (> 10^7 ft^2 of floor area with an average size of 64,500,000 ft^2) demonstrated average estimated costs ranging from $315 million for Scenario 2 - Remove & Recycle to $765 million for Scenario 3 – Decon, Rubblize & Cap. Scenario 6 – Decon & C&D Disposal (the current baseline case) was again fifth at $536 million. Table 11-8 lists the scenarios in rank order based on calculated fatalities.

The large facilities followed the same trends as the small and intermediate facilities with characterization being a major cost for all scenarios. Capping costs overwhelm all other costs for Scenarios 3 (Decon & Cap), 4 (Rubblize & Cap), and 5 (Crush & On-site Disposal). Component costs for each scenario are shown in Table 11-9. Figure 11-6 depicts the cost of each major component as a percentage of the total direct costs for the scenario.

Table 11-8. Rank Ordered Costs for Average Large Facilities

Scenario	Average Total Cost per Site ($ Million)	Average Cost per ft^2
Scenario 2 - Treat & Recycle	315	4.90
Scenario 1 - Remove & Recycle	380	5.39
Scenario 4 - Rubblize & Cap	481	7.49
Scenario 5 - Crush & On-Site Disposal	514	8.01
Scenario 6 - Decon & C&D Disposal	536	8.33
Scenario 3 - Decon, Rubblize, & Cap	765	11.90

Table 11-9. Component Cost Contributions for Average Large Facilities

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	117	119	56	56	56	113
Decontamination and Demolition	143	96	77	76	72	124
Load, Haul and Disposal	70	68	7	0	0	135
Site Clean-up & Decontamination	1.45	1.45	3.83	12.88	1.95	1.45
Capping	0	0	388	189	228	0

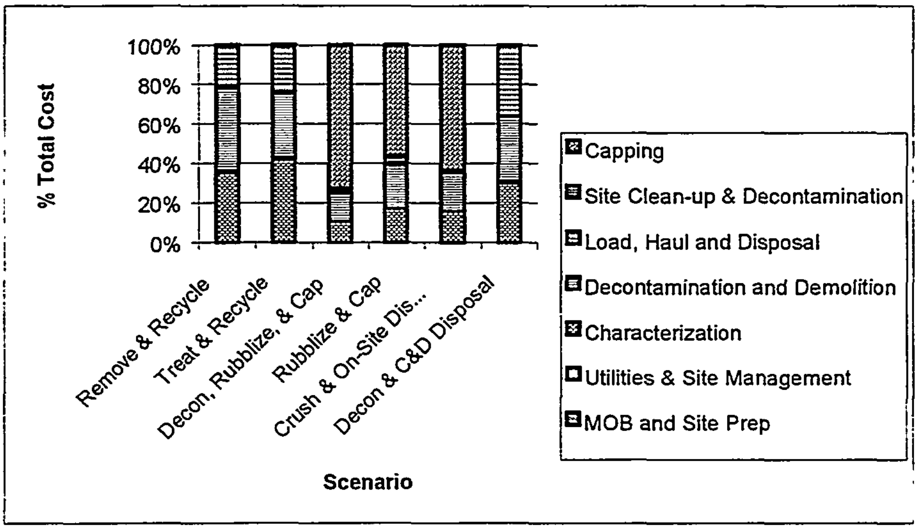

Figure 11-6. Component Cost Contributions for Average Large Facilities

CHAPTER 12 – REGULATORY OVERVIEW

Introduction

The following excerpts from the Solid Waste Disposal Act (SWDA)[9] clearly show that Congress' intent is to reduce the disposal of solid and hazardous wastes in landfills and to promote the reuse of materials whenever possible.

> ...that the economic and population growth of our nation, and the improvements in the standard of living enjoyed by our population, have required increased industrial production to meet our needs, and have made necessary the demolition of old buildings, and the provision of highways and other avenues of transportation, which, together with related industrial, commercial, and agricultural operations, have resulted in a rising tide of scrap, discarded, and waste materials;...[10]
>
> ...although land is too valuable a national resource to be needlessly polluted by discarded materials, most solid waste is disposed of on land in open dumps and sanitary landfills;...[11]
>
> ...millions of tons of recoverable material which could be used are needlessly buried each year;...[12]
>
> ...conserve valuable material and energy resources by... encouraging process substitution, materials recovery, properly conducted recycling and reuse, and treatment...[13]

However, the implementation of this broad national policy has become a very complex and often difficult task due to the stringent and in many cases competing requirements of Federal and State environmental laws and regulations and their subsequent interpretation by the Federal and State judicial systems.

Such is the case with recycling concrete from the Department of Energy (DOE) complex. Decontamination and Decommissioning activities, which incorporate the recycling of contaminated concrete, must be conducted in accordance with the following Federal Laws and their implementing regulations:

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[9] 42 USC § 6901 et seq.

[10] 42 USC § 6901(a)(2).

[11] 42 USC§ 6901(b)(1).

[12] 42 USC § 6901(c)(1).

[13] 42 USC § 6902 (a)(6).

- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)[14] implemented under 40 CFR 300-302,
- The Resource Conservation and Recovery Act (RCRA)[15] implemented under 40 CFR 260-272,
- The Clean Water Act [16] implemented under 40 CFR 104-140, 401-471,
- The Clean Air Act[17] implemented under 40 CFR 50-99,
- The Toxic Substances Control Act[18] implemented under 40 CFR 700-766,
- The Safe Drinking Water Act [19] implemented under 40 CFR 141-149,
- The Atomic Energy Act[20] implemented under 10 CFR 20-71, 830-835,
- The Occupational Safety and Health Act[21] implemented under 29 CFR 1910, 1926, 1960,
- The Hazardous Materials Transportation Act[22] implemented under 49 CFR 171-177.

State environmental regulations, many of which mirror the Federal requirements must also be obeyed. In addition to the binding requirements of the Federal and State laws and regulations, numerous DOE orders and standards, and Environmental Protection Agency (EPA) and Nuclear Regulatory Commission (NRC) guidances provide auxiliary instructions and insights on complying with applicable laws. Finally, relevant case law provides the courts' interpretations of ambiguities and conflicts pertaining to the specific application of the laws and regulations.

Approach

Since the examination of the legal and regulatory aspects of recycling contaminated concrete can become very complicated, a three-tier approach has been used in this examination. The first tier is an overview of the pertinent laws and regulations that apply to the recycling of contaminated concrete. The second tier is the examination of relevant case law on recycling activities. The third tier is the impact of these laws and regulations to the various scenarios. Figure 12-1 illustrates the tiered approach.

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[14] 42 USC § 9601 et seq.
[15] 42 USC § 6901 et seq.
[16] 33 USC § 12551 et seq.
[17] 42 USC § 7401 et seq.
[18] 7 USC § 136 et seq.
[19] 42 USC § 300f et seq.
[20] 42 USC § 2011 et seq.
[21] 29 USC § 651 et seq.
[22] 49 USC § 1761 et seq.

Types of Waste

Integral to understanding which laws and regulations are relevant and applicable to recycling of contaminated concrete is a clear definition and understanding of the types of wastes encountered during D&D activities. Waste types included: solid wastes, hazardous wastes, α emitting wastes not defined as transuranic radioactive wastes, low level radioactive wastes (LLW), and mixed hazardous and radioactive wastes (Mixed Wastes).

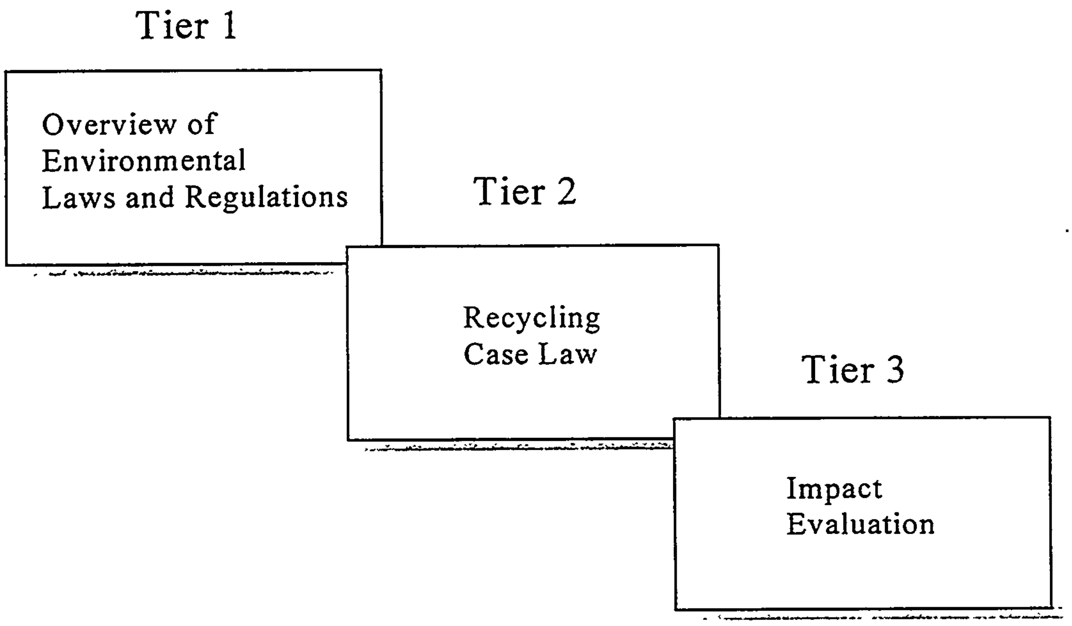

Figure 12-1. Three-Tier Approach to Legal/Regulatory Evaluation Solid Waste.

In 40 CFR 261.2, the EPA defines a solid waste as any material that has been discarded by being (1) abandoned, (2) recycled, or (3) considered inherently waste-like. The term "abandoned" includes materials that are disposed of, burned or incinerated, or accumulated or treated prior to conducting such activities. However, under 40 CFR 261.4(a)(4), EPA excludes source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954 (42 USC § 2011 et seq.). The Atomic Energy Act provides the following definitions: *source material* - uranium, thorium, or any other material determined to be source material, or ores containing one or more of the foregoing materials; *special nuclear material* - plutonium, uranium enriched in the isotope 233 or 235, or any other material determined to be special nuclear material, or any material artificially enriched by any of the foregoing; *by-product material* - any radioactive material yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material or the tailings or wastes produced by the extraction or concentration of uranium or thorium.

Hazardous Waste

A solid waste becomes a hazardous waste when it meets the criteria presented in 40 CFR 261.3. Under RCRA, EPA classifies hazardous waste as either characteristic or listed.

Characteristic wastes fall under the following four classifications:

1. Ignitable - flashpoint < 60 degrees Celsius or a non-liquid that is capable, under standard temperature and pressure of causing fire through friction, absorption of moisture, or spontaneous chemical changes and, when ignited, burns vigorously enough to create a hazard.
2. Corrosive - have a pH ≤ 2 or pH ≥ 12.5 or that corrode steel (SAE 1020) at a rate 6.35 mm/yr. at 55 degrees Celsius.
3. Reactive -
   - Normally unstable and readily undergo violent changes without detonating
   - React violently with water
   - Form potentially explosive mixtures with water
   - When mixed with water, generate toxic gases, vapors, or fumes in sufficient quantity to present a danger to human health or the environment; or
   - Cyanide or sulfide bearing waste that can generate toxic gases, vapors, or fumes in sufficient quantity to pose a threat to human health and environment when exposed to pH conditions between 2 and 12.5.
4. Toxic - based on a toxicity characteristic leaching procedure test (TCLP). Wastes that fail are classified as hazardous wastes.

Listed wastes are described in 40 CFR 261.31-33 and encompass the following:

- F wastes - wastes from non-specific sources.
- K wastes - wastes from specific sources.
- P wastes and U wastes - discarded commercial chemicals.

Additionally, if a solid waste is mixed with one or more hazardous wastes and is not excluded under 40 CFR 260.20 or 260.22, the solid waste is considered a hazardous waste.[23]

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[23] 40 CFR 261.3(a)(2)(iv).

Transuranic Wastes

Transuranic wastes (TRU) contain more than 100 nanocurries (nCi) of alpha emitting transuranic isotopes (atomic number greater than 92), with half-lives greater than twenty (20) years, per gram of waste exclusive of high level wastes.[24]

Low Level Wastes

The Low Level Radioactive Waste Policy Act defines Low Level Wastes (LLW) as any radioactive waste not classified as HLW, TRU, Special Nuclear Material, or by-product material. Low Level Wastes are further classified as Class A, B, or C as detailed in 10 CFR 61.55-56:

- Class A wastes are primarily short-lived radionuclides that have minimal disposal requirements.
- Class B wastes contain greater concentrations of radionuclides than Class A wastes and must be in a stable form prior to disposal.
- Class C wastes generally have longer half-lives than Class A or B wastes and therefore have more stringent disposal requirements.

Mixed Wastes

Mixed wastes are solid wastes that contain both hazardous and radioactive components. The major problem with mixed wastes is that EPA regulates the hazardous component and the NRC regulates the radioactive component. EPA, NRC, and DOE are working to develop comprehensive and cohesive regulations for mixed wastes. Currently, mixed wastes are covered by a set of guidelines which include: the October 4, 1989 EPA-NRC Guidance on the Definition and Identification of Commercial Mixed Low Level Radioactive and Hazardous Waste; March 13, 1987 EPA-NRC Siting Guidelines for the Disposal of commercial Mixed Low Level Radioactive and Hazardous Wastes; and DOE Order 5820.2A Management of Defense LLW.

Types of Scenarios

To simplify the analysis of the laws and regulations impacting the recycling of contaminated concrete, only three of the six scenarios need analysis but Scenarios 1 and 2 are sufficiently similar to be treated as one. Decontamination and recycling (Scenarios 1 and 2) and rubblizing in-place without decontaminating (Scenario 4) present different and untried approaches. The remaining scenarios present tested alternatives (clean burial, on-site disposal facilities, and the current practice). The two options are illustrated in Figure 12-2.

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[24] 40 CFR 191.02(i).

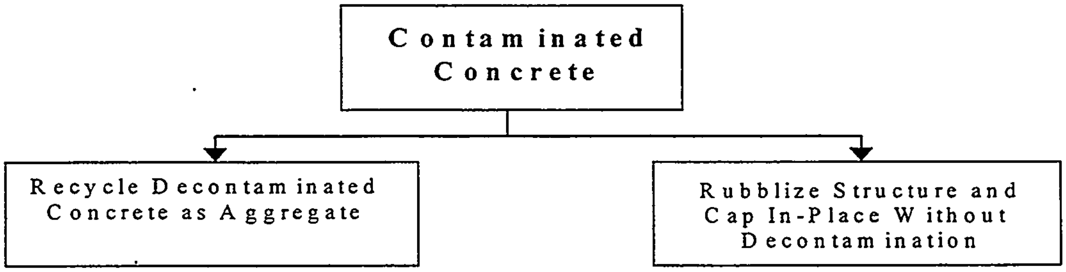

Figure 12-2. Scenarios Examined as Part of the Legal Review

The aforementioned laws and regulations will govern the decision as to whether the contaminated concrete:

1. May be decontaminated and recycled,
2. May be rubblized in-place

Routine environmental compliance associated with D&D operations has been addressed in a comprehensive manner elsewhere (DOE, 1995) and will not be included in this analysis.

Regulatory Overview

A brief review of the major regulatory drivers, including CERCLA; RCRA; NEPA; and DOE, NRC, and EPA free release criteria, is presented in the following.

CERCLA

The Comprehensive Environmental Response, Compensation, and Liability Act , also known as Superfund, addresses releases and threatened releases of hazardous and radioactive substances from abandoned waste sites. Once triggered, CERCLA mandates a very regimented approach to all activities at the site. CERCLA may be triggered in one of three ways: Occurrence of an actual release, the threat of an imminent release, or the initiation of decommissioning activities pursuant to "The Policy on Decommissioning of Department of Energy Facilities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)," May 22, 1995 (DOE, 1995c).

CERCLA has two major impacts on potential recycling activities. The first impact is that once triggered, the CERCLA process must be followed. This means that any recycling activities conducted in concert with a CERCLA response action (either removal or remedial) must be incorporated into the Removal Decision Document/Record of Decision process. This includes establishing an Administrative Record and providing opportunities for public input into the decision making process.[25]

The second, and potentially more critical impact is the future liability associated with the final use of the recycled concrete and the disposal of the process wastes and contaminated concrete. In the first instance, if free release levels change and recycled concrete exceeds these levels, CERCLA could be triggered. Second, if the wastes are placed in a disposal facility on-site or off-site and the disposal facility has a release at some point in the future, any and all parties which contributed waste to the facility may be liable for the remediation of the site under CERCLA Section 107.[26]

RCRA

The Resource Conservation and Recovery Act (RCRA) regulates the generation, transportation, storage, and disposal of solid and hazardous wastes. While RCRA does not directly regulate radioactive wastes, its potential impact on the recycling of contaminated concrete may be substantial due to the significant volumes of concrete contaminated with hazardous wastes and mixed wastes.

As with CERCLA, RCRA may be triggered in the D&D process by several different circumstances. The first is the designation of the facility in question as a permitted or interim status Treatment, Storage, or Disposal (TSD) facility. Any D&D activities (which include recycling) at RCRA facilities must comply with RCRA TSD closure requirements. A second trigger is the generation of any hazardous wastes during the D&D activities. The third trigger is the presence of mixed wastes. When the hazardous and radioactive components can not be separated, the wastes must meet both AEA and RCRA requirements.

Once triggered, RCRA impacts recycling contaminated concrete through several of its sections and implementing rules and regulations. 40 CFR 268 - Land Disposal Restrictions restricts land disposal of hazardous wastes. Recycling of hazardous materials is addressed under 40 CFR 261.6. The RCRA Debris Rule[27] elucidated the applicability of RCRA to debris contaminated with hazardous wastes. RCRA's Corrective Action Management Rule[28] establishes criteria for handing remediation wastes at TSD facilities. Finally, the proposed Hazardous Waste Identification Rule (HWIR)[29] proposes contamination levels for low-risk solid wastes, that have been designated hazardous because they are listed, or have been mixed with, derived from, or contain listed hazardous wastes, to exit the RCRA regulatory system.

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[25] 40 CFR 300.

[26] 42 USC § 9607.

[27] 57 FR 37194.

[28] 58 FR 8658.

[29] 60 FR 66344.

NEPA

The National Environmental Policy Act[30] requires that environmental values and impacts be given full consideration in Federal planning and decision making. Proposed actions may be excluded from NEPA review, require an environmental assessment (EA), or necessitate the preparation of a full environmental impact statement (EIS). DOE NEPA regulations[31] provide categorical exclusions for demolition and CERCLA Removal/RCRA Corrective Actions taking less than 12 months; however, actions that require siting, construction or expansion of TSDs or may disturb hazardous substances, pollutants, contaminants, or petroleum products to the extent there would be any uncontrolled releases do not qualify for a categorical exclusion.

Release Criteria

Release criteria, the surface or volumetric levels of contamination below which the risks to public health and the environment are acceptable, is one of the keys to a feasible recycling program. The release criterion establishes the level of decontamination that must be achieved before the material may be recycled or reused. The following discuss current release criteria.

DOE Order 5400.5

DOE Order 5400.5 - Radiation Protection of the Public and the Environment establishes standards to protect the public and the environment from undue risk to radiation. DOE Order 5400.3, Chapter IV, defines residual radioactivity as any radioactive material that is in or on soil (including rubble and debris), air, equipment, or structures as a consequence of past operations or activities. It establishes the following limits:

- Basic public dose of 100 mrem/year from residual and background radiation
- Interior building gamma radiation less than 20 µR/hr above background
- Surface contamination guidelines (See Table 12-1).

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[30] 42 USC § 4321 et seq.

[31] 10 CFR 1021, Appendix B.

Table 12-1. Surface Contamination Guidelines

Radionuclides	Allowable Total Residual Surface Contamination (dpm/100cm^2)		
	Average	Maximum	Removable
Transuranics, I-235, I-129, Ra-226, Ac-227, Ra-228, Th-228, Th-230, Pa-231	Reserved	Reserved	Reserved
Th-Natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-234, U-232, Th-232	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay product alpha emitters	5,000	15,000	1,000
Beta-gamma emitters except Sr-90 and others noted above	5,000	15,000	1,000

ALARA

As Low As Reasonably Achievable (ALARA) describes the management and control of exposure to and release of radioactive material. It is not a dose limit rather it is a methodology "in relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account."(ICRP, 1997)

10 CFR 20 Standards for Protection Against Radiation, Subpart E - Radiological Criteria for Decommissioning (Proposed)[32]

This rule proposed by the NRC would establish free release criteria for NRC licensees for residual radiation. The residual radiation is not to exceed a Total Effective Dose Equivalent (TEDE) of 15 mrem per year provided the residual radioactivity has been reduced to levels as low as reasonably achievable (ALARA).

NRC Reg Guide 1.86

NRC Regulatory Guide 1.86 - Termination of Operating Licenses for Nuclear Reactors establishes the release criteria for non-DOE facilities similar to those presented in DOE Order 5400.3

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[32] 59 FR 43228.

NRC Recycling Rule

The Nuclear Regulatory Commission has developed an enhanced rule making plan for promulgating a rule governing the recycling of radioactively contaminated materials. As with the EPA Clean-up Rule, the recycling rule will be risk based and was scheduled to be proposed in 1998.

EPA Cleanup Rule

Under the Atomic Energy Act and Reorganization Act Number 3, EPA was delegated the authority to promulgate standards for the clean-up of radioactively contaminated sites including soil, groundwater, surface water, air, and structures. EPA is in the process of developing this rule and it was scheduled to be proposed in the Fall of 1997. The concept for the proposed rule is to establish clearance (release) criteria based upon a protective dose. The rule will provide radionuclide values for both surface and mass contamination.

IAEA Safety Series No. 89

The International Atomic Energy Agency Safety Series 89 - Principles for the Exemption of Radiation Sources and Practices from Regulatory Control establishes an individual dose of 10 μSv/yr (1.0 mrem/yr) as the threshold for trivial doses (IAEA, 1988).

IAEA Safety Series 111-G-1.5 (Draft)

The International Atomic Energy Agency Safety Series 111-G1-1.5 - Clearance Levels for Radionuclides in Solid Materials has proposed unconditional clearance (release) levels for naturally occurring radionuclides (IAEA, 1995).

Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)[33]

MARSSIM is a multi-agency (EPA, NRC, DOE, and DOD) document whose objective is to "describe standardized and consistent approaches for surveys of soil surfaces and building surfaces, which provide a high degree of assurance that established release criteria, limits, guidelines, and conditions of the regulatory agencies are satisfied, while at the same time encouraging an effective use of resources. The techniques, methodologies, and philosophies that form the bases of this manual were developed to be consistent with current Federal limits, guidelines, and procedures."

Existing Case Law

Westlaw-Lexis was searched for case law pertaining to recycling concrete, metals contaminated with hazardous materials, and hazardous materials. Our search revealed no reported cases involving the recycling of concrete, either

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[33] NUREG-1575, EPA 402-R-97-016, F.R. February 11, 1998.

contaminated or uncontaminated. There was, however, a considerable volume of case law concerning the recycling of metals, hazardous materials (wastes), and metals contaminated with hazardous wastes. Nearly all of the case law, in this area, involved the determination of liability under CERCLA for past actions at a site. Five (5) cases, which may provide some insight into potential problem areas for recycling contaminated concrete, are presented. Four (4) of the cases are from the Federal court system and one (1) is from a State court. Appendix G lists the results of the case law search.

In *Owen Electric Steel Company v. Browner*[34] the US Court of Appeals Fourth Circuit found that slag produced as a by-product of steel production and temporarily stored on-site was "discarded" and therefore a solid waste subject to RCRA regulation. This finding was in light of the slag being recycled and used as roadbed material. The US Court of Appeals Eleventh Circuit in *US EPA v ILCO, Inc.*[35] found a secondary lead smelter in violation of RCRA for treating, storing, and disposing of a hazardous waste due to the lead components of spent batteries processed on the site. Both of these cases indicate the need for either RCRA permitting of any recycling operations or securing a RCRA exemption for the activities. The parallels of recycling contaminated concrete and the *Owen v. Browner* decision are especially important given the ultimate use of the slag as roadbed material (the primary intended use of the recycled concrete aggregate).

Insight into the possibility of recycling the concrete without first decontaminating it may be found in *USS Cabot/Dedalo Museum Foundation v. US Customs Service.*[36] In this case, the Dedalo Foundation was trying to export a surplus air craft carrier to India for salvage of the metals, materials, equipment, and components. The vessel was contaminated with PCBs. The US District Court ordered that since the vessel was to be "demolished" it must first be decontaminated in compliance with TSCA requirements prior to export. This case supports the need to either decontaminate the concrete or obtain a RCRA (or if necessary TSCA) permit prior to commencing recycling activities.

In *City of Chicago v. Asphalt Recovery Systems,*[37] the Appellate Court of Illinois ruled that in the absence of a permit to recycle, construction debris constituted waste and therefore the operation of an illegal dump. This case again emphasizes the need to permit the recycling activities under RCRA.

As for liability of potential end users of the recycled concrete, such as contractors building roads or ready-mix firms selling fresh concrete, those users

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[34] *Owen Electric Steel Company v. Browner*, 37 F.3d 146 (Fourth Cir. 1994).

[35] *US EPA v. ILCO, Inc*, 996 F.2d 1126 (Eleventh Cir 1993).

[36] *USS Cabot/Dedalo Museum Foundation v. US Custom Service*, 1995 WL 14354 (E.D.La.).

[37] *City of Chicago v. Asphalt Recovery Systems*, 596 N.E.2d. 74 (Appel. Court of IL 1992).

once removed from the actual production of the aggregate may have little CERCLA liability to worry about. In *Douglas County v. Gould, Inc*,[38] the US District Court ruled that sellers of lead plates made from recycled batteries were not liable for cleanup costs since the seller did not ship materials to the site and did not arrange for treatment of the lead at the site. This relieved the seller of the lead plates of liability for CERCLA response costs to clean-up the recycling site. While, this would not relieve the DOE from ultimate liability, it would increase the potential acceptance of the recycled aggregate by removing one potential liability from the end user.

Recycling with Decontamination

The scenario of greatest interest and potentially greatest return, both environmentally and economically, is to decontaminate the concrete and produce a usable product such as aggregate or fill material. This option will:

- Generate revenue from the sale of recycled material (or, offset the cost of virgin material),
- Reduce the volume of LLW facility capacity needed for disposal, and
- Reduce the volume of virgin material that must be produced and its attendant environmental impact.

The basic concept of this scenario is as follows:

- The concrete structure is decontaminated by either treating the concrete surface to extract the contamination or by removing the top layer of the concrete surface,
- The contaminated material is disposed at a LLW facility,
- The structure is demolished,
- Steel reinforcement is removed and recycled
- The concrete rubble is crushed and screened,
- Screen fines are disposed at a C&D landfill, and
- The recycled concrete is used as aggregate, base material, or fill.
  The recycled concrete may be used on-site for DOE projects or may be sold as aggregate/fill on the commercial market

The requirements of the applicable sections of the pertinent environmental laws and regulations which govern the discharge and release of material to the environment during the decontamination, demolition, and crushing components of the scenario must be met. Environmental compliance during these routine D&D activities is detailed in the DOE Decommissioning Resource Manual, DOE/EM-0246 and other DOE Orders, Standards, and Manuals.

There are four major areas of environmental concern other than general compliance issues for this scenario: Fulfilling the requirements of NEPA, meeting

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[38] *Douglas County v. Gould*, Inc, 871 F.Supp. 1242 (US District Court 1994).

RCRA recycling limitations, complying with free release levels, and potential long term liability from CERCLA and product liability.

NEPA

NEPA requires that for every major Federal action, a detailed statement on the project's environmental impact be prepared. The Statement should include:[39]

- The environmental impact of the proposed action,
- Adverse environmental effects which can not be avoided,
- Alternatives to the proposed action,
- The relationship between short-term uses and long-term productivity, and
- Any irreversible and irretrievable commitments of resources involved.

Under 10 CFR 1021, Subpart D, DOE has established groups of actions that are categorically excluded from the NEPA process or require only an Environmental Assessment. Appendix B categorically excludes relocation, demolition, and disposal of buildings and CERCLA removal and similar actions under RCRA meeting cost and time limits. These two categorical exclusions could provide the basis to exempt recycling activities associated with a single building or those D&D activities conducted as CERCLA removal actions. However, Appendix C, requires the preparation of an environmental assessment (EA) for major projects and the siting/construction/operation of on-site waste storage and disposal facilities. This section of 10 CFR 1021 may require the preparation of an EA for recycling activities involving large facilities, multiple facilities, or installation wide D&D/recycling efforts. Additionally, the establishment of a DOE-wide concrete recycling program may trigger the preparation of an EA due to the potential impacts on local economies of the production of large quantities of aggregate.

RCRA

As a threshold matter, facilities that have not been officially closed must first comply with the formal closure requirements that have been filed with the State before demolition can occur. These requirements will differ for containment buildings and those that are merely warehouses of hazardous wastes. Those closure requirements will be discussed below.

Recycling Solid Wastes

Under RCRA, the first requirement is to define the type of waste. Since hazardous wastes are a subset of solid wastes, the first determination is if the material is a solid waste. Unfortunately, determining if a material is a solid waste can be rather difficult. However, once the solid waste determination has been made, determining if it is a hazardous waste is fairly straight forward

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[39] 42 USC § 4332.

(Needleman, 1994). For our purposes, materials are solid waste if they are "used in a manner constituting disposal."[40] Materials are used in a manner constituting disposal if they are recycled by application to or placement on the land in a way that meets the broad definition of "disposal" found at RCRA section 1004(3). Additionally, materials that are used to produce a product that is applied to or placed on the land, as well as the product itself, are solid wastes.

Second, all of the above materials are solid waste if they are recycled by being burnt to recover energy or used to produce a fuel or are otherwise contained in fuels.[41]

Third, spent materials, listed sludges and by-products, and scrap metal are solid wastes if they are recycled by being reclaimed. Characteristic sludges and by-products and commercial chemical products are not.[42] A material is "reclaimed" if it is processed to recover a usable product or if it is regenerated.[43] In response to the ruling of the D.C. Circuit in *American Mining Congress v. EPA*[44] that the EPA had exceeded its authority in regulating certain reclaimed materials, the EPA proposed on January 18, 1988, to set forth in § 261.31-32 the factors it will take into consideration when it brings sludges or by-products under the ambit of regulation. The EPA proposed several factors and states in the preamble to the regulations that "[t]he ultimate object in applying these factors is to determine whether the sludges or by-products are being utilized in ongoing, continuous, manufacturing processes."[45] As of the date of this document the proposed factors have not been finalized.

Fourth, all of the above materials, except commercial chemical products, are deemed solid waste when they are "accumulated speculatively."[46] A material is accumulated speculatively when it is accumulated before being recycled in any manner.[47] This definition does not apply, however, if it can be shown that:

a. The material is potentially recyclable and has a feasible means of being recycled; and
b. At least 75% of the material by weight or volume is either recycled or transferred to a different site for recycling within a calendar year commencing January 1.

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[40] 40 CFR 261.2(c)(1)(i)-(ii).
[41] 40 CFR 261.2(c)(2)(i)-(ii).
[42] 40 CFR 261.2(c)(3).
[43] 40 CFR 261.2(c)(4).
[44] *American Mining Congress v. EPA*, 824 F.2d 1177 (D.C. App. 1987).
[45] 53 Fed. Reg. 519 (1988).
[46] 40 CFR 261.2(c)(4) (1987).
[47] 40 CFR 261.1(c)(8).

The 75% turnover calculation must be determined separately for each material of the same type that is recycled in the same way. Materials accumulating in units exempt from regulation under section 261.4(c), i.e., hazardous wastes temporarily exempted while they are in a product or raw material storage unit, pipeline, vessel, or the like, are not included in making the calculation, nor are materials which are already deemed solid wastes. Additionally, once materials are removed from accumulation for recycling, e.g., by actually being recycled, they are no longer in this category.

If the waste meets the definition of a solid waste and is a mixture of a hazardous (or more than one hazardous waste) and a solid waste, the waste is a hazardous waste.[48] Concrete and concrete rubble contaminated with hazardous wastes fall under this definition. Furthermore, contaminated concrete meets the definition of a recyclable material under 40 CFR 261.2(c).

Requirements for Recyclable Materials

Once it is determined that the waste is a recyclable material, it must be ascertained to what extent the material is regulated and the steps necessary for compliance. Recyclable materials are not regulated in precisely the same manner as hazardous waste in general. Determining exactly how a particular recyclable material is regulated, however, is again not an overly simple task.

The regulations setting forth requirements for recyclable materials are found at 40 CFR § 261.6. They are somewhat confusing in that they set forth a number of materials which are "exempted" from regulation under the section, when in fact those materials are subject to other, often more stringent, regulations. The scheme is as follows.

Generators and transporters of "non-exempt" recyclable materials are subject to the applicable requirements of Part 262 (governing generators)[49] and Part 263 (governing transporters)[50] of the RCRA regulations. Additionally, they are subject to the notification requirements set forth at section 3010 of RCRA.[51]

Owners or operators of facilities that store recyclable materials before they are recycled are regulated under all applicable provisions of Subparts A through L of Parts 264 and 265 and Parts 266, 270, and 124.[52] They must also comply with the notice provisions of section 3010 of RCRA. Parts 264 and 265 govern treatment, storage, and disposal facilities, although only those sections applicable to storage facilities would apply. Part 266 governs permit application

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[48] 40 CFR 261.3(a)(2)(iii).

[49] 40 CFR 262.

[50] 40 CFR 263.

[51] 40 CFR 261.6(b).

[52] 40 CFR 261.6(c)(1).

procedures. The recycling process itself, unless it is covered under Part 266, is exempt from regulation. Strangely, owners and operators of facilities that recycle recyclable materials without storing them before they are recycled are subject only to the notification requirements of section 3010 of RCRA and the manifesting requirements of 40 CFR §§ 265.71 and 265.72.[53]

Certain recyclable materials are "exempt" from the above regulations, but are subject to separate regulations under Part 266.[54] The word "exempt" is in quotations because Part 266 regulations often cross-reference the regulations applicable to generators, transporters, and treatment, storage and disposal facilities so that one who deals with these materials must comply with those regulations via the provisions of Part 266 in any event.

The EPA regulates recyclable materials subject only to the applicable subparts of Part 266, as follows: (1) recyclable materials "used in a manner constituting disposal," i.e., land-applied, are regulated under Subpart C; (2) hazardous wastes (recyclable materials) burned for energy recovery in boilers and industrial furnaces not regulated under Subpart O of Parts 264 or 265 are regulated under Subpart D; (3) used oil exhibiting one or more characteristics of hazardous waste and burned in boilers and industrial furnaces not regulated under Subpart O of Parts 264 or 265 are regulated under Subpart E; (4) recyclable materials from which precious metals are reclaimed are regulated under Subpart F (Subpart F requires compliance only with the manifest system and certain record keeping requirements applicable to storage facilities);[55] and (5) spent lead-acid batteries that are being reclaimed are regulated under Subpart G.

Finally, certain recyclable materials are altogether exempt from RCRA regulation.[56] These materials are: (1) reclaimed industrial ethyl alcohol, (2) used batteries returned to a battery manufacturer for regeneration, (3) used oil that exhibits a hazardous waste characteristic but is recycled in some way other than being burned for energy recovery, (4) scrap metal, and (5) various fuels, oil, and cokes from petroleum refinery operations meeting certain detailed criteria. The regulations should be consulted in detail for these substances.

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[53] 40 CFR 261.6(b)(2)(i)-(ii).

[54] 40 CFR 261.6(a)(2).

[55] It should be noted that the EPA Regional Director has the authority, pursuant to 40 CFR §260.40-41, to require, on a case-by-case basis, that recyclable materials from which precious metals are reclaimed be subject to regulation under Parts 262-66, 270, and 124. The criteria and procedures for these case-by-case determinations are set forth in the regulations in detail.

[56] 40 CFR 261.6(a)(3) (1987).

Obtaining a Variance

Subject to a number of standards and criteria, the EPA may, on a case-by-case basis, determine that certain recycled materials are not solid wastes and are thus not regulated under RCRA.[57] The types of recycled materials for which such a variance may be granted are: (1) materials that are speculatively accumulated without sufficient amounts being recycled, (2) materials that are reclaimed and then reused within the original primary production process in which they are generated, and (3) materials that have been reclaimed but that must be reclaimed further before the materials are completely recovered.

In order to obtain a variance, application must be made to the EPA Regional Administrator in the region where the recycling operation is located. The procedure for applying for a variance is not addressed in the same detail in the regulations as are procedures for de-listing petitions and equivalent testing method applications. The regulation provides only that the application must address certain relevant regulatory criteria.[58]

Obtaining a variance from the classification of a recycled material as a solid waste could be beneficial. Once the material is no longer considered a solid waste by virtue of the variance, compliance with the applicable regulations of RCRA is no longer necessary for as long as the variance is in effect. Obviously, the lack of need to comply could save a great deal of time and money. Depending on such factors as the amount of material involved, the likelihood of being able to make the necessary demonstrations, the cost of application, and the cost-savings that would result from obtaining the variance, DOE may or may not want to proceed with the application.

On May 26, 1998, the EPA issued the final rule on changes to 40 CFR 148, 261, 266, 268, and 271 regulating the recycling of mineral processing secondary materials.[59] While not specifically directed to contaminated concrete recycling, the language speaks to the issues of recycling concrete rubble with minimal amounts of hazardous material. Although the EPA has specifically addressed mineral processing wastes, the language of the rule bodes well for recycling efforts universally.

The rule opens with a general statement of intent. "The intended effect of this proposal is to *encourage safe recycling of mineral processing secondary materials by reducing regulatory obstacles to recycling*, while ensuring that hazardous wastes are properly treated and disposed." (Emphasis provided.)

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[57] 40 CFR 260.30.

[58] 40 CFR 260.33(a).

[59] 63 FR 28556-28753, Land Disposal Restrictions Phase IV:.

The EPA sets forth guidelines that create a classification of recyclable materials that will no longer be classified as waste.

To be excluded from the definition of waste, the materials must be managed to meet certain conditions such as being legitimately recycled, stored on a pad only for short periods, and not causing contamination. Mineral processing secondary materials would also be excluded from Federal waste regulations if they are returned to benefication units and meet certain conditions. If the materials do not meet the conditions excluding them from being wastes, and they test hazardous, they must be treated to meet land disposal restrictions, which are newly proposed in this rule.

EPA will make a judgment as to whether materials for recycling or products in the recycling process are not "solid waste" materials. The first step in this process is to determine whether or not the concrete has had excessive exposure to hazardous waste and whether it has retained levels of waste or has retained characteristics of those wastes. If the DOE decides that a waste is covered under RCRA, it should pursue exemption under the recycling statutes of RCRA. There is no precedent for recycled concrete, but the criteria for "recyclable" solid waste is universal and therefore, the EPA's approach with regard to metal and chemical recycling can be applied directly to concrete recycling.

Sham Recycling

The DOE would encounter little resistance if it were able to convince the EPA that the end product of a concrete recycling project would have a legitimate beneficial use. The DOE however, should keep in mind the experiences of Marine Shale. In *US v Marine Shale Processors*,[60] a company that claimed that it could produce reusable metal sludge took in a significant amount of revenues at the front end and then stockpiled the materials without ever re-selling or using them as they had advertised.

The EPA, in response to activities like this, discussed the issue of Sham recycling and identified factors they would use to assess the viability of a recycling project in Hazardous Waste Management System: Definition of Solid Waste Rule[61]:

> "First. Where a secondary material is ineffective or only marginally effective for the claimed use, the activity is not recycling but surrogate disposal. An example (provided in the comments) is use of certain heavy metal sludges in concrete. The sludges did not

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[60] *US v Marine Shale Processors*, 81 F.3d 1329 (5th Cir, 1996).

[61] 50 FR 614-668.

> contribute any significant element to the concrete's properties, and so we would not regard this activity as legitimate recycling."[62]

This section of the preamble was a clear reference to the activities of Marine Shale. Moreover, more important perhaps than the issue of actual use, is the issue of storage and the period of time between "treatment" or recycling and commercial application.

Land Disposal Restriction Storage Prohibition

RCRA §3004(j) prohibits the storage of wastes that have been prohibited from land disposal, unless that storage is for the purpose of accumulating sufficient quantities of hazardous wastes to facilitate proper recovery, treatment, or disposal. The Land Disposal Restriction applies to wastes that have been stored after the LDR effective date. However, once waste are removed from storage, DOE will have to comply with LDR treatments provisions.

Transporting wastes from one storage unit to another located on one's property does not constitute removal from storage and thus would not trigger LDR's. However, if DOE transports wastes to an off-site facility, that would constitute removal from storage and would trigger Land Disposal Restrictions.

Hazardous Waste Identification Rule[63]

The EPA has created a list of hazardous wastes based on certain classifications: the presence of constituents listed in appendix to 40 CFR part 261, the manifestation of one or more hazardous waste characteristics, or the potential to impose detrimental effects on the environment. The EPA has determined that these waste contain "toxic" constituents that pose unacceptable risks for environmental and human exposure. The EPA further believes that these constituents are "mobile" enough to reach human or environmental receptors.

There are four lists promulgated by the EPA that classify different hazardous wastes: 40 CFR 261.31, 261.32, 261.33(e) and 261.33(f). The four lists are broken down into two sets. One set describes hazardous wastes while the second list describes discarded chemical products.

In 1980, the EPA promulgated two sets of rules that dealt directly with the classification of listed wastes: the "mixture" rule and the "derived from" rule.

> Without a "mixture" rule, generators of hazardous wastes could potentially evade regulatory requirements by mixing listed

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[62] 50 FR 638.

[63] 60 FR 6634-366469.

> hazardous wastes with other hazardous wastes or non-hazardous solid wastes to create "new" waste that arguably no longer met the listing description, but continued to pose a serious hazard...Similarly without a "derived from" rule, hazardous waste generators and owners and operators of hazardous waste treatment, storage, and disposal facilities could potentially evade regulation by minimally processing or managing a hazardous waste and claiming that resulting residue was no longer the listed waste, despite the continued hazards that could be posed by the residue even though it does not exhibit a characteristic.[64]

The EPA, in implementing the "mixture" or "derived from" rules, neglected to address the concept of concentration. That is, the EPA never established de-minimis levels required for proper application of the two rules. Moreover, mixtures with extremely low concentrations levels still fell under the rubric of the "mixture" or "derived from" rule.

The "Mixture" and "Derived From" rules have enjoyed a storied evolution. Suits by various interested parties lead to judicial demands that the EPA's revise its rules.[65] At various times during the last decade, Congress also voiced its displeasure with the EPA. Various deadlines have been established and pushed forward with the most recent deadline for a notice and final rulemaking set for December 15, 1996 not being met. Recent meetings have failed to reach a consensus on de-minimis levels, but it is expected that a de-minimis exit rule will eventually be established.

The rule as proposed "allows rapid exemptions for mixtures and derived from wastes that present no significant threats to human health and the environment."[66] The rules will remain in force for mixtures that continue to pose a threat to the environment. For this project, the HWIR rule could have an immediate effect on treatment procedures or even avoiding initial classification as a hazardous waste under RCRA. The rule would establish a generic set of constituent specific exemption levels for listed hazardous wastes. Wastes with hazardous constituent concentrations below the generic exemption levels would be conditionally exempt from Subtitle C. The rule would be self-implementing requiring no prior governmental approval or review of documentation before wastes would be eligible for exit. Claimants would be required to meet certain

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[64] Proposed Rule 40 CFR Parts 260, 261, 266, and 268 [60 FR-66343-66469] Hazardous Waste Management System: Identification and Listing of Hazardous Waste Identification Rule (HWIR), Thursday, December 21, 1995 at 8, 9.

[65] See *Shell Oil v EPA*, F. 2d 741 (DC Cir. 1991); *Mobile Oil Corp. v. EPA*, 35 F. 3d 579 (DC Cir. 1994); and *Environmental Technology Council v. Browner*, C.A. No. 94-2119 (TFH) (D.D.C. 1994). Each of these cases challenged the EPA's promulgation of the "mixture" and "derived from" rules and lead to various court demands for reform.

[66] 60 FR 6634-66469.

prerequisites in addition to the generic constituent concentration levels before the wastes would be considered non-hazardous. Certain record keeping, testing conditions, and notification requirements would also be enforced.

In its rulemaking, EPA has suggested which constituents it believes will be likely to pose risks to ecological receptors. The EPA has not set benchmarks for all the constituents in its programs. As a matter of efficiency, EPA has set forth suggested exit levels for 191 specific constituents. "The Agency's proposed option for establishing exit values is based on risk modeling to a hazard quotient of 1 and 1 x 10^{-6} cancer risk. The Agency chose a hazard quotient of 1 as its toxicity benchmark for non-carcinogens because evaluation of these compounds presumes there is a threshold exposure above which individuals would be at significant risk of suffering the adverse effects attributable to the compound. The HQ is Agency's best attempt to estimate that level."[67]

The EPA proposes to use oral reference doses and inhalation reference concentrations as the basis for developing the exit criteria for non-carcinogenic constituents. It further proposes to use the "oral cancer slope factor and inhalation cancer unit risk basis for developing exit levels for carcinogenic constituents unless the non-carcinogenic effects occur at more limiting levels."[68]

The EPA had to backcalculate exit levels based upon what constituent concentration in a waste would not exceed the target risk. The equations used were taken from Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustion Emissions. The Science Advisory Board is currently making suggestions for revisions. These revisions will affect the equations used in EPA's analysis if the revisions are incorporated into the current instruments.

The EPA has currently proposed two exit tables: Table A which establishes exit levels for constituents with modeled or extrapolated risk-based levels which can be reliably quantified and Table B which presents quantitation-based exit levels for constituents with methods that cannot reliably quantify the modeled or extrapolated risk based levels. These tables are not included as they are subject to comment and revision and should probably be considered relevant only in their final form.

The EPA has proposed a sub-section in the HWIR proposal that addresses the issue of dilution.[69] The EPA continues to characterize dilution as an "environmentally inappropriate" means of reducing concentrations. The EPA defends its position on a number of grounds, all related to the fact that dilution

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[67] 60 FR 66351.

[68] 60 FR 66352.

[69] 60 FR 66385 Section VII.

would have no effects on the actual mass of toxicant released into the environment. For this reason the EPA proposes to continue its ban on dilution except as provided under the LDR program under CFR 40 268.3(b).

"The EPA proposes three approaches to data evaluation in its rulemaking:

1. Generators would be required to evaluate their waste based on the maximum detected concentrations of the exemption constituents.
2. Analytical results are evaluated in terms of an upper confidence limit around an average concentration.
3. Allow facilities to use long term average data to demonstrate compliance without consideration of the upper confidence limit.

For any of the three approaches, representative samples would be collected in support of exemption under today's proposed rule, consisting of a sufficient number of samples to represent the "spatial and temporal variability of the waste characteristics, regardless of how the sample number is determined."[70]

When and if the EPA chooses one of these approaches to data evaluation, the effects will be far-reaching. This decision is an important one because the EPA here decides whether to use average levels for deciding compliance or whether individual samples should control. The EPA has proposed a system whereby an exit level controls for average concentrations and a second exit level controls for peak readings in any individual sample. This will allow a few individual samples to register above the first "average level" while still insuring that no individual sample poses a significant human or ecological effect.

Moreover, the proposed HWIR program would provide a flexible structure to different areas of RCRA. The legal effects on this proposal could be enormous in that HWIR would provide a road map for compliance with and exit from RCRA. If the EPA provides, as it has in its proposal, a table listing de-minimis exit levels for hazardous waste constituents, the logistics of a treatment or recycling program would be simplified. It is anticipated that EPA will publish an updated proposed rule by October 31, 1999 and the final rule by April 30, 2001. (EPA 530-F-97-052 March 1998)

On November 30, 1998, EPA issued its Final Rule on Hazardous Remediation Waste Management Requirements (HWIR-Media) (63FR65874-65947) which will first make "permits for treating, storing and disposing of remediation wastes

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[70] 60 FR at 66387.

faster and easier to obtain; second, they provide that obtaining these permits will not subject the owner and/or operator to facility-wide corrective action; third, they create a new kind of unit called a "staging pile" that allows more flexibility in storing remediation waste during cleanup; fourth, they exclude dredged materials from RCRA Subtitle C if they are managed under an appropriate permit under the Marine Protection, Research and Sanctuaries Act or the Clean Water Act; and fifth, they make it faster and easier for States to receive authorization when they update their RCRA programs to incorporate revisions to the Federal RCRA regulations."

CERCLA

Many DOE sites in the United States are currently classified as National Priority List (NPL) sites. Recycling materials from a NPL/CERCLA site presents a number of additional regulatory obstacles. Most relevant to DOE would be the CERCLA Off-site Rule[71] that applies to materials taken from a CERCLA site to be used for a purpose other than disposal. The Off-Site rule sets forth stipulations for hazardous materials taken from CERCLA sites during remedial and removal activities.

DOE will have to be concerned about the designation of waste management facilities for CERCLA wastes. DOE waste management facilities that might receive waste from CERCLA activities at other DOE sites or from CERCLA activities at other locations of their own site, would be required to qualify as acceptable under the Off-site Rule. This process would be an administrative burden and might trigger the need or accelerate the schedule for facility wide investigations. The Off-site Rule effectively establishes the need for DOE to assess the likelihood of receiving CERCLA waste from Off-Site, evaluate whether on-site hazardous waste management facilities would be deemed acceptable, and determine actions required to make them acceptable.

For a concrete recycling project, there is the possibility that the crusher and screen could be transported "on-site" thus avoiding regulation under the Off-site Rule. The EPA defines "on-site" as any area within CERCLA defined boundaries. Thus, if the equipment was on DOE property but was not within the CERCLA defined area, it would be considered "Off-site" and would be regulated accordingly. Certainly, if processing were to occur at another DOE facility, the Off-Site Rule would apply.

The CERCLA Off-Site Rule does not address recycling specifically. However, by referring projects to Subtitle C of RCRA, the EPA points regulation in a certain direction. A project that sets out to recycle CERCLA waste presents

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[71] 58 FR 49200-49218.

an unusual set of circumstances. In light of how recent the Off-Site Rule is (three years old), it is difficult to predict the EPA's reaction to a CERCLA site recycling its own materials using its own processes. The regional offices of the EPA are likely to consider an Off-Site recycling project on a case by case basis. The EPA would likely take into consideration, the nature of the materials to be recycled as well as the actual process of recycling and the potential impacts that could arise.

If DOE facilities are classified as CERCLA sites, the process of administration and documentation could be facilitated if the concrete processing occurred on the actual CERCLA sites rather than Off-Site at other facilities. Once the process has been documented and presented to the EPA, the regional offices could set forth de-minimis levels for emissions and hazardous characteristics, etc. The Off-Site Rule generally applies to DOE when they use external facilities to process wastes.

After the concrete has been decontaminated and recycled into aggregate, the threat of liability under CERCLA Section 107[72] still exists. Section 107 establishes liability for the costs associated with removal and remedial actions, natural resource damages, health assessments, and any other response cost associated with the release of hazardous substances with:

- Generators of the hazardous substance,
- Current owners and operators of the site or facility,
- Past owners and operators of the site or facility,
- Transporters, and
- Arrangers of transportation and disposal of hazardous substances.

CERCLA 107 liability may result from three scenarios. The first is a release from the disposal facility that accepted either the decontamination wastes or the contaminated rubble. Unfortunately, this scenario exists for both recycling and disposal options. The second possibility for Section 107 liability is the accidental release and subsequent use of concrete that did not meet the free release levels. DOE and its contractors would be liable for all damages caused by the contaminated concrete and the costs associated with remediation (removal) of the contaminated product. The final Section 107-liability scenario is the possibility of changes in the free release criteria to a more stringent level. The recycled concrete would then be considered hazardous and could trigger CERCLA.

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[72] 42 USC § 9607.

Free Release

As discussed earlier, there are currently no laws or regulations that establish free release criteria. DOE Order 5400.5 - Radiation Protection of the Public and the Environment establishes a basic dose of 100 mrem/year above background that should not be exceeded. The order establishes a threshold of 20 μR/hr of gamma radiation for the interiors of buildings scheduled to be reused. Residual soil radiation standards are derived from the basic dose limits through a pathway analysis. Finally, surface contamination levels for structures, equipment, and salvageable scrap are set forth. However, no volumetric release levels exist for rubble such as the concrete to be recycled.

Fortunately for radioactively contaminated concrete, nearly all contamination is found near the surface within the first three centimeters (Bechtel, 1994; Dickerson, 1995; USNRC, 1994). Proper application of decontamination technologies prior to demolition of the facility should result in concrete rubble well below the surface contamination criteria of DOE Order 5400.5.

A second alternative for free release does exist. Based on the 100 mrem/year dose limit, volumetric (or mass) release levels may be determined. The contaminated concrete could be crushed, transforming the surface contamination into volumetric contamination. Results of model runs by the German Commission for Radiation Protection (SSK)(Thierfeldt, 1995) and actual results from the Formerly Used Sites Remedial Action Program (FUSRAP) (Kopotic, 1996) indicate that crushing the contaminated concrete will provide a final material which meets the established soil free-release criteria. The FUSRAP program has employed this process, with the concurrence of the appropriate State regulatory agencies, at three locations (Aliquippa Forge Site, PA; C.H. Schnoor Site, PA; and Colonie Site, NY). The final average volumetric contamination levels for the sites ranged from 7.5 pCi/g to 15.5 pCi/g which were well below the soil free release levels of 35 to 50 pCi/g which had been established for the sites. Based upon the German and FUSRAP experiences, requests for site specific variances for volumetric release criteria hold substantial promise for recycling contaminated concrete.

State Regulations

Each State has an agency that serves as the State's equivalent of the EPA. The following presents the Tennessee regulatory scheme as an example of States' approaches.

The Tennessee Solid Waste Disposal Act would control for any recycling or disposal activities within Tennessee. The division that monitors solid waste disposal activity is the Division of Solid Waste Management (Gaba and Stever, 1992). Possible relevant statutes can be found in language of the Tennessee

Solid Waste Disposal Act Section 68-31-101 under Unlawful methods of disposal: "construction or operation of a solid waste processing or disposal site in violation of the rules and regulations or in such a manner as to create a public nuisance." (Section 68-31-104) The fines for non-compliance are substantial (five thousand dollars [$5,000.00] per day per incident).

If approval were given for the concrete recycling project under solid waste disposal or management, further negotiations would have to be entered into with the Department of Radiological Health. The Department would either disapprove the levels offered by the project or might set de-minimis levels that met with their satisfaction for State activity involving radioactive materials.

Moreover, all of the requirements that are imposed at the Federal level are imposed at the State level as well. Depending on the State, State regulatory schemes could be even more complex than Federal regulatory schemes.

The recent experience of using a rock crusher at several FUSRAP sites to crush concrete for reuse provides insight into the differing State approaches. The rock crusher was used in four recent applications: Pennsylvania, New York, Missouri, and Ohio. The process was generally straightforward. Concrete taken from DOE facilities was crushed into rubble and the rubble was to be used as "back fill" at the same sites from which it was taken.

In order to navigate Federal and State regulatory schemes, test runs were conducted during which precise measurements of air emissions and water emissions were taken as well as measurements of hazardous content and radioactivity in the final product. These results were evaluated and, once internal DOE approval was received, were disseminated to the four States in which DOE sites intended to use the rock crusher.

The States of Missouri, New York and Pennsylvania allowed the crushed concrete to be used as fill material. The rock crusher, however, encountered resistance in Ohio. The Ohio NRC refused to allow DOE to reuse certain crushed concrete that exhibited any traces of radiation. This material was sent to a LLW facility for disposal.

Molten Metal Technologies

Regulatory schemes at the State level are as complicated as Federal regulatory schemes. Consider the experiences of Molten Metal Technologies in Massachusetts.

The experience of Molten Metal Technology, Inc. (MMT) of Waltham, Massachusetts, illustrates the barriers that Massachusetts law once erected for companies that are trying to develop new recycling technologies. MMT is one example of a company that was advancing a new recycling technology to deal with non-hazardous and hazardous waste, while facing a State regulatory regime that was not designed to accommodate MMT's needs (Rosenberg, 1994/1995).

Massachusetts's regulatory compromise in the case of MMT and their CEP recycling process suggests possible approaches to negotiating with State agencies.

Molten Metal Technology (MMT), a Massachusetts based firm, introduced a process technology called Catalytic Extraction Processing in 1993. Catalytic Extraction Processing dissolves solid metallic waste in a bath of molten metal and converts the constituent parts into a new functional material. Metal used in the Catalytic Extraction Process is categorized as "hazardous" and is controlled under Federal RCRA statutes as well as Massachusetts recycling regulations (Rosenberg, 1994/1995).

The process discussed in this instrument involves cement rubble but the applicable Federal and State regulations are likely to resemble the regulations that affected MMT. MMT's experiences while "negotiating" a compromise with Massachusetts's regulatory agencies reveal impediments similar to those that a cement-recycling project is likely to encounter at the State level.

> "MMT's experience demonstrates how the law may hinder the development and marketing of innovative hazardous waste recycling technologies (Rosenberg, 1994/1995)." Moreover, MMT's experiences in bringing their recycling process to market reflect the lag in environmental regulation as process technologies develop advanced solutions to the problem of excess hazardous solid waste.
>
> ...special permitting laws had to both encourage companies to invest in research and development (R&D) for new technologies that recycle hazardous waste, and safeguard the public and the environment. MADEP recognized this need and worked closely with MMT to develop new regulations to cover activities similar to those of MMT.
>
> The MMT experience offers valuable insight and guidance into how the law should evolve in response to technological innovation. Also, by looking at MMT's experience, other similarly situated companies can learn how to operate under the law as it now stands, and regulators in other States can modify and develop their laws to include provisions for permitting research and development facilities like MMT's Fall River Facility (Rosenberg, 1994/1995).

MMT has since gone into bankruptcy.

Rubblize In-Place

The other scenario to be addressed is rubblizing the structure in-place. This option will:

- Eliminate the costs of concrete decontamination,
- Eliminate the need to transport the waste material to an off-site disposal facility, and
- Eliminate the cost of off- or on-site disposal.

The basic concept of this scenario is as follows:

- The structure is demolished in-place but not decontaminated, and
- The rubble is capped.

There are two major areas of environmental concern other than general compliance issues for this scenario: meeting mixed waste disposal requirements, and long term liability from CERCLA.

Mixed Waste Disposal Facility Requirements

Capping the rubblized, contaminated concrete would entail meeting the RCRA and NRC requirements of 40 CFR 264 and 10 CFR 61.[73] These regulations detail the design, construction, and monitoring for hazardous and LLW waste disposal facilities. The major concern for this scenario would be triggering the RCRA requirement for a liner due to hazardous materials associated with the concrete rubble.[74] It would be essential that the volumetric contaminant levels be below the RCRA triggers or exhibit no mobility.

Depending on the type of hazardous material associated with the concrete, the land disposal restrictions under 40 CFR 268 may be triggered. In the event that a hazardous material prohibited from land disposal is associated with the concrete, a variance from land disposal restrictions may be required.[75]

The closure requirements of any State permit and/or Federal Facilities Agreement would have to be met or amended prior to reusing of the contaminated concrete to construct a disposal facility.

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[73] 10 CFR 61 - Licensing Requirements for Land Disposal of Radioactive Wastes.

[74] 40 CFR 264.

[75] 40 CFR 268.8.

CERCLA

In the event that the mixed waste facility released contaminants to the environment at some point in the future, CERCLA Section 107 liability could come into play.

CHAPTER 13 – SOCIAL AND POLITICAL CONSIDERATIONS[76]

Public Participation

Public involvement in DOE decision making entered a new phase in 1987 when Executive Order 12580, "Superfund Implementation," was signed. It required EPA to list all the federal facilities (not just those facilities within EPA) needing a preliminary assessment for environmental cleanup. Prior to this time, federal facilities were exempt from Superfund requirements. EPA released its "docket" in 1988, which identified forty DOE facilities needing assessment (U.S. DOE 1992).[77] By 1989, DOE had evaluated these facilities and since then, the agency has been subject to the CERCLA requirements for public involvement. Specifically, Section 117 and 113(k) of CERCLA mandate the opportunity for citizens to comment on DOE's proposed cleanup and development projects. In addition, Section 117(e) provides reimbursement to individuals that are affected by site contamination for expenses related to reviewing CERCLA documents, such as hiring experts to interpret technical information.

In 1994, these requirements were further strengthened when NEPA provisions were integrated into the CERCLA process.[78] Because of the integration, DOE must now hold public scoping meetings, notify the public of agency activities, allow citizens to comment on proposed DOE projects and policies, file agency administrative records in publicly accessible locations, and hold public hearings (U.S. EPA 1992).

While CERCLA requires citizen participation in DOE decision making, the agency has struggled with citizen involvement as a whole. A number of groups have called for stronger citizen involvement mechanisms in DOE decision making. The National Commission on Superfund requested an expanded public role in DOE decision making to strengthen the agency's policies (The Keystone Center and ELC 1994). The Federal Facilities Environmental Restoration Dialogue Committee recommended that managers of DOE facilities improve their

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[76] This Chapter was prepared at the Vanderbilt Institute for Public Policy Studies, independently of the rest of the volume and represents a theoretical approach to public participation and may not in all cases reflect positions that DOE is allowed to take under current US laws and policies. Additionally, the interviewees cited represent a limited spectrum of DOE stakeholders.

[77] By 1991, the docket of federal facilities requiring preliminary assessment under CERCLA included 75 DOE facilities (U.S. DOE 1992).

[78] In June 1994, then-Secretary of DOE, Hazel R. O'Leary, issued the agency's new policy on the National Environmental Protection Act. It states that while DOE will rely predominantly on the CERCLA process for reviewing environmental remediation actions, the agency will follow the public participation tenets of NEPA. The goal of integrating these two policies was to minimize paperwork, delay, and resource expenditures, and to eliminate overlapping legislative requirements (U.S. DOE 1995c).

interaction with individuals and institutions affected by agency cleanup operations (Applegate and Sarno 1996).

This section explores the importance of citizen participation, its continuum of involvement, and its role in DOE. To frame the discussion, a definition of the "public" is provided. It is followed by a brief theoretical and pragmatic discussion on the importance of citizen involvement in decision making. Finally, a typology of citizen participation provides some texture to the discussion and a theoretical template against which to analyze DOE's public involvement policy.

Who is the public? A definition

One of the most fundamental questions in public participation debates is who is included in the "public." In general, the public can be divided into two broad classifications. The first classification addresses what can be called the direct public. It includes all organized or unorganized groups of citizens or citizen representatives who can (a) provide information useful to solving the issue at hand or (b) otherwise affect the ability to implement the eventual decision (Thomas 1993). It comprises special interests such as corporate organizations (e.g., business lobbies, labor unions, program beneficiaries), consumer, citizen, and environmental groups. In addition, it includes state and local governments that are affected by the potential policy, residential groups (either organized homeowners' associations or unorganized residents who are geographically targeted by a decision), and advisory committees that involve representatives of any of the above groups. Finally, the direct public comprises any unorganized individual who is affected by the proposed action because of proximity or risk.

The second broad category of the "public" includes individuals that are not directly affected by the proposed project or public policy. This group can be called the indirect public. Here, individuals are affected by the action later in time and/or removed in distance. The indirect public is largely comprised of three sub-populations. The first sub-group includes future populations that could potentially be affected by the decision at hand. The second sub-population is closely related to the first. It includes individuals that are physically removed from the affected area, but who may be directly impacted by the proposed project or policy if they chose to travel to the area of proximity. Finally, the third sub-population is perhaps the most abstract segment of the indirect public. It includes those individuals that are intrinsically affected by a policy decision. Individuals may, for example, derive utility from the existence of a natural resource by implementing a proposed project or policy even if they themselves do not physically use or visit that site (Hanley and Spash 1993). By changing the characteristics of that resource, an individual's non-use value may change for better or worse.

Because of the abstract nature of the indirect public, it is difficult (and sometimes impossible) to include them in governmental negotiations. So, the degree of effect to indirect populations is often too complex to evaluate. In addition, assigning nonuse values to a resource or determining the degree of health and property effect for future populations can be an imprecise and arduous task. For these reasons, decision makers (and analysts) tend to focus on estimating the effect to direct populations rather than those individuals that are indirectly affected.[79]

Why Include the Public?

While both CERCLA and NEPA mandate public participation in DOE decision making, it is also desirable for a number of reasons. Sociologists, political scientists, and philosophers agree that citizen involvement is necessary for democracy. The sociological perspective argues that postwar American society has witnessed the erosion of institutions such as the family, workplace, organized religion, and the physical community through which individuals form political alliances and take political initiatives. Absent such institutions, citizens are more susceptible to anti-democratic events such as manipulation by a totalitarian elite (Cole 1974).

Unlike the sociologists' concern with the debilitating effects that inadequate participation might have on democratic systems and social order, the political science and philosophical perspectives emphasize the unfavorable consequences on the individual's social and psychological development. Classical theorists such as Plato, Rousseau, Mill, and Dewey stressed the importance of direct public participation in government affairs. Plato emphasized that in a stable society each individual contributes to the whole to which he or she belongs. By denying citizens access to government affairs, individuals' contributions to society is diminished. The result is a threat to society's existence altogether.

Later, Rousseau and Mill expanded upon Plato's theory. These theorists claimed that civic participation guards against the domination of a few elites. Both scholars identified the psychological benefits of citizens feeling in control of their destinies because citizens expect to be able to influence collective decisions that affect them, even if they may not choose to exert that influence.[80]

Similarly, Dewey reasoned that public involvement has educational benefits; it creates a populace that understands its government affairs (Dewey 1929, 1930). In addition, citizen involvement strengthens society by building a sense of community. Dewey reasoned that the product of an educated public

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[79] Applied economic theory has attempted to account for the degree of affect to indirect populations with some success.

[80] These arguments are shared by Almond and Verba (1961).

and strong community is greater social tolerance, which is the root of social change. Contemporary political philosophers and political scientists extend the classical arguments for citizen participation and its role in public education. Their primary tenet is that public involvement guards against a vast system of institutions that maintains an ignorant populace.

In addition to the theoretical arguments for citizen involvement, there are also several pragmatic reasons to incorporate the public into governmental decision making. Participation is essential for improving services to citizens who are affected by a particular decision. Studies of lay judgments about technological hazards reveal a sensitivity to the social and political values that government models do not often acknowledge (Fiorino 1990). Also, citizens often see problems, issues, and solutions that experts miss (Isaacson 1986). For example, it was citizen observations rather than scientific experts that identified the risks of DES[81] and Agent Orange (Brown 1987). By promoting citizen participation, government officials can identify public concerns and values in open forums and draw on the expertise citizens have on the issues at hand.

Citizen involvement in institutional decision making also helps prevent organizations from supplying information and making recommendations in conformity with their past practice (Fiorino 1990). While historical information is useful in policy development, if used exclusively, institutions will gradually become rigid, bureaucratized organizations which do not change over time. In contrast, institutions that incorporate citizen information into their decision making process are more likely to create a policy or program that is a better reflection of the wants and needs of their constituencies.

Citizen participation has additional benefits beyond creating better policy. It also injects accountability into decision making. Citizens who are informed of and participate in a policy making process are more likely to monitor that policy's implementation. Should the policy's implementation course stray from its original intent, citizens will possess the knowledge to question such activity and demand agency accountability.

By including the public in an agency's decision making process and holding itself accountable to citizen scrutiny, public perceptions of both the agency and its decisions are likely to improve. When citizens have the opportunity to influence the policies that govern them, the result is increased public trust in government.[82] Public distrust has been and will continue to be an issue for many governmental institutions to overcome.

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[81] DES (diethyl-stillbestrol) is a synthetic estrogen drug that was given to millions of pregnant women from 1938-1971. The drug was later associated with cancer and reproductive problems.

[82] La Porte and Metlay (1996) define trust as "the belief that those with whom you interact will take your interests into account, even in situations where you are not in a position to recognize, evaluate, and/or

Increased accountability is only one public involvement method to ameliorate citizen distrust. There are many others. For example, public participation gives citizens access to information that would otherwise be kept internal to the institution. Citizens that are equipped with agency information are less likely to speculate about what criteria shape the eventual policy. In addition, information supplies citizens with the proper tools to make realistic demands upon the agency.

Finally, while the literature shows public involvement is beneficial to both citizens and government, in practice, organizational officials are often reluctant to solicit citizen inputs because it may prolong the amount of time required to complete the decision making process. It is important to understand the alternatives to limited delays. When citizens are not satisfied with their role in a decision making processes, they often take matters into their own hands. Excluded citizens frequently respond by forming opposition groups that seek to influence the policy decisions through litigation or legislative challenges (Susskind 1994). Such confrontational approaches often do not produce fair or efficient outcomes. Indeed, they generally halt the proposed agency action, absorb more budgetary resources than if the public were included at the onset, and create ill feelings and mistrust that an agency must confront in future interactions (Susskind 1994).

While the evidence on the merits of involving the public in policy making is great, there is disagreement, however, over the desirable degree of and procedure for participation, as well as the role the public plays in the decision making process (Almond and Verba 1961; Barber 1984; Fiorino 1989; Pollak 1985; Renn et al. 1984, Renn et al. 1993; Rosener 1978; Schrader-Frechette 1985). It occurs because institutions generally seek to limit the role that the public plays in decision making. In contrast, the public generally seeks to expand its influence. In order to better understand why these differences exist, the following section explores the typology of public participation. It examines to what degree enhanced public participation is likely to be effective so that it satisfies both the organization's and citizens' needs.

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thwart a potentially negative course of action by 'those trusted.'" These authors argue that when individuals say government has lost its public trust and confidence, then members of the public believe that agencies, government contractors, and politicians do not intend to take their interests into account and do not have the competence/capability to act if they tried to do so. When individuals say government has lost their trust and confidence, then these members of the public believe that agencies, government contractors, and politicians neither intend to take their interests into account nor do they have the competence/capability to act if they tried to do so.

Citizen Participation

Sherry Arnstein (1969), the former Chief Advisor on Citizen Participation for Model Cities under the U.S. Department of Housing and Urban Development, provided some of the earliest pragmatic insights on the multiple roles of public involvement in government affairs. Arnstein notes that while everyone applauds the inclusion concept, during its implementation differences abound. Bureaucratic organizations and their leaders amass power in order to justify their existence. Because an increase in citizen power necessitates bureaucrats to relinquish power, they will likely dismiss citizen demands (Wilson 1989).

Arnstein developed a typology of citizen participation to better understand the different levels of public involvement and their usefulness. In her discussion, she uses the image of an eight-rung ladder, where each rung corresponds to a scope of citizen power in determining decisions. At the bottom of the participation ladder lies traditional (rhetorical) participation, while at the top is a high degree of citizen power, as seen in Table 13-1. Arnstein's metaphor, which by her own admission is a gross simplification of a complex and finely graded continuum, is helpful for exploring the role that public participation can play in organizational decision making. It also offers a means to later compare DOE's citizen involvement strategies to the continuum Arnstein describes.

At the bottom of the ladder, are *manipulation* and *therapy*. *Manipulation* is an illusory form of participation, in which citizens are placed on agency-sponsored advisory committees to "rubber stamp" official decisions. Such participation is used to serve an organization's public relations objectives rather than to influence its decision making.

Therapy has a similar lack of influence on decision making. Its aim is to educate citizens and "cure" them of their pathological views of the policy or program. Indeed, therapeutic strategies generally seek to justify an institution's decisions after they are made. Like manipulative approaches, therapeutic strategies do not substantively promote participation--they are generally no more than publicity devices.

The next rungs of citizen participation in Arnstein's typology -- *informing*, *consultation*, and *placation* -- promote minimal participation if used on their own. They are, however, precursors to richer forms of public participation. Each of these strategies provide citizens with a better understanding of their rights, responsibilities, obligations, and alternatives. Examples of *informing* strategies include press releases, newsletters, pamphlets, and brochures. While informing is an important part of public involvement, it lacks an exchange of ideas because of its emphasis on information flow from the decision maker to the citizen as opposed to the citizen to the decision maker. Thus, it should be coupled with other more participatory types of citizen involvement strategies that are discussed later.

Table 13-1. Public Participation Ladder

Public Participation Strategy	Characteristics	Examples
Traditional		
1. Manipulation	· Illusory form of participation · Used for public relations	Agency advisory committees
2. Therapy	· Education to cure pathological views	Decision-by-agency (decide, announce, defend)
Minimal–**includes all of the above strategies, but also:**		
3. Informing	· Precursor to richer forms of public participation. · Provides citizens with a better understanding of their rights, responsibilities, obligations, and alternatives. · Lacks a genuine exchange of ideas.	Public documents, press releases, pamphlets, brochures, news-letters
4. Consultation	· Adds a single reverse flow of information from citizens to decision makers. · Lacks a genuine exchange of ideas.	Attitude surveys, neighborhood meetings, public hearings, and public comment periods
5. Placation	· Citizens advise. · Agency maintains *complete* decision making authority. Iterative reverse flow of information from citizens to decision-makers.	Scoping meetings, informal question/answer meetings, field trips, citizen advisory committees
Moderate– **includes all of the above strategies, but also:**		
6. Partnership	· Citizens and decision makers *share* planning responsibilities · Citizens and decision makers *share* decision making responsibilities.	Negotiations (mitigation and compensation, reg-neg, charettes, and ADR) and workshops
7. Delegated Power	· Citizens have decision making authority.	Citizens may have a majority of seats on a democratic decision making board, or limited veto power such as a referendum.
Maximal– **includes all of the above strategies, but also:**		
8. Citizen Control	Citizens are in charge of analysis, policy, management, and governance of programs.	Local veto power/ballots, participatory research

Consultation is the fourth rung on Arnstein's ladder. It is a process whereby an organization actively solicits citizen comments on an issue. Consultation goes beyond those public participation methods already mentioned because it incorporates a reverse flow of information from citizens to decision makers, although, in a rudimentary form. Some examples of consultation strategies include soliciting written public comments and holding public hearings.[83] Another form of consultation is the public survey, which obtains information on broad public opinions. Surveys incorporate the views of the "uninterested but affected public"--those individuals who do not typically attend public hearings and often lack representation in policy development (Milbrath 1981). Surveys, however, are often un- or underutilized because they are generally a more expensive public involvement strategy than are public hearings.

Placation allows citizens to advise decision makers on the issue at hand. Some examples of placation techniques include, informal question/answer meetings, field trips, citizen advisory committees. Many environmental agencies such as the U.S. Forest Service, Bureau of Land Management, Environmental Protection Agency, and DOE routinely use placation strategies to fulfill the statutory requirements. While these tools are useful, they tend to perpetuate a paternalistic position in which the agency official determines the legitimacy of citizen inputs and uses his or her own judgment to make the "best" decision. Like the effects of consultation strategies, placative strategies often alienate citizens who participate in government affairs because their input may bear no consequence on the final decision.

The ideal in participation theory, is to achieve a level of participation that is more than therapeutic or oppositional; one in which "citizens share in governing" (Thompson 1970). True participation occurs when citizens exercise decision authority or codetermine policies in collaboration with government officials (Fiorino 1990; Susskind 1994). In such situations, even an initially unpopular policy can gain public support and have a better chance of being implemented if it is reached in an open and democratic process (Buck 1984). According to Arnstein such citizen collaboration occurs on the next three rungs of her public involvement ladder.

On the sixth rung, *partnership*, the public negotiates with decision makers. Citizens and decision makers share planning and decision making responsibilities in some negotiated fashion. Some types of partnerships include charettes, workshops, and any other interactive meeting between various public representatives and institutional representatives. These forums typically involve several days of intense negotiations in which the goal is to reach a consensus and produce recommendations for institutional action (Hale 1993).

In the seventh rung, *delegated power*, citizens have the main decision making authority in particular areas or programs of wider policy decisions. For

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[83] Public hearings are among the most widely utilized forms of citizen participation in government decision making (Cole and Caputo 1983).

example, citizens may have a majority of seats on a democratic decision making board. Citizens also may have the ability to veto certain governmental decisions if the institution cannot negotiate a satisfactory solution. Thus, the public does more than influence decision making--it makes the decisions. One example of delegated power is a referendum, which is used mainly for local-level, single-issue decisions.

Finally, Arnstein places *citizen control* at the top rung of the citizen participation ladder. At this level, citizens are in full charge of the management and governance of programs. Citizens are also licensed to direct the scientific studies that are central to the decision at hand. Examples of situations where a public organization has implemented citizen control strategies are limited because they rarely occur in any institutional setting.

While Arnstein's model represents the full continuum of public participation, it is understood that the last two rungs of the ladder – delegated power and citizen control – are not always achievable or even desirable. The ladder does, however, offer a basis for evaluating DOE's public participation efforts and their necessity in developing a comprehensive recycling policy.

Public Involvement in DOE

On July 29, 1994, DOE responded to its increasing citizen involvement requirements by publishing an agency-wide public participation policy (U.S. DOE 1996b). The policy states that the agency is committed to candid information exchanges and ongoing two-way communication using a variety of mechanisms (U.S. DOE 1996b), which are described in Table 13-2.

Table 13-2. Key Aspects of DOE's Public Involvement Policy

Objective	Policy Specifications
• Openness and Respect	Whether formal or informal, all participation activities will be conducted in a spirit of openness, with respect for different perspectives and a genuine quest for diversity of information and ideas.
• Database Access	DOE will work to establish, announce, and manage topical databases of reliable, timely information and make it available to the public via telephone, computer, and public information repositories.

Central to the policy is "agency openness." The policy specifies that DOE will conduct all participation activities in a spirit of openness and that the agency will respect different perspectives, information, and ideas. It also states that the agency will work to establish, announce, and manage topical databases of information and make them available to the public via telephone and computer.

To achieve the policy's goals, DOE has implemented several programs and activities. They are summarized in Table 13-3. As part of the policy's implementation, the Office of Environmental Management (EM) established an information center and maintains an 800 number, electronic bulletin board with email access to all DOE employees, and a library of program information (U.S. EPA 1996).[84] DOE has also hired "Public Participation Coordinators" at each of its major sites. The coordinators serve as a central point of contact for all citizen involvement activities. This individual is also responsible for ensuring that the agency's public participation activities provide meaningful and timely opportunities for citizens to influence EM's policies.

Table 13-3. DOE's Strategy for Implementing its Public Involvement Policy

Implementation Outcome	Activities
• Formation of DOE Information Center	· 800 access number · Electronic bulletin board with e-mail access to all DOE employees · Library of program information · Information repositories
• Creation of Public Participation Coordinators (PPC)	· Serves as a central point of contact for all public participation activities. · Ensures that DOE public participation activities provide "meaningful, timely opportunities for citizens to influence EM's policies"
• Enhanced Public Education	· Site tours · Agency newsletters, fact sheets, general brochures · Environmental curriculum materials for students and teachers
• Formation of DOE's Office of Intergovernmental and Public Accountability	· Ensures that EM provides opportunities for public participation at the national level · Ensures public participation by minority and low-income stakeholders · Provides on-going training program for senior and mid-level managers, and supervises EM information · Manages the 11 SSABs and the national EM Advisory Board · Engages in a national dialogue with State and Tribal leaders

Similarly, the Office of Public Accountability maintains an on-going public participation training program for senior and mid-level managers, manages EM's information center, and manages 11 site-specific advisory boards (SSAB). It also oversees the national EM Advisory Board and maintains a national dialogue with state and tribal leaders.

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[84] The 800 number receives approximately 1,500 inquiries a month and an estimated 2,000 citizens regularly use the electronic bulletin board (U.S. DOE 1996b).

Finally, the agency established information repositories for citizens to access declassified DOE materials. The repositories contain information about DOE sites and the CERCLA program. Press releases, site reports, site sampling documentation, and reports on any response actions taken at a facility are all available at the repositories and various public institutions across the nation (U.S. DOE 1995a, U.S. DOE 1996a).

Comparing DOE's public participation policy against Arnstein's framework, each of the agency's implementation strategies can be described as either informative or consultative. They rely on one-way communication techniques such as information exchange, employee training, and routine public hearings. As noted earlier, these techniques are problematic if they are the single forum for citizen participation because they do not incorporate a process where the decision maker or agency representative listens to the public's comments and restates them to the public. So, the public cannot confirm that their concerns were properly communicated. Another problem with these techniques is that they have little, if any, impact on final decisions (Kasperson 1986; Checkoway 1981; Sinclair 1977).

DOE's creation of SSABs, however, may be the exception to the agency's more typical one-way communication techniques. They constitute DOE's movement to a higher level of citizen involvement.

The SSABs are one of DOE's most recent efforts to improve two-way communication with the public. SSABs were established after numerous stakeholders recommended that DOE enhance its two-way relations with the public. Since then, the boards have become the primary vehicle for direct community input into DOE's environmental restoration and waste management process (ICMA and ECA 1996). Their mission is to provide informed recommendations to DOE concerning the public health, safety, environmental, and waste management aspects of all past, present, and future agency activities, and their associated costs and benefits (ICMA and ECA 1996). EM began establishing SSABs at major sites throughout the DOE complex as early as 1993, although to date, some of the SSABs are still developing and not fully functional. As of January 1996, DOE had established 11 SSABs[85] in close cooperation with state environmental agencies and regional EPA offices (U.S. EPA 1996).

Each SSAB consists of a panel of community members, industry representatives, and DOE officials who were identified by an independent convenor and nominated for potential SSAB membership (Applegate and Sarno 1996). DOE has encouraged membership that is broadly representative at the

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[85] The SSABs are located at the Hanford, Idaho, Nevada, Monticello, Fernald, Los Alamos, Oak Ridge, Pantex, Rocky Flats, Sandia, and Savannah River sites (U.S. EPA 1996).

community, state, and regional levels (ICMA and ECA 1996).[86] Members are appointed by the Assistant Secretary for Environmental Management (U.S. EPA 1996).[87]

Stakeholder Perceptions

To understand more about public perceptions of DOE's public involvement strategy, nine expert stakeholders were interviewed.[88] These individuals discussed their perceptions of how DOE's public involvement policy has been applied and its perceived effectiveness. They also suggested several citizen participation strategies that DOE should implement in its future decision making that would improve upon the agency's public involvement process and better meet both the public's and the organization's needs.

The expert stakeholders were identified from among participants of previous DOE workshops and SSAB membership. Each stakeholder had first-hand knowledge of DOE's public involvement strategies. In addition, each respondent had been involved in DOE activities for at least six years and had an understanding of DOE activities both during and after the Cold War. A list of the interviewees is found in Appendix H.

Even though this sample was not intended to be statistically representative, the results are useful for an exploratory analysis. The responses do contain several common themes, however. Each interviewee was asked a total of twelve open-ended questions, which are found in Appendix I. It should be emphasized that, unless otherwise indicated, these results represent the perceptions of the interviewees and are not "facts." Indeed, it is likely that some of the perceptions reported below are not based on evidence. Perceptions, however, still convey important information and may indicate areas in DOE's public involvement processes that can be strengthened.

DOE's Past and Present

Every stakeholder reported that, prior to 1990, national security requirements largely prohibited public involvement. During this time, citizen access to both DOE decision makers and agency information was very restricted. If it occurred at all, citizen involvement was in the form of public hearings where agency officials released only limited amounts of information

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[86] The degree of local involvement from the community and government representatives varies among SSABs.

[87] The boards typically consist of between 15 and 30 members who are appointed for a period of two years. Membership is staggered so that at least one-third of the membership is retained each year for continuity (U.S. EPA 1996).

[88] An expert stakeholder is defined here as an individual who has been involved in DOE activities both during and after the Cold War. To be expert, the individual must have had extensive first-hand knowledge of DOE's public involvement strategies and participated in DOE citizen involvement programs for at least six years.

about a proposed project or policy. The stakeholders used adjectives such as "elitist," "arrogant," and "paternalistic" to describe DOE during this time. The characterizations are due, in part, to the stakeholders' belief that DOE officials discounted the general public's capacity to synthesize complex issues of nuclear science and thus excluded the public from the decision making process.

Every stakeholder noted, however, that DOE's public involvement culture has become more inclusionary in recent years. The change is due, in part, to several legal actions by environmental groups and workers unions against the agency. As a result, the stakeholders report that citizen access to agency information has improved. The declassification of documents, creation of DOE public information centers, and newly established Internet access to agency information have all facilitated the public's knowledge of DOE operations.

Agency Commitment

When the stakeholders were asked about the level of commitment DOE officials have to incorporate the public into the decision making process, the responses fell into two categories: top-level commitment (DOE's secretary and division directors) and lower- to mid-level commitment (agency bureaucrats, managers, and scientists). The stakeholders believe that a *few* top level DOE officials are committed to incorporating the public in decision making. Recent actions that demonstrate this commitment include the agency's new public participation policy, its theme of "openness," its recently published reports on fostering public trust,[89] and its self-imposed internal assessments on stakeholder involvement.[90]

The stakeholders reported a lesser degree of commitment by lower-level DOE bureaucrats, scientists, and managers. The respondents felt that the middle- and lower-level agency employees are less supportive of citizen involvement because they are generally insulated from public scrutiny. In addition, agency bureaucrats, scientists, and managers are more likely to be careerists who were employed by DOE during the time that it excluded the public from agency decision making (i.e., prior to 1990). As a result, the stakeholders believe that these employees do not fully accept the agency's new position on public inclusion because they do not recognize that public participation may benefit the agency and its policies. Susskind (1994) agrees and reports that while agencies such as DOE have become more participatory at higher organizational levels, the paternalistic approach to decision making is still very prevalent at the local level.

The respondents gave some general examples to illustrate their belief that site-level DOE officials are not very committed to public involvement. They

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[89] See DOE 1993.

[90] See DOE 1995b.

reported, for example, that their most basic requests for DOE information are frequently handled with hesitancy at the site-level. Often public requests for information are treated by DOE agents as burdensome tasks and an impediment to project management rather than as a right of citizenship.[91] In addition, several stakeholders noted that most public involvement directives that are generated at the top-levels are not being implemented at the site-level. Finally, other stakeholders noted that even when the agency solicits citizen inputs on various projects, rarely does it consider citizens' recommendations when it comes time to make a final decision.

The *general* lack of commitment for citizen participation (at all DOE levels) is evident in several agency activities, too. For example, one stakeholder noted that as recently as July 1996, DOE released its 10-year long-term stewardship plan that was prepared without soliciting the public. Another stakeholder reported that he had been involved in several multi-site decision-making processes that were negotiated by numerous representatives of the public. The citizens groups had reached consensus on the issues and recommended a DOE policy to be implemented, yet the agency largely ignored it and gave no explanation for doing so. Several other respondents supported this anecdote.

Other stakeholder concerns about DOE's commitment to public involvement pertained to *when* DOE makes its decisions. Most of the stakeholders noted that they believe DOE makes many of its policy decisions (though it may not publicly acknowledge) prior to public involvement. As a result, these individuals believe that public participation is largely a futile exercise. This perception, no doubt, is enhanced by the lack of feedback the public receives during the decision making process.

Both the stakeholder perceptions and DOE's description of its public involvement policy indicate that DOE citizen involvement strategies are the equivalent to Arnstein's description of *placation*, in which the public advises on policy actions and the agency maintains all decision making authority. One general outcome of this technique, however, is that the public becomes frustrated with its inability to influence the decision making process. The stakeholders noted that their cumulative frustration also causes them to question agency actions and elevate their overall distrust for DOE decision making. In such a situation, public involvement has added little value to either the agency or the citizens who participate.

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[91] U.S. EPA (1996) verifies the stakeholders' perception that DOE officials are often unwilling to fulfill citizen requests for information, which is a serious impediment to effective public participation.

The SSAB: DOE's Experiment with 2-Way Communications

As noted earlier, the SSAB is DOE's experiment with two-way communication. The role of the SSAB is to facilitate interactions between the public and DOE, thereby minimizing citizen frustration and distrust. While the literature states that it is too early to evaluate SSAB effectiveness,[92] the interviews yielded very strong opinions about SSAB efficacy. For example, several stakeholders noted that they are wary of the role SSABs play in DOE decision making. Their discomfort is due, in part, to the interviewees' historical interactions with DOE, but it also reflects their concern that SSAB members are not democratically elected to their positions and so are not necessarily representive of the general public's concerns. These respondents fear that DOE officials may assume that SSAB recommendations are congruent with the views of the general public, which they often are not.

Other stakeholders noted distrust for SSAB members because of conflicting member interests which may compromise the board's recommendations to DOE. The conflict arises because often SSAB members maintain employment that is contingent upon whether specific DOE policies are implemented. For example, industry contractors who benefit from DOE projects are often SSAB members. Other conflicts of interest arise from local government representatives having a dual role in city government and in SSAB activities. A few stakeholders reported that because many DOE sites have such a large presence in their communities, the local economy is dependent, in part, on agency activities. Thus, some elected officials tend to support DOE projects and ignore those public recommendations that might constrain the agency's long-term employment presence in the community. Because of this tendency, local officials who hold positions on some SSABs may bias the board's recommendations to DOE.[93]

Other stakeholders stated that in most SSABs the local government is *under-represented*, which has caused strained relationships between the boards and local officials. These sentiments were shared in a recent study which stated that local governments are often omitted from DOE decision making (ICMA and ECA 1996). Such an omission causes a disconnect between the DOE site activities and the adjacent city's planning activities. It also creates ill feelings between DOE officials and local government representatives.

Problems associated with under-representation of local officials on SSABs were also iterated at a recent workshop of local government officials. The

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[92] See, for example, ICMA and ECA 1996.

[93] The concern was largely attributed to one DOE site. The Savannah River DOE facility that was mentioned by several stakeholders as a site that has too much local governmental involvement in SSAB activities. These interviewees believed that the local officials had too many conflicting interests to be involved in SSAB activities.

participants, who included mayors, county executives, and other local government officials, showed an overwhelming distrust of SSAB activities because the boards often exclude city officials from their affairs.[94] The participants felt that SSABs do not adequately represent the views of either the local citizenry or the local governments.

While DOE's SSAB guidance policy states that the boards neither constitute a complete public participation program nor do they satisfy specific statutory or regulatory requirements for public participation (U.S. DOE 1995d), several stakeholders believe that DOE relies too heavily on the SSABs to represent the general public's perceptions. These stakeholders are concerned that the agency uses the SSABs' advice in lieu of soliciting input from the affected population. The respondents noted, however, that there are exceptions. Both Hanford and Fernald were commended for their ability to engage citizens in dialogue and balance SSAB recommendations with the general public's concerns.

Several of the stakeholders were sympathetic to DOE's position. They recognize that the agency *is* interested in citizen involvement, but struggling with *how* to incorporate citizen views adequately. The interviewees noted, for example, that the public has greater access to site-level information than they did even five years ago. The documents, however, are still generally of low quality[95] and low public value. For example, DOE documents rarely place public health and ecological risks into comparative formats so that the public can better gauge the overall risk of a potential policy. Instead, the DOE information materials are generally more intimidating than they are informative because they contain numerous pages of scientific notation and risk calculations. Another criticism with DOE public education materials is that they rarely address the educational and cultural needs of the community in which the documents are intended to target. So, agency attempts at informing the public about its activities may often times be ineffective.

Besides the SSAB experiment, the stakeholders noted that DOE has attempted to expand its conventional public involvement strategies by using focus groups and stakeholder meetings to fulfill the legal requirements of CERCLA. These strategies, by definition, include specific factions of the public and exclude the public at-large. The interviewees stated that conflict often arises when using these public involvement strategies because the excluded factions exert their demands later in the policy development process. The stakeholders

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[94] *Cleaning Up After the Cold War: The Role of Local Governments in the Environmental Cleanup and Reuse of Federal Facilities*, International City/County Management Association (ICMA) and Energy Communities Alliance (ECA), December 6-7, 1996, San Antonio, TX.

[95] DOE documents that are of low quality contain excessive amounts of jargon and scientific notation. They are also poorly written and are difficult to understand.

believe that if DOE modifies its citizen involvement techniques so that the general public has an opportunity to participate too, this conflict would largely be remedied.

In summary, the stakeholders indicated numerous areas of DOE's public involvement plan that are weak and should be strengthened. They generally fall into four general categories:

- Commitment/responsiveness
- Inclusiveness
- Information
- Partnerships and Public Meetings

Table 13-4 explains each of the four areas further.

Stakeholder Recommendations

The interviews asked the stakeholders about their opinions of alternative nuclear waste management strategies for concrete, such as recycling, and whether they believed they were viable alternatives to storage. This question yielded more diverse answers than any other. The responses ranged from guardedly optimistic to strongly opposed to concrete recycling.

The universal qualifier was that the process *must* be safe for both DOE workers and the surrounding populations. Those more optimistic respondents also qualified their answers by stating that the agency must demonstrate the *need* for recycling and *if* that need is proven, then recycling must be economical. In general, though, the critical factors for stakeholders' approval of the policy include a better understanding of DOE's analyses on free releases,[96] economic feasibility, and any potential risks. In addition, the respondents noted that the agency's monitoring plan would be critical to their approval or disapproval of the potential policy.

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[96] A free release occurs when the level of residual radiation is below a certain threshold and no restrictions apply to its use, thus it is free to release without the possibility of putting individuals at risk.

Table 13-4. Stakeholder Perceptions of the General Implementation of DOE's Public Participation Policy

Issue	Issue Explained
1. Commitment/Responsiveness	· Decision makers at *all* agency levels are not committed to public involvement. · The reasons for dismissing public recommendations are not documented and explained to the public.
2. Inclusiveness	· Many meetings are not accessible to all interested parties and are often by invitation only. · The public should be included at the *beginning* of the planning process, not after the decision is made. · Focus groups are misused and often replace citizen inclusion.
3. Information	· Information that is supplied to the public is often not clear, concise, and thorough. · Information is rarely put in context so that the public can better understand the comparative risks. · Information is seldom disseminated in new, non-traditional forms (beyond newspaper announcements and newsletters)
4. Partnerships and Public Meetings	· The public is rarely partners in the DOE decision making process. · The agency typically relies too heavily on public hearings, which have little impact on final decisions.

One stakeholder showed little optimism about implementing a concrete recycling program. This individual questioned whether DOE officials would really know whether the materials were decontaminated and whether DOE workers and the public would be at risk. Another stakeholder was more strongly opposed to a concrete recycling program. She believed that recycling "is an insane endeavor and should not be considered in any scenario because there is too much uncertainty about free releases."

Every stakeholder was opposed to decontaminated concrete being released for use in the commercial sector. Instead, most respondents believed that if reuse occurs at all, the concrete materials should be reused/recycled within each respective site. The stakeholders by and large did not support DOE reusing the concrete throughout the DOE complex (e.g. Pantex ships its concrete for use at Fernald) because of the risks due to potential accidents along the transportation corridors.

While the disparity in comments may seem discouraging, their overarching implication is that information will be key to negotiating the agency's concrete reuse policy. Indeed, there was unanimous agreement amongst the stakeholders on the type of role the public should play in the policy decision, although the form of public participation strategies differed slightly.

In general, the stakeholders suggested that DOE employ a two-pronged approach to community involvement. The first component emphasizes public education and information dissemination. The second focuses on dialogue and negotiation between DOE and the public. The approach is discussed in detail below.

Public Education

Information is fundamental to citizen involvement. It is impossible for anyone--citizen, bureaucrat, or elected official--to make rational decisions without data and information pertinent to the issue at hand. Information allows citizens to examine issues intelligently, single out particular problems, and develop goals and solutions.

The more traditional means of conveying information to the public include newspaper announcements or agency newsletters, but there are many others. The stakeholders were asked what types of strategies they felt would be most helpful in conveying information about concrete recycling. The respondents thought that concrete recycling issues are too complex to convey in a newspaper or press release because of their scientific nature. So, they recommended that DOE rely on face-to-face interactions as the primary vehicle to educate the public. Personal interactions are excellent forums for learning because they provide an opportunity for the public to ask questions, provide comments, and receive immediate feedback from DOE officials. Such a forum also helps to minimize miscommunication between the public and agency representatives.

The stakeholders did emphasized that a portion of DOE's public education plan should incorporate written materials. A key factor to the effectiveness of these written materials, however, is that they are clear and concise such that a person unfamiliar with either concrete recycling or the agency's operations can read the material and understand the issue at hand.

Information Sources and Dissemination

The stakeholders recommended that DOE employ a broad array of public information sources such as agency newsletters, press releases, the Internet,[97] interest group newsletters, neighborhood newsletters, church announcements,

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[97] One stakeholder noted that DOE's home page needs to be updated more often if it is going to be a serious public information tool.

radio, newspaper articles (rather than newspaper announcements[98]), and relevant trade association publications (such as the *Weapons Complex Monitor*, *Energy News Daily*, and others). In addition, several stakeholders noted that DOE should create electronic information materials that are easily transferable into interest group newsletters so that organizations can more rapidly deliver DOE information to its constituencies.

Most of the stakeholders also suggested that DOE use as many existing forums as possible to facilitate public education. For example organizations such as SSABs, political action coalitions, environmental associations, churches, neighborhood alliances, and others have established networks for communication and can more easily disseminate information to their constituencies through newsletter publications and meetings. In addition, local governmental groups such as environmental boards, public health departments, zoning commissions, and local re-use authorities should be used for information exchange. These organizations are also highly effective at initiating community dialogue because they often maintain extensive mailing lists of individuals interested in local issues.

An additional component to information dissemination is timeliness. DOE should give citizens ample time to read and process the agency's information before they are expected to provide comment. One stakeholder noted that for citizen action groups, adequate lead-times typically involve at least six weeks. Often, interest groups require longer lead-times than do direct citizen communications (which require about four weeks advance notice) because membership meetings are generally held on a monthly basis. In order for a special interest organization to publish DOE's public meeting information in its newsletters, call its members, and build constituency interest prior to a monthly meeting, it is imperative that interest groups receive project/policy information very early.

Information Relevance and Focus Groups

To address the task of meeting the public's information needs, the stakeholders recommended that DOE use focus groups to review the agency's public information plan and its relevant literature to determine whether the agency's message is understood *before* documents are disseminated to the public at-large. Focus groups can also help ensure that only the most relevant issues are conveyed to the public and that materials are thorough and balanced. In addition, the groups can place risk information into context so that the public can better understand the potential overall risks. Focus groups are an appropriate tool to use in this situation because they do not *substitute* for

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[98] Newspaper announcements are typically small advertisements in the classified section. They are located in the back of the newspaper and are often overlooked by otherwise interested readers.

inclusive public participation, but rather, *facilitate* future involvement in a more efficient manner.

Agency Candor

Finally, the stakeholders recommended that DOE should be up-front with citizens about its policy positions, both in public interactions and written materials. The stakeholders note that no matter what side of an issue is taken--popular or unpopular, the agency's responsibility is to let interested parties know its position and explain why such a position is taken. Such disclosure will help citizens trust DOE decision making because they will better understand the constraints that bind the issue at hand.

Public Dialogue and Negotiation

A public participation plan that is based on informing alone is not sufficient. Information only provides a *basis* for dialogue and should be accompanied by various two-way communication strategies such as partnerships. When citizens and decision makers form partnerships, they share planning and decision making responsibilities in a negotiated fashion.

Citizen partnership, however, is radically different from DOE's traditional approach to public dialogue. In general, the agency relies on public hearings to engage citizens in discussion. The respondents noted, however, that their experiences with public hearings have shown that they are ineffective forms of public engagement. They stated that individuals who voice their concerns at public hearings see few, if any, of their suggestions incorporated into DOE's final policies.[99]

An additional problem with public hearings is that they typically incorporate poor and overly technical presentations and a bias toward participation by parties having a clear economic stake in the decision (Checkoway 1981). For these reasons, the stakeholders suggested that in lieu of public hearings, DOE should rely on citizen partnerships to negotiate its policies. In such situations, all those individuals affected by the proposed policy understand and agree with the decision criteria that form DOE's concrete reuse policy. One example of such a forum is what the respondents called a "workshop."

Workshop Approach

The stakeholders suggested that a workshop approach be used at both the national and local level so that all of the affected parties have an opportunity to participate in the planning process. During the initial stages of policy planning,

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[99] Cole and Caputo (1983) verify that public hearings have little impact on policy outcomes and offer little merit to policy making.

national workshops should be used to shape the direction of DOE's concrete recycling policy. (DOE successfully utilized a workshop approach in its recent metals recycling debate.) The goal of the national workshops is to formulate a national policy that both addresses the public's concerns and is congruent with agency constraints.

At the first meeting, the agenda is focused on the educational component of the policy so that the participants fully understand the issues at hand. At the end of the meeting, DOE should solicit participant comments on critical features to be included in the agency's policy. Before the second workshop, the agency will have incorporated the stakeholder concerns into its proposed national strategy. Then, during the second meeting, the proposed policy is given back to the stakeholders for review and further debate. This feedback process is important because it helps to ensure that miscommunication has not occurred.

After consensus is reached at the national meetings, a series of site-level workshops should be convened. Local workshops are important to tailor the implementation process so that it meets site-specific concerns. Local meetings also help ensure that *local* citizens' concerns are incorporated into the final policy. The same two-stage format should be used at the local level, although more workshops may be necessary to address the issues that are specific to a particular site and to reach consensus on the issues. It is possible, however, that local views are consistent with those embodied in the proposed national policy and consensus may be easily reached. If so, then only one local level workshop may be all that is necessary.

Meeting Times, Venue, and Frequency

The stakeholders recommended that the national meetings be held in a location other than the DOE headquarters in Metropolitan Washington DC. Meetings held at DOE headquarters are problematic for two reasons. First, the stakeholders felt that a more neutral meeting location would better facilitate negotiations. Other venues where the meetings might be convened include universities, hotel conference facilities, etc. Second, Washington DC is far removed from most citizens at the site-level, which makes it difficult for many citizens to attend the meetings because of time limitations and cost of travel. The national meetings should therefore, be held in a more centrally located region or in two different regional venues to accommodate as many of the potential workshop participants as possible.

Finally, to achieve maximum citizen representation, several respondents recommended that the public meeting times not always be held during DOE business hours. Weekend and evening meetings are more appropriate for the general population to attend because most interested citizens have schedules that conflict with meetings during typical business hours. (A number of DOE installations hold weekend and evening meetings.)

Citizen Representation

Representation is another important factor in public involvement. Without question, sophisticated and organized groups have an easier path to participation. Those who are not as well organized, however, should also be encouraged to participate in DOE's decision making process. Encouraging the "silent citizenry" to become involved in DOE affairs is a difficult task, especially if the agency does not fully understand who its public is. To address this issue, the stakeholders were asked to identify groups of individuals that DOE should make a special effort to include in the decision making processes--those that would not necessarily participate otherwise. Some respondents noted that DOE is already efficient at facilitating discussions with those interest groups that are focused on issues associated with nuclear waste. These respondents felt, however, that DOE should take a broader strategy and involve more *general* interest groups such as neighborhood associations and churches, which are more likely to represent the broad population. In addition, low-income and minority households, (both of which are often less represented in DOE discussions than are individuals from highly educated, professional, and Caucasian households) may be more easily involved through discussions with church and neighborhood associations.

Other groups that DOE should engage in discussions include the *general* environmental community (not just those organizations associated with nuclear-related issues) and tribal leaders. In addition, because of the nature of concrete recycling and its potential for transport, most of the stakeholders believed that the communities along the potential transportation corridors should also be included in discussions. Finally, DOE should solicit representation from workers' unions, vendors, and other individuals and organizations that may be affected by the production, treatment, or disposal of concrete.

Table 13-5. Stakeholder Recommendations for DOE's Public Involvement Strategy

General Recommendation	Specific Recommendation	Desired Outcome
Public Education	• Written materials should be published/broadcast in: · Agency newsletters · Press releases · DOE's Internet homepage · Interest group newsletters · Neighborhood newsletters · Church announcements · Radio · Newspaper articles (rather than announcements) · Trade association publications	• Public will be informed participants in the decision making process • Increased efficiency will be achieved in public involvement process
	• Written materials should be: · Clear · Concise · Thorough · Balanced • Focus group should review the public involvement plan for recommendations and final approval • Focus group should review DOE information materials to determine if the general public will understand their message	
Partnerships and Dialogue	• Citizens should be partners in decision making, not just advisors	• Public trust of DOE activities will increase • Planning efficiency will increase • Fewer judicial interruptions will occur
	• The public should be involved at the initial stages of the decision making process and citizen views should be solicited well in advance of CERCLA's point for public hearings--at which point primary decisions have already been made	
	• A 2-stage workshop approach should be employed: · National Workshops should be used at the beginning planning stages · Local workshops should be used later in the planning process to assess site-specific issues	
	• Interactions with the public should be more inclusive · Schedule meetings at diverse times · Utilize more existing forums for communication	
	• SSABs should partner with grassroots organizations to make SSABs more democratic	

In summary, the stakeholders' responses, while ranging widely in their initial thoughts on concrete reuse, were surprisingly consistent on *how* DOE agency should engage the public in discussion. In general, they suggested a two-pronged approach that emphasizes public education and negotiation, as seen in Table 13-5. Several important facets of public education are information dissemination, focus groups (to ensure the information's relevance), and agency candor. Similarly, those factors that are most important for negotiation are agency partnerships with the public, workshops, appropriate meeting times and venues, SSAB partnership, and adequate citizen representation.

Affected Population--Demographic and Economic Characteristics

An important question for DOE to address when formulating its public involvement strategy for concrete reuse is environmental justice. Using data from the U.S. Bureau of Census, we analyzed the demographic and economic characteristics of the residents surrounding the affected DOE sites to better understand the affected population at the site-level. In addition, we examined the resident characteristics around Envirocare, the potential waste disposal site.

Data

The health effects resulting from an accident show that radiological effects are generally expected to occur within roughly a 10 mile radius of the accident site (see Section 9 – Calculated risks). For this reason, we analyzed the distribution of affected populations at the 1 mile, 10 mile, and 25 mile circular areas around each of the affected DOE sites and Envirocare. Finally, an analysis of state population characteristics was also included for comparison. The source for our estimations is the 1990 U.S. Bureau of Census (BOC 1990).

Population data were analyzed at the census tract level. Each census tract consists of approximately 6,000 households. This type of analysis was employed because it captures many of the finer spatial characteristics nearer to the sites that a broader analysis (by zip code, metropolitan area, or county-level) would likely miss.

After the census tract data were extracted, they were transferred into a geographic information system (GIS). The GIS was used to estimate the characteristics of the affected population because some of the census tracts lay partially inside an estimated radius boundary. So, it accounted for the portion of the tract (the specific households) that lay within the estimation boundary. Finally, the racial and ethnic characteristics of the population and median household income were evaluated for those dwellings within the 1 mile, 10 mile, and 25 mile distances around each site. The results are shown in Table 13-6.

It should be noted that the household income estimations may not be as accurate as those for demographic characteristics. The less accurate estimates are a result of census tracts that reported no inhabitants, yet positive incomes. In such instances, the median income was manually calculated. At some of the sites, however, the manual estimation method required manipulations of thousands of records which were too great a task, and so median income could not be recomputed. The sites that were specifically affected by faulty household income estimations were Argonne National Labs, West at the 10 and 25 mile radii, the Nevada Test Site at the 1 and 10 mile radii, and Envirocare at each of its radii. Thus, the income data provided for these sites are not as reliable as the demographic estimations.

Table 13-6. Social and Demographic Characteristics of the Affected Population

SITE NAME	Radii Distance	Median Household Income	Population Total	Caucasian Population	African Amer. Population	Hispanic Population	Amer. Ind. Population
Argonne Nat'l. Lab East	1 mile	$47,000	1,711	1,678	4	45	2
	10 miles	$49,936	469,601	421,236	22,378	17,254	679
	25 miles	$31,700	4,977,198	3,199,064	1,289,442	628,928	8,726
Argonne Nat'l. Lab West	1 mile	$22,456	12	11	0	1	0
	10 miles	$24,374	932	828	1	97	25
	25 miles	$24,374	5,347	4,773	6	571	112
Brookhaven Nat'l. Lab	1 mile	$48,309	848	780	39	38	2
	10 miles	$45,997	309,950	288,939	13,029	17,232	976
	25 miles	$49,229	1,023,578	936,780	48,789	69,174	2,450
Energy Tech. Ctr.	1 mile	$37,365	28,454	18,095	908	10,850	125
	10 miles	$52,215	871,266	667,422	29,008	188,953	3,613
	25 miles	$39,628	4,411,694	2,646,645	528,620	1,404,76	18,199
Hanford Site	1 mile	$0	0	0	0	0	0
	10 miles	$36,101	5,877	5,532	24	344	89
	25 miles	$29,756	144,186	120,439	1,959	24,114	1,083
Lawrence Nat'l. Lab	1 mile	$26,817	41,545	25,863	6,324	3,315	211
	10 miles	$33,743	897,306	456,999	216,349	93,971	4,971
	25 miles	$40,023	3,222,082	2,029,506	421,334	410,408	18,102
Lawrence Nat'l Lab	1 mile	$46,261	10,381	8,905	189	1,438	89
	10 miles	$58,773	138,879	122,126	4,179	11,918	792
	25 miles	$42,317	1,666,178	1,135,304	152,883	291,554	11,289
Los Alamos Nat'l. Lab	1 mile	$51,071	461	431	2	60	4
	10 miles	$40,107	23,953	21,092	79	5,403	1,479
	25 miles	$30,274	95,801	73,529	333	47,857	8,509
Morgantown Tech. Ctr.	1 mile	$18,235	8,641	7,842	329	117	15
	10 miles	$22,160	75,852	72,204	1,709	725	227
	25 miles	$20,588	275,727	265,412	7,408	1,714	571
Nevada Test Site	1 mile	$0	1	1	0	0	0
	10 miles	$0	83	63	16	4	2
	25 miles	$22,021	2,887	2,677	75	186	71
Oak Ridge	1 mile	$39,382	1,399	1,301	51	28	5

SITE NAME	Radii Distance	Median Household Income	Population Total	Caucasian Population	African Amer. Population	Hispanic Population	Amer. Ind. Population
	10 miles	$31,986	134,529	127,150	5,106	1,016	366
	25 miles	$24,803	555,779	513,084	36,046	3,232	1,645
Pantex Plant	1 mile	$13,581	6,088	3,278	188	3,517	59
	10 miles	$25,394	164,344	137,101	9,148	23,174	1,395
	25 miles	$25,661	188,218	159,413	9,470	25,063	1,530
Paducah Gas. Diffusion Site	1 mile	$10,911	4,819	3,071	1,695	32	23
	10 miles	$20,321	69,560	62,347	6,824	421	111
	25 miles	$21,374	139,993	130,983	8,334	664	297
Portsmouth Gas. Diffusion Site	1 mile	$27,921	1,193	1,159	14	0	6
	10 miles	$17,451	62,410	59,945	2,000	213	295
	25 miles	$17,927	167,326	162,652	3,798	360	554
Rocky Flats Plant	1 mile	$44,738	558	532	3	42	4
	10 miles	$36,872	228,607	215,573	1,534	13,617	1,043
	25 miles	$28,220	1,591,662	1,368,015	84,040	214,096	12,408
Sandia Nat'l. Lab	1 mile	$19,837	8,141	5,900	159	3,679	292
	10 miles	$28,826	457,696	354,957	12,499	168,986	12,602
	25 miles	$28,802	548,106	425,508	14,166	200,384	19,265
Savannah River	1 mile	$22,054	19	9	9	1	0
	10 miles	$22,054	1,896	933	898	65	0
	25 miles	$21,107	219,244	131,737	84,535	2,445	528
Envirocare (for disposal)	1 mile	$25,852	2	1	0	1	0
	10 miles	$25,852	198	143	7	54	5
	25 miles	$25,852	1,215	888	43	325	31

Results

The racial and ethnic characteristics of the residents living near each of the affected areas are analyzed in series of graphical representations in Appendix J. In general, the data show great variation in median household income from site to site. For example, median household income ranges from just under $11,000 near the Pantex Plant to about $59,000 near the Lawrence Livermore National Laboratories. Also, the median incomes are greater around the laboratories than around the industrial production facilities. Median household income surrounding the 25 mile radius of the labs is approximately $37,000 as compared to the $24,000 median annual income of households located near industrial production facilities.

Another notable finding is that significant minority populations exist around some of the sites. Minority populations are individuals classified by the U.S. Bureau of Census as Negro/Black/African American, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, and other non-White persons (U.S.

DOE 1995b). Argonne East, Energy Tech., Lawrence Berkeley Labs, Los Alamos Labs, Paducah, Pantex, Portsmouth, Sandia Labs, and Savannah River all have significant minority populations residing in close proximity to the DOE facilities, as seen in column two of Table 13-7.

At each of these sites, minority populations account for greater than 35 percent of the total population. These findings are important because they identify groups of individuals that DOE should seek to engage during its public involvement process so that its negotiations and citizen input address the general community's concerns. Population identification will also help DOE managers to better understand the characteristics of the affected public and which populations should be included during its negotiations. By doing so, the agency can tailor its citizen education program to better meet the social needs of its constituency and so public participation is more likely to be effective. Table 13-8 shows the *specific* percentage of individuals at the various sites mentioned above that have significant minority populations (35 percent or more of the total population) living nearby.

Table 13-7. Sites Near Significant Minority Populations and Low-Income Households

Site Name	Significant Minority Population as a Percent of Total Population	Minority Population that is Significantly Greater than State Avg.	Median Household Incomes Significantly Lower than State Avg.
· Argonne Labs East	X	X	X
· Energy Tech.	X	X	
· Hanford		X	
· Lawrence Berkeley	X	X	
· Los Alamos Labs	X		
· Nevada Test Site		X	X
· Paducah	X	X	X
· Pantex	X	X	X
· Portsmouth			X
· Sandia Labs	X		X
· Savannah River	X	X	X
· Envirocare	X	X	

Table 13-9 also compares the characteristics of those individuals living around each site to the state population characteristics. The third column shows that while minority populations living nearby several sites account for less than 35 percent of the total population, the minority population is still significantly greater than their state's average percentage. Significance, here, is defined as a local minority population percentage that is 10 percent or more of the state's average percentage. For example, at the 25-mile radius from the Nevada Test

Site, approximately 19 percent of the individuals in the community are African American. Conversely, about 6 percent of Nevada's total population is African American. The situation is similar at Argonne Labs East, Energy Tech., Hanford, Lawrence Berkeley Labs, Paducah Plant, Pantex, and Savannah River, as seen in Table 13-9. Additionally, at Envirocare, 31 percent of the individuals living within 25 miles of the waste disposal firm are minorities as compared to Utah's total minority population, which is 7 percent. DOE should make a special effort to engage these minority populations in discussion during its public involvement process so that it receives representative input.

Table 13-8. Percentage of Minorities Living Around Each Site

Site Name	Miles from Site	Percent of Site Population that are Minorities
· Argonne Labs East	25	38%
· Energy Tech	1 25	39% 42%
· Lawrence Berkeley	10	41%
· Los Alamos	25	44%
· Paducah	1	36%
· Pantex	1	53%
· Sandia Labs	10 25	35% 35%
· Savannah River	1 10 25	53% 51% 40%
· Envirocare	1	50%

Table 13-9. Sites Where Minority Populations are Significantly Greater than the State Average

Site Name	Affected Minority Population	Miles from Site	Affected Minority Population to Total Affected Population	Average State Minority Population
· Argonne Labs East	African Amer.	25	25%	15%
· Energy Tech	Hispanic	1	36%	25%
· Hanford	Hispanic	10	16%	5%
· Lawrence Berkeley	African Amer.	1 10 25	17% 28% 15%	7%
· Nevada Test Site	African Amer.	10	19%	6%
· Paducah	African Amer.	1	35%	7%
· Pantex	Hispanic	1	50%	23%
· Savannah River	African Amer.	1 10	47% 47%	30%

Site Name	Affected Minority Population	Miles from Site	Affected Minority Population to Total Affected Population	Average State Minority Population
Envirocare	All Minority Populations	1 10 25	50% 32% 31%	7%

Low-income households are an often overlooked sub-population that should be included in DOE negotiations. Indeed, they comprise a significant portion of the affected population around several sites. Low-income households are those dwellings for which the median income is 80 percent or less than the median household income for the state (U.S. DOE 1995b).[100] A large percentage of the dwellings surrounding DOE's Nevada, Paducah, Pantex, Portsmouth, Sandia Labs and Savannah River facilities are low-income households. At the 25 mile radius from the Nevada Test Site, the median household income is 69 percent of Nevada's state median household income. At the Paducah's, Pantex's, and Sandia Labs' 1 mile radius, it is 44, 48, and 79 percent, respectively. Portsmouth's median household income at the 10 and 25 mile radii are 58 percent and 60 percent of Ohio's average, respectively. Finally, at Savannah River's 10 mile and 25 mile radius household income is between 73 and 77 percent of South Carolina's median household income.

Of particular importance are three sites: Paducah, Pantex, and Savannah River, which are characterized by significant minority populations. These sites may fall into a category called "environmental justice." Environmental justice has come to denote that minority and low-income communities bear a disproportionate risk burden compared to higher income, non-minority populations. Often, environmental injustice is attributed to the lack of political power, differential enforcement of environmental regulations, and basic social inequities that low-income minority communities bear. For our analysis to be more definitive, the census data for household income need to be disaggregated further to determine the spatial distribution of low-income households and minority populations around each site. Such an analysis will show which specific communities are affected, the characteristics of these individuals, and their relative degree of risk.

Recognizing the potential for disproportionate risks DOE should, at the very least, design its site-specific information materials in a manner that considers the cultural and social diversity of the affected population. By doing so, public education will more likely be effective and the individuals who are engaged in DOE discussions will more likely represent the general population.

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[100] The "80 percent" is based on definitions used by the U.S. Department of Housing and Urban Development (U.S. DOE 1995b).

Focus groups can be a particularly useful tool for determining the public education needs at these sites and are discussed further in the next section.

Suggested Public Participation Model

There are three dimensions to consider in DOE's public participation plan: the degree of public involvement, the degree of equity achieved, and the efficiency of the process. The degree of public involvement, in terms of both the numbers of people and their level of commitment to the process, is a function of the techniques employed, the nature of the issue, attitudes of the public, and various power relationships (Crosby, Kelly, and Schaefer 1986). It is often difficult to attain both high intensity of participation and involvement of large numbers of people because most techniques cannot facilitate both simultaneously. DOE is thus faced with the value judgment of which option might produce a more effective kind of participation--100 people participating once or 10 people participating 10 times each.

The second important dimension of a public involvement plan is the degree of equity achieved. Equity is the relative degree of representation, that is, the extent to which all potential opinions and values were heard. Efficiency of process is the third element. It is the amount of time, personnel, and other DOE resources required to reach a given decision. The smaller the amount of such resources, the more efficient the decision making is said to be. Because public involvement cases are generally complex, with multiple variables affecting their outcome, it is difficult to maintain an efficient participation process. For example, a typical policy decision involves multiple smaller decisions, multiple publics (both organized and unorganized citizens), and numerous agents of government at varying levels within and outside DOE. For these reasons, the complexity of policy decisions makes efficiency difficult to achieve.

It is unlikely that high efficiency is compatible with the attainment of high levels of citizen involvement or equity because is not possible to achieve the three maxima simultaneously (Crosby, Kelly and Schaefer 1986). Consequently, any suggested public participation model that DOE implements will trade off each of these objectives against the others. The overall goal, however, is that the degree to which any one of these three variables is negotiated will not significantly compromise the overall quality of citizen involvement or the resulting policy. The preferred model for public participation, which is discussed below, considers each of these three tradeoffs. It adopts both the theoretical and pragmatic recommendations posited in the previous sections, as well as the stakeholders' suggestions and concerns.

The Workshop as a Public Participation Tool

The workshop is suggested here as the strategy that DOE should use to negotiate its concrete recycling policy. The goal of the workshop approach is consensus through negotiation, or "consensual" negotiation. It is a technique for group decision making that incorporates the demands of those citizens most affected by the concrete recycling policy and negotiates with them on the potential policy's form and its implementation provisions. In order for the workshop approach to have the most effect, DOE should make every effort to employ it *before* key decisions are made so that public has an opportunity to shape the policy.[101]

We suggest that the workshop approach be used at both the national and local level so that all of the affected parties have an opportunity to participate in the planning process. During the initial stages of policy planning, national workshops should be used to shape the policy's direction. As noted earlier, DOE utilized a similar model in its recent metals recycling debate. This strategy was also recommended by the stakeholders we interviewed in Section 4. It involves at least two national meetings. The goal of the national workshops is to formulate a national policy that both addresses the public's concerns and is congruent with agency constraints.

At the first meeting, the agenda should be focused on the educational component of the policy so that the participants fully understand the issues at hand. At the end of the meeting, DOE should solicit participant comments on the critical features to be included in the agency's policy. Before the second workshop, the agency should have incorporated the stakeholder concerns into its proposed national strategy. Then, during the second meeting, the proposed policy should be returned to the stakeholders for review and further debate. This feedback process is important because it helps to insure that miscommunication has not occurred. After consensus is reached at the national meetings, a series of site-level workshops should be convened. Local workshops are important to tailor an implementation process so that the policy will meet site-specific concerns. Local meetings also help insure that *local* citizen concerns are incorporated into the final policy provisions. The same two-stage format should be used at the local level, although more workshops may be necessary to address the issues that are specific to a particular site and to reach consensus on the issues. It is possible, however, that local views are consistent with those embodied in the proposed national policy and consensus may be easily reached. If so, then only one local level workshop may be all that is necessary.

The potential problem with the workshop technique, however, is that the participating individuals may not be representative of the general public. Representation is particularly important because decision effectiveness may suffer when relevant information and/or acceptance is not obtained from the affected population (Thomas 1993). There are two strategies that DOE should employ in order to achieve and maintain representation. First, DOE should make

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[101] This suggestion is also recommended in U.S. DOE (1993).

a concerted effort to locate the community leaders affected by its concrete reuse/recycling policy. This should be done by identifying the members and the representatives from each of the following four groups (Heberlein 1976):

- Those individuals holding positions of formal authority and organizational responsibility in their communities;
- Persons who from newspaper file searches appear to have assumed important community roles in the past;
- Individuals identified by members of groups 1 or 2 above as future leaders in the community;
- Persons not included in the first 3 groups but whose interests seem relevant based on interviews with members of these groups.

Individuals in significant community roles include those persons who lead neighborhood, environmental, and civic associations. They also include tribal, union, and church leaders. In addition, members of the media, local government officials, and minority associations should be included. By utilizing existing information channels such as churches, neighborhood associations, the general environmental community, DOE worker unions, trade associations, tribes, vendors, SSABs, and local governments, the agency can more readily identify the members of the four categories mentioned above. As noted in Sections 3 and 4, the agency should use caution, though, and not rely on SSABs as the primary vehicle to receive citizen input. SSAB members are not democratically elected to their positions and so do not necessarily represent the general public's concerns. In addition, the boards are not altogether trusted by DOE stakeholders.

The second recommended strategy for participant selection supplements the stakeholder identification approach above with a random selection procedure. This technique incorporates individuals that are randomly selected from the community from jury rolls, voter registration lists, or registrants of motor vehicles to serve as "expert" representatives of the public.[102] The representatives may be reimbursed for their time and effort (as are jury members). The random selection and reimbursement technique is particularly relevant at the sites mentioned in Section 6 that have significant minority and low-income populations living in their immediate proximity. Such a process will better insure that the recommended policy considers the cultural values of the community.[103] The sample should be stratified by age, race, and income. Twenty to thirty randomly sampled individuals along with a sampling of the influential community leaders

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[102] This technique is also advocated by Heberlein (1976) and Crosby, Kelly, and Schaefer (1986).

[103] U.S. EPA 1996 supports this suggestion. It argues that DOE should employ public involvement approaches that incorporate input from communities of color and low-income households.

should give DOE a relatively good representation of public values to shape its concrete recycling policy (Heberlein 1976).

While the random selection process should ensure sample representation from all potentially affected populations, *anyone* who is interested in participating should be allowed to do so, especially at the local level. The risk of excluding interested members of the public is that the recommendations posited by workshop participants may appear biased. Such a perception may prompt excluded citizens who are frustrated by their inability to influence the decision making process to use the judicial system as a vehicle to air their concerns. The result is likely to be a more lengthy planning process that is less amiable. In addition, when citizens are forced to use the judicial system to get their views heard, it perpetuates citizen distrust of DOE activities. Thus, it is to DOE's advantage to be as inclusive as possible during its citizen involvement process.

Workshop Facilitation

Because participant selection can often be a lengthy process, DOE should employ a neutral facilitator. The facilitator can help recruit workshop participants so that the selection process is perceived to be fair and participant selection is expedited. In addition, he or she can assist workshop members during negotiations to reach agreement and ensure that each participant has equal time to speak. The facilitator should be "nonpartisan" with respect to the outcome, but well informed of the issues at hand. In order to insure neutrality, the facilitator should have the support of *all* the workshop participants so that they may feel confident in the facilitator's process guidance. Most important, he or she should also be someone skilled and experienced at managing dialogue among groups.

Public Education

As noted in Section 4, public education will be fundamental to citizens' understanding and approval (or disapproval) of the DOE's concrete recycling policy. Information will also be the *basis* for all dialogue between DOE and its constituency. It allows citizens to examine the concrete reuse issues intelligently, single out particular problems, and develop goals and solutions. So, it is important that DOE's public education materials are understandable and provide enough information to create dialogue, but not so much to overwhelm the public with superfluous details. In order to achieve this balance, we recommend that the agency should assemble focus groups to review and revise the literature it intends to disseminate to the public. Focus group members might include workshop participants or other interested citizens who understand the educational and cultural needs of the community in which they live. They should be employed to help insure that citizens are provided with contextual information rather than highly technical details.[104] By doing so, the general public will be more likely to understand the information and participate more meaningfully.

Agency Action

Finally, once the public and DOE agree on a set of policy recommendations for agency action, DOE should make every effort to incorporate it into the agency's final concrete recycling policy. Provisions that DOE decides not to incorporate should be responded to in follow-up meetings with the public and in personal communication.

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[104] One recommended means to achieve this includes placing public health and ecological risks into comparative formats so that the public can better gauge the overall risk of the concrete reuse policy.

CHAPTER 14 - RECYCLING GOALS

Establishing the Concrete Recycling Goal for DOE

The economic and risk analysis must be combined with an understanding of how concrete is recycled, the state of the concrete recycling industry, and when and why it is done, to establish a realistic concrete recycling goal. To understand better current industry practices, an industry-wide survey of commercial recycling (Deal, 1997) and research on governmental concrete recycling efforts was performed. The results of this work show the continued growth and the success of concrete recycling.

Survey of Commercial Concrete Recycling Industry

A survey of commercial concrete recyclers across the nation determined:

- concrete recycling industry to be active in at least 32 states
- recyclers process an average of 86,000 cubic yards of concrete per year, primarily from demolition and road work
- the crushed concrete is most often used as subbase material (69%), asphalt pavements (8%), general fill (8%), concrete pavements (5%), or riprap (3%).

The average processing cost was reported to be $3.10/ton, ranging from $1.60 to $6.00/ton. Crushed concrete sold for an average of $4.90/ton, ranging from $0.75 to $15.00/ton.

Government Concrete Recycling

Department of Energy

Several sites within the U.S. Department of Energy (DOE) complex, as well as the Formerly Utilized Sites Remedial Action Program (FUSRAP), have recycled concrete. FUSRAP has crushed concrete rubble and used it as fill material on five projects, saving an estimated $4.5 million (Darby, et al., 1997 and Seay, 1996). Six DOE sites have reported some level of concrete recycling (Haupt, 1997; Sanow, 1997; and LANL 1996). The feasibility of recycling concrete rubble has been studied at two additional sites. Details are given in Appendix K.

Department of Defense

The DOD Military Departments has reported ongoing concrete recycling efforts at nine sites nationwide and overseas. These sites are recycling concrete rubble produced from base construction projects. Information on selected projects is detailed in Appendix K.

Department of Transportation

Many State Department of Transportation offices are encouraging concrete recycling in their projects. A survey of State DOT offices showed that 32 states are recycling concrete or are allowing it to be used in some projects. Uses of recycled concrete varied from state to state. The most common use for recycled concrete in DOT projects was subbase material, others include: granular fill, concrete barriers, and riprap.

The Concrete Recycling Goal for DOE D&D Activities

Based on industry practice and the ultimate end use, recycling 100% of the concrete volume is not practical. We recommend two goals for DOE D&D concrete recycling, depending upon the end use. When the recycled rubble is used as:

- general fill material: recycle at least 70% of the concrete rubble produced;
- aggregate in roadway and other new construction: recycle at least 55% of the concrete rubble produced.

The goals are based on the percent of the concrete rubble that will be ultimately usable taking into account:

- 10% to 15% of the concrete being contaminated,
- 15% to 30% of the material being lost or deemed unusable for some uses after the crushing/screening process, and
- 5% to 10% of the rubble volume being rebar material.

Therefore, 15% to 55% of the concrete rubble is potentially not recyclable, depending upon end use. This leaves a range of 45% to 85% of the material available for recycled product use. We have established the proposed goals by taking 80% of the upper limit for each end use to provide an "entropy" factor for site and project managers. The "entropy" factor accounts for site and project specific demands and restrictions.

Implementation of these goals will allow the DOE to reduce the volume of waste concrete being sent to C&D landfills by at least 45%. This will also reduce the volume of raw materials needed for new construction and reduce the environmental burden of producing virgin aggregate and fill.

Potential Savings

Using the total volume of concrete available for recycling throughout the DOE complex (380,000,000 ft^3) and the scenario costs developed by the economic model, potential complex-wide scenario costs were developed. The costs for large facilities were used to compute the complex-wide costs since they represent the estimated costs for approximately 85% of the concrete in the complex.

Table 14-1. Complex – Wide Costs

Costs	Scenarios Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Cost ($ /ft^2)	5.37	4.91	11.92	7.50	8.03	8.31
Complex-Wide Cost ($)	2.04E+09	1.87E+09	4.53E+09	2.85E+09	3.05E+09	3.16E+09

The baseline case, Scenario 6 – Decon & C&D Disposal is estimated to cost $3.16 billion dollars complex-wide. Scenario 1 – Remove & Recycle is estimated to cost $2.04 billion offering potential savings of $1.1 billion over the baseline case. Scenario 2 – Treat & Recycle is estimated to cost $1.87 billion offering potential savings of nearly $1.3 billion over the baseline case, complex-wide. Scenarios 4 – Rubblize & Cap and 5 – Crush & On-Site Disposal offer savings of $310 million and $110 million, respectively, over the baseline case. Scenario 3 – Decon, Rubblize, and Cap at $4.53 billion is more expensive than the baseline case.

Although there are some uncertainties, the scenarios used the same variables and the rankings should be correct even if the exact values are not. Costs for Scenarios 1 and 2 should be lower than the values shown since they represent a random choice of the technologies used in each iteration. In actuality, the most suitable technology, price taken into account, would be chosen for each specific use. However, Scenario 6 – Decon & C&D Disposal did not include costs for legal and public interaction, depletion of natural resources, or equivalent aggregate purchases and would cost even more.

CHAPTER 15 – CONCLUSIONS AND RECOMMENDATIONS

This analysis of the of the feasibility of recycling radiologically contaminated concrete has resulted in the following conclusions and recommendations:

Risk

1. While all risks in disposing of concrete are low, the risk of fatalities from recycling concrete rubble at DOE facilities is lower than the risk of fatalities from the current practice.

2. Non-radiation transportation fatalities overshadowed all other sources of risks for all scenarios and all sizes of facilities

3. Fatalities from radiation exposures, including those during the transport of wastes were the highest for the four scenarios that incorporated decontamination technologies.

4. Lost work days followed the trend for fatalities with the risk from recycling concrete rubble at DOE facilities being lower than the risk from the current practice.

5. Construction risks dominated the causes of lost workdays for all scenarios except Scenario 5 - Crush and On-site Disposal. Scenario 5 exhibited nearly equal numbers of lost work days from both transportation and construction due to the volume of material hauled for construction of the on-site LLW disposal facility.

Costs

6. The analysis indicates that recycling concrete is less expensive than the current practice. If the costs projected for decontamination by surface treatment technologies can be realized in full-scale projects, then recycling contaminated concrete will be significantly cheaper than the current practice.

7. There are a several intangibles that favor recycling that we have not attempted to quantify in this report. The first is the favorable public reaction from being "green" by avoiding the environmental impacts of developing and utilizing a new source of natural aggregate. Second, by recycling the time at which a new source of virgin aggregate is needed can be delayed; thereby, delaying the considerable expenditures for environmental reviews and permits for a new facility. One cost of overcoming public apprehension of recycled material is a cost tunt we have not attempted to estimate.

8. Rubblizing structures in-place without first decontaminating them appears to be an economically viable alternative once a threshold volume of between 150,000 and 200,000 cf is reached.

Legal/Regulatory

9. Recycling decontaminated concrete appears to be an acceptable alternative within the existing legal framework.

10. Adoption of a policy to decontaminate and recycle concrete as part of the D&D process would most likely require the preparation of an EA if covering an entire facility.

11. Compliance with RCRA would require:
    - Closure of the facility in accordance with existing RCRA closure plans or modification of those plans.
    - Possibly obtaining a variance to recycle the material as non-hazardous wastes.

12. The proposed HWIR Rule may allow concrete to exit the RCRA regulatory control after decontamination.

13. All recycling activities at NPL sites must comply with the CERCLA Off-Site Rule.

14. Potential CERCLA Section 107 liability exists for any recycled concrete and any on-site or off-site disposal facility.

15. Rubblizing contaminated buildings in-place and capping appears to be an acceptable alternative under current legal and regulatory requirements. Provided RCRA and NRC requirements for capping and monitoring are met.

Social

16. The public education plan for soliciting stakeholder input into any concrete recycling policy decision should be reviewed by a focus group to ensure:
    - the public can understand DOE's message
    - information materials are clear, concise, thorough, and balanced

17. Meetings with stakeholders should include:
    - diverse times that include evenings or weekends
    - diverse locations outside of Washington DC
    - neutral venues such as universities or conference facilities
    - flexible agendas open to citizen input
    - neutral facilitator(s) to run the meeting

18. DOE should ensure that the following affected populations are included in all stakeholder considerations:
    - Citizens surrounding each processing and reuse site
    - Communities along potentially affected transportation corridors
    - Concrete vendors
    - DOE contractors
    - DOE workers who may be handling and transporting the materials
    - Environmental groups (both DOE-related and general environmental groups)
        - Local governments
        - Low-income populations
        - Minority populations
        - State Environmental Management Agencies
        - Tribal groups

19. To enhance Stakeholder trust and public participation effectiveness, DOE should:
    - Include the public at the beginning stages of evaluation and planning
    - Maintain continuous public interaction
    - Keep public abreast of new developments
    - Formally respond to any suggestions that are excluded from DOE's final policy

Recycling Goals

20. The potential savings from recycling concrete, on a complex-wide basis, range at a minimum between \$1.1 and \$1.3 billion depending the the decontamination technology used.

21. Two goals for DOE concrete recycling, depending upon the end use, are recommended:
    - general fill material: recycle at least 70% of the concrete rubble;
    - aggregate in roadway and other new construction: recycle at least 55% of the concrete rubble.

CHAPTER 16 – RECOMMENDED ADDITIONAL RESEARCH

1. Many of the structures within the DOE complex have non-radiological contamination in addition to radiological contamination. Examination of the effect of non-radiological contamination on the various scenarios should be explored.

2. Since many of the costs associated with the economic model have very site specific components, the model should be validated for two to three specific sites. These sites should include a large facility such as Hanford, a medium size facility such as K-25 GDP, and a small facility such as one of the National Laboratories. This would allow the investigation of local costs and the impact on local market conditions of recycled aggregate.

3. The problems associated with rebar, estimated to be as much as 17,000 tons (Rimando, 1997), should be investigated in a manner similar to this research.

4. The potential disproportionate rates of risk exposure to low-income and minority households should be further explored by disagreggating the census data to determine the spatial distribution of low-income households and minority populations around each site. Such an analysis will show which specific communities are affected, the characteristics of these individuals, and the degree of effect.

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APPENDIX A – RISK MODEL DETAILS

RISK SPREADSHEET MODEL

The risk model was programmed in Microsoft Excel Version 5.0 for Windows, making use of Palisade Corporation's @RISK risk analysis and simulation add-in. The spreadsheet consist of a single workbook with eleven (11) worksheets.

The spreadsheet is a useful analysis tool with the capacity to: **1)** estimate fatalities associated with each decommissioning scenario addressed in this paper (including distinction between the following causative agents: transportation, construction, radiological), and; **2)** estimate lost-days from non-fatal injuries associated with each decommissioning scenario addressed in this paper (including distinction between the following causative agents: transportation and construction). Amongst other features, the model includes: **1)** site-specific considerations for facility size, LLW haulage distances, and surrounding population densities; **2)** computations for radiological consequences of accidents during the transport of removed contaminated surfaces to the LLW disposal facility, including route specific population density estimates; **3)** consideration of several removal and treatment technologies currently in use in D&D activities, and; **4)** comparison to fatal and non-fatal risk associated with the generation of virgin aggregate.

Global parameters that affect each scenario, such as selection of facility for analysis, floor area, concrete thickness, concrete density, transportation distances, and contaminant concentration, are entered into a single table that is linked to each scenario risk estimate. Separate sheets are also used to compute the exposure to surrounding populations from releases of radioactive constituents due to accidents during transport of LLW to the disposal facility, and fence-line population exposure during the site work. Each worksheet is described in detail next.

Sheet: Parms (Parameters)

Parameters that are common to each scenario risk estimate are entered on the **"Parms"** sheet in the appropriate location. In addition to providing a place for user-entered common data, this sheet contains calculations/estimates of several other common values. Other sheets link to the **Parms** data, as discussed in subsequent sections.

The data entered on the **Parms** sheet is summarized in Table A-1.

Table A-1. Parms Sheet – Basic Global Data Risk

Parameter	Units	Cell/ Row	Comments/Source
Total Area	ft^2	D6	Range Name: TOTALAREA Calculation: User Entered Comment: Total floor area (contaminated and uncontaminated)
% Contaminated (floor area)	%	D7	Range Name: **Parms:**D7 Calculation: @RISK: RiskTlognorm(15,5,0.1,100) Comment: The percentage of the total floor area (TOTALAREA) that is contaminated.
Contaminated Area	ft^2	D8	Range Name: AREA Calculation: TOTALAREA*D7/100 (**Parms**:D6*D7/100) Comment: Represents contaminated floor areas.
Thickness	in	D9	Range Name: THICKNESS Calculation: User Entered Comment: Floor-slab thickness; Estimated at typical 12 inches for light-industrial use
Depth of Contamination	in	D10	Range Name: DEPTH Calculation: User Entered Comment: default is 1 inch.
Density	lbs/ft^3	D11	Range Name: CONCDENSITY Calculation: User Entered Comment: Density of concrete; Default = 150 lbs/ft^3
Bulk Concrete	%	D12	Range Name: BULK Calculation: User Entered Comment: Segment of concrete to be removed in bulk, as a % of contaminated floor area (AREA). Default is 0% (not used).

Parameter	Units	Cell/ Row	Comments/Source
Rubble Expansion Divisor	%	D13	Range Name: EXPANSION Calculation: User Entered Comment: Volume of concrete typically increases as it is removed from structures during demolition. A value of 70% is typical (Haffner, 1994). Used as reciprocal of expanded volume. Default is 0.70, or 1/0.7=1.43.
C&D Landfill	mi	D19	Range Name: DISTCANDD Calculation: User Entered Comment: Typical distance that rubble must be hauled for disposal at a C&D landfill. Default is 50-miles.
On-site Facility	mi	D20	Range Name: DISTONSITE Calculation: User Entered Comment: The distance that the recycled concrete aggregate is to be hauled for market delivery (FOB point), including the haul distance for any on-site use of the aggregate
Rebar Scrap Yard	mi	D21	Range Name: DISTREBAR Calculation: User Entered Comment: Assumed distance to nearest scrap yard that would purchase the reclaimed rebar. Default is 20-miles.
LLW Disposal Facility	mi	D22	Range Name: DISTLLW Calculation: VLOOKUP(D44,TRANSRISK,4) Comment: Distance that LLW (removed surfaces, bulk segments, etc) must be hauled for disposal. Site-specific, depending on facility being analyzed.
Prior to Release	test/yd^3	D23	Range Name: **Parms**:D23 Calculation: User Entered Comment: Default is 1/40 yd; (0.025/yd;).

Parameter	Units	Cell/ Row	Comments/Source
Surface Contamination	dpm/ 100cm^2	D24	Range Name: **Parms**:D24 Calculation: +I22+J22+K22 Comment: Initial surface contamination concentration, composed of ^{60}Co, ^{137}Cs, and U components. Used to compute surface treatment required
Facility		D27 to D43	Range Name: **Parms**:D27 to **Parms**:D43 Calculation: User entered (by an "x") Comment: Selects the facility being investigated. Sets an index number (**Parms:**D44) which is used in table lookups.
Facility Index		D44	Range Name: **Parms**:D44 Calculation: MAX(D27:D43) Comment: Index value for selected facility. Cell is hidden.

Table Notes: [A] - all tons are "short tons" or 2,000 lbs

In addition to the parameters listed in Table A-1, there are several other important values computed on the **Parms** sheet. Most of these other values are not entered by the user, but are computed based on data entered elsewhere; the few values that are entered have been estimated or computed, are considered semi-fixed, and are not intended to be changed. Other data/calculations presented on the **Parms** sheet are listed in Table A-2.

Table A-2. Parms Sheet - Computed Additional Global Data Risk

Parameter	Units	Cell/ Row	Comments/Source
^{60}Co contamination	dpm/100cm^2	I22	Range Name: **Parms**:I22 Calculation: @RISK: RiskTlognorm(105000,59700,0,7500000) Comment: Mean and max based on NRC (1994)
^{137}Cs contamination	dpm/100cm^2	J22	Range Name: **Parms**:J22 Calculation: @RISK: RiskTlognorm(34300,19500,0,2400000) Comment: Mean and max based on NRC (1994)
U contamination	dpm/100cm^2	K22	Range Name: **Parms**:K22 Calculation: @RISK: RiskTlognorm(19100,11400,0,1100000) Comment: Mean and max based on NRC (1994)

Parameter	Units	Cell/ Row	Comments/Source
^{235}U contamination	dpm/100cm^2	K24	Range Name: **Parms**:K24 Calculation: 0.03*K22 Comment: Total uranium assumed to consist of 3%^{235}U isotope
^{238}U contamination	dpm/100cm^2	L24	Range Name: **Parms**:L24 Calculation: 0.97*K22 Comment: Total uranium assumed to consist of 97%^{238}U isotope
Contamination (surface)	pCi/g	I25 to L25	Range Name: **Parms**:I25 to **Parms**:L25 Calculation: (**Parms**:I24,J24,K24 or L25)/100/(2.54***Parms**:D10)/60/37000000000/**Parms**:D11/454*0.3048^3*100^3/0.000000000001 Comment: Computes mass based contamination, assuming contamination is uniformly spread throughout 1-inch surface.
Contamination (homogenized bulk)	pCi/g	I25 to L25	Range Name: **Parms**:I25 to **Parms**:L25 Calculation: (**Parms**:I25, J25, K25 or L25)***Parms**:D7/100/**Parms**:D9 Comment: Computes mass based contamination, assuming contamination is uniformly spread throughout 12-inch concrete slab.
Total Contamination (homogenized bulk)	pCi/m^2	N25	Range Name: **Parms**:N25 Calculation: **Parms**:D24/100/60/37000000000*100^2*1000000000000 Comment: Converts total surface contamination to units of pCi/m^2.
Bulk Linear Feet	ft	E12	Range Name: **Parms**:E12 Calculation: 2*(AREA*BULK/100)^2*{2+@trunc([AREA*BULK/100/10]^2)} Comment: Computes the linear feet of concrete that must be cut in order to remove the bulk segment of contaminated concrete, as well as additional cutting to parcel it into 10 sq ft (max) pieces. Segment is considered square.
% Increase in Volume	%	E13	Range Name: **Parms**:E13 Calculation: (100/EXPANSION-1)*100 Comment: Computes the actual increase in volume resulting from demolition of concrete (instead of reporting as a divisor)

Parameter	Units	Cell/ Row	Comments/Source
Surface Contamination Free Release Standard	dpm/100 cm^2	E24	Range Name: **Parms:**E24 Calculation: User Entered Comment: The concentration to which surfaces will be treated. Default set at 10 dpm/100 cm^2 (approximate practical lower level of detection).
Surface Removed (no bulk removed)	yd^3	L3	Range Name: **Parms:**L3 Calculation: AREA*DEPTH/12/27/(EXPANSION/100) Comment: The volume of concrete dislodged following the application of a surface removal technology
Surface Removed (bulk removed)	yd^3	M3	Range Name: **Parms:**M3 Calculation: (AREA*(1-BULK/100))/12/27/(EXPANSION/100) Comment: The volume of concrete dislodged following the application of a surface removal technology; contaminated (and treated) area has been reduced by the BULK amount
Bulk	yd^3	M4	Range Name: **Parms:**M4 Calculation: AREA*THICKNESS/12*BULK/100/27 Comment: The volume of bulk contaminated concrete removed
Total Volume (no surface or bulk removal)	yd^3	L5	Range Name: **Parms:**L5 Calculation: TOTALAREA*THICKNESS/12/27/(EXPANSION/100) Comment: The total volume of concrete following rubblizing of facility (no surface removal or bulk removal has occurred)
Total Volume (no surface removal, but bulk removed)	yd^3	M5	Range Name: **Parms:**M5 Calculation: (TOTALAREA-AREA*BULK/100) *THICKNESS/12/27/(EXPANSION/100) Comment: Total volume of concrete remaining following bulk removal of a segment (with no additional surface removal)
Total Volume (surface removal, no bulk removed)	yd^3	L6	Range Name: **Parms:**L6 Calculation: (TOTALAREA*THICKNESS/12-AREA*DEPTH/12)/27/ (EXPANSION/100) Comment: Volume of concrete rubblized following surface removal of contaminated area

Parameter	Units	Cell/ Row	Comments/Source
Total Volume (surface removal and bulk removed)	yd ³	M6	Range Name: **Parms:**M6 Calculation: (TOTALAREA*THICKNESS/12-AREA*THICKNESS* BULK/100/12-AREA*(1-BULK/100)*DEPTH/12)/27/ (EXPANSION/100) Comment: Volume of concrete rubblized following surface and bulk removal
Aggregate (no surface removal, no bulk removed)	yd ³	L7	Range Name: **Parms:**L7 Calculation: **Parms:**N7*2000/141/27 Comment: The volume of aggregate produced from rubblizing and crushing concrete, when no surface or bulk has been removed. Volume was computed using 70% of concrete rubble tonnage (30% of concrete is lost as fines), and a density of ~141 lbs/ft; (NRC, 1989)
Aggregate (no surface removal, bulk removed)	yd ³	M7	Range Name: **Parms:**M7 Calculation: **Parms:**O7*2000/141/27 Comment: The volume of aggregate produced from rubblizing and crushing concrete, when no surface has been removed. However, a bulk segment has been removed. Volume was computed using 70% of concrete rubble tonnage (30% of concrete is lost as fines), and a density of ~141 lbs/ft; (NRC, 1989)
Aggregate (surface removed, no bulk removed)	yd ³	L8	Range Name: **Parms:**L8 Calculation: **Parms:**N8*2000/141/27 Comment: Same as L7, but here the surface has also been removed to a depth of DEPTH inches
Aggregate (surface removed, bulk removed)	yd ³	M8	Range Name: **Parms:**M8 Calculation: **Parms:**O8*2000/141/27 Comment: Same as M7, but here the surface has also been removed to a depth of DEPTH inches
Fines (no surface removal, no bulk removed)	yd ³	L9	Range Name: **Parms:**L9 Calculation: **Parms:**N9*2000/CONCDENSITY/27 Comment: Upon rubblizing and crushing concrete, 30% of the mass is assumed to be converted to "fines." This calculates the volume of fines generated, assuming the fines have a density similar to concrete.

Parameter	Units	Cell/ Row	Comments/Source
Fines (no surface removal, bulk removed)	yd^3	M9	Range Name: **Parms:**M9 Calculation: **Parms:**O9*2000/CONCDENSITY/27 Comment: Same as L9, but a bulk segment of concrete was removed prior to crushing and rubblizing the concrete.
Fines (surface removed, no bulk removed)	yd^3	L10	Range Name: **Parms:**L10 Calculation: **Parms:**N10*2000/CONCDENSITY/27 Comment: Same as L9, but the surface has been removed to a depth of DEPTH inches prior to rubblizing and crushing.
Fines (surface removed, bulk removed)	yd^3	M10	Range Name: **Parms:**M10 Calculation: **Parms:**O10*2000/CONCDENSITY/27 Comment: Same as L9, but a bulk segment and the surface have been removed.
Surface Removed (no bulk removed)	tons	N3	Range Name: **Parms:**N3 Calculation: **Parms:**L3*27*(CONCDENSITY*EXPANSION/100) /2000 Comment: The weight of the surface removed, computed from the volume of the surface removed. The density of the surface is reduced due to volume expansion.
Surface Removed (bulk removed)	tons	O3	Range Name: **Parms:**O3 Calculation: **Parms:**M3*27*(CONCDENSITY*EXPANSION/100) /2000 Comment: Same as N3, but bulk removal is taken into account.
Bulk	tons	O4	Range Name: **Parms:**O4 Calculation: CONCDENSITY***Parms:**M4*27/2000 Comment: The weight of the bulk concrete that is removed.
Total (no surface or bulk removal)	tons	N5	Range Name: **Parms:**N5 Calculation: **Parms:**L5*27*(CONCDENSITY*EXPANSION/100) /2000 Comment: The weight of the rubble generated when there is no surface removal or bulk removal.

Parameter	Units	Cell/ Row	Comments/Source
Total (no surface removal, but bulk removed)	tons	O5	Range Name: **Parms:O5** Calculation: **Parms:**M5*27*(CONCDENSITY*EXPANSION/100)/2000 Comment: Same as N5, but a bulk segment has been removed.
Total (surface removal, no bulk removed)	tons	N6	Range Name: **Parms:N6** Calculation: **Parms:**L6*27*(CONCDENSITY*EXPANSION/100)/2000 Comment: Same as N5, but surface has been removed.
Total (surface removal and bulk removed)	tons	O6	Range Name: **Parms:O6** Calculation: **Parms:**M6*27*(CONCDENSITY*EXPANSION/100)/2000 Comment: Same as O5, but surface has been removed.
Aggregate (no surface removal, no bulk removed)	tons	N7	Range Name: **Parms:N7** Calculation: **Parms:**N5*0.7 Comment: 70% (by weight) of crushed rubble is salvageable aggregate.
Aggregate (no surface removal, bulk removed)	tons	O7	Range Name: **Parms:O7** Calculation: **Parms:**O5*0.7 Comment: Same as N7, but with bulk removed.
Aggregate (surface removed, no bulk removed)	tons	N8	Range Name: **Parms:N8** Calculation: **Parms:N6***0.7 Comment: Same as N7, but with surface removed.
Aggregate (surface removed, bulk removed)	tons	O8	Range Name: **Parms:O8** Calculation: **Parms:**O6*0.7 Comment: Same as O7, but with surface removed.
Fines (no surface removal, no bulk removed)	tons	N9	Range Name: **Parms:N9** Calculation: **Parms:**N5*0.3 Comment: 30% (by weight) of crushed rubble is wasted as fines.
Fines (no surface removal, bulk removed)	tons	O9	Range Name: **Parms:O9** Calculation: **Parms:**O5*0.3 Comment: Same as N9, but with bulk removed.
Fines (surface removed, no bulk removed)	tons	N10	Range Name: **Parms:N10** Calculation: **Parms:**N6*0.3 Comment: Same as N9, but with surface removed.

Parameter	Units	Cell/ Row	Comments/Source
Fines (surface removed, bulk removed)	tons	O10	Range Name: **Parms**:O10 Calculation: **Parms**:O6*0.3 Comment: Same as O9, but with surface removed.
Tons of Rebar	tons	G12 G13 G15 G16	Range Name: **Parms**:G12, **Parms**:G13, **Parms**:G15, and **Parms**:G16 Calculation: O5*0.07, O6*0.07, N5*0.07, N6*0.07 Comment: Weight of rebar generated per weight of concrete rubblized. Typically varies from 5 to 10%, with an average of 7% (Hahn, 1996)

Sheet: Scenario 1

Twenty different technologies to execute the surface removal are considered, and these are selected at random during the simulation. Fatal and non-fatal risks are classified as transportation, construction, and/or radiation-causing injuries.

For each simulation, the technology to be used is selected at random using the @risk discrete function. The appropriate project duration, waste generation, and number of waste-filled drums are then computed based on the selected technology. The technology selection and associated calculations are performed in an area titled "REMOVALTECH" Risks are determined based on project duration, distance to the LLW disposal facility, contaminant concentration, and other factors. Radiation-exposure calculations are made in a separate table titled "Rad Risk"

The Scenario 1 calculations are carried out as summarized in Tables A-3 to A-5.

Table A-3. Scenario 1 Risk Table Calculations

Item	Row /Cell	Calculation/ Details	Comments/Source
travel of workers to site - 50 miles	5	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK Transportation risk only
set up job trailer	6	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 manhours (D6) + 1 trip @ 50 miles D6/8 = 2.9 mandays (F6) !FATALNONRAD*F6+VLOOKUP(4,TRUCKRISK,13) N/A NONFATAL*F6+VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK
construct access road - 100 yd^3 of gravel	7	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.067 manhours/yd^2 (D7) D7/6*12*3*100/8 = 5 mandays (F7) FATALNONRAD*F7 N/A NONFATAL*F7 assume 6" deep gravel
install chain link fence around perimeter	8	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 manhours/ft (D8) D8*4*SQRT(TOTALAREA/3)*1.1/8 (F8) FATALNONRAD*F8 N/A NONFATAL*F8 Area to be fenced is total + 10%
grade	9	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	8 manhours/acre (D9) D9*TOTALAREA/3/43560*1.5/8 (F9) FATALNONRAD*F9 N/A NONFATAL*F9 Area to be graded is total + 50%

Item	Row /Cell	Calculation/ Details	Comments/Source
characterize building for action	10	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	2.2x10^{-3} manhours / ft^2 (D10) D10*TOTALAREA/8 FATALNONRAD*F10 P10 NONFATAL*F10 Rad risk discussed elsewhere
transport of samples to lab	11	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK Transport risk only; no exposure to technicians assumed
technology (selected in cell Y38)	12	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	V39 ft^2/hr ;V39=VLOOKUP(2,REMOVALTECH,Y38+1) V40;V40=VLOOKUP(3,REMOVALTECH,Y38+1) FATALNONRAD*F12 P12 NONFATAL*F12 rate varies with technology selection
collect waste and load on train	13	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 mh/ft^3 (D13) D13/3*V46*55/7.48/8 (F13) FATALNONRAD*F13 P13 NONFATAL*F13 any secondary waste generated disposed of as LLW
collect debris and load into dump trucks	14	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.012 mh/yd^3 (D14) D14***Parms**L3/8 (F14) FATALNONRAD*F14 P14 NONFATAL*F14 one inch removed surface disposed of as LLW

Item	Row /Cell	Calculation/ Details	Comments/Source
haul LLW to EnviroCare	15	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	**Parms**D22 miles (D15) N/A VLOOKUP(**Parms**D44,TRANS RISK,13)*(**Parms**N3+V46*230/ 2000)/80 P15 VLOOKUP(**Parms**D44,TRANS RISK,14)* NONFATALRAIL includes accident risk
unload LLW at EnviroCare	16	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	10 min for 4 drums, 0.5 mh per 40 yd^3 dump V46*10/4/60/8+**ParmsN3**/2000 /80*0.5/8 (F16) FATALNONRAD*F16 P16 NONFATAL*F16 for drums and bulk rail car waste
demolish concrete slab only	17	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.035 mh/yd^2 (D17) for 12" slab D17/8*TOTALAREA/9 (F17) FATALNONRAD*F17 N/A NONFATAL*F17
crush concrete - load on crusher, screen	18	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	200 tph (D18) **Parms**N6/D18/8 (F18) FATALNONRAD*F18 N/A NONFATAL*F18
transport to sale point (FOB)	19	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	**Parms**D20 (D19) --> 0.1 miles default N/A VLOOKUP(2,TRUCKRISK,13)/ 20***Parms**L8 N/A VLOOKUP(2,TRUCKRISK,14)* NONFATALTRUCK/20***Parms** L8

Item	Row /Cell	Calculation/ Details	Comments/Source
separate rebar	20	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	100 tpd (D20) **Parms**G16/D20 (F20) FATALNONRAD*F20 N/A NONFATAL*F20
test rebar	21	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.00000686 mh/lb (D21) D21/8***Parms**G16*2000 FATALNONRAD*F21 N/A NONFATAL*F21
load and haul rebar	22	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	**Parms**D21 (D22) N/A VLOOKUP(3,TRUCKRISK,13)/ 80***Parms**G16 N/A VLOOKUP(3,TRUCKRISK,14)/ 80***Parms**G16 *NONFATALTRUCK
population exposure during remediation	23	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	VLOOKUP(**Parms**D44,TRANS RISK,3) (D23) SUM(F12:F14) N/A P23 N/A calculated for project duration only
site cleanup	24	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.008 mh/yd ^{2} (D24) D24*TOTALAREA/9*1.5/8 (F24) FATALNONRAD*F24 N/A NONFATAL*F24
remove job trailer, fence	25	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 mh + 50 mi (D25) D25/8 (F25) FATALNONRAD*F25+VLOOK UP(4,TRUCKRISK,13) N/A NONFATAL*F25+VLOOKUP(4, TRUCKRISK,14)* NONFATALTRUCK

Item	Row /Cell	Calculation/ Details	Comments/Source
demobilization travel of workers	26	Units:	50 mi (D26)
		Duration:	N/A
		Fatal Risk:	VLOOKUP(4,TRUCKRISK,13)
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	VLOOKUP(4,TRUCKRISK,14)
load fines	27	Units:	0.012 mh/yd^3 (D27)
		Duration:	D27***Parms**L10/8 (F27)
		Fatal Risk:	FATALNONRAD*F27
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	NONFATAL*F27
haul fines	28	Units:	50 mi (D28)
		Duration:	N/A
		Fatal Risk:	VLOOKUP(1,TRUCKRISK,13)/ 20***Parms**L10
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	VLOOKUP(1,TRUCKRISK,14)/ 20***Parms**L10* NONFATALTRUCK

Table A-4. Scenario 1 Risk Table Supplementary Calculations

Item	Row/ Cell	Calculation/ Details	Comments/Source
Technology Output Rate	36 V39	Units: Duration: Value: Comment:	ft^2/hr N/A VLOOKUP(2,REMOVALTECH,Y38+1) table lookup based on technology selected
Technology Duration	37 V40	Units: Duration: Value: Comment	rate in ft^2/hr given in Row 36 AREA/B36/8*(DEPTH/0.25) for 3-inch per pass VLOOKUP(3,REMOVALTECH,Y38+1) different techs may require different # passes to remove 1"
Drums of Waste Generated	45 V46	Units: Drums: Comment: Value:	55-gal drums of ancillary waste associated with technology (ROUNDUP(AREA/1000,0)+0.75*AREA*DEPTH/0.25/55) includes 1 drum/1,000 ft^2 or part thereof, and additional drums from additional waste, if any VLOOKUP(4,REMOVALTECH,Y38+1)
Selection of Technology	Y38	Calculation: Comment:	@RISK: RiskDiscrete({1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20},{50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50}) Each technology has an equivalent chance of being selected per iteration

Table A-5. Scenario 1 Rad Risk Calculations

Item	Cell/Row	Calculation/Details	Comments/Source
Facility Floor Area	L7	Units: Calculation: Comment:	m^2 TOTALAREA*0.3048^2 conversion of floor area to metric units
Contaminated Floor Area	L8	Units: Calculation: Comment:	m^2 AREA*0.3048^2 conversion of contaminated floor area to metric units
Characterization Regression Slope	O7	Units: Calculation: Comment:	N/A -(180.582-15.0193*LN(L7)) slope of regression depends on total facility size (for uncontaminated area dose)
Characterization Intercept Slope	O8	Units: Calculation: Comment:	N/A 7138.55*L7^(-1.00172) intercept of regression depends on total facility size (for uncontaminated area dose)
Characterization Contaminated Area Dose	M10	Units: Calculation: Comment:	mrem/yr (10.6053*(1-EXP(-0.00146*L8))+7.9/(1+EXP(0.7365-0.00005*L8)))*0.1*ParmsN24/10000 equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength
Characterization Uncontaminated Area Dose	N10	Units: Calculation: Comment:	mrem/yr (+O7+O8*L8)*0.00001*ParmsN24/10000 uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength

Item	Cell/Row	Calculation/Details	Comments/Source
Characterization Total Dose	O10	Units: Calculation: Comment:	rem **Parms**D7/100*F10*M10/1000/365+(1-**Parms**D7/100)*F10*N10/1000/365 % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Characterization Radiological Fatalities	P10	Units: Calculation: Comment:	fatalities O10*FATALRAD conversion of rem to fatalities using 5x10^{-4}deaths per rem
Surface Removal Dose	M12	Units: Calculation: Comment:	mrem/yr (-0.1204+0.20446*LN(L8))* **Parms**N24/10000 linear relationship between contaminated area size and exposure derived from RESRAD-BUILD; also impacted by source strength
Surface Removal Total Dose	O12	Units: Calculation: Comment:	rem F12*M12/1000/365 worker exposed for project duration at rate computed in M12
Surface Removal Radiological Fatalities	P12	Units: Calculation: Comment:	fatalities O12*FATALRAD conversion of rem to fatalities using 5x10^{-4}deaths per rem
Waste Collection Dose	M13	Units: Calculation: Comment:	mrem/yr (11.14303*(1-EXP(-0.07472*L8))+1.76962/(1+EXP(2.21943-0.00327*L8)))*100***Parms**M25/100 a first-order and logistics fit to the data, from RESRAD-BUILD modeling; depends on source size and strength

Item	Cell/Row	Calculation/Details	Comments/Source
Waste Collection Total Dose	O13	Units: Calculation: Comment:	rem F13*M13/1000/365 conversion of units based on activity duration
Waste Collection Radiological Fatalities	P13	Units: Calculation: Comment:	fatalities O13*FATALRAD conversion of rem to fatalities using 5x10^{-4}deaths per rem
Debris Loading Dose	M14	Units: Calculation: Comment:	mrem/yr 38.927*L8^(-0.15277)***Parms**M25/100 power fit from RESRAD-BUILD modeling
Debris Loading Total Dose	O14	Units: Calculation: Comment:	rem M14/1000/365*F14 conversion of units based on activity duration
Debris Loading Radiological Fatalities	P14	Units: Calculation: Comment:	fatalities O14*FATALRAD conversion of rem to fatalities using 5x10^{-4}deaths per rem
LLW haulage Dose	M15	Units: Calculation: Comment:	mrem VLOOKUP(**Parms**D44,TRANSRISK,6)+(VLOOKUP(**Parms**D44,TRANSRISK,10))*(**Parms**N3+V46*230/2000)/80*1000 accidental and incident-free rail transport rad risk
LLW haulage Total Dose	O15	Units: Calculation: Comment:	rem M15/1000 risk is already in mrem; converted to rem for consistency
LLW haulage Radiological Fatalities	P15	Units: Calculation: Comment:	fatalities O15*FATALRAD conversion of rem to fatalities using 5x10^{-4}deaths per rem

Item	Cell/Row	Calculation/Details	Comments/Source
LLW unloading Dose	M16	Units: Calculation: Comment:	mrem/yr 38.927*L8^(-0.15277)***ParmsM25/100** LLW must be unloaded at disposal facility; equation derived from RESRAD-BUILD
LLW unloading Total Dose	O16	Units: Calculation: Comment:	rem F16*M16/1000/365 conversion of units based on activity duration
LLW unloading Radiological Fatalities	P16	Units: Calculation: Comment:	fatalities O16*FATALRAD conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Population Exposure	M22	Units: Calculation: Comment:	rem 'Population Exposure'!B32 computed in rem for Scenario 1 on another spreadsheet
Population Fatalities	P22	Units: Calculation: Comment:	fatalities M22*FATALRAD conversion of rem to fatalities using $5x10^{-4}$deaths per rem

Sheet: Scenario 2

The Scenario 2 sheet estimates the fatal and non-fatal risk for decontamiantion to free release levels by nine surface treatment technologies.

The Scenario 2 calculations are very similar to the calculations described previously for Scenario 1. The calculations are carried out as summarized in Table A-6.

Table A-6. Scenario 2 Risk Table Calculations

Item	Row/Cell	Calculation/ Details	Comments/Source
travel of workers to site - 50 miles	5	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK Transportation risk only
set up job trailer	6	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 manhours (D6) + 1 trip @ 50 miles D6/8 = 2.9 mandays (F6) !FATALNONRAD*F6+ VLOOKUP(4,TRUCKRISK,13) N/A NONFATAL*F6+VLOOKUP(4,TRUCKRISK,14) *NONFATALTRUCK
construct access road - 100 yd^3 of gravel	7	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.067 manhours/yd^2 (D7) D7/6*12*3*100/8 = 5 mandays (F7) FATALNONRAD*F7 N/A NONFATAL*F7 assume 6" deep gravel
install chain link fence around perimeter	8	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 manhours/ft (D8) D8*4*SQRT(TOTALAREA/3)*1.1/8 (F8) FATALNONRAD*F8 N/A NONFATAL*F8 Area to be fenced is total + 10%
grade	9	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	8 manhours/acre (D9) D9*TOTALAREA/3/43560*1.5/8 (F9) FATALNONRAD*F9 N/A NONFATAL*F9 Area to be graded is total + 50%
characterize building for	10	Units: Duration:	$2.2x10^{-3}$ manhours / ft^2 (D10) D10*TOTALAREA/8

Item	Row/Cell	Calculation/ Details	Comments/Source
action		Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	FATALNONRAD*F10 P10 NONFATAL*F10 Rad risk discussed elsewhere
transport of samples to lab	11	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK Transport risk only; no exposure to technicians assumed
technology (selected in cell N51)	12	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	K54ft^2/hr; K54=VLOOKUP(3,TREATMENTTECH,N51+1) K51;K51=VLOOKUP(2,TREATMENTTECH,N51+1) FATALNONRAD*F12 P12 NONFATAL*F12 rate varies with technology selection
collect waste and load on train	13	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 mh/ft^3 (D13) D13/3*K62*55/7.48/8 - K62 is no. of drums waste FATALNONRAD*F13 P13 NONFATAL*F13 any secondary waste generated disposed of as LLW
collect debris and load into dump trucks	14	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.012 mh/yd^3 (D14) 0 FATALNONRAD*F14 P14 NONFATAL*F14 no surface is removed
haul LLW to EnviroCare	15	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	**Parms**D22 miles (D15) N/A VLOOKUP(ParmsD44,TRANSRISK,13)* (K62*230/2000)/80 P15

Item	Row/Cell	Calculation/ Details	Comments/Source
		Comment:	VLOOKUP(ParmsD44,TRANSRISK,14)* NONFATALRAIL although no rubble, must transport secondary waste drums; includes accident risk
unload LLW at EnviroCare	16	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	10 min for 4 drums K62*10/4/60/8 FATALNONRAD*F16 P16 NONFATAL*F16 unloading of drums only
demolish concrete slab only	17	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.035 mh/yd² (D17) for 12" slab D17/8*TOTALAREA/9 (F17) FATALNONRAD*F17 N/A NONFATAL*F17
crush concrete - load on crusher, screen	18	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	200 tph (D18) **Parms**N5/D18/8 (F18) FATALNONRAD*F18 N/A NONFATAL*F18
transport to sale point (FOB)	19	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	**Parms**D20 (D19) --> 0.1 miles default N/A VLOOKUP(2,TRUCKRISK,13)/20* **Parms**L7 N/A VLOOKUP(2,TRUCKRISK,14)*NONFATALTRUCK/20*ParmsL7
separate rebar	20	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	100 tpd (D20) **Parms**G15/D20 (F20) FATALNONRAD*F20 N/A NONFATAL*F20
test rebar	21	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.00000686 mh/lb (D21) D21/8*ParmsG15*2000 FATALNONRAD*F21 N/A NONFATAL*F21

Item	Row/Cell	Calculation/ Details	Comments/Source
load and haul rebar	22	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	**Parms**D21 (D22) N/A VLOOKUP(3,TRUCKRISK,13)/80* **Parms**G15 N/A VLOOKUP(3,TRUCKRISK,14)/80* **Parms**G15 *NONFATALTRUCK
population exposure during remediation	23	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	VLOOKUP(**Parms**D44,TRANSRISK,3) (D23) SUM(F12:F14) N/A P23 N/A calculated for project duration only
site cleanup	24	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.008 mh/yd^2 (D24) D24*TOTALAREA/9*1.5/8 (F24) FATALNONRAD*F24 N/A NONFATAL*F24
remove job trailer, fence	25	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 mh + 50 mi (D25) D25/8 (F25) FATALNONRAD*F25+VLOOKUP(4,TRUCKRISK,13) N/A NONFATAL*F25+VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK
demobilization travel of workers	26	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	50 mi (D26) N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)
load fines	27	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.012 mh/yd^3 (D27) D27***Parms**L9/8 (F27) FATALNONRAD*F27 N/A NONFATAL*F27
haul fines	28	Units: Duration: Fatal Risk:	50 mi (D28) N/A VLOOKUP(1,TRUCKRISK,13)/20*

Item	Row/Cell	Calculation/ Details	Comments/Source
		Fatal Rad-risk: Nonfatal Risk:	**Parms**L9 N/A VLOOKUP(1,TRUCKRISK,14)/20* **Parms**L9* NONFATALTRUCK

Table A-7. Scenario 2 Risk Table Supplementary Calculations

Item	Row/Cell	Calculation/ Details	Comments/Source
Technology Output Rate	52 K54	Units: Duration: Value: Comment:	ft^2/hr N/A VLOOKUP(3,TREATMENTTECH,N51+1) table lookup based on technology selected
Treatment Efficiency	37	Units: Duration: Value: Comment:	% N/A based on literature review, estimates used to calculate no. passes treatment needed
Contamination Remaining after 1 Pass	38 to 47	Units: Duration: Value: Comment:	true(<999) or false(999) - is level below *de minimus* level on **Parms**E24? N/A typical: IF(+**Parms**D24*((100-B$37)/100)^2<**Parms**E24,2,999) treatment assumed to proceed linearly with each pass until desired reduction is achieved.
Number of Passes Needed	49	Units: Duration: Value: Comment:	N/A N/A typical: MIN(B38:B47) indicates total number of passes required
Technology Duration	51 or K51	Units: Duration: Value: Comment	rate in ft^2/hr given in Row 51 AREA/F52/8*F49 - i.e., times number of passes needed VLOOKUP(2,TREATMENTTECH,N51+1) select total duration to apply technology multiple times
Drums of Waste Generated	61 or K62	Units: Drums: Comment: Value:	55-gal drums of ancillary waste associated with technology ROUNDUP(AREA/1000,0)+0.045*AREA/55*E49 includes 1 drum/1,000 ft^2 or part

Item	Row/Cell	Calculation/ Details	Comments/Source
			thereof, and additional drums from additional waste, if any VLOOKUP(4,TREATMENTTECH,N51+1)
Selection of Technology	N51	Calculation: Comment:	RiskDiscrete({1,2,3,4,5,6,7,9},{50,50,50,50,50,50,50,50}) Each technology has an equivalent chance of being selected per iteration

Table A-8. Scenario 2 Rad Risk Calculations

Item	Cell/Row	Calculation/Details	
Facilty Floor Area	L7	Units: Calculation: Comment:	m^2 TOTALAREA*0.3048^2 conversion of floor area to metric units
Contaminated Floor Area	L8	Units: Calculation: Comment:	m^2 AREA*0.3048^2 conversion of contaminated floor area to metric units
Characterization Regression Slope	O7	Units: Calculation: Comment:	N/A -(180.582-15.0193*LN(L7)) slope of regression depends on total facility size (for uncontaminated area dose)
Characterization Intercept Slope	O8	Units: Calculation: Comment:	N/A 7138.55*L7^(-1.00172) intercept of regression depends on total facility size (for uncontaminated area dose)
Characterization Contaminated Area Dose	M10	Units: Calculation: Comment:	mrem/yr (10.6053*(1-EXP(-0.00146*L8))+7.9/(1+EXP(0.7365-0.00005*L8)))*0.1***Parms**N24/10000 equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength

Item	Cell/Row	Calculation/Details
Characterization Uncontaminated Area Dose	N10	Units: mrem/yr Calculation: (+O7+O8*L8)*0.00001***Parms**N24/10000 Comment: uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength
Characterization Total Dose	O10	Units: rem Calculation: **Parms**D7/100*F10*M10/1000/365+(1-**Parms**D7/100)*F10*N10/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Characterization Radiological Fatalities	P10	Units: fatalities Calculation: O10*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Surface Treatment Dose	M12	Units: mrem/yr Calculation: (-0.1204+0.20446*LN(L8))***Parms**N24/10000 Comment: linear relationship between contaminated area size and exposure derived from RESRAD-BUILD; also impacted by source strength
Surface Treatment Total Dose	O12	Units: rem Calculation: F12*M12/1000/365 Comment: worker exposed for project duration at rate computed in M12
Surface Removal Radiological Fatalities	P12	Units: fatalities Calculation: O12*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem

Item	Cell/Row	Calculation/Details
Waste Collection Dose	M13	Units: mrem/yr Calculation: (11.14303*(1-EXP(-0.07472*L8))+1.76962/(1+EXP(2.21943-0.00327*L8)))*100***Parms**M25/100 Comment: a first-order and logistics fit to the data, from RESRAD-BUILD modeling; depends on source size and strength
Waste Collection Total Dose	O13	Units: rem Calculation: F13*M13/1000/365 Comment: conversion of units based on activity duration
Waste Collection Radiological Fatalities	P13	Units: fatalities Calculation: O13*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Debris Loading Dose	M14	Units: mrem/yr Calculation: 38.927*L8^(-0.15277)***Parms**M25/100 Comment: power fit from RESRAD-BUILD modeling
Debris Loading Total Dose	O14	Units: rem Calculation: M14/1000/365*F14 Comment: conversion of units based on activity duration
Debris Loading Radiological Fatalities	P14	Units: fatalities Calculation: O14*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
LLW haulage Dose	M15	Units: mrem Calculation: VLOOKUP(**Parms**D44,TRANSRISK,6)+(VLOOKUP(**Parms**D44,TRANSRISK,10))*(+K62*230/2000)/80*1000 Comment: accidental and incident-free rail transport rad risk
LLW haulage Total Dose	O15	Units: rem Calculation: M15/1000 Comment: risk is already in mrem; converted to rem for consistency

Item	Cell/Row	Calculation/Details
LLW haulage Radiological Fatalities	P15	Units: fatalities Calculation: O15*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
LLW unloading Dose	M16	Units: mrem/yr Calculation: 38.927*L8^(-0.15277)***ParmsM**25/100 Comment: LLW must be unloaded at disposal facility; equation derived from RESRAD-BUILD
LLW unloading Total Dose	O16	Units: rem Calculation: F16*M16/1000/365 Comment: conversion of units based on activity duration
LLW unloading Radiological Fatalities	P16	Units: fatalities Calculation: O16*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Population Exposure	M22	Units: rem Calculation: 'Population Exposure'!B33 Comment: computed in rem for Scenario 2 on another spreadsheet
Population Fatalities	P22	Units: fatalities Calculation: M22*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem

Sheet: Scenario 3

The Scenario 3 sheet estimates the fatal and non-fatal risk if contaminated surface areas were to be decontaminated, the facility demolished, and the site capped in-place. The calculations are carried out as summarized in Table A-9.

Table A-9. Scenario 3 Risk Table Calculations

Item	Row/Cell	Calculation/Details	
travel of workers to site - 50 miles	5	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK Transportation risk only
set up job trailer	6	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 manhours (D6) + 1 trip @ 50 miles D6/8 = 2.9 mandays (F6) !FATALNONRAD*F6+ VLOOKUP(4,TRUCKRISK,13) N/A NONFATAL*F6+VLOOKUP(4,TRU CKRISK,14) *NONFATALTRUCK
construct access road - 100 yd^3 of gravel	7	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.067 manhours/yd^2 (D7) D7/6*12*3*100/8 = 5 mandays (F7) FATALNONRAD*F7 N/A NONFATAL*F7 assume 6" deep gravel
install chain link fence around perimeter	8	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 manhours/ft (D8) D8*4*SQRT(TOTALAREA/3)*1.1/8 (F8) FATALNONRAD*F8 N/A NONFATAL*F8 Area to be fenced is total + 10%
grade	9	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	8 manhours/acre (D9) D9*TOTALAREA/3/43560*1.5/8 (F9) FATALNONRAD*F9 N/A NONFATAL*F9 Area to be graded is total + 50%

Item	Row/Cell	Calculation/Details	
characterize building for action	10	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	2.2x10^{-3} manhours / ft^2 (D10) D10*TOTALAREA/8 FATALNONRAD*F10 P10 NONFATAL*F10 Rad risk discussed elsewhere
transport of samples to lab	11	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK Transport risk only; no exposure to technicians assumed
technology (selected in cell AH46)	12	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	AG41 ft^2/hr ;AG41=VLOOKUP(3,BOTHTECH,AH46+1) AG42 hr: AG42=VLOOKUP(2,BOTHTECH,AH46+1) FATALNONRAD*F12 P12 NONFATAL*F12 rate varies with technology selection - only removal technologies are used
collect waste and load on train	13	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 mh/ft^3 (D13) D13/3*AF62*55/7.48/8 FATALNONRAD*F13 P13 NONFATAL*F13 any secondary waste generated disposed of as LLW
collect debris and load into dump trucks	14	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.012 mh/yd^3 (D14) IF(AH46<20,+D14***Parms**L3/8,0) FATALNONRAD*F14 P14 NONFATAL*F14 one inch removed surface disposed of as LLW

Item	Row/Cell	Calculation/Details	
haul LLW to EnviroCare	15	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	**Parms**D22 miles (D15) N/A VLOOKUP(**Parms**D44, TRANSRISK,13)*(**Parms**N3+AF62 *230/2000)/80, P15 VLOOKUP(**Parms**D44,TRANSRISK,14)* NONFATALRAIL includes accident risk
unload LLW at EnviroCare	16	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	10 min for 4 drums, 0.5 mh per 40 yd^3 dump AF62*10/4/60/8+**Parms**N3/2000/80 *0.5/8 FATALNONRAD*F16 P16 NONFATAL*F16 for drums and bulk rail car waste
demolish concrete slab only	17	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.035 mh/yd^2 (D17) for 12" slab D17/8*TOTALAREA/9 (F17) FATALNONRAD*F17 N/A NONFATAL*F17
transport cap material to site	18	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	50 miles N/A C58*VLOOKUP(1,TRUCKRISK,13) /20 N/A VLOOKUP(1,TRUCKRISK,14)*NONFATALTRUCK/20*C58 volume cap material required is computed in C58; haulage is by truck; no natural bg radiation accounted for.
consolidate rubble	19	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.006 mh/yd^3 D19***Parms**L6/8 FATALNONRAD*F19 N/A NONFATAL*F19 remaining concrete is uncontaminated

Item	Row/Cell	Calculation/Details	
phase 1a cap	20	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	260.25 mh/acre C57*5*D20/8 FATALNONRAD*F20 N/A NONFATAL*F20 no. 5 acre caps needed computed in C57
phase 1b cap	21	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	260.25 mh/acre C57*5*D21/8 FATALNONRAD*F21 N/A NONFATAL*F21 no. 5 acre caps needed computed in C57; capping broken into several phases
phase 2 cap	22	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	520.5 mh/acre C57*5*D22/8 FATALNONRAD*F22 N/A NONFATAL*F22 no. 5 acre caps needed computed in C57
population exposure during remediation	23	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	VLOOKUP(**Parms**D44,TRANSRIS K,3) (D23) SUM(F12:F14) N/A P22 N/A calculated for project duration only
install monitoring wells	24	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.432 mh/ft ROUNDUP((**Parms**L5*27/6/43560) *1.5/5,0)*4*20*D24/8 FATALNONRAD*F24 N/A NONFATAL*F24 4 wells per cap, 20 ft deep each

Item	Row/Cell	Calculation/Details
well operation	25	Units: 0.5 md/well + 50 miles Duration: (D25*C57*4)*60 Fatal Risk: FATALNONRAD*F25+(VLOOKUP(4,TRUCKRISK,13)*2*60) Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F25+VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK*2*60 Comment: wells checked 2/yr for 30 years; includes transportation risk (one roundtrip per year)
cap maintenance	26	Units: 5 acre/day + 50 miles Duration: C57*5/D26*30 Fatal Risk: FATALNONRAD*F26+VLOOKUP(4,TRUCKRISK,13)*2*30 Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F26+VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK*2*30 Comment: cap mowed once per year; includes roundtrip transportation
cap refertilization and reseeding	27	Units: 5 acre/day Duration: C57*5/D27*30 Fatal Risk: FATALNONRAD*F26+VLOOKUP(4,TRUCKRISK,13)*2 Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F27 Comment: cap reseeded/fertilized once per year
site cleanup	28	Units: 0.008 mh/yd^2 (D28) Duration: D28*TOTALAREA/9*1.5/8 (F28) Fatal Risk: FATALNONRAD*F28 Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F28
remove job trailer, fence	29	Units: 22.857 mh + 50 mi (D29) Duration: D29/8 (F29) Fatal Risk: FATALNONRAD*F29+VLOOKUP(4,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F29+VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK

Item	Row/Cell	Calculation/Details
demobilization travel of workers	30	Units: 50 mi (D30) Duration: N/A Fatal Risk: VLOOKUP(4,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: VLOOKUP(4,TRUCKRISK,14)

Table A-10. Scenario 3 Risk Table Supplementary Calculations

Item	Row/Cell	Calculation/Details
Technology Output Rate	53 AG41	Units: ft^2/hr Duration: N/A Value: VLOOKUP(3,BOTHTECH,AH46+1) Comment: table lookup based on technology selected
Technology Duration	52 AG42	Units: rate in ft^2/hr given in Row52 Duration: AREA/L53/8*(DEPTH/0.25)- ¼ inch per pass Value: VLOOKUP(2,BOTHTECH,AH46+1) Comment different techs may require different # passes to remove 1"
Drums of Waste Generated	61 AF62	Units: 55-gal drums of ancillary waste associated with technology Drums: (ROUNDUP(AREA/1000,0)+0.75*AREA*DEPTH/0.25/55) Comment: includes 1 drum/1,000 ft^2 or part thereof, and additional drums from additional waste, if any Value: VLOOKUP(4,BOTHTECH,AH46+1)
Selection of Technology	AH46	Calculation: RiskDiscrete({1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20},{50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50}) Comment: Each technology has an equivalent chance of being selected per iteration
Cap Area	C56	Units: acres Duration: N/A Value: (+**Parms**L5*27/6/43560)*1.5 Comment: the area of cap required, in acres using 50% for side slopes and 6-ft high fill
No. Caps	C57	Units: N/A Duration: N/A Value: ROUNDUP(C56/5,0) Comment: the number of 5-acre caps needed
Cap Material	C58	Units: yd^3 Duration: N/A Value: IF(C57=1,C56*43560/27*4,C57*5*43560/27*4) Comment: volume of cap material needed, assuming 4-ft thick cover is used

Table A-11. Scenario 3 Rad Risk Calculations

Item	Cell/Row	Calculation/Details
Facilty Floor Area	L7	Units: m^2 Calculation: TOTALAREA*0.3048^2 Comment: conversion of floor area to metric units
Contaminated Floor Area	L8	Units: m^2 Calculation: AREA*0.3048^2 Comment: conversion of contaminated floor area to metric units
Characterization Regression Slope	O7	Units: N/A Calculation: -(180.582-15.0193*LN(L7)) Comment: slope of regression depends on total facility size (for uncontaminated area dose)
Characterization Intercept Slope	O8	Units: N/A Calculation: 7138.55*L7^(-1.00172) Comment: intercept of regression depends on total facility size (for uncontaminated area dose)
Characterization Contaminated Area Dose	M10	Units: mrem/yr Calculation: (10.6053*(1-EXP(-0.00146*L8))+7.9/(1+EXP(0.7365-0.00005*L8)))*0.1***Parms**N24/10000 Comment: equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength
Characterization Uncontaminated Area Dose	N10	Units: mrem/yr Calculation: (+O7+O8*L8)*0.00001***Parms**N24/10000 Comment: uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength

Item	Cell/Row	Calculation/Details
Characterization Total Dose	O10	Units: rem Calculation: **Parms**D7/100*F10*M10/1000/365 +(1-**Parms**D7/100)*F10*N10/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Characterization Radiological Fatalities	P10	Units: fatalities Calculation: O10*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Surface Removal Dose	M12	Units: mrem/yr Calculation: (-0.1204+0.20446*LN(L8))***Parms** N24/10000 Comment: linear relationship between contaminated area size and exposure derived from RESRAD-BUILD; also impacted by source strength
Surface Removal Total Dose	O12	Units: rem Calculation: F12*M12/1000/365 Comment: worker exposed for project duration at rate computed in M12
Surface Removal Radiological Fatalities	P12	Units: fatalities Calculation: O12*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Waste Collection Dose	M13	Units: mrem/yr Calculation: (11.14303*(1-EXP(-0.07472*L8))+ 1.76962/(1+EXP(2.21943-0.00327 *L8)))*100***Parms**M25/100 Comment: a first-order and logistics fit to the data, from RESRAD-BUILD modeling; depends on source size and strength
Waste Collection Total Dose	O13	Units: rem Calculation: F13*M13/1000/365 Comment: conversion of units based on activity duration

Item	Cell/Row	Calculation/Details
Waste Collection Radiological Fatalities	P13	Units: fatalities Calculation: O13*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Debris Loading Dose	M14	Units: mrem/yr Calculation: 38.927*L8^(-0.15277)* **Parms**M25/100 Comment: power fit from RESRAD-BUILD modeling
Debris Loading Total Dose	O14	Units: rem Calculation: M14/1000/365*F14 Comment: conversion of units based on activity duration
Debris Loading Radiological Fatalities	P14	Units: fatalities Calculation: O14*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
LLW haulage Dose	M15	Units: mrem Calculation: VLOOKUP(**Parms**D44,TRANSRISK,6)+(VLOOKUP(**Parms**D44,TRANSRISK,10))*(**Parms**N3+AF62*230/2000)/80*1000 Comment: accidental and incident-free rail transport rad risk
LLW haulage Total Dose	O15	Units: rem Calculation: M15/1000 Comment: risk is already in mrem; converted to rem for consistency
LLW haulage Radiological Fatalities	P15	Units: fatalities Calculation: O15*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
LLW unloading Dose	M16	Units: mrem/yr Calculation: 38.927*L8^(-0.15277)* **Parms**M25/100 Comment: LLW must be unloaded at disposal facility; equation derived from RESRAD-BUILD
LLW unloading Total Dose	O16	Units: rem Calculation: F16*M16/1000/365 Comment: conversion of units based on activity duration

Item	Cell/Row	Calculation/Details	
LLW unloading Radiological Fatalities	P16	Units:	fatalities
		Calculation:	O16*FATALRAD
		Comment:	conversion of rem to fatalities using 5x10^{-4}deaths per rem
Population Exposure	M22	Units:	rem
		Calculation:	'Population Exposure'!B34
		Comment:	computed in rem for Scenario 3 on another spreadsheet
Population Fatalities	P22	Units:	fatalities
		Calculation:	M22*FATALRAD
		Comment:	conversion of rem to fatalities using 5x10^{-4}deaths per rem

Sheet: Scenario 4

The Scenario 4 sheet estimates the fatal and non-fatal risk if the facility is demolished, and the site capped in-place. The calculations are carried out as summarized in Tables A-12 to A-15.

Table A-12. Scenario 4 Risk Table Calculations

Item	Row/Cell	Calculation/Details	
travel of workers to site - 50 miles	5	Units:	1 trip @ 50 miles
		Duration:	N/A
		Fatal Risk:	VLOOKUP(4,TRUCKRISK,13)
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK
		Comment:	Transportation risk only
set up job trailer	6	Units:	22.857 manhours (D6) + 1 trip @ 50 miles
		Duration:	D6/8 = 2.9 mandays (F6)
		Fatal Risk:	!FATALNONRAD*F6+ VLOOKUP(4,TRUCKRISK,13)
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	NONFATAL*F6+VLOOKUP(4,TRUCKRISK,14) *NONFATALTRUCK

Item	Row/Cell	Calculation/Details	
construct access road - 100 yd^3 of gravel	7	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.067 manhours/yd^2 (D7) D7/6*12*3*100/8 = 5 mandays (F7) FATALNONRAD*F7 N/A NONFATAL*F7 assume 6" deep gravel
install chain link fence around perimeter	8	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 manhours/ft (D8) D8*4*SQRT(TOTALAREA/3)*1.1/8 (F8) FATALNONRAD*F8 N/A NONFATAL*F8 Area to be fenced is total + 10%
grade	9	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	8 manhours/acre (D9) D9*TOTALAREA/3/43560*1.5/8 (F9) FATALNONRAD*F9 N/A NONFATAL*F9 Area to be graded is total + 50%
characterize building for worker PPE	10	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.0008 manhours / ft^2 (D10) D10*TOTALAREA/8 FATALNONRAD*F10 P10 NONFATAL*F10 Rad risk discussed elsewhere
transport of samples to lab	11	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK Transport risk only; no exposure to technicians assumed
demolish concrete slab only	12	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.035 mh/yd^2 (D17) for 12" slab D12/8*TOTALAREA/9 FATALNONRAD*F12 N/A NONFATAL*F12

Item	Row/Cell	Calculation/Details
transport cap material to site	13	Units: 50 miles Duration: N/A Fatal Risk: C44/20*VLOOKUP(1,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: VLOOKUP(1,TRUCKRISK,14)*NONFATALTRUCK/20*C44 Comment: volume cap material required is computed in C44; haulage is by truck; no natural bg radiation accounted for.
consolidate rubble	14	Units: 0.006 mh/yd^4 Duration: D14***Parms**L5/8 Fatal Risk: FATALNONRAD*F14 Fatal Rad-risk: P14 Nonfatal Risk: NONFATAL*F14 Comment: concrete is contaminated
phase 1a cap	15	Units: 260.25 mh/acre Duration: C43*5*D15/8 Fatal Risk: FATALNONRAD*F15 Fatal Rad-risk: P15 Nonfatal Risk: NONFATAL*F15 Comment: no. 5 acre caps needed computed in C43; cap fill is contaminated
phase 1b cap	16	Units: 260.25 mh/acre Duration: C43*5*D16/8 Fatal Risk: FATALNONRAD*F16 Fatal Rad-risk: P16 Nonfatal Risk: NONFATAL*F16 Comment: no. 5 acre caps needed computed in C43; cap fill is contaminated
phase 2 cap	17	Units: 520.5 mh/acre Duration: C43*5*D17/8 Fatal Risk: FATALNONRAD*F17 Fatal Rad-risk: P17 Nonfatal Risk: NONFATAL*F17 Comment: no. 5 acre caps needed computed in C43; cap fill is contaminated

Item	Row/Cell	Calculation/Details	
install monitoring wells	18	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.432 mh/ft ROUNDUP((**Parms**L5*27/6/43560)* 1.5/5,0)*4*20*D18/8 FATALNONRAD*F18 P18 NONFATAL*F18 4 wells per cap, 20 ft deep each
well operation	19	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.5 md/well + 50 miles D19*C43*4*400 FATALNONRAD*F19+(VLOOKUP(4, TRUCKRISK,13)*2*400) P19 NONFATAL*F19+VLOOKUP(4,TRU CKRISK,14)*NONFATALTRUCK*2*4 00 wells checked 4/yr for 100 years; includes transportation risk (one roundtrip per year)
.cap maintenance	20	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	5 acre/day + 50 miles C43*5/D20*100 FATALNONRAD*F20+(VLOOKUP(4, TRUCKRISK,13)*2*100) P20 NONFATAL*F20+VLOOKUP(4,TRU CKRISK,14)*NONFATALTRUCK*2*1 00 cap mowed once per year; includes roundtrip transportation
cap refertilization and reseeding	21	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	5 acre/day C43*5/D21*100 FATALNONRAD*F21 P21 NONFATAL*F21 cap reseeded/fertilized once per year
site cleanup	22	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.008 mh/$^{yd^2}$ (D22) D22*TOTALAREA/9*1.5/8 (F22) FATALNONRAD*F22 N/A NONFATAL*F22

Item	Row/Cell	Calculation/Details	
remove job trailer, fence	23	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 mh + 50 mi (D23) D23/8 (F23) FATALNONRAD*F23+VLOOKUP(4, TRUCKRISK,13) N/A NONFATAL*F23+VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK
demobilization travel of workers	24	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	50 mi (D24) N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)
population exposure during remediation	25	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	VLOOKUP(**Parms**D44,TRANSRISK, 3) (D25) SUM(F12:F15) N/A P25 N/A calculated for project duration only

Table A-13. Scenario 4 Risk Table Supplementary Calculations

Item	Row/Cell	Calculation/Details	
Technology Output Rate	53 AG41	Units: Duration: Value: Comment:	ft^2/hr N/A VLOOKUP(3,BOTHTECH,AH46+1) table lookup based on technology selected
Technology Duration	52 AG42	Units: Duration: Value: Comment	rate in ft^2/hr given in Row52 AREA/L53/8*(DEPTH/0.25)- ¼ inch per pass VLOOKUP(2,BOTHTECH,AH46+1) different techs may require different # passes to remove 1"
Drums of Waste Generated	61 AF62	Units: Drums: Comment: Value:	55-gal drums of ancillary waste associated with technology (ROUNDUP(AREA/1000,0)+0.75*AREA * DEPTH/0.25/55) includes 1 drum/1,000 ft^2 or part thereof,

Item	Row/Cell	Calculation/Details
		and additional drums from additional waste, if any VLOOKUP(4,BOTHTECH,AH46+1)
Selection of Technology	AH46	Calculation: RiskDiscrete({1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20},{50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50}) Comment: Each technology has an equivalent chance of being selected per iteration
Cap Area	C42	Units: acres Duration: N/A Value: (+**Parms**L5*27/6/43560)*1.5 Comment: the area of cap required, in acres using 50% for side slopes and 6-ft high fill
No. Caps	C43	Units: N/A Duration: N/A Value: ROUNDUP(C42/5,0) Comment: the number of 5-acre caps needed
Cap Material	C44	Units: yd ^{3} Duration: N/A Value: IF(C43=1,C42*43560/27*4,C43*5*43560/27*4) Comment: volume of cap material needed, assuming 4-ft thick cover is used

Table A-14. Scenario 4 Rad Risk Calculations

Item	Cell/Row	Calculation/Details
Facilty Floor Area	L7	Units: m^2 Calculation: TOTALAREA*0.3048^2 Comment: conversion of floor area to metric units
Contaminated Floor Area	L8	Units: m^2 Calculation: AREA*0.3048^2 Comment: conversion of contaminated floor area to metric units

Item	Cell/Row	Calculation/Details
Demolition Regression Slope	O7	Units: N/A Calculation: 1657.97*L7^(-0.48033) Comment: slope of regression depends on total facility size (for demolition, from contaminated area)
Demolition Intercept Slope	O8	Units: N/A Calculation: 4507.29*L7^(-1.15627) Comment: intercept of regression depends on total facility size
Characterization Regression Slope	P7	Units: N/A Calculation: -(180.582-15.0193*LN(L7)) Comment: slope of regression depends on total facility size (for uncontaminated area dose)
Characterization Intercept Slope	P8	Units: N/A Calculation: 7138.55*L7^(-1.00172) Comment: intercept of regression depends on total facility size (for uncontaminated area dose)
Characterization Contaminated Area Dose	M10	Units: mrem/yr Calculation: (10.6053*(1-EXP(-0.00146*L8))+7.9/(1+EXP(0.7365-0.00005*L8)))*0.1***Parms**N24/10000 Comment: equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength
Characterization Uncontaminated Area Dose	N10	Units: mrem/yr Calculation: (+P7+P8*L8)*0.00001***Parms**N24/10000 Comment: uses slope and intercept in cells P7 and P8 to compute final regression equation; modified by source strength
Characterization Total Dose	O10	Units: rem Calculation: **Parms**D7/100*F10*M10/1000/365+(1-**Parms**D7/100)*F10*N10/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)

Item	Cell/Row	Calculation/Details
Characterization Radiological Fatalities	P10	Units: fatalities Calculation: O10*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Demolition Contaminated Area Dose	M12	Units: mrem/yr Calculation: 0.209/10000***Parms**N24 Comment: equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength
Demolition Uncontaminated Area Dose	N12	Units: mrem/yr Calculation: (O7+O8*L8)*0.00001***Parms**N24/10000 Comment: uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength
Demolition Total Dose	O12	Units: rem Calculation: (**Parms**D7/100)*F12*M12/1000/365+(1-**Parms**D7/100)*F12*N12/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Demolition Radiological Fatalities	P12	Units: fatalities Calculation: O12*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Consolidate Rubble Dose Rate	M14	Units: mrem/yr Calculation: (2.67549*(1-EXP(-0.01603*L7))+0.38093*(1-EXP(-0.0000042*L7)))***ParmsM**26/1 Comment: regression equation from RESRAD-BUILD for homogenized rubble
Consolidate Rubble Total Dose	O14	Units: rem Calculation: M14/1000/365*F14 Comment: units conversion based on project duration
Consolidate Rubble Rad Fatalities	P14	Units: fatalities Calculation: O14*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem

Item	Cell/Row	Calculation/Details
Phase 1a Cap Dose Rate	M15	Units: mrem/yr Calculation: IF(C43=1,(11.3505+0.42683*LN(C42*43560*0.3048^2))***Parms**M26/1.247115,15.43***Parms**M26/1.247115) Comment: different equations from RESRAD, depending on cap area
Phase 1a Cap Total Dose	O15	Units: rem Calculation: M15/1000/365*F15 Comment: units conversion based on project duration
Phase 1a Cap Rad Fatalities	P15	Units: fatalities Calculation: O15*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Phase 1b Cap Dose Rate	M16	Units: mrem/yr Calculation: 2.46***Parms**M26/1.247115 Comment: constant dose rate
Phase 1b Cap Total Dose	O16	Units: rem Calculation: M16/1000/365*F16 Comment: units conversion based on project duration
Phase 1b Cap Rad Fatalities	P16	Units: fatalities Calculation: O16*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Phase 2 Cap Dose Rate	M17	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: constant dose rate
Phase 2 Cap Total Dose	O17	Units: rem Calculation: M17/1000/365*F17 Comment: units conversion based on project duration
Phase 2 Cap Rad Fatalities	P17	Units: fatalities Calculation: O17*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
MW Dose Rate	M18	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: same rate as for fully capped site
MW Total Dose	O18	Units: rem Calculation: M18/1000/365*F18 Comment: units conversion based on project duration

Item	Cell/Row	Calculation/Details
MW Rad Fatalities	P18	Units: fatalities Calculation: O18*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Monitoring Activities Dose Rate	M19	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: same rate as for fully capped site
Monitoring Activities Total Dose	O19	Units: rem Calculation: M19/1000/365*F19 Comment: units conversion based on project duration
Monitoring Activities Rad Fatalities	P19	Units: fatalities Calculation: O19*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Mowing Dose Rate	M20	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: same rate as for fully capped site
Mowing Total Dose	O20	Units: rem Calculation: M20/1000/365*F20 Comment: units conversion based on project duration
Mowing Rad Fatalities	P20	Units: fatalities Calculation: O20*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Refert. Dose Rate	M21	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: same rate as for fully capped site
Refert. Total Dose	O21	Units: rem Calculation: M21/1000/365*F21 Comment: units conversion based on project duration
Refert. Rad Fatalities	P21	Units: fatalities Calculation: O21*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Population Exposure	M22	Units: rem Calculation: 'Population Exposure'!B35 Comment: computed in rem for Scenario 4 on another spreadsheet

Item	Cell/Row	Calculation/Details
Population Fatalities	P22	Units: fatalities Calculation: M22*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem

Sheet: Scenario 5

Scenario 5 involves the construction of an on-site disposal facility using the aggregate reclaimed from the decommissioned DOE facility. No surface decontamination/removal activity is conducted, so additional exposure to workers is anticipated before and during construction.. Additional sources of radiological exposure result from crushing and handling contaminated aggregate, temporary storage of the aggregate, and pouring slabs and walls with the contaminated aggregate. Fines are disposed of in the new facility, and four monitoring wells are installed and monitored for a period of 100 years. Calculations and spreadsheets are detailed in Tables A-15 to A-18.

Table A-15. Scenario 5 Risk Table Calculations

Item	Row/Cell	Calculation/Details	
travel of workers to site - 50 miles	5	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK Transportation risk only
set up job trailer	6	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 manhours (D6) + 1 trip @ 50 miles D6/8 = 2.9 mandays (F6) FATALNONRAD*F6+ VLOOKUP(4,TRUCKRISK,13) N/A NONFATAL*F6+VLOOKUP(4,TRUCKRISK,14) *NONFATALTRUCK
construct access road - 100 yd^3 of gravel	7	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.067 manhours/yd^2 (D7) D7/6*12*3*100/8 = 5 mandays (F7) FATALNONRAD*F7 N/A NONFATAL*F7 assume 6" deep gravel
install chain link fence around perimeter	8	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.16 manhours/ft (D8) D8*4*SQRT(TOTALAREA/3)*1.1/8 (F8) FATALNONRAD*F8 N/A NONFATAL*F8

Item	Row/Cell	Calculation/Details	
		Comment:	Area to be fenced is total + 10%
grade	9	Units:	8 manhours/acre (D9)
		Duration:	D9*TOTALAREA/3/43560*1.5/8 (F9)
		Fatal Risk:	FATALNONRAD*F9
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	NONFATAL*F9
		Comment:	Area to be graded is total + 50%
characterize building for action	10	Units:	2.2x10^{-3} manhours / ft^2 (D10)
		Duration:	D10*TOTALAREA/8
		Fatal Risk:	FATALNONRAD*F10
		Fatal Rad-risk:	P10
		Nonfatal Risk:	NONFATAL*F10
		Comment:	Rad risk discussed elsewhere
transport of samples to lab	11	Units:	1 trip @ 50 miles
		Duration:	N/A
		Fatal Risk:	VLOOKUP(4,TRUCKRISK,13)
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK
		Comment:	Transport risk only; no exposure to technicians assumed
demolish concrete slab only	12	Units:	0.035 mh/yd^2 (D12) for 12" slab
		Duration:	D12/8*TOTALAREA/9
		Fatal Risk:	FATALNONRAD*F12
		Fatal Rad-risk:	P12
		Nonfatal Risk:	NONFATAL*F12
separate rebar	13	Units:	100 tpd (D13)
		Duration:	**Parms**G15/D13 (F13)
		Fatal Risk:	FATALNONRAD*F13
		Fatal Rad-risk:	P13
		Nonfatal Risk:	NONFATAL*F13
		Comment:	some exposure will result from rebar contact
test rebar	14	Units:	0.00000686 mh/lb (D21)
		Duration:	D14/8***Parms**G15*2000
		Fatal Risk:	FATALNONRAD*F14
		Fatal Rad-risk:	N/A
		Nonfatal Risk:	NONFATAL*F14
load and haul rebar	15	Units:	25 miles
		Duration:	N/A
		Fatal Risk:	VLOOKUP(3,TRUCKRISK,13)/80***Parms**G16
		Fatal Rad-risk:	

Item	Row/Cell	Calculation/Details
		Nonfatal Risk: N/A VLOOKUP(3,TRUCKRISK,14)/80***Parms**G15*NONFATALTRUCK
crush and screen concrete	16	Units: 200 tph (D18) Duration: **Parms**N5/D16/8 Fatal Risk: FATALNONRAD*F16 Fatal Rad-risk: P16 Nonfatal Risk: NONFATAL*F16
Store Aggregate	17	Units: 0.01 mh/yd ^{3} Duration: D17***Parms**L7/8 Fatal Risk: FATALNONRAD*F17 Fatal Rad-risk: P17 Nonfatal Risk: NONFATAL*F17 Comment:: moving contaminated aggregate into a storage pile
Construct Facility - Excavate Cell	18	Units: 0.04 mh/yd ^{3} Duration: (((X13/X7)+(X14/X8)+(X15/X7)+(X16/X8))* Fatal Risk: 2000/27)*D18/8 Fatal Rad-risk: FATALNONRAD*F18 Nonfatal Risk: N/A Comment: NONFATAL*F18 Excavating site for LLW disposal facility
Construct Facility - Haul liner material	19	Units: 50 miles Duration: N/A Fatal Risk: (X13*2000/X7/27+X14*2000/X8/27)/15* Fatal Rad-risk: VLOOKUP(1,TRUCKRISK,13) Nonfatal Risk: N/A (X14*2000/X7/27+X15*2000/X8/27)/15* VLOOKUP(1,TRUCKRISK,14)*NONFATATRUCK
Construct Facility - place synthetic membrane	20	Units: 5000 ft^2/day Duration: X11*43560/D20 Fatal Risk: FATALNONRAD*F20 Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F20
Construct Facility - place soil liner	21	Units: 0.025 mh/yd^3 Duration: ((X11/X8*27)+((X14/X7)+(X15/X8)*2 Fatal Risk: 000/27))*D21/8 Fatal Rad-risk: FATALNONRAD*F21

Item	Row/Cell	Calculation/Details
		Nonfatal Risk: N/A NONFATAL*F21
Construct Facility - Haul lift material	22	Units: 50 miles Duration: N/A Fatal Risk: (X16/X8*2000/27)/15*VLOOKUP(1,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: (X16/X8*2000/27)/15*VLOOKUP(1,TRUCKRISK,14)* NONFATALTRUCK
Construct Facility - place fill	23	Units: 0.025 mh/yd^3 Duration: (X15/X7+X17/X8)*2000/D23/8 Fatal Risk: FATALNONRAD*F23 Fatal Rad-risk: P23 Nonfatal Risk: NONFATAL*F23
Capping - Haul cap material	24	Units: 50 miles Duration: N/A Fatal Risk: X18*6/27/15*VLOOKUP(1,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: X18*6/27/15*VLOOKUP(1,TRUCKRISK,14)* RISKNONFATALTRUCK
Capping - hase 1a cap	25	Units: 260.25 mh/acre Duration: X12/43560*D25/8 Fatal Risk: FATALNONRAD*F25 Fatal Rad-risk: P25 Nonfatal Risk: NONFATAL*F25
Capping - hase 1b cap	26	Units: 260.25 mh/acre Duration: X12/43560*D26/8 Fatal Risk: FATALNONRAD*F26 Fatal Rad-risk: P26 Nonfatal Risk: NONFATAL*F26
Capping - phase 2 cap	27	Units: 520.5 mh/acre Duration: X12/43560*D27/8 Fatal Risk: FATALNONRAD*F27 Fatal Rad-risk: P27 Nonfatal Risk: NONFATAL*F27
site cleanup	28	Units: 0.008 mh/yd^2 Duration: D28*TOTALAREA/9*1.5/8 Fatal Risk: FATALNONRAD*F28 Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F28

Item	Row/Cell	Calculation/Details
remove job trailer, fence	29	Units: 22.857 mh + 50 mi Duration: D29/8 Fatal Risk: FATALNONRAD*F29+VLOOKUP(4,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F29+VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK
demobilization travel of workers	30	Units: 50 mi Duration: N/A Fatal Risk: VLOOKUP(4,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK
load fines	31	Units: 0.012 mh/yd^3 Duration: D31***Parms**L9/8 Fatal Risk: FATALNONRAD*F31 Fatal Rad-risk: N/A Nonfatal Risk: NONFATAL*F31
population exposure during remediation	32	Units: VLOOKUP(**Parms**D44,TRANSRISK,3) people/mi^2 Duration: SUM(F12:F17) Fatal Risk: N/A Fatal Rad-risk: P32 Nonfatal Risk: N/A
install monitoring wells	33	Units: 0.432 mh/ft Duration: 4*20*D33/8 Fatal Risk: FATALNONRAD*F33 Fatal Rad-risk: P33 Nonfatal Risk: NONFATAL*F33
well operation	34	Units: 0.5 md/well + 50 miles Duration: D34*4*400 Fatal Risk: FATALNONRAD*F34+(VLOOKUP(4,TRUCKRISK,13)*2*400) Fatal Rad-risk: P34 Nonfatal Risk: NONFATAL*F34+VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK*2*400 Comment: wells checked 4/yr for 100 years; includes transportation risk (one roundtrip per year)
Cap	35	Units: 0.5 acres/day + 50 miles

Item	Row/Cell	Calculation/Details
Maintenance		Duration: X12/D35*100 Fatal Risk: FATALNONRAD*F35+(VLOOKUP(4,TRUCKRISK,13)*2*100) Fatal Rad-risk: P35 Nonfatal Risk: NONFATAL*F35+VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK*2*100 Comment: wells checked 4/yr for 100 years; includes transportation risk (one roundtrip per year)

Table A-16. Scenario 5 Risk Table Supplementary Calculations - Disposal Facility

Item	Row/ Cell	Calculation/Details
Volume of Concrete	X11	Units: ft^3 Value: **Parms**D6*1 Comment: Total volume of concrete
Area of Liner	X12	Units: ft^2 Value: X11/8 Comment: area of LLW facility liner in ft^2
Gravel for Liner	X13	Units: tons Value: X12*1.5*X7/2000 Comment: volume of gravel for LLW facility liner
Clay for Liner	X14	Units: tons Value: X12*4*X8/2000 Comment: volume of clay for LLW facility liner
Volume of concrete fill	X15	Units: tons Value: X11*X7/2000 Comment: volume of concrete placed in LLW facility
Clay for intermediate lifts	X16	Units: tons Value: X12*2*X8/2000 Comment: volume of clay for intermediate lifts in LLW facility

Table A-17. Scenario 5 Rad Risk Calculations

Item	Cell/Row	Calculation/Details	
Facilty Floor Area	L7	Units: Calculation: Comment:	m^2 TOTALAREA*0.3048^2 conversion of floor area to metric units
Contaminated Floor Area	L8	Units: Calculation: Comment:	m^2 AREA*0.3048^2 conversion of contaminated floor area to metric units
Demolition Regression Intercept	O7	Units: Calculation:	N/A 1657.97*L7^(-0.48033)
Demolition Regresion Slope	O8	Units: Calculation:	N/A 4507.29*L7^(-1.15627)
Characterization Regression Intercept	P7	Units: Calculation:	N/A -(180.582-15.0193*LN(L7))
Characterization Regression Slope	P8	Units: Calculation:	N/A 7138.55*L7^(-1.00172)
Characterization Contaminated Area Dose	M10	Units: Calculation: Comment:	mrem/yr (10.6053*(1-EXP(-0.00146*L8))+7.9/(1+EXP(0.7365-0.00005*L8)))*0.1***Parms**N24/10000 equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength
Characterization Uncontaminated Area Dose	N10	Units: Calculation: Comment:	mrem/yr (+P7+P8*L8)*0.00001***Parms**N24/10000 uses slope and intercept in cells P7 and P8 to compute final regression equation; modified by source strength

Item	Cell/Row	Calculation/Details
Characterization Total Dose	O10	Units: rem Calculation: **Parms**D7/100*F10*M10/1000/365+(1-**Parms**D7/100)*F10*N10/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Characterization Radiological Fatalities	P10	Units: fatalities Calculation: O10*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Demolition Contaminated Area Dose	M12	Units: mrem/yr Calculation: 0.209/10000***Parms**N24 Comment: equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength
Demolition Uncontaminated Area Dose	N12	Units: mrem/yr Calculation: (O7+O8*L8)*0.00001***Parms**N24/10000 Comment: uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength
Demolition Total Dose	O12	Units: rem Calculation: (**Parms**D7/100)*F12*M12/1000/365+(1-**Parms**D7/100)*F12*N12/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Demolition Radiological Fatalities	P12	Units: fatalities Calculation: O12*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Rebar Separation (Contaminated) Dose	M13	Units: mrem/yr Calculation: 0.209/10000***Parms**N24 Comment: constant exposure rate

Item	Cell/Row	Calculation/Details
Rebar Separation (Uncontaminated) Dose	N13	Units: mrem/yr Calculation: (O7+O8*L8)*0.00001*ParmsN24/10000 Comment: uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength
Rebar Separation Total Dose	O13	Units: rem Calculation: (ParmsD7/100)*F13*M13/1000/365+(1-ParmsD7/100)*F13*N13/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Rebar Separation Fatalities	P13	Units: fatalities Calculation: O13*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Crush Concrete (Contaminated) Dose Rate	M16	Units: mrem/yr Calculation: 0.209/10000*ParmsN24
Crush Concrete (Uncontaminated) Dose Rate	N16	Units: mrem/yr Calculation: (O7+O8*L8)*0.00001*ParmsN24/10000 Comment: uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength
Crush Concrete Total Dose	O16	Units: rem Calculation: (ParmsD7/100)*F16*M16/1000/365+(1-ParmsD7/100)*F16*N16/1000/365 Comment: units conversion based on project duration and time spent doing each type of concrete
Crush Concrete Rad Fatalities	P16	Units: fatalities Calculation: O16*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Store Aggregate Dose Rate	M17	Units: mrem/yr Calculation: 5.07043/(1+EXP(0.45933-0.03939*S18))*ParmsM26/1.247115 Comment: from RESRAD, depending on volume of aggregate stored

Item	Cell/Row	Calculation/Details
Store Aggregate Total Dose	O17	Units: rem Calculation: M17/1000/365*F17 Comment: units conversion based on project duration
Store Aggregate Rad Fatalities	P17	Units: fatalities Calculation: O17*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Place Fill Material	M23	Units: mrem/yr Calculation: IF(X13=1,(11.3505+0.42683*LN(X12*43560*0.3048^2))*ParmsM26/1.247115,15.43*ParmsM26/1.247115) Comment: from RESRAD, depending on volume of aggregate stored
Place Fill Material	O23	Units: rem Calculation: M23*F23/1000/365 Comment: units conversion based on project duration
Place Fill Material	P23	Units: fatalities Calculation: O23*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Phase 1a Cap	M25	Units: mrem/yr Calculation: IF(X13=1,(11.3505+0.42683*LN(X12*43560*0.3048^2))*ParmsM26/1.247115,15.43*ParmsM26/1.247115) Comment: from RESRAD, depending on volume of aggregate stored
Phase 1a Cap	O25	Units: rem Calculation: M25*F25/1000/365 Comment: units conversion based on project duration
Phase 1a Cap	P25	Units: fatalities Calculation: O25*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Phase 1b Cap	M26	Units: mrem/yr Calculation: 2.46*ParmsM26/1.247115 Comment: from RESRAD, depending on volume of aggregate stored

Item	Cell/Row	Calculation/Details
Phase 1b Cap	O26	Units: rem Calculation: M26*F26/1000/365 Comment: units conversion based on project duration
Phase 1b Cap	P26	Units: fatalities Calculation: O26*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Phase 2 Cap	M27	Units: mrem/yr Calculation: 0.0111*ParmsM26/1.247115 Comment: from RESRAD, depending on volume of aggregate stored
Phase 2 Cap	O27	Units: rem Calculation: M27*F27/1000/365 Comment: units conversion based on project duration
Phase 2 Cap	P27	Units: fatalities Calculation: O27*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Population Exposure	M32	Units: rem Calculation: ‘Population Exposure'!B36 Comment: computed in rem for Scenario 5 on another spreadsheet
Population Fatalities	P32	Units: fatalities Calculation: M32*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
MW Dose Rate	M33	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: same rate as for fully capped site
MW Total Dose	O26	Units: rem Calculation: M33*F33/1000/365 Comment: units conversion based on project duration
MW Rad Fatalities	P33	Units: fatalities Calculation: O33*FATALRAD Comment: conversion of rem to fatalities using $5x10^{-4}$deaths per rem
Monitoring Activities Dose Rate	M34	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: same rate as for fully capped site

Item	Cell/Row	Calculation/Details
Monitoring Activities Total Dose	O34	Units: rem Calculation: M34*F34/1000/365 Comment: units conversion based on project duration
Monitoring Activities Rad Fatalities	P34	Units: fatalities Calculation: O34*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Cap Maintenance Activities Dose Rate	M35	Units: mrem/yr Calculation: 0.0111***Parms**M26/1.247115 Comment: same rate as for fully capped site
Cap Maintenance Activities Total Dose	O35	Units: rem Calculation: M35*F35/1000/365 Comment: units conversion based on project duration
Cap Maintenance Activities Rad Fatalities	P35	Units: fatalities Calculation: O35*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem

Sheet: Scenario 6

Scenario 6 represents the current DOE decontamination and decommissioning practice of decontamination, demolition, and the concrete debris is disposed of in a C&D landfill. Scenario 6 calculations are detailed in Tables 18 through 20.

Table A-18. Scenario 6 Risk Table Calculations

Item	Row /Cell	Calculation/Details
travel of workers to site – 50 miles	5	Units: 1 trip @ 50 miles Duration: N/A Fatal Risk: VLOOKUP(4,TRUCKRISK,13) Fatal Rad-risk: N/A Nonfatal Risk: VLOOKUP(4,TRUCKRISK,14)* Comment: NONFATALTRUCK Transportation risk only

Item	Row /Cell	Calculation/Details	
set up job trailer	6	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 manhours (D6) + 1 trip @ 50 miles D6/8 = 2.9 mandays (F6) !FATALNONRAD*F6+VLOOKUP(4,TRUCKRISK,13) N/A NONFATAL*F6+VLOOKUP(4,TRUCKRISK,14) *NONFATALTRUCK
construct access road – 100 yd^3 of gravel	7	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.067 manhours/$^{yd^2}$ (D7) D7/6*12*3*100/8 = 5 mandays (F7) FATALNONRAD*F7 N/A NONFATAL*F7 assume 6" deep gravel
install chain link fence around perimeter	8	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	0.16 manhours/ft (D8) D8*4*SQRT(TOTALAREA/3)*1.1/8 (F8) FATALNONRAD*F8 N/A NONFATAL*F8 Area to be fenced is total + 10%
grade	9	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	8 manhours/acre (D9) D9*TOTALAREA/3/43560*1.5/8 (F9) FATALNONRAD*F9 N/A NONFATAL*F9 Area to be graded is total + 50%
characterize building for action	10	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	2.2×10^{-3} manhours / ft^2 (D10) D10*TOTALAREA/8 FATALNONRAD*F10 P10 NONFATAL*F10 Rad risk discussed elsewhere
transport of samples to lab	11	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	1 trip @ 50 miles N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)*NONFATALTRUCK Transport risk only; no exposure to technicians assumed

Item	Row /Cell	Calculation/Details
technology (selected in cell AH46)	12	Units: AG41 ft^2/hr ;AG41=VLOOKUP(3,A32:AE59,AH46+1) Duration: AG42 hr: AG42=VLOOKUP(2,A32:AE59,AH46+1) Fatal Risk: FATALNONRAD*F12 Fatal Rad-risk: P12 Nonfatal Risk: NONFATAL*F12 Comment: rate varies with technology selection – only removal technologies are used
collect waste and load on train	13	Units: 0.16 mh/ft^3 (D13) Duration: D13/3*AF60*55/7.48/8 Fatal Risk: FATALNONRAD*F13 Fatal Rad-risk: P13 Nonfatal Risk: NONFATAL*F13 Comment: any secondary waste generated disposed of as LLW
collect debris and load into dump trucks	14	Units: 0.012 mh/yd^3 (D14) Duration: D14***Parms**L3/8 Fatal Risk: FATALNONRAD*F14 Fatal Rad-risk: P14 Nonfatal Risk: NONFATAL*F14 Comment: one inch removed surface disposed of as LLW
haul LLW to EnviroCare	15	Units: **Parms**D22 miles (D15) Duration: N/A Fatal Risk: VLOOKUP(**Parms**D44,TRANSRISK,13)*(**Parms**N3+AF60*230/2000)/80 Fatal Rad-risk: P15 Nonfatal Risk: VLOOKUP(**Parms**D44,TRANSRISK,14)* NONFATALRAIL Comment: includes accident risk
unload LLW at EnviroCare	16	Units: 10 min for 4 drums, 0.5 mh per 40 yd^3 dump Duration: AF60*10/4/60/8+**Parms**N3/2000/80*0.5/8 Fatal Risk: FATALNONRAD*F16 Fatal Rad-risk: P16 Nonfatal Risk: NONFATAL*F16 Comment: for drums and bulk rail car waste

Item	Row /Cell	Calculation/Details	
demolish concrete slab only	17	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.035 mh/yd^2 (D17) for 12” slab D17/8*TOTALAREA/9 (F17) FATALNONRAD*F17 N/A NONFATAL*F17
Load rubble/debris	18	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.018 mh/yd^3 (D18) D18***Parms**L6/8 FATALNONRAD*F18 N/A NONFATAL*F18
transport to C&D facility	19	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	50 miles N/A **Parms**L6/20*VLOOKUP(1,TRUCKRISK,13), N/A **Parms**L6/20*VLOOKUP(1,TRUCKRISK,14)*NONFATALTRUCK
separate rebar	20	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	100 tpd (D20) **Parms**G16/D20 (F20) FATALNONRAD*F20 N/A NONFATAL*F20
test rebar	21	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.00000686 mh/lb (D21) D21/8***Parms**G16*2000 FATALNONRAD*F21 N/A NONFATAL*F21
load and haul rebar	22	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	25 miles N/A VLOOKUP(3,TRUCKRISK,13)/80***Parms**G16 N/A VLOOKUP(3,TRUCKRISK,14)/80***Parms**G16*NONFATALTRUCK

Item	Row /Cell	Calculation/Details	
population exposure during remediation	23	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk: Comment:	VLOOKUP(**Parms**D44,TRANSRISK,3) (D23) SUM(F12:F14) N/A P22 N/A calculated for project duration only
site cleanup	24	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	0.008 mh/yd^2 (D24) D24*TOTALAREA/9*1.5/8 (F24) FATALNONRAD*F24 N/A NONFATAL*F24
remove job trailer, fence	25	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	22.857 mh + 50 mi (D25) D25/8 (F25) FATALNONRAD*F25+VLOOKUP(4,TRUCKRISK,13) N/A NONFATAL*F25+VLOOKUP(4,TRUCKRISK,14)* NONFATALTRUCK
demobilization travel of workers	26	Units: Duration: Fatal Risk: Fatal Rad-risk: Nonfatal Risk:	50 mi (D26) N/A VLOOKUP(4,TRUCKRISK,13) N/A VLOOKUP(4,TRUCKRISK,14)

Table A-19. Scenario 6 Risk Table Supplementary Calculations

Item	Row/Cell	Calculation/Details	
Technology Output Rate	53 AG41	Units: Duration: Value: Comment:	ft²/hr N/A VLOOKUP(3,A32:AE59,AH46+1) table lookup based on technology selected
Technology Duration	52 AG42	Units: Duration: Value: Comment	rate in ft²/hr given in Row52 AREA/L53/8*(DEPTH/0.25)- ¼ inch per pass VLOOKUP(2,A32:AE59,AH46+1) different techs may require different # passes to remove 1"

Item	Row/Cell	Calculation/Details	
Drums of Waste Generated	61 AF62	Units:	55-gal drums of ancillary waste associated with technology
		Drums:	(ROUNDUP(AREA/1000,0)+0.75*AREA* DEPTH/0.25/55)
		Comment:	includes 1 drum/1,000 ft² or part thereof, and additional drums from additional waste, if any
		Value:	VLOOKUP(4,A32:AE59,AH46+1)
Selection of Technology	AH46	Calculation:	RiskDiscrete({1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20},{50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50})
		Comment:	Each technology has an equivalent chance of being selected per iteration

Table A-20. Scenario 6 Rad Risk Calculations

Item	Row/Cell	Calculation/Details	
Facilty Floor Area	L7	Units:	m^2
		Calculation:	TOTALAREA*0.3048^2
		Comment:	conversion of floor area to metric units
Contaminated Floor Area	L8	Units:	m^2
		Calculation:	AREA*0.3048^2
		Comment:	conversion of contaminated floor area to metric units
Characterization Regression Slope	O7	Units:	N/A
		Calculation:	-(180.582-15.0193*LN(L7))
		Comment:	slope of regression depends on total facility size (for uncontaminated area dose)
Characterization Intercept Slope	O8	Units:	N/A
		Calculation:	7138.55*L7^(-1.00172)
		Comment:	intercept of regression depends on total facility size (for uncontaminated area dose)

Item	Row/Cell	Calculation/Details
Characterization Contaminated Area Dose	M10	Units: mrem/yr Calculation: (10.6053*(1-EXP(-0.00146*L8))+7.9/(1+EXP(0.7365-0.00005*L8)))*0.1* **Parms**N24/10000 Comment: equation regressed from RESRAD-BUILD predictions; depends on size of contaminated area and source strength
Characterization Uncontaminated Area Dose	N10	Units: mrem/yr Calculation: (+O7+O8*L8)*0.00001* **Parms**N24/10000 Comment: uses slope and intercept in cells O7 and O8 to compute final regression equation; modified by source strength
Characterization Total Dose	O10	Units: rem Calculation: **Parms**D7/100*F10*M10/1000/365+(1-**Parms**D7/100)*F10*N10/1000/365 Comment: % of time spent in contaminated zone, remainder in uncontaminated zone (same characterization rate, but different doses)
Characterization Radiological Fatalities	P10	Units: fatalities Calculation: O10*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Surface Removal Dose	M12	Units: mrem/yr Calculation: (-0.1204+0.20446*LN(L8))* **Parms**N24/10000 Comment: linear relationship between contaminated area size and exposure derived from RESRAD-BUILD; also impacted by source strength
Surface Removal Total Dose	O12	Units: rem Calculation: F12*M12/1000/365 Comment: worker exposed for project duration at rate computed in M12
Surface Removal Radiological Fatalities	P12	Units: fatalities Calculation: O12*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem

Item	Row/Cell	Calculation/Details
Waste Collection Dose	M13	Units: mrem/yr Calculation: (11.14303*(1-EXP(-0.07472*L8))+1.76962/(1+EXP(2.21943-0.00327*L8)))*100***Parms**M25/100 Comment: a first-order and logistics fit to the data, from RESRAD-BUILD modeling; depends on source size and strength
Waste Collection Total Dose	O13	Units: rem Calculation: F13*M13/1000/365 Comment: conversion of units based on activity duration
Waste Collection Radiological Fatalities	P13	Units: fatalities Calculation: O13*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
Debris Loading Dose	M14	Units: mrem/yr Calculation: 38.927*L8^(-0.15277)***Parms**M25/100 Comment: power fit from RESRAD-BUILD modeling
Debris Loading Total Dose	O14	Units: rem Calculation: M14/1000/365*F14 Comment: conversion of units based on activity duration
Debris Loading Radiological Fatalities	P14	Units: fatalities Calculation: O14*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem
LLW haulage Dose	M15	Units: mrem Calculation: VLOOKUP(**Parms**D44,TRANSRISK,6)+VLOOKUP(**Parms**D44,TRANSRISK,10))*(**Parms**N3+AF60*230/2000)/80 Comment: accidental and incident-free rail transport rad risk
LLW haulage Total Dose	O15	Units: rem Calculation: M15/1000 Comment: risk is already in mrem; converted to rem for consistency
LLW haulage Radiological Fatalities	P15	Units: fatalities Calculation: O15*FATALRAD Comment: conversion of rem to fatalities using 5x10^{-4}deaths per rem

Item	Row/Cell	Calculation/Details	
LLW unloading Dose	M16	Units:	mrem/yr
		Calculation:	38.927*L8^(-0.15277)***Parms**M25/100
		Comment:	LLW must be unloaded at disposal facility; equation derived from RESRAD-BUILD
LLW unloading Total Dose	O16	Units:	rem
		Calculation:	F16*M16/1000/365
		Comment:	conversion of units based on activity duration
LLW unloading Radiological Fatalities	P16	Units:	fatalities
		Calculation:	O16*FATALRAD
		Comment:	conversion of rem to fatalities using 5x10^{-4}deaths per rem
Population Exposure	M22	Units:	rem
		Calculation:	'Population Exposure'!B37
		Comment:	computed in rem for Scenario 6 on another spreadsheet
Population Fatalities	P22	Units:	fatalities
		Calculation:	M22*FATALRAD
		Comment:	conversion of rem to fatalities using 5x10^{-4}deaths per rem

Sheet: Air Dispersion

The "Air Dispersion" spreadsheet calculates the potential dose to the public living in the transportation corridor from accidental releases of contaminated material in the event of a rail accident. The model accounts for ^{60}Co, ^{137}Cs, ^{235}U, and ^{238}U constituents causing exposure via immersion, inhalation, and groundshine (from gamma-rays, beta-rays, and alpha-rays). The contamination is assumed to become air-borne with different sized particulates, although for ^{137}Cs the worst case between solid and volatilization is used. Gaussian puff model equations, with random meteorological conditions (wind speed, stability), and Slade dispersion coefficients are incorporated into a discrete integration to compute exposure to the public. Detailed spreadsheet formulae are presented in Table A-21.

Table A-21. Air Dispersion Calculations

Item	Cell/Col	Calculation/Details
Wind Speed at 10 m	C2	Units: m/sec Calculation: RiskTnormal(3.979,1.06,0,10) Comment: Based on national US average NOAA data
Wind Speed at Ground Level	F2	Units: m/sec Calculation: IF(C$3=1,C2*(2/10)^0.08,IF(C$3=2,+C2*(2/10)^0.15,C2*(2/10)^0.4)) Comment: Conversions of wind speed to ground level, based on atmospheric stability
Atmospheric Stability	C3	Units: N/A Calculation: MAX(I2:I6) Comment: calculated in column I, where stability is determined based on wind speed
Stability for u<2m/sec	I2	Units: N/A Calculation: IF(C2<=2,RiskDiscrete({1,2,3},{60,20,20}),0) Comment: if wind speed is less than 2m/sec, ambient is in unstable condition ~60% of time
Stability for 2< u<3m/sec	I3	Units: N/A Calculation: IF(AND(C2>2,C2<=3),RiskDiscrete({1,3},{60,40}),0) Comment: typically, environment is unstable or stable at this wind speed

Item	Cell/Col	Calculation/Details
Stability for 3<u<5m/sec	I4	Units: N/A Calculation: IF(AND(C2>3,C2<=5),RiskDiscrete({1,2,3},{60,20,20}),0) Comment: stability at this wind speed interval
Stability for 5< u<6m/sec	I5	Units: N/A Calculation: IF(AND(C2>5,C2<=6),RiskDiscrete({1,2},{30,70}),0) Comment: stability at this interval
Stability for u>6m/sec	I6	Units: N/A Calculation: IF(C2>6,RiskDiscrete({1,2},{20,80}),0) Comment: last wind speed interval
^{238}U payload concentration	C7	Units: pCi/gm Calculation: **Parms**L25 Comment: rail car load 235U load
^{235}U payload concentration	C8	Units: pCi/gm Calculation: **Parms**K25 Comment: rail car load 238U load
^{60}Co payload concentration	C9	Units: pCi/gm Calculation: **Parms**I25 Comment: rail car load 60Co load
^{137}Cs payload concentration	C10	Units: pCi/gm Calculation: **Parms**J25 Comment: rail car load 137Cs load
Source Volume	C11	Units: kg Calculation: **Parms**N3*2000*454/1000 Comment: total mass of concrete rubble/debris being transported - not including any drums that may be transported
Dumping Rate (Sand)	A12	Units: kg/Mg Calculation: 0.0016*((F2+22.352)/2.2)^1.3*(2.5/2)^(-1.4) Comment: rate of sand emissions from “dumping” per USEPA Superfund Technical Guidance Series
Dumping Rate (Cement Dust)	A13	Units: kg/Mg Calculation: 0.2*0.0016*((F2+22.352)/2.2)^1.3*(2.5/2)^(-1.4) Comment: rate of cement dust emissions from dumping; 0.2 is particle size coefficient
Dumping Rate (Dust)	A14	Units: kg/Mg Calculation: 0.11*0.0016*((F2+22.352)/2.2)^1.3*(2.5/2)^-(1.4) Comment: rate of dust emissions from dumping

Item	Cell/Col	Calculation/Details
Sand Settling Velocity	E12	Units: m/sec Calculation: RiskTnormal(7.65,3.01,0,15) Comment: Based on Ledbetter (1972)
Cement Dust Settling Velocity	E13	Units: m/sec Calculation: RiskTnormal(0.25,0.1,0,0.5) Comment: Typical range of settling velocities for "cement dust"
Dust Settling Velocity	E14	Units: m/sec Calculation: RiskTnormal(0.0004,0.000164,0,0.0008) Comment:
Sand Emissions	G12	Units: kg Calculation: A12*C11*1000/1000000 Comment: units of emission are in kg/Mg, or kg/1,000,000 g
Cement Dust Emissions	G13	Units: kg Calculation: A13*C11*1000/1000000 Comment:
Dust Emissions	G14	Units: kg Calculation: A14*C11*1000/1000000 Comment:
Total Mass Emissions	G15	Units: g Calculation: SUM(G12:G14)*1000 Comment: total mass of particulates launched/emitted
^{60}Co activity launched	G16	Units: Ci Calculation: G15*C9*0.000000000001 Comment: of all particles launched, the no. of Ci of activity due to ^{60}Co
^{137}Cs activity launched	G17	Units: Ci Calculation: G15*C10*0.000000000001 Comment:
^{238}U activity launched	G18	Units: Ci Calculation: G15*C8*0.000000000001 Comment:
^{235}U activity launched	F18	Units: Ci Calculation: G15*C7*0.000000000001 Comment:
Total Exposure	C16	Units: person-rem Calculation: R423+MAX(Z423,AG423)+AO423+AW423 Comment: the total exposure to surrounding populations resulting from accidents

Item	Cell/Col	Calculation/Details
Distance Downwind	A	Units: m Calculation: 10+A22 Comment: downwind distance integration step; discrete integration continues to ~4 km
y	B	Units: m Calculation: IF(C$3=1,0.14*A21^0.92,IF(C$3=2,0.06*A21^0.92,0.02*A21^0.89)) Comment: Slade lateral dispersion coefficient, based on atmospheric stability
z	C	Units: m Calculation: IF(C$3=1,0.53*A21^0.73,IF(C$3=2,0.15*A21^0.7,0.05*A21^0.61)) Comment: vertical dispersion coefficient
plume width	D	Units: m Calculation: 3*2*B21 Comment: not used, but calculated for interests' sake
arc angle	E	Units: degrees, ° Calculation: 2*ATAN(0.5*D22/A22)*180/PI() Comment: not used
area	F	Units: m^2 Calculation: 0.5*D23*A23-SUM(F$21:F22) Comment: estimated area per integration - assumes growing, repeated triangles (or pie slices)
population exposed	G	Units: persons Calculation: VLOOKUP(+**Parms**D44,TRANSRISK,3)*F23/5280^2/0.3048^2 Comment: based on the facility being assessed (transportation corridor population density), and plume area
effective plume height	H	Units: m Calculation: SQRT(PI()/2)*C23 Comment: effective plume height, used in Gaussian model with settling velocity to account for deposition of particulates
sand downwind concentration	I	Units: g/m^3 Calculation: ($G$12*1000)/((2*PI())^1.5*$B23*$B23*$C23)*EXP(-($E$12/$F$2/$H23*$A23+1/2/$C23^2))*0.4167 Comment: Puff model dispersion; averaged by FAD factor; accounts for settling

Item	Cell/Col	Calculation/Details
cement dust downwind concentration	J	Units: g/m^3 Calculation: (\$G\$13*1000)/((2*PI())^1.5*\$B23*\$B23*\$C23)*EXP(-(\$E\$13/\$F\$2/\$H23*\$A23+1/2/$\$C23^{2}$))*0.4167 Comment: same as above
dust downwind concentration	K	Units: g/m^3 Calculation: (\$G\$14*1000)/((2*PI())^1.5*\$B23*\$B23*\$C23)*EXP(-(\$E\$14/\$F\$2/\$H23*\$A23+1/2/$\$C23^{2}$))*0.4167 Comment: same as above
average downwind ^{60}Co concentration	L	Units: pCi/m^3 Calculation: SUM(I23:K23)*C\$9*0.4167 Comment: total grams ^{60}Co-laden particulates passing a 10-metre integration step...averaged again for passage of puff longitudinally
short duration ^{60}Co inhalation	M	Units: pCi Calculation: L24*18/86400*10/\$F\$2 Comment: assumes 18 m^3/day breathing rate, and duration spent breathing contaminated air based on wind velocity
internal ^{60}Co inhalation dose	N	Units: rem/pers Calculation: 51.1*1.5*0.4/70000/0.073*M23*0.000001 Comment: internal dose from inhalation; based on Lamarsh (1983)
external dose (^{60}Co)	O	Units: rem/pers Calculation: 0.229*L23*0.000000000001*0.318*10/\$F\$2 Comment: external beta dose from immersion; Lamarsh (1983)
external dose (^{60}Co)	P	Units: rem/pers Calculation: 0.262*L23*0.000000000001*1.253*10/\$F\$2 Comment: external gamma dose from immersion; Lamarsh (1983)

Item	Cell/Col	Calculation/Details
dose groundshine (^{60}Co)	Q	Units: rem/pers Calculation: (\$C\$5*3600)*0.0062/F23*(SUM(I22:K22) -SUM(I23:K23))*6*B22*H22*0.4167*C\$9 *0.000000000001 Comment: exposure from ground deposited radionuclides until emergency response team can arrive; calculates difference between air borne concentrations per integration (difference must have been deposited on ground)
total exposure, ^{60}Co	R	Units: rem Calculation: SUM(N23:Q23)*G23 Comment: total exposure per route, multiplied by population living in plume area
average downwind ^{137}Cs concentration	T	Units: pCi/m^3 Calculation: SUM(I24:K24)*C\$10*0.4167 Comment: total grams ^{137}Cs-laden particulates passing a 10-metre integration step averaged again for passage of puff longitudinally
short duration ^{137}Cs inhalation	U	Units: pCi Calculation: T24*18/86400*10/\$F\$2 Comment: assumes 18 m^3/day breathing rate, and duration spent breathing contaminated air based on wind velocity
internal ^{137}Cs inhalation dose	V	Units: rem/pers Calculation: 51.1*0.59*0.75/70000/0.00997*U24*0.000001 Comment: internal dose from inhalation; based on Lamarsh (1983)
external dose (^{137}Cs)	W	Units: rem/pers Calculation: 0.229*T23*0.000000000001*0.514*10/\$F\$2 Comment: external beta dose from immersion; Lamarsh (1983)
external dose (^{137}Cs)	X	Units: rem/pers Calculation: 0.262*T24*0.000000000001*0.662*10/\$F\$2 Comment: external gamma dose from immersion; Lamarsh (1983)

Item	Cell/Col	Calculation/Details
dose groundshine (^{137}Cs)	Y	Units: rem/pers Calculation: (\$C\$5*3600)*0.00366/F23*(SUM(I22:K22)-SUM(I23:K23))*6*B22*H22*0.4167*C\$10*0.000000000001 Comment: exposure from ground depositied radionuclides until emergency response team can arrive; calculates difference between air borne concentrations per integration (difference must have been deposited on ground)
total exposure, ^{137}Cs - volatile	Z	Units: rem Calculation: SUM(V24:Y24)*G24 Comment: total exposure per route, multiplied by population living in plume area
average downwind ^{137}Cs concentration (volatile)	AB	Units: Ci/m^3 Calculation: (\$E\$10)/(PI()*\$C\$2*\$B23*\$C23)*0.4167 Comment: different Gaussian equation, with no settling and assuming “instant” volatilization of all ^{137}Cs
short duration ^{137}Cs inhalation (volatile)	AC	Units: Ci Calculation: 18*AB22/86400*10/\$F\$2 Comment: inhaled activity
internal ^{137}Cs inhalation dose (volatile)	AD	Units: rem/pers Calculation: 51.1*0.59*0.75/70000/0.00997*AC22*1000000 Comment:
external dose (^{137}Cs) (volatile)	AE	Units: rem/pers Calculation: 0.229*AB23*0.514 Comment:
external dose (^{137}Cs) (volatile)	AF	Units: rem/pers Calculation: 0.262*AB24*0.662 Comment:
total exposure, ^{137}Cs (volatile)	AG	Units: rem Calculation: SUM(AD23:AF23)*G23 Comment:
average downwind ^{235}U concentration	AI	Units: pCi/m^3 Calculation: SUM(I23:K23)*C\$8*0.4167 Comment:

Item	Cell/Col	Calculation/Details
short duration ^{235}U inhalation	AJ	Units: pCi Calculation: AI22*18/86400*10/$F$2 Comment:
internal ^{235}U inhalation dose	AK	Units: rem/pers Calculation: 0.0025/1000*AJ23 Comment: based on dose conversion factor from RESRAD (Yu,)
external dose (^{235}U)	AM	Units: rem/pers Calculation: 0.262*AI23*0.000000000001*0.165*10/$F$2 Comment:
dose groundshine (^{235}U)	AN	Units: rem/pers Calculation: ($C$5*3600)*0.0009048/F24*(G$18-SUM(I24:K24)*6*B24*H24*0.4167*C$10*0.000000000001) Comment:
total exposure, ^{235}U	AO	Units: rem Calculation: SUM(AK24:AN24)*G24 Comment:
average downwind ^{238}U concentration	AQ	Units: pCi/m^3 Calculation: SUM(I25:K25)*C$7*0.4167 Comment:
short duration ^{238}U inhalation	AR	Units: pCi Calculation: AQ26*18/86400*10/$F$2 Comment:
internal ^{238}U inhalation dose	AS	Units: rem/pers Calculation: 0.0024/1000*AR27 Comment: based on dose conversion factor from RESRAD (Yu,)
external dose (^{238}U)	AU	Units: rem/pers Calculation: 0.262*AQ24*0.000000000001*0.0496*10/$F$2 Comment:
dose groundshine (^{238}U)	AV	Units: rem/pers Calculation: ($C$5*3600)*0.000321/F23*(F$18-SUM(I23:K23)*6*B23*H23*0.4167*C$10*0.000000000001) Comment:
total exposure, ^{238}U	AW	Units: rem Calculation: SUM(AS23:AV23)*G23 Comment:

Sheet: Population Exposure

The "Population Exposure" spreadsheet calculates the potential dose to the public living in the immediate vicinity of the selected facility. Risk projections are made using Gaussian plume models and the same radionuclide contaminants as the Air Disersion Sheet. However, exposure is not integrated, but computed as a single value for a group of residents living one-mile from the facility (assumed fence-line distance). Actual facility population densities around the facility are used to estimate exposure, and the entire population is assumed to be in the plume swath (conservative). Exposure only occurs during the duration of the project, and the emission rate is not accidental but fixed at 0.22 g/sec. Detailed spreadsheet formulae are presented in Table A-22.

Table A-22. Population Exposure Calculations

Item	Cell /Col	Calculation/Details	
Wind Speed at 10 m	C2	Units: Calculation: Comment:	m/sec RiskTnormal(3.979,1.06,0,10) Based on national US average NOAA data
Wind Speed at Ground Level	F2	Units: Calculation: Comment:	m/sec IF(C$3=1,C2*(2/10)^0.08,IF(C$3=2,+C2*(2/10)^0.15,C2*(2/10)^0.4)) Conversions of wind speed to ground level, based on atmospheric stability
Atmospheric Stability	C3	Units: Calculation: Comment:	N/A MAX(H2:H6) calculated in column H, where stability is determined based on wind speed
Stability for u<2m/sec	H2	Units: Calculation: Comment:	N/A IF(C2<=2,RiskDiscrete({1,2,3},{60,20,20}),0) if wind speed is less than 2m/sec, ambient is in unstable condition ~60% of time
Stability for 2< u<3m/sec	H3	Units: Calculation: Comment:	N/A IF(AND(C2>2,C2<=3),RiskDiscrete({1,3},{60,40}),0) typically, environment is unstable or stable at this wind speed
Stability for 3<u<5m/sec	H4	Units: Calculation: Comment:	N/A IF(AND(C2>3,C2<=5),RiskDiscrete({1,2,3},{60,20,20}),0) stability at this wind speed interval

Item	Cell /Col	Calculation/Details
Stability for 5< u<6m/sec	H5	Units: N/A Calculation: IF(AND(C2>5,C2<=6),RiskDiscrete({1,2},{30,70}),0) Comment: stability at this interval
Stability for u>6m/sec	H6	Units: N/A Calculation: IF(C2>6,RiskDiscrete({1,2},{20,80}),0) Comment: last wind speed interval
^{238}U payload concentration	C7	Units: pCi/gm Calculation: **Parms**L25 Comment: rail car load 235U load
^{235}U payload concentration	C8	Units: pCi/gm Calculation: **Parms**K25 Comment: rail car load 238U load
^{60}Co payload concentration	C9	Units: pCi/gm Calculation: **Parms**I25 Comment: rail car load 60Co load
^{137}Cs payload concentration	C10	Units: pCi/gm Calculation: **Parms**J25 Comment: rail car load 137Cs load
Source Volume	C11	Units: kg Calculation: **Parms**N3*2000*454/1000 Comment: total mass of concrete rubble/debris being transported - not including any drums that may be transported
Dumping Rate (Sand)	A12	Units: g/sec Calculation: 0.47*0.222 Comment: typical emission rate is 0.222 g/sec; assume 47% sand
Dumping Rate (Cement Dust)	A13	Units: g/sec Calculation: 0.23*0.222 Comment: assume 23% composed of cement dust
Dumping Rate (Dust)	A14	Units: g/sec Calculation: 0.3*0.222 Comment: ...and 30% as dust
Sand Settling Velocity	E12	Units: m/sec Calculation: RiskTnormal(7.65,3.01,0,15) Comment: Based on Ledbetter (1972)
Cement Dust Settling Velocity	E13	Units: m/sec Calculation: RiskTnormal(0.25,0.1,0,0.5) Comment: Typical range of settling velocities for "cement dust"

Item	Cell /Col	Calculation/Details	
Dust Settling Velocity	E14	Units:	m/sec
		Calculation:	RiskTnormal(0.0004,0.000164,0,0.0008)
		Comment:	
Distance Downwind	A	Units:	m
		Calculation:	1609
		Comment:	exposure considered at 1-mile (1609 metres)
y	B	Units:	m
		Calculation:	IF(C$3=1,0.14*A21^0.92,IF(C$3=2,0.06*A21^0.92,0.02*A21^0.89))
		Comment:	Slade lateral dispersion coefficient, based on atmospheric stability
z	C	Units:	m
		Calculation:	IF(C$3=1,0.53*A21^0.73,IF(C$3=2,0.15*A21^0.7,0.05*A21^0.61))
		Comment:	vertical dispersion coefficient
plume width	D	Units:	m
		Calculation:	3*2*B21
		Comment:	not used, but calculated for interests' sake
arc angle	E	Units:	degrees, °
		Calculation:	2*ATAN(0.5*D22/A22)*180/PI()
		Comment:	not used
population exposed	G	Units:	persons
		Calculation:	VLOOKUP(+**Parms**D$44,TRANSRISK,15)
		Comment:	based on the facility being assessed, actual surrounding population
effective plume height	H	Units:	m
		Calculation:	SQRT(PI()/2)*C23
		Comment:	effective plume height, used in Gaussian model with settling velocity to account for deposition of particulates
sand downwind concentration	I	Units:	g/m^3
		Calculation:	$A$12/(3.14*$F$2*$B23*$C23)*EXP(-($E$12/$F$2/$H23*$A23+1/(2*$C23^2)))
		Comment:	continuous source plume model dispersion
cement dust downwind concentration	J	Units:	g/m^3
		Calculation:	$A$13/(3.14*$F$2*$B23*$C23)*EXP(-($E$13/$F$2/$H23*$A23+1/(2*$C23^2)))
		Comment:	same as above

Item	Cell /Col	Calculation/Details
dust downwind concentration	K	Units: g/m^3 Calculation: `$A$14/(3.14*$F$2*$B23*$C23)*EXP(-($E$14/$F$2/$H23*$A23+1/(2*$C23`^{2}`)))` Comment: same as above
average downwind ^{60}Co concentration	L	Units: pCi/m^3 Calculation: SUM(I23:K23)*C$9*0.4167 Comment: total grams ^{60}Co-laden particulates passing fenceline receptor...averaged by FAD factor
short duration ^{60}Co inhalation	M	Units: pCi Calculation: L23*18*(Scenario Duration) Comment: assumes 18 m^3/day breathing rate for project duration
internal ^{60}Co inhalation dose	N	Units: rem/pers Calculation: 51.1*1.5*0.4/70000/0.073*M23*0.000001 Comment: internal dose from inhalation; based on Lamarsh (1983)
external dose (^{60}Co)	O	Units: rem/pers Calculation: 0.229*L23*0.000000000001*0.318*(Scenario Duration)*86400 Comment: external beta dose from immersion; Lamarsh (1983)
external dose (^{60}Co)	P	Units: rem/pers Calculation: 0.262*L23*0.000000000001*1.253*(Scenario Duration)*86400 Comment: external gamma dose from immersion; Lamarsh (1983)
total exposure (^{60}Co)	R	Units: rem Calculation: SUM(N23:Q23)*G23 Comment: total exposure to population
average downwind ^{137}Cs concentration	T	Units: pCi/m^3 Calculation: SUM(I23:K23)*C$10*0.4167 Comment: total grams ^{137}Cs-laden particulates passing fenceline
short duration ^{137}Cs inhalation	U	Units: pCi Calculation: T23*18*(Scenario Duration) Comment: assumes 18 m^3/day breathing rate, and duration spent breathing contaminated air based on wind velocity

Item	Cell /Col	Calculation/Details
internal ^{137}Cs inhalation dose	V	Units: rem/pers Calculation: 51.1*0.59*0.75/70000/0.00997*U23*0.000001 Comment: internal dose from inhalation; based on Lamarsh (1983)
external dose (^{137}Cs)	W	Units: rem/pers Calculation: 0.229*T23*0.000000000001*0.514*(Scenario Duration)*86400 Comment: external beta dose from immersion; Lamarsh (1983)
external dose (^{137}Cs)	X	Units: rem/pers Calculation: 0.262*T23*0.000000000001*0.662*(Scenario Duration)*86400 Comment: external gamma dose from immersion; Lamarsh (1983)
total exposure, ^{137}Cs - volatile	Z	Units: rem Calculation: SUM(V24:Y24)*G24 Comment: total exposure to surrounding population
average downwind ^{235}U concentration	AI	Units: pCi/m^3 Calculation: SUM(I23:K23)*C$8*0.4167 Comment:
short duration ^{235}U inhalation	AJ	Units: pCi Calculation: AI24*18*(Scenario Duration) Comment:
internal ^{235}U inhalation dose	AK	Units: rem/pers Calculation: 0.0025/1000*AJ23 Comment: based on dose conversion factor from RESRAD (Yu,)
external dose (^{235}U)	AM	Units: rem/pers Calculation: 0.262*AI24*0.000000000001*0.165*(Scenario Duration)*86400 Comment:
total exposure (^{235}U)	AO	Units: rem Calculation: SUM(AK24:AN24)*G24 Comment:
average downwind ^{238}U concentration	AQ	Units: pCi/m^3 Calculation: SUM(I23:K23)*C$7*0.4167 Comment:

Item	Cell /Col	Calculation/Details
short duration ^{238}U inhalation	AR	Units: pCi Calculation: AQ23*18*(Scenario Duration) Comment:
internal ^{238}U inhalation dose	AS	Units: rem/pers Calculation: 0.0024/1000*AR23 Comment: based on dose conversion factor from RESRAD (Yu,)
external dose (^{238}U)	AU	Units: rem/pers Calculation: 0.262*AQ23*0.000000000001*0.0496*(Scenario Duration)*86400 Comment:
total exposure (^{238}U)	AW	Units: rem Calculation: SUM(AS23:AV23)*G23 Comment:
Scenario 1 Population Exposure	B32	Units: rem Calculation: SUM(R32,Z32,AO32,AW32) Comment:
Scenario 1 Project Duration	C32	Units: man-days Calculation: 'Scenario 1'!F23 Comment:
Scenario 2 Population Exposure	B33	Units: rem Calculation: SUM(R33,Z33,AO33,AW33) Comment:
Scenario 2 Project Duration	C33	Units: man-days Calculation: 'Scenario 2'!F23 Comment:
Scenario 3 Population Exposure	B34	Units: rem Calculation: SUM(R34,Z34,AO34,AW34) Comment:
Scenario 3 Project Duration	C34	Units: man-days Calculation: 'Scenario 3'!F23 Comment:
Scenario 4 Population Exposure	B35	Units: rem Calculation: SUM(R35,Z35,AO35,AW35) Comment:
Scenario 4 Project Duration	C35	Units: man-days Calculation: 'Scenario 4'!F25 Comment:
Scenario 5 Population Exposure	B36	Units: rem Calculation: SUM(R36,Z36,AO36,AW36) Comment:

Item	Cell /Col	Calculation/Details
Scenario 5 Project Duration	C36	Units: man-days Calculation: 'Scenario 5'!F25 Comment:
Scenario 6 Population Exposure	B37	Units: rem Calculation: SUM(R37,Z37,AO37,AW37) Comment:
Scenario 6 Project Duration	C37	Units: man-days Calculation: 'Scenario 6'!F23 Comment:

Sheet: Risk Factors

The "Risk Factors" spreadsheet performs risk calculations for rail and truck transport radiation fatalities and lost-days. Actual rail and truck transportation risks are computed for both accident and incident-free risk where appropriate. The rail transportation risk table incorporates the exposure to corridor-populations from the "Air Dispersion" spreadsheet. This spreadsheet also contains general risk factors that are necessary to compute fatalities and lost-days in the individual scenarios. Detailed calculations and formulae for the "Risk Factors" spreadsheet are summarized in Tables A-23 through A-25.

Table A-23. Risk Factors Calculations: Rail

Item	Cell/Row		Calculation/Details
Point of Origin	B	Units: Calculation: Comment:	N/A N/A each of the DOE facilities subject to analysis
Population Density	C	Units: Calculation: Comment:	persons/mi^2 N/A average population density in the transportation corridor between the facility and EnviroCare, as established by INTERLINE 5.0 modeling.
Route Length	D	Units: Calculation: Comment:	miles N/A rail route length between facility and EnviroCare, as established by INTERLINE 5.0 modeling.
Rail Accident Rate	E	Units: Calculation: Comment:	accidents/km 3.73E-07 national rail accident rate for rail transport
R_{ace} Rail Accident Exposure	F	Units: Calculation: Comment:	rem 'Air Dispersion'!C16*1.609*D6*E6 exposure from accident model, times number of accidents; computed separately for each facility but displayed only for the facility under analysis

Item	Cell/Row	Calculation/Details
Shipment Duration	G	Units: hrs Calculation: N/A Comment: determined from INTERLINE 5.0 modeling
On-link Traffic Density	H	Units: vehicles/hr Calculation: 4 Comment: based on work by Raj *et al.* (1996)
Crew Size	I	Units: persons Calculation: 2 Comment: assumed
R_{IFE} Rail Incident-Free Exposure	J	Units: rem/car Calculation: (0.00000595*C7/2.59*G7+0.0000112*H7*G7^{2}/D7/1.609+0.000764*I7*G7+0.0000249*D7*1.609+0.024)*$R$8 Comment: based on Raj *et al.* (1996), scaled by source strength
Fatal Accident Rate	K	Units: accidents/km Calculation: 6.84E-08 Comment: national rail accident fatality rate
Chemical Exhaust Risk	L	Units: fatality/km Calculation: 1.30E-07 Comment: based on Rao (1982)
Non-rad Accident Risk	M	Units: fatalities/car Calculation: (+K7+L7)*D7*1.609 Comment:
Non-fatal Accidents	N	Units: accidents/trip Calculation: E8*1.609*D8 Comment: accident rate times route length gives the number of accidents during the trip
Population	O	Units: persons Calculation: N/A Comment: the actual population living within 1 mi^{2} of the facility (used in Population Exposure calculation)
Actual Source Activity	R6	Units: pCi Calculation: **Parms**M25*80*2000*454 Comment: assumes 80-ton rail car

Item	Cell/Row	Calculation/Details
Exposure Rate	R7	Units: mrem/hr Calculation: R6*0.00000000103/365/24 Comment: from RESRAD-BUILD modeling, at a distance of 1-m with ¼" iron shielding
Conversion Ratio	R8	Units: unitless Calculation: R7/13 Comment: Raj *et al.* (1996) exposure rate was based on regulatory permissible exposure of 13 mrem; incident-free exposure is scaled by this ratio to account for "actual" exposure rate.

Table A-24. Risk Factors Calculations: Truck

Item	Cell/Row	Calculation/Details
Point of Origin	B	Units: N/A Calculation: N/A Comment: types of transport missions that will occur by truck, as opposed to rail
Population Density	C	Units: persons/mi^2 Calculation: 100 (16 for on-site work) Comment: typical population density
Route Length	D	Units: miles Calculation: N/A Comment: assumed
Truck Accident Rate	E	Units: accidents/km Calculation: 6.51E-07 Comment: national truck accident rate
Truck Accident Exposure	F	Units: N/A Calculation: N/A Comment: no rad material is transported by truck
Shipment Duration	G	Units: hrs Calculation: 0.5/20*D30 Comment: assume 40 mph average speed
On-link Traffic Density	H	Units: vehicles/hr Calculation: 780 Comment: based on work by Raj *et al.* (1996)

Item	Cell/Row	Calculation/Details
Crew Size	I	Units: persons Calculation: 2 Comment: assumed
Incident-Free Exposure	J	Units: N/A Calculation: N/A Comment: no rad material is transported by truck
Fatal Accident Rate	K	Units: accidents/km Calculation: 3.10E-08 Comment: national truck accident fatality rate
Chemical Exhaust Risk	L	Units: fatality/km Calculation: 1.30E-07 Comment: based on Rao (1982)
Accident Risk	M	Units: fatalities/shipment Calculation: K30*D30*1.609+L30*D30*1.609 Comment:
Non-fatal Accidents	N	Units: accidents/trip Calculation: E30*1.6093*D30 Comment: accident rate times route length gives the number of accidents during the trip

Table A-25. Risk Factors

Item	Cell/Row	Calculation/Details
Fatal: non-rad	C39	Units: deaths/man-day Calculation: RiskTnormal(0.000001108176,2.60280171015772E-07,0,1) Comment: truncated normal distribution, based on literature review
Fatal: Rad	C40	Units: deaths/rem Calculation: 5.00E-04 Comment: conversion rate for rad exposure to fatalities
Fatal: Mining	C41	Units: deaths/man-day Calculation: RiskUniform(0.00000053,0.00000227) Comment: fatalities per man-day worked in surface mines, based on literature review
Nonfatal: nonrad	C42	Units: lost days/man day Calculation: RiskTnormal(0.00461,0.00127,0,1 Comment:

Item	Cell/Row	Calculation/Details
Nonfatal: truck	C43	Units: lost days/accident Calculation: RiskLognorm(25.33,0.2*25.33) Comment: days lost per accident, with mean of 25.33 and st. dev of approximately 20%
Nonfatal: rail	C44	Units: lost days/accident Calculation: RiskLognorm(48.53, 0.2*48.53) Comment:
Nonfatal: mining	C45	Units: lost days/man day Calculation: RiskTriang(0.00471,0.00532,0.0145) Comment:

Sheet: Risk Summary

The results of each scenario analysis are summarized on one sheet for ease of comparison and archiving. The formulae are self-explanatory, and no computation occurs on this sheet. It is strictly informational.

APPENDIX B – RISK MODEL SCREENS

Title:	Scenario Risk Analysis Table -- Common Parameters
Description:	Parameter values common to all scenarios
Date:	Mar-97

Parameter		**Units**	**Value**				
Physical	Total Area	ft²	8,577,000				
	% Contaminated	%	14.98881152	RiskTriang(0.1,15,100)			
	Contaminated Area	ft²	1,285,590				
	Thickness	in	12				
	Depth of Contamination	in	1.0				
	Density	lbs/cuf	150				
	Bulk Concrete	%	0	0.00	Linear feet, 10' segs	0.00	tons of rebar
	Rubble Expansion Divisor	%	70	43	% increase in vol	0.00	
Distances	C&D Landfill	mi	50				
	On-site Facility	mi	0.1			45029.25	tons of rebar
	Rebar Scrap Yard	mi	25			44466.80	
	LLW Disposal Facility	mi	469				
Characterization	Prior to Release	test/yd3	0.025	Required level of Contamiantion			
	Surface Contamination	dpm/100 cm²	158,027	10 dpm/100 cm² DL			

concrete volumes:		yd3:	tons:
surface removed:		5668.39	8034.94
bulk:			
total, no surface rem.:		453809.52	643275.00
total, surface rem.:		448141.14	635240.06
aggregate, nsr:		236560.28	450292.50
aggregate, sr:		233605.49	444668.04
fines, nsr:		95300.00	192982.50
fines, sr:		94109.64	190572.02

Facility:		**Selection**	
IDAHO	Idaho National Laboratory		
NEVADA	Nevada Test Site	x	2
RFLATS	Rocky Flats Plant		
LBERK	Lawrence Berkeley Lab		
LLIV	Lawrence Livermore NL		
ETEC	Energy Tech. Engr. Ctr.		
HANFORD	Hanford Site		
LOSALA	Los Alamos NL		
PANTEX	Pantex Plant		
SANDIA	Sandia NL		
ARGEAST	Argonne NL East		
PAD	Paducah Gas. Diff Site		
PORT	Portsmouth Gas Diff Site		
ORNL	Oak Ridge NL		
MORGAN	Morgantown Energy Tech		
SAVRIV	Savannah River Site		
BROOK	Brookhaven NL		

ratios: 158,027	104,756	34,220	19,051			
	^{60}Co	^{137}Cs	^{235}U	^{238}U		
dpm/100 cm²:	104,756	34,220	572	18,479	pCi/m²:	7.12E+06
pCi/g surface	77.2485946	25.2345539	0.421448116	13.62682242	116.531419	
pCi/g homog.	0.964887187	0.315196644	0.005264172	0.170208227	1.45555623	

Scenario 1 - Surface Removal, Demolition, Recycle
Table Name: Scenario_1

No.	Task Description	Comment	Rate	Processing Units	Total man days	Fatal Risk (deaths) Non-rad	Radiological	Nonfatal Risk (lost workdays)	Reference
1	Site Prep	travel of workers to site - 50 miles	1	50 miles	NA	1 05E 05		1 33E 03	estimate
2		set up job trailer	22 857	mh/each + 50 mi	2 9	1 37E 05		1 45E 02	Means, p 12
3		construct access road - 100 yd3 of gravel	0 047	mh/yd3	5 0	5 57E 06		2 32E 02	Means, p12
4		install chain link fence around perimeter	0 16	mh/ft	148 8	1 65E 04		6 86E 01	Means, p 12
5		grade	8	mh/acre	91 5	1 09E 04		4 54E 01	Means, p 37
6	Characterization	characterize building for action	3 2E 03	mh/ft2	2326 5	2 51E 03	6 41E 04	1 07E+01	
7		transport of samples to lab	1	50 miles	NA	1 05E 05		1 33E 03	estimate
8	Surface Removal	Explosive	100	ft2/hr	1607 0	1 78E 03	3 56E 03	7 41E+00	Economic report
9		collect waste (from removal technology) - 55 drums, load on train	0 16	mh/3 ft3	63 0	6 99E 05	1 30E 04	2 91E 01	w/55-ga drums
10		collect debris and load into dump trucks	0 012	mh/yd3	8 5	9 42E 06	8 86E 08	3 92E 02	Means, p 41
11	LLW disposal	haul LLW to EnviroCare	463 41	miles	NA	1 53E 02	2 36E 07	1 36E 02	estimate - 1 trip
12		unload LLW at EnviroCare	0 5/0 17	bulk/ drum	6 7	7 43E 06	6 91E 08	3 09E 02	10min 4, bulk 0 5hrs/40 yd3
13	Demolition	demolish concrete slab only	0 035	mh/yd3	4169 4	4 62E 03		1 92E+01	Dykins and Epps, 1987
14		crush concrete - load on crusher, screen	200	tph	377 03	4 40E 04		1 83E+00	Busse
15		transport to sale point (FOB)	0 1	miles	NA	3 31E 04		4 13E 02	mo 20 cy trucks - multi trips
16	Rebar	separate rebar	100	tpd	444 7	4 93E 04		2 05E+00	Busse
17		test rebar	6 86E 06	mh/lb	76 3	8 45E 05		3 52E 01	
18		load and haul rebar	25	miles	NA	2 93E 03		3 49E 01	e - check the no. shipments
19	Population	Exposure during remediation	1	people for	173 10	0 00E+00	3 33E 09	0 00E+00	
20	Clean up	site cleanup	0 001	mh/yd2	1429 5	1 58E 03		6 55E+00	Means, p 56
21		remove job trailer, fence	22 857	mh/each + 50 miles	2 9	1 37E 05		1 45E 02	Means, p 12
22		demobilization travel of workers	1	50 miles	NA	1 05E 05		5 24E 05	estimate
23	Fixes	load	0 012	mh/yd3	141 16	1 56E 04		6 51E 01	Means, p 41
24		haul	50	miles	NA	6 61E 02		8 33E+00	estimate

Rad Risk.

796 829 37 total area, m2
119,435 25 cont area, m2

		characterization
Intercept		23 51
Slope		0 01

	Cont Area Dose	Clean Area Dose	Sum Dose, rem	Deaths:
	1314.29	7.41	1 30E+00	6 41E 04
	1,435.75		7 11E+00	3 56E 03
	1504.75		2 60E 01	1 30E 04
	7.40		1 77E 04	8 86E 08
	0.47		4 71E 04	2 36E 07
	7.40		1 40E 04	6 91E 08
Population	6 66E-06			3 33E 09

Scenario 1 Summary:

	Radiological	Non Rad	Transport	Construction
Fatalities	4 34E 03	9 62E 02	8 47E 02	1 21E 02
Lost Workdays		5 91E+01	8 73E+00	5 04E+01
Total Duration	11100 8 man days			

Trans. Fatal	Trans. Non f	Total Cost
1 05E 05	1 33E 03	
1 0539E 05	0 001326854	3 16032E 06
		5 57E 06
		1 65E 04
		1 09E 04
		2 51E 03
1 05E 05	1 33E 03	
		1 78E 03
		6 99E 05
		9 42E 06
1 53E 02	1 36E 02	
		7 43E 06
		4 62E 03
		4 40E 04
3 31E 04	4 13E 02	
		4 93E 04
		8 45E 05
2 93E 03	3 49E 01	
		1 58E 03
1 0536E 05	0 001326854	3 16532E 06
1 05E 05	5 24E 05	
		1 56E 04
6 61E 02	8 33E+00	
8.41E 02	8.73E+00	1.21E 02

select

	Abrasive Jetting Ice	Abrasive Jetting Plastic Pellet	Abrasive Jetting Sand	Abrasive Jetting Soft Media	Carbon Dioxide (CO2 Centrifugal	(CO2) Compressed air	(CO2) Blasting	Drill and Spall	Electro hydraulic Scabbling	Explosive	Grinding	Water High pressure	Water Ultra-high Press	Laser Heating	Microwave Scabbling	Milling	Mechanical Scabbling	Shot Blasting	Soda Blasting	Strippable Coating			
1	Abrasive Jetting Ice	Abrasive Jetting Plastic Pellet	Abrasive Jetting Sand	Abrasive Jetting Soft	Carbon Dioxide (C	(CO2) Compres	(CO2) Blasting	Drill and Spall	Electro hydraulic Scab	Explosive	Grinding	Water High pressure	Water Ultra high Pres	Laser Heating	Microwave Sca	Milling	Mechanic	Shot Blasting	Soda Blasting	Strippable Coating			
2	100 00	240 00	47 00	80 00	60 00	60 00	50 00	6 00	30 00	100 00	100 00	370 00	60 00	150 00	40 00	2 50	300 00	1515 00	180 00	100 00			
3	6427 951822	2478 313359	13876 49324	16069 87955	10713 25304	10713 25304	12855 90364	20783 13259	21426 50607	1606 988	6427 951822	1737 284276	10713 25304	4285 301215	2001 734944	64279 518	4285 301	424 287249	3571 084346	6427 951822		Tech	10 5
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1606 98796		
																					Explosive		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
drums																							
4	1,216	1 216	22 267	3 314	1 216	1,216	1,216	1,216	21,409	1,216	1,216	1,216	1 216	1,216	1 216	1 216	1,216	1 216	24 660	1,216			
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1216		

Scenario 2 - Surface Treatment, Demolition, Recycle
Table Name: Scenario 2

No.	Task Description	Comment	Processing Rate	Processing Units	Processing Total man-days	Fatal Risk Non-rad	Fatal Risk Radiological	Nonfatal Risk (lost workdays)	Reference	Trans Fatal	Trans Non-f	fatal const
1	Site Prep	travel of workers to site - 50 miles	1	50 miles	NA	1 05E 05		1 33E 03	estimate	1 05E 05	1 33E 03	
2		set up job trailer	22.857	mh/each + 50 mi	2 9	1 37E 05		1 45E 02	Means, p 12	1 0539E 05	0 001326854	3 16622E 06
3		construct access road - 100 yd3 of gravel	0 067	mh/yd2	5 0	5 57E 06		2 32E-02	Means, p12			5 57E-06
4		install chain link fence around perimeter	0.16	mh/ft	148 8	1 65E 04		6 86E 01	Means, p 12			1 65E 04
5		grade	8	mh/acre	98 5	1 09E-04		4 54E-01	Means, p 37			1 09E-04
6	Characterization	characterize building for action	2.2E-03	mh/ft2	2226 5	2 28E-03	6 48E-04	1 07E+01				2 58E-03
7		transport of samples to lab	1	50 miles	NA	1 05E-05		1 33E-03	estimate	1 05E 05	1 33E 03	
8	Surface Treatment	Chemical Gel	100	ft2/hr	9641 9	1 07E-02	2 13E 02	4 45E+01	economic rpt			1 07E-02
9		collect waste (from treatment technology) - fill drums, load on truck	0.16	mh/3 ft3	372 4	4 13E-04	7 68E 04	1 72E+00	k62=no drums			4 13E 04
10		collect debris and load into dump trucks	0.012	mh/yd3	0.0	0 00E+00	0 00E+00	0 00E+00	Means, p 41			0 00E+00
11	LLW disposal	haul LLW to EnviroCare	468 61	miles	NA	1 63E-03	2 52E-08	1 36E-02	estimate	1 63E 03	1 36E 02	
12		unload LLW at EnviroCare	0.17	mh/4 drums	39 6	4 38E-05	4 12E 07	1 82E-01	drums 10min/4			4 38E 05
13	Demolition	demolish concrete slab only	0 035	mh/yd2	4169 4	4 62E 03		1 92E+01	Dykstra and Eppr, 1987			4 62E 03
14		crush concrete - load on crusher, screen	200	tph	402.0	4 46E-04		1 85E+00	Busse			4 46E-04
15		transport to sale point (FOB)	0 1	miles	NA	3 32E 04		4 19E 02		3 32E 04	4 19E 02	
16	Rebar	separate rebar	100	tpd	450 3	4 99E-04		2 08E+00	Busse			4 99E-04
17		test rebar	6 86E-06	mh/lb	77 2	8 56E-05		3 56E-01				8 56E-05
18		load and haul rebar	25	miles	NA	2 97E 03		3 73E-01	estimate	2 97E 03	3 73E 01	
19	Population	Exposure during remediation	143 54	people/mi² for	1007 55	0 00E+00	1 93E 08	0 00E+00				
20	Clean up	site cleanup	0 008	mh/yd2	1429 5	1 58E 03		6 59E+00	Means, p 56			1 58E 03
21		remove job trailer, fence	22 857	mh/each + 50 mi	2 9	1 37E 05		1 45E 02	Means, p 12	1 0539E 05	0 001326854	3 16622E-06
22		demobilization travel of workers	1	50 miles	NA	1 05E 05		5 24E-05	estimate	1 05E 05	5 24E 05	
23	Fines	load	0 012	mh/yd3	143 0	1 58E 04		6 59E 01	Means, p 41			1 58E-04
24		haul	50	miles	NA	6 61E 02		8 43E+00	estimate	6 61E 02	8 43E+00	
										7.11E-02	8.86E+00	2 14E-02

Rad Risk:

			characterization	
796,829 37 total area, m2		Intercept	23 51	
119,435 25 cont area, m2		Slope	0 01	
Cont Area Dose	Clean Area Dose		Sum Dose, rem	Deaths.
1314.29	7 61		1 30E+00	6 48E-04
1,615.75			4 27E+01	2 13E 02
1504.73			1 54E+00	7 68E-04
7.60			0 00E+00	0 00E+00
0.05			5 03E-05	2 52E 08
7.60			8 24E 04	4 12E-07

Population 3.87E 05 1 93E 08

Scenario 2 Summary:

	Radiological	Non-Rad	Transport	Construction
Fatalities	2 28E 02	9 25E 02	7 11E 02	2 14E 02
Lost Workdays		9 79E+01	8 86E+00	8 90E+01
Total Duration	20317 3 man days			

		Chelation	Chemical Extraction	Chemical Foam	Chemical Gel	Electrokinetic	ashlamp Clean	LaserAblation	icrobial Degradati	Sponge Blasting	
	1										
select											
		Chelation	Chemical Extraction	Chemical Foam	Chemical Gel	Electrokinetic	Flashlamp Cleaning	Laser Ablation	Microbial Degradation	Sponge Blasting	
efficiency, %		90	90	82 5	82 5	77 5	90	90	80	90	
pass 1		999	999	999	999	999	999	999	999	999	
pass 2		999	999	999	999	999	999	999	999	999	
pass 3		999	999	999	999	999	999	999	999	999	
pass 4		999	999	999	999	999	999	999	999	999	
pass 5		5	5	999	999	999	5	5	999	5	
pass 6		6	6	6	6	999	6	6	999	6	
pass 7		7	7	7	7	7	7	7	7	7	
pass 8		8	8	8	8	8	8	8	8	8	
pass 9		9	9	9	9	9	9	9	9	9	
pass 10		10	10	10	10	10	10	10	10	10	
Number of passes needed		5	5	6	6	7	5	5	7	5	
	2	8034 939777	8034 939777	9641 927733	9641 927733	11248 91569	6695 783148	9452 870326	1124891 569	13391 5663	9641 93
	3	100	100	100	100	100	120	85	1	60	
		0	0	0	0	0	0	0	0	0	100
											Chemical Gel
		0	1	2	3	4	5	6	7	8	
No of drums											
	4	6,545	6,545	7,597	7,597	8 649	6,545	6,545	8,649	10,028	
		0	0	0	0	0	0	0	0	0	7597 08

Tech 4 625

Scenario 3 - Surface Removal, Demolish, Cap, Monitor
Table Name: Scenario 3

No.	Task Description	Comment	Rate	Processing Units	Total man-days	Risk Total Nonrad	Risk Total Radiological	Residual Risk	Reference
1	Site Prep	travel of workers to site - 30 miles	1	30 miles	NA	1.03E-03		1.33E-03	estimate
2		set up job trailer	22.837	mh/each + 30 mi	2.9	1.37E-03		1.45E-03	Means, p 12
3		construct access road - 100 yd3 of gravel	0.067	mh/yd3	5.0	5.57E-06		3.32E-03	Means, p12
4		install chain link fence around perimeter	0.16	mh/ft	148.8	1.61E-04		6.16E-01	Means p 12
5		grade	8	mh/acre	99.5	1.09E-04		4.54E-01	Means p 37
6	Characterization	characterize building for action	2.7E-03	mh/ft2	2236.5	2.38E-03	6.48E-04	1.07E+01	
7		transport of samples to lab	1	30 miles	NA	1.03E-03		1.33E-03	estimate
8	Removal	Explosive	100	ft2/hr	16070	1.71E-03	3.56E-03	7.41E+00	economic report
9		collect waste (from technology) - fill drums, load on truck	0.16	mh/55 ft3	43.0	6.09E-05	1.30E-04	2.91E-01	all 55-gal drums
10		collect debris and load into dump trucks	0.012	mh/yd3	8.3	9.42E-06	8.84E-08	3.92E-03	Means p 41
11	LLW disposal	haul LLW to EnviroCare	468.61	miles	NA	1.33E-02	2.36E-07	1.56E-03	estimate
12		unload LLW at EnviroCare	0.5/0.17	box/drum	6.7	5.43E-06	4.91E-08	3.09E-03	drums 10min/d, box 0.5hr/40 yd3
13	Demolition	demolish concrete slab	0.033	mh/yd2	4169.4	4.62E-03		1.92E+01	Dykman and Epps, 1987
14	Capping	transport capping material to site	30	miles	NA	3.11E-01		4.01E+01	4 ft cap over 8.3 acres
15		consolidate rubble	0.006	mh/yd3	336.1	3.72E-04		1.35E+00	Means, p 43/242 2000
16		phase 1a unload material, initial spreading	260.25	mh/acre	2211.7	2.54E-03		1.05E+01	
17		phase 1b unload material, initial spreading	260.25	mh/acre	2211.7	2.54E-03		1.05E+01	COE (stratified), 1996
18		phase 2 groomed/final cover	520.5	mh/acre	4377.3	5.07E-03		2.11E+01	COE, 1996
19	Population	Exposure during remediation	143.54	people/km2 for	713.29	0.00E+00	1.32E-08	0.00E+00	
20	Monitoring	install water wells	0.437	mh/ft	291.6	3.23E-04		1.34E+00	Means, p 21
21		operation of monitoring equipment (for 30 yrs)	0.5	mh/week + 30 mi	540.0	1.84E-03		2.63E+00	
22	Cap maintenance	annual mowing (for 30 yrs)	5	acre/day + 30 mi	421.9	1.10E-03		2.02E+00	estimate
23		refertilization/reseeding (mileage included above)	5	acre/day	421.9	4.41E-04		1.93E+00	Means, p 74
24	Cleanup	site cleanup	0.008	mh/yd2	1429.5	1.58E-03		6.59E+00	Means, p 56
25		remove job trailer, fence	22.837	mh/each + 30 mi	2.9	1.37E-03		1.45E-03	Means, p 12
26		demobilization	1	30 miles	NA	1.03E-03		1.33E-03	estimate

Rad Risk

						Trans. Fatal	Trans Non-f
						1.03E-03	1.33E-03
				characterization		1.0370E-03	0.001326834
796,829.33	total area, m2		Intercept	23.51			
119,435.33	cont area, m2		Slope	0.01			
	Cont Area Dose	Clean Area Dose		Sum Dose, rem	Deaths		
	131.29	7.61		1.30E+00	6.48E-04	1.03E-03	1.33E-03
	1,833.78			7.11E+00	3.56E-03		
	1114.13			2.60E-01	1.30E-04		
	7.60			1.77E-04	8.84E-08		
	0.47			4.71E-04	2.36E-07	1.33E-02	1.56E-03
	7.60			1.42E-04	4.91E-08		
						3.11E-01	4.01E+01
Population	2.71E-01				1.32E-08		

Scenario 3 Summary:

	Radiological	Non Rad	Transport	Construction		
					0.001364674	0.159722301
Fatalities	6.34E-03	3.56E-01	3.32E-01	2.33E-02	6.32E-04	7.96E-03
Lost Workdays		1.37E+02	4.04E+01	9.70E+01		
Total Duration	21748.1 man days					
					1.03E-03	1.33E-03
					1.03E-03	1.33E-03
					3.16E-01	4.01E+01

	1 Abrasive Jetting Ice	Abrasive Jetting Plastic Pellet	Abrasive Jetting Sa	Carbon Dioxide (C	(CO2) Compr	(CO2) Blasting	Drill and Spall	Electro-hydraulic Scabbling	Explosive	Grinding	Water High pressure	Water Ultra high Pr	Laser Heating	Microwave Sca	Milling	Mechanical Sca	Shot Blasting	Soda Blasting	Strippable Coating
select	Abrasive Jetting Ice	Abrasive Jetting Plastic Pellet	Abrasive Jetting Sand	Abrasive Jetting Soft Media	Carbon Dioxide (CO2) Centrifuged	(CO2) Compressed air	(CO2) Blasting	Drill and Spall	Electro-hydraulic Scabbling	Explosive	Grinding	Water High pressure	Water Ultra high Press	Laser Heating	Microwave Scabbling	Milling	Mechanical Scabbling	Shot Blasting	Soda Blasting	Strippable Coating
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	6421951.922	2678313.239	13676.40324	16049.87935	10713.23304	10713.23304	12853.90364	2678313.239	21406.30607	1606.99	6421951.922	17377.284276	10713.23304	4283.301215	2008.754944	64279.3	4283.301315	424.287289	3371.084346	642193 days
3	100.00	240.00	47.00	80.00	60.00	60.00	30.00	6.00	30.00	100.00	100.00	37.00	60.00	150.00	40.00	2.50	300.00	1515.00	180.00	100.00 m2/s
drums 4	1,256	1,256	33,267	3,314	1,256	1,256	1,256	1,256	21,409	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256	24,660	1,256
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Cap Area, acres 70.33
Cap Material Needed 453309.5 yd3
No. of wells required 18

	Chelation	Chemical Extraction	Chemical Foam	Chemical Gel	Electrokinet	Flashlamp Cl	Laser Ablati	Microbial D	Sponge Blasting
	Chelation	Chemical Extraction	Chemical Foam	Chemical Gel	Electrokinetic	Flashlamp Cleaning	Laser Ablation	Microbial Degradation	Sponge Blasting
efficiency, %	90	90	82.5	82.5	77.5	90	90	80	90
pass 1	999	999	999	999	999	999	999	999	999
pass 2	999	999	999	999	999	999	999	999	999
pass 3	999	999	999	999	999	999	999	999	999
pass 4	999	999	999	999	999	999	999	999	999
pass 5	5	5	999	999	999	5	5	999	5
pass 6	6	6	6	6	999	6	6	999	6
pass 7	7	7	7	7	7	7	7	7	7
pass 8	8	8	8	8	8	8	8	8	8
pass 9	9	9	9	9	9	9	9	9	9
pass 10	10	10	10	10	10	10	10	10	10
Number of passes needed	5	5	6	6	7	5	5	7	5
	8034.939392	8034.939777	9641.921733	9641.921733	11248.9157	6695.783148	8453.8703	11248.9157	13391.5643
	100	100	100	100	100	100	83	1	60
	0	0	0	0	0	0	0	0	0
	21	22	23	24	25	26	27	28	29
0	6,545	6,545	7,597	7,597	8,649	6,545	6,545	8,649	10,010
	0	0	0	0	0	0	0	0	0

1256

100
1606.99
Explosive

Tech 13.5

Scenario 4 - Demolish in place, Cap, Monitor
Table Name: Scenario_4

No.	Task Description	Comment	Rate	Processing Units	Total man days	Risk - Fatal (deaths) Non rad	Risk - Fatal (deaths) Radiological	Nonfatal Risk (lost workdays)	Reference	Trans. Fatal.	Trans. Non f
1	Site Prep	travel of workers to site - 50 miles	1	50 miles	NA	1 05E-05		1 33E-03	estimate	1 05E-05	1 33E-03
2		set up job trailer	22.857	mh/each + 50 mi	2.9	1.37E-05		1.45E-02	Means, p.12	1 0539E-05	0 001326854
3		construct access road - 100 yd3 of gravel	0 067	mh/yd2	5.0	5.57E-06		2 32E-02	Means, p12		
4		install chain link fence around perimeter, 3-story building	0 16	mh/ft	148 8	1.65E-04		6.86E-01	Means, p 12		
5		grade, three stories	8	mh/acre	98.5	1.09E-04		4 54E-01	Means, p 37		
6	Characterization	characterize building for action	2 2E-03	mh/ft2	2326.5	2 58E-03	6 29E-04	1 07E+01	same as Sc. 17		
7		transport samples to lab	1	50 miles	NA	1 05E-05		1 33E-03	estimate	1.05E-05	1.33F-03
8	Demolition	concrete slab only	0 035	mh/yd2	4169.4	4 62E-03	1.30E-04	1.92E+01	Dykins and Epps, 1987		
9	Capping	haul material for cap to site	50	miles	NA	3.19E-01		4.01E+01		3 19E-01	4.01E+01
10		consolidate rubble	0 006	mh/yd3	340.4	3 77E-04	2.07E-06	1.57E+00	means, p.43#242-5000		
11		phase 1a cap	260 25	mh/acre	2287.7	2.54E-03	#REF!	1.05E+01			
12		phase 1b cap	260.25	mh/acre	2287.7	2 54E-03	9 00E-06	1 05E+01	COE (stricker), 1996		
13		phase 2 cap	520.5	mh/acre	4575 3	5 07E-03	8 12E-08	2.11E+01	COE, 1996		
14	Monitoring well	installation of monitoring wells	0.432	mh/ft	19.4	2 15E-05	3 45E-10	8 96E-02	20 ft deep		
15		monitoring activities (for 100 yrs)	0 5	md/well + 50 mi	3600 0	1.24E-02	6 39E-08	1.77E+01	estimate	8 43E-03	1.06E+00
16	Cap maintenance	annual mowing (for 100 yrs)	5	acre/day + 50 mi	1406 4	3 67E-03	2 50E-08	6 75E+00	estimate	0 00210779	0 265370834
17		refertilization/reseeding (mileage included above)	5	acre/day	1406.4	1 56E-03	2.50E-08	6.48E+00	estimate		
18	Clean up site	site cleanup, fence	0.008	mh/yd2	476.5	5 28E-04		2.20E+00	Means, p.56		
19		remove job trailer	22.857	mh/each + 50 mi	2.9	1.37E-05		1.45E-02	Means, p.12	1 0539E-05	0.001326854
20		demobilization	1	50 miles	NA	1 05E-05		1.33E-03	estimate	1.05E-05	1.33E-03
21	Population	Exposure during remediation	143 54	people/mi^2 for:	605 67	0 00E+00	1.16E-08	0 00E+00		3.29E-01	4.15E+01
22											

Rad Risk:

			demolition	characterization
796,819.37	total area, m2	Intercept.	2.43	23 51
119,435.25	cont. area, m2	Slope	0 00	0 01
	Cont Area Dose	Clean Area Dose	Sum Dose, rem	Deaths:
	1314.29	0.59	1.26	6.29E-01
	148.77	0.59	0.26	1.30E-04
	4.43		4 13E-03	2 07E-06
	#REF!		#RFF!	#REF!
	2.87		1.80E-02	9.00E-06
	1.296E-02		1.62E-04	8.12E-08
	1.296E-02		6 90E-07	3 45E-10
	1.296E-02		1.28E-04	6 39E-08
	1.296E-02		4.99E-05	2 50E-08
	1.296E-02		4 99E-05	2 50E-08
Population.	2.32E-05			1 16E-08

Scenario 4 Summary:

	Radiological	Non-Rad.	Transport	Construction
Fatalities.	#REF!	3 55E-01	3.29E-01	2 57E-02
Lost Workdays:		1.48E+02	4 15E+01	1.07E+02
Total Duration.	23759 3 man-days			

Cap Area, acres:	70 32	
Cap Material Needed:	433809 5	
No. of wells required.	18	yds3

Scenario 5 - On-site disposal facility
Table Name: Scenario 5

No.	Task Description	Comment	Processing Rate	Processing Units	Processing Total man-days	Risk - Fatal Non-rad	Risk - Fatal Radiological	Nonfatal Risk (lost workdays)	Reference
1	Site Prep	travel of workers to site - 50 miles	1	50 miles	N/A	1 05E-05	N/A	1 33E 03	estimate
2		set up job trailer	22 857	each + 5	2 9	1 37E 05	N/A	1 45E 02	Means, p 12
3		construct access road - 100 yd3 of gravel	0 067	mh/yd2	5 0	5 57E 04	N/A	2 32E 02	Means, p12
4		install chain link fence around perimeter	0 16	mh/ft	148 8	1 65E 04	N/A	6 86E 01	Means, p 12
5		grade	8	mh/acre	93 5	1 09E 04	N/A	4 54E 01	Means, p 37
6	Characterization	characterize building for action	2 2E 03	mh/ft2	2326 5	2 51E 03	6 41E 04	1 07E+01	
7		transport of samples to lab	1	50 miles	N/A	1 05E 05	N/A	1 33E 03	
8	Demolition	demolish concrete slab	0 035	mh/yd2	4169 4	4 62E-03	1 30E-04	1 92E+01	Dykins and Epps, 1987
9	Rebar	separate rebar	100	tpd	450 3	4 93E 04	1 41E 05	2 01E+00	Busse
10		test rebar	6 85E 05	mh/lb	77 2	8 56E-05	N/A	3 54E-01	
11		transport clean to scrap yard	25	miles	N/A	2 93E-03	N/A	3 73E 01	estimate
12	Concrete	crush and screen concrete	200	tph	432 0	4 46E 04	1 26E-05	1 85E+00	Busse
13		store aggregate	0 01	mh/yd3	295 7	3 31E 04	9 31E-07	1 30E+00	Means, p 35
14	Construct Facility	Excavate Cell	0 04	mh/yd3	3 08E+03	3 41E 03	N/A	1 42E+01	Means'95, p 36
15		haul material for liner	50 00	miles	N/A	1 53E 01	N/A	1 93E+01	
16		place synthetic membrane	5000	ft2/day	214 4	2 38E 04	N/A	9 89E 01	
17		Place (Clay+Gravel+Protective Layer)	0 025	mh/yd3	1 68E+03	1 86E 03	N/A	7 72E+00	
18		haul fill material	50	miles	N/A	5 51E-02	N/A	7 02E+00	
19		place concrete & fill material	0 025	mh/yd3	1 241	1 38E 03	3 06E-05	5 72E+00	
20	Capping	haul cap material	50	miles	N/A	1 67E-01	N/A	2 11E+01	
21		phase 1a cap	260 25	mh/acre	1201 0	1 33E 03	2 96E-05	5 54E+00	
22		phase 1b cap	260 25	mh/acre	1201 0	1 33E 03	4 72E 06	5 54E+00	COE (stricker), 1996
23		phase 2 cap	520 5	mh/acre	2402 0	2 66E-03	4 26E 08	1 11E+01	COE, 1995
24	Clean up	site cleanup	0 003	mh/yd2	1429 5	1 58E 03	N/A	6 59E+00	Means, p 56
25		remove job trailer, fence	22 857	each + 5	2 9	1 37E 05	N/A	1 45E 02	Means, p 12
26		demobilization travel of workers	1	50 miles	N/A	1 05E 05	N/A	1 33E-03	estimate
27	Fines	load	0 012	mh/yd3	143 0	1 58E-04	N/A	6 59E 01	Means, p41
28	Population	Exposure during remediation	143 54	pple/m²	933 64	N/A	1 79E 08	N/A	
29	Monitoring well	installation of monitoring wells	0 432	mh/ft	11 9	1 32E 05	2 11E 10	5 41E 02	20 ft deep
30		monitoring activities (for 100 yrs)	0 5	/well + 5	2200 0	1 09E 02	3 90E 08	1 12E+01	estimate
31	Cap Maintenance	annual mowing (for 100 yrs)	5	/day + 5	738 4	2 91E 03	1 31E 08	3 67E+00	estimate
32		refertilization/reseeding (mileage included above)	5	acre/day	738 4	8 18E 04	1 31E 08	3 40E+00	estimate

Rad Risk:

			demolition	characterization
796829 37 total area, m2		Intercept	2 43	23 51
119,435 25 cont. area, m2		Slope	0 00	0 01

	Cont Area Dose	Clean Area Dose	Sum Dose, rem	Deaths:
	1314 39	7.61	1 30E+00	6 41E 04
	148.77	0.59	2 60E 01	1 30E 04
	148 77	0.59	2 81E 02	1 41E 05
	148 77	0.59	2 51E 02	1 26E 05
	2.30		1 86E 03	9 31E 07
	18 01		6 12E 02	3 06E 05
	18.01		5 93E 02	2 96E 05
	3.87		9 45E 03	4 72E 06
	1.296E-02		8 53E 05	4 26E 08
Population	3.58E-05			1 79E 08
	1.296E 02		4 22E 07	2 11E 10
	1.296E-02		7 81E 05	3 90E 08
	1.296E-02		2 62E 05	1 31E 08
	1.296E-02		2 62E 05	1 31E 08

Scenario 5 Summary:

	Radiological	Non Rad	Transport	Construction
Fatalities	8 73E 04	4 17E 01	3 90E 01	2 69E 02
Lost Workdays		1 61E+02	4 91E+01	1 12E+02
Total Duration	23709 1 man days			

storage area
volume agg 180863 3 m3

Unit Wt Gravel	115 lb/ft3
Unit Wt Clay	100 lb/ft3

Disposal Facility:	
Volume Of Material	8,577,000 ft3
Total Area	1072125 ft2
Cap Area	36 93 acres
Gravel for Liner	92,471 tons
Clay for Liner	214,425 tons
Gravel for Cap	493,178 tons
Clay for Cap	107,213 tons
[illegible]	11

Trans. Fatal.	Trans. Non f
1 05E-05	1 33E 03
1 0533E 05	0 0013326154
1 05E 05	1 33E 03
2 93E 03	3 73E-01
1 53E 01	1 93E+01
5 51E 02	7 02E+00
1 67E 01	2 11E+01
1 0533E 05	0 0013326154
1 05E 05	1 33E 03
0 00843116	1 061483337
0 00210779	0 265370834
3.90E 01	4 91E+01

Scenario 6 - Surface Removal, Demolition, C&D Disposal
Table Name: Scenario 6

No.	Task Description	Comment	Rate	Processing Units	Total man days	Fatal Risk Normal	Fatal Risk Radiological	Nonfatal Risk (lost work days)	Reference
1	Site Prep	travel of workers to site - 30 miles	1	30 miles	NA	1.05E-05		1.33E-03	estimate
2		set up job trailer	22837	mi/trailer + 50 mi	39	1.37E-05		1.45E-03	Means, p 12
3		construct access road 100 yd3 of gravel	0.047	mh/yd3	50	5.57E-06		2.37E-03	Means, p 12
4		install chain link fence around perimeter	0.16	mh/ft	1408	1.65E-04		6.84E-01	Means, p 12
5		grade	8	mh/acre	91.5	1.09E-04		4.34E-01	Means, p 27
6	Characterization	characterize building for action	2.28E-03	mh/ft2	2326.5	2.58E-03	6.48E-04	1.07E+01	
7		transport samples to lab	1	30 miles	NA	1.05E-05		1.33E-03	estimate
8	Removal	Explosive	100	ft2/hr	1407.0	1.78E-03	3.56E-03	7.41E+00	Economic report
9		collect waste (from technology) - fill drums, load on truck	0.16	mh/ft3	61.0	6.99E-05	1.30E-04	2.91E-01	[illegible] drums
10		collect debris and load into dump trucks	0.013	mh/yd3	8.5	9.42E-06	8.84E-08	3.92E-02	Means, p 41
11	LLW disposal	haul LLW to Envirocare	461.48	miles	NA	1.53E-02	1.24E-06	1.36E-02	estimate
12		unload LLW at Envirocare	0.5/0.17	bulk/drum	6.7	7.43E-06	6.91E-08	3.09E-02	drum = 10 min/ft, bulk: 0.5 hr/40 yd3
13	Demolition	demolish structure & slab	0.015	mh/yd3	4189.4	4.62E-03		1.92E+01	Dykstra and Epps, 1987
14		load rubble/debris	0.018	mh/yd3	1008.3	1.11E-03		4.65E+00	[illegible] and load
15		transport to C&D facility	30	miles	NA	3.15E-01		3.96E+01	estimate
16	Rebar	separate rebar	100	kg/h	444.7	4.93E-04		2.03E+00	Bass
17		load rebar	6.84E-06	mh/lb	76.3	8.45E-05		3.51E-01	
18		load and haul rebar	25	miles	NA	2.93E-03		3.69E-01	estimate
19	Population	Exposure during remediation	140.54	people/mi² for	401.81	0.00E+00	9.44E-09	0.00E+00	
20	Cleanup	site cleanup	0.008	mh/yd3	1429.5	1.58E-03		6.59E+00	Means, p 36
21		remove job trailer, fence	22837	mi/trailer+30 miles	39	1.37E-05		1.45E-02	Means, p 12
22		demobilization travel of worker	1	30 miles	NA	1.05E-05		1.33E-03	estimate

Rad Risks:

				characterization	
796829.37	total area, m2		Intercept	23.51	
110,435.23	cont. area, m2		Slope	0.01	
	Cont Area Dose	Clean Area Dose		Sum Dose, rem	Deaths
	1311.29		7.61	1.30E+00	6.48E-04
	1,618.75			7.11E+00	3.56E-03
	150.473			2.60E-01	1.30E-04
	7.60			1.77E-04	8.84E-08
	2.48			2.48E-03	1.24E-06
	7.60			1.40E-04	6.91E-08
Pop. doses	1.89E-05				9.44E-09
	Radiological	Non Rad		Transport	Construction
Fatalities	4.34E-03	3.46E-01		3.33E-01	1.26E-02
Lost Workdays		9.26E+01		4.00E+01	5.26E+01
Total Duration	11839.7	man days			

Trans. Fatal.	Trans. Non f	fed	rad fed	lost work	fed transport normal	rad	total fed	non transport fed normal	rad	lost days transport	nontransport
1.05E-05	1.33E-03	1.05E-05		0.001327	1.05E-05		1.05E-05	0	0	0.001327	0
1.0539E-05	0.001326454	1.37E-05		0.0145	1.05E-05		1.37E-05	3.17E-06	0	0.001327	0.013172286
		5.57E-06		0.023168			5.57E-06	5.57E-06	0		0.023167939
		0.000165		0.686027			0.000165	0.000165	0		0.68602739
		0.000109		0.433909			0.000109	0.000109	0		0.433909475
		0.002578	0.000648	10.72647			0.003227	0.002578	0.000648		10.72647099
1.05E-05	1.33E-03	1.05E-05		0.001327	1.05E-05		1.05E-05	0	0	0.001327	0
		0.001781	0.003557	7.409081			0.005338	0.001781	0.003557		7.409080735
		6.99E-05	0.00013	0.290643			0.0002	6.99E-05	0.00013		0.290644766
		9.42E-06	8.84E-08	0.039201			9.51E-06	9.42E-06	8.84E-08		0.039201403
1.53E-02	1.36E-02	0.015301	1.24E-06	0.013640	0.015301	1.24E-06	0.015302	0	0	0.013640	0
		7.43E-06	6.91E-08	0.030893			7.5E-06	7.43E-06	6.91E-08		0.030893477
		0.00462		19.22307			0.00462	0.00462	0		19.22304429
		0.001117		4.648287			0.001117	0.001117	0		4.648287475
3.15E-01	3.96E+01	0.314842		39.6413	0.314842		0.314842	0	0	39.6413	0
		0.000493		2.030139			0.000493	0.000493	0		2.030139376
		8.45E-05		0.351402			8.45E-05	8.45E-05	0		0.351402313
2.93E-03	3.69E-01	0.002929		0.368156	0.002929		0.002929	0	0	0.368156	0
		0.001584		6.590766			0.001584	0.001584	0		6.590765584
		1.37E-05		0.0145	1.05E-05		1.37E-05	3.17E-06	0	0.001327	0.013172286
1.0539E-05	0.001326434	1.05E-05		0.001327	1.05E-05		1.05E-05	0	0	0.001327	0
1.05E-05	1.33E-03										
3.33E-01	4.00E+01										
				0.333143	1.24E-06		0.012431	0.004335	40.03023		53.5307311

	Abrasive Jetting Ice	Abrasive Jetting Plastic Pellet	Abrasive Jetting	Abrasive Jetting Soft	Carbon Dioxide (CO2	(CO2) Compress	(CO2) Blasting	Drill and Spall	Electrohydraulic Scabbling	Explosive	Grinding	Water High pressure	Water Ultra high Press	Laser Heating	Microwave Scab	Milling	Mechanica	Shot Blasting	Soda Blasting	Strippable Coating		Chelation	Chemical	Chemical	Chemical	Electrokin	Flashlamp	Laser Abla	Microbial	Sponge Blasting	
1 select	Abrasive Jetting Ice	Abrasive Jetting Plastic Pellet	Abrasive Jetting Sand	Abrasive Jetting Soft Media	Carbon Dioxide (CO2 Centrifugal)	(CO2) Compressed air	(CO2) Blasting	Drill and Spall	Electro hydraulic Scabbling	Explosive	Grinding	Water High pressure	Water Ultra high Press.	Laser Heating	Microwave Scabbling	Milling	echanic Scabbling	Shot Blasting	Soda Blasting	Strippable Coating		Chelation	Chemical Extraction	Chemical Foam	Chemical Gel	ectrokinetics	Flashlamp Cleaning	Laser Ablation	Microbial egradation	Sponge Blasting	
																					efficiency, %	90	90	82.5	82.5	77.5	90	90	80	90	
																					pass1	999	999	999	999	999	999	999	999	999	
																					pass2	999	999	999	999	999	999	999	999	999	
	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	pass3	999	999	999	999	999	999	999	999	999	
	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	pass4	999	999	999	999	999	999	999	999	999	
																					pass5	5	5	999	999	999	5	5	999	5	
	0		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19 pass6	6	6	6	6	999	6	6	999	6	
																					pass7	7	7	7	7	7	7	7	7	7	
																					pass8	8	8	8	8	8	8	8	8	8	
																					pass9	9	9	9	9	9	9	9	9	9	
																					pass10	10	10	10	10	10	10	10	10	10	
																					Number of passes needed	5	5	6	6	7	5	5	7	5	
2	6427.951822	2678.313339	13476.49324	16069.87935	10713.23304	10713.23304	12855.90364	26783.13339	31426.50607	1606.928	6427.951822	1551.146673	10713.23304	4285.301215	2008.734844	6427.952	4285.301	424.297249	3371.084346	6427.952	days	803.494	803.494	9641.928	9641.928	11248.92	6695.783	8453.87	11248.93	13391.5663	
3	100.00	24.00	47.00	80.00	60.00	60.00	50.00	6.00	30.00	100.00	100.00	370.00	60.00	150.00	40.00	2.50	300.00	1511.00	100.00	100.00	rate	100	100	100	100	130	120	85	1	40	
																						0	0	0	0	0	0	0	0	0	
																						21	22	23	24	25	26	27	28	29	
drums 4	1,284	1,284	22,267	3,334	1,284	1,284	1,284	1,284	71,409	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	24,660	1,284		6,543	6,543	7,597	7,597	8,640	6,545	6,543	8,640	10003	
	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	1284

Case Parameters:

Facility:	NEVADA	
LLW Haul Distance:	469	miles
Floor Area:	8,577,000	ft^2
Contaminated Area:	1,285,590	ft^2

11100.8
20317.3
21748.1
23759.3
23709.1
11889.7

Scenario 1: Explosive

	Radiological	Non-Rad.
Fatalities:	4.34E-03	9.68E-02
Lost Workdays:		5.91E+01
Total Duration:	11100.8	man-days

Scenario 2: Chemical Gel

	Radiological	Non-Rad.
Fatalities:	2.28E-02	9.25E-02
Lost Workdays:		9.79E+01
Total Duration:	20317.3	man-days

Scenario 3: Explosive

	Radiological	Non-Rad.
Fatalities:	4.34E-03	3.59E-01
Lost Workdays:		1.37E+02
Total Duration:	21748.1	man-days

Scenario 4:

	Radiological	Non-Rad.
Fatalities:	#REF!	3.55E-01
Lost Workdays:		1.48E+02
Total Duration:	23759.3	man-days

Scenario 5:

	Radiological	Non-Rad.
Fatalities:	8.71E-04	4.17E-01
Lost Workdays:		1.61E+02
Total Duration:	23709.1	man-days

Scenario 6: Explosive

	Radiological	Non-Rad.
Fatalities:	4.34E-03	3.46E-01
Lost Workdays:		9.26E+01
Total Duration:	11889.7	man-days

	Fatalities				**Lost Workdays**		
Scenario	**Rad**	**Trans.**	**Const.**	**Total**	**Trans.**	**Const.**	**Total**
1	4.34E-03	8.47E-02	1.21E-02	1.01E-01	8.75E+00	5.04E+01	59.14
2	2.28E-02	7.11E-02	2.14E-02	1.15E-01	8.86E+00	8.90E+01	97.89
3	4.34E-03	3.36E-01	2.33E-02	3.64E-01	4.04E+01	9.70E+01	137.36
4	#REF!	3.29E-01	2.57E-02	#REF!	4.15E+01	1.07E+02	148.23
5	8.71E-04	3.90E-01	2.69E-02	4.18E-01	4.91E+01	1.12E+02	160.94
6	4.34E-03	3.33E-01	1.26E-02	3.50E-01	4.00E+01	5.26E+01	92.58

Accident Dispersion Model Component **Stability:**

wind speed at 10 m: 3.98 m/sec wind speed 2.09 0
Plume Stability: 1.6 (1-unstable,2-neutral, 3-stable) 0
Emergency 1.6
Response time: 1.7 hrs 0
0

	U-238 Source:	13.63	pCi/gm -- total:	0.0994176	Ci		Aggregate Activity:	0.24	pCi/gm U-238		
	U-235 Source:	0.42	pCi/gm -- total:	0.0030748	Ci			0.01	pCi/gm U-235		
	Co-60 Source:	77.25	pCi/gm -- total:	0.5635845	Ci			1.38	pCi/gm Co-60		
	Cs-137 Source:	25.23	pCi/gm -- total:	0.1841044	Ci			0.45	pCi/gm Cs-137		
Dump Rt:	Source Volume:	7,295,725	kg (rubble only - no drums)					2.08	pCi/gm Total		
0.027	Rubble Fractions:	0.00	sand	7.6365676	m/sec de	195.4116649					
0.005	(by weight)	0.00	cement dust	3E-01	m/sec de	39.08233298					1
0.003		0.00	dust	4E-04	m/sec de	21.49528314					2
		0.00				255,989	grams particulates launched				3
	Total Exposure:	0.0098484	rem			1.97748E-05	Ci Co-60 activity launched				4
						6.45978E-06	Ci Cs-137 activity launched, particulate				
					3.5E-06	1.07886E-07	Ci U-238, U-235 activity launched, particulate				

Co-60 puff-release - particulate only - uses FAD

Distance (m)	**sigma-y (m)**	**sigma-z (m)**	**plume width (99.74%)**	**arc angle (degrees)**	**area (m2)**	**population exposed**	**eff plume height, z (m)**	**maximum C (time integral - total "dose") (g sand/m3)**	**(g c.dust/m3)**	**(g dust/m3)**	**Avg Exposure (pCi/m3)**
0	0.0	0.0	0.0	0.0	0.0	0.000	0.0				
40	0.5	0.5	3.2	4.6	64.0	0.004	0.6	0.0	0.3	451.7	1.45E+04

Transportation Risk Assesment - Rail Transport 0 001991004 0.0719*C5/2 59*D5*E5*1 609-0 000674

		Radiological Accident Risk Data				Incident Free Radiological Risk Data				Nonrad. Accident Risk			Non-fatal Accident	Population
	Point of Origin	Pop Density	Route Length	Accident Rate	RACR	Shipment Duration	On link Traffic Density	Crew Size	RIFR	Fatal Accident Rate	Chemical (Exhaust) Risk	RNAE		
		(persons/mi2)	(miles)	(accid./km)	(rem/ship)	(hrs)	(veh./hr.)	(no. of people)	(person-rem)/ca	(accid./km)	(mortality/km)	(fatal/km)	(accidents/km)	(people) /site
1	IDAHO	489.75	326 61	3 73E-07		6 53	4	2		6 84E-08	1 30E-07	1.04E-04	1.96E-04	35
2	NEVADA	143 54	468 61	3 73E-07	1.96E-05	9.37	4	2	4.61E-06	6 84E-08	1 30E-07	1.50E-04	2.81E-04	1
3	RFLATS	366 65	600 01	3.73E-07		12.00	4	2		6 84E-08	1.30E-07	1.91E-04	3.60E-04	2,741
4	LBERK	404 22	742 85	3 73E-07		14 85	4	2		6 84E-08	1.30E-07	2.37E-04	4.46E-04	9,726
5	LLIV	263 31	750 51	3 73E-07		15 02	4	2		6 84E-08	1.30E-07	2.40E-04	4.50E-04	986
6	ETEC	714 15	793.49	3 73E-07		15 87	4	2		6 84E-08	1 30E-07	2.53E-04	4.76E-04	8,168
7	HANFORD	290 35	810.96	3.73E-07		16 22	4	2		6 84E-08	1.30E-07	2.59E-04	4.87E-04	40
8	LOSALA	245.86	941.97	3 73E-07		18 83	4	2		6.84E-08	1 30E-07	3.01E-04	5.65E-04	632
9	PANTEX	221 11	973 94	3.73E-07		19.48	4	2		6.84E-08	1.30E-07	3.11E-04	5.85E-04	2,895
10	SANDIA	245 98	994 34	3.73E-07		19.88	4	2		6.84E-08	1.30E-07	3.17E-04	5.97E-04	5,387
11	ARGEAST	259.49	1540.8	3.73E-07		30.82	4	2		6.84E-08	1.30E-07	4.91E-04	9.25E-04	5,181
12	PAD	147.88	1688.73	3.73E-07		33.77	4	2		6.84E-08	1.30E-07	5.38E-04	1.01E-03	392
13	PORT	238 66	1897.79	3.73E-07		37.95	4	2		6.84E-08	1 30E-07	6.06E-04	1.14E-03	824
14	ORNL	188 08	2024.01	3.73E-07		40 48	4	2		6.84E-08	1.30E-07	6.46E-04	1.21E-03	1,378
15	MORGAN	256 65	2046.47	3.73E-07		40 93	4	2		6 84E-08	1.30E-07	6.53E-04	1.23E-03	340
16	SAVRIV	301.32	2204 15	3.73E-07		44.08	4	2		6.84E-08	1.30E-07	7.04E-04	1.32E-03	18
17	BROOK	610.02	2466.14	3.73E-07		49.32	4	2		6 84E-08	1.30E-07	7.87E-04	1.48E-03	2,032

Transportation Risk Assesment - Truck Transport 1.48E-06*C29/2 59*G29+0 000126*H29*G29^2/D29/1.609+0 00173*I29*G29+3 18E-05*D29*1 609+0 0093

		Radiological Accident Risk Data				Incident Free Radiological Risk Data				Non-rad. Accident Risk			Non-fatal Accident
	Point of Origin	Pop. Density	Route Length	Accident Rate	RACR	Shipment Duration	On-link Traffic Density	Crew Size	RIFR	Fatal Accident Rate	Chemical (Exhaust) Risk	RNAE	
		(persons/mi2)	(miles)	(accid./km)	(person-rem)/ship	(hrs)	(veh./hr.)	(no. of people)	(person-rem)/ship	(accid./km)	(mortality/km)	(fatal/ship)	(accidents/ship)
1	C&D Haul	100	50	6 51E-07	0.00E+00	1.25	780	2	0.0000	3.10E-08	1.00E-07	1.03E-05	5.24E-03
2	FOB point-onsite	15.53	0.1	6.51E-07	0.00E+00	0 0025	780	2	0.0000	3.10E-08	1.00E-07	2.11E-08	1.05E-07
3	Rebar scrap yard	100	25	6 51E-07	0.00E+00	0.625	780	2	0.0000	3.10E-08	1 00E-07	5.31E-06	2.62E-03
4	Mob /Demob.	100	50	6 51E-07	0.00E+00	1.25	780	2	0.0000	3 10E-08	1.00E-07	1.03E-05	5.24E-03

**ship = shipment*

Risk Factors:

Factor	Value	Units
Fatal - Non. rad	1.11E-06	deaths/man-day
Fatal - Rad	5 00E-04	deaths/rem
Fatal - Mining	1.40E-06	deaths/man-day
Nonfatal (non rad)	4.61E-03	lost days/man-day
Nonfatal (truck)	25 33	lost days/accident
Nonfatal (rail)	48 53	lost days/accident
Nonfatal (mining)	8 18E-03	lost days/man-day

Probability Functions

	Mean	Variance
Nonfatal (truck)	2 533E+01	5 066E+00
Nonfatal (rail)	4 853E+01	9 706E+00

Economic Conversion Factors:

	Factor	Value ($)
1	Fatalities	200,000
2	Lost Workdays	100

APPENDIX C – COST MODEL DETAILS

Probabilistic Model Documentation
Sheet: Parms (Parameters)

Parameters that are common to each scenario risk estimate are entered on the **"Parms"** sheet in the appropriate location. In addition to providing a place for user-entered common data, this sheet contains calculations/estimates of several other common values. Other sheets link to the **Parms** data, as discussed in subsequent sections.

Table C-1. Parms Sheet - Basic Global Cost Data

Parameter	Units	Cell/Row	Comments/Source
Total Area	ft²	D5	Range Name: TOTALAREA Calculation: VLOOKUP(G51,'FINAL RISK MODEL.XLS'!LLWMILES,6) Comment: Total floor area (contaminated and uncontaminated)
Facility	NA	C6	Range Name: FACILIITY Calculation: VLOOKUP(G51,'FINAL RISK MODEL.XLS'!LLWMILES,3) Comment: Displays name of selected facility
% Contaminated (Floor Area)	%	D7	Range Name: **Parms**:D7 Calculation: Tlognorm(15,5,0.1,100) Comment: The percentage of the total floor area (TOTALAREA) that is contaminated.
Contaminated Area	ft²	D8	Range Name: AREA Calculation: TOTALAREA*D7/100 (**Parms**:D6*D7/100) Comment: Represents contaminated floor areas.
Thickness	in	D9	Range Name: THICKNESS Calculation: User Entered (in inches) Comment: Floor-slab thickness; Estimated at typical 12 inches for light-industrial use

Parameter	Units	Cell/Row	Comments/Source	
Depth of Contamination	in	D10	Range Name: Calculation: Comment:	DEPTH User Entered (in inches) Default is 1 inch.
Density	lbs/ft^3	D11	Range Name: Calculation: Comment:	CONCDENSITY User Entered Density of concrete; Default = 150 lbs/ft^3
Fines	%	D12	Range Name: Calculation: Comment:	FINES User Entered % of rubble lost as fines during crushing and screening; Default is 30%.
Demolition	\$/ft^2	D13	Range Name: Calculation: Comment:	 \$1/ft^2 Based on total ft^2 of structure
Crushing	\$/ton*	D14	Range Name: Calculation: Comment:	COSTCRUSH Lognorm(3.12,1.06) The cost of crushing rubble per ton.
Rebar Salvage Value	\$/ton	D15	Range Name: Calculation: Comment:	**Parms**:D15 Uniform(37.5,62.5) The scrap value of rebar per ton.
Aggregate Sale Value	\$/ton	D16	Range Name: Calculation: Comment:	**Parms**:D16 Triang(2.1,4.02,8.04) The resale value of recycled aggregate per ton.
Fill Sale Value	\$/ton	D17	Range Name: Calculation: Comment:	**Parms**:D17 Triang(2.1,4.02,8.04) The resale value of recycled fill per ton.
C & D Disposal Fee	\$/yd^3	D17	Range Name: Calculation: Comment:	**Parms**:D17 Tnormal(24.99,17,0.1,93) Fees for disposal of Construction & Demolition derbies.
LLW Disposal Fee	\$/ft^3	D18	Range Name: Calculation: Comment:	**Parms**:D18 User Entered Fee charged for disposal of class A LLW. Default is \$60/ft^3 (Gresalfi & Tallarico 1995)

Parameter	Units	Cell/Row	Comments/Source
Mobilization	mi.	D19	Range Name: **Parms**:D19 Calculation: Triang(25,50,500) Comment: Distance to mobilize management crew to site. Most likely value = 50 miles.
Railhead	mi.	D20	Range Name: **Parms**:D20 Calculation: User Entered Comment: Distance to the closest railhead from the site. Default value is 0.5 miles.
LLW Disposal Facility	mi.	D21	Range Name: **Parms**:D21 Calculation: VLOOKUP(G51,'FINAL RISK MODEL.XLS'!LLWMILES,5) Comment: Distance that LLW must be hauled for disposal. Envirocare is default facility.
Aggregate Reuse Site	mi.	D22	Range Name: **Parms**:D22 Calculation: Triang (5,20,75) Comment: The distance to nearest scrap yard. Most likely value = 20.
Fill Resue Site	mi.	D23	Range Name: **Parms**:D22 Calculation: Triang (5,20,75) Comment: The distance to nearest scrap yard. Most likely value = 20.
Rebar Scrap Yard	mi.	D24	Range Name: **Parms**:D23 Calculation: Triang (5,25,125) Comment: The distance to nearest scrap yard. Most likely value = 25.
C&D Landfill	mi.	D25	Range Name: **Parms**:D23 Calculation: Triang(5,25,75) Comment: The distance that rubble must be hauled for disposal at a C&D landfill. Most likely value = 20 miles.

Parameter	Units	Cell/Row	Comments/Source
Cap Material	mi.	D26	Range Name: **Parms**:D24 Calculation: Triang(5,25,75) Comment: The distance that capping material is hauled. Most likely value = 25 miles.

Table Notes: * - all tons are "short tons" or 2,000 lbs

In addition to the parameters listed in Table C-1, there are several other important values computed on the **Parms** sheet. Most of these other values are not entered by the user, but are computed based on data entered elsewhere; the few values that are entered have been estimated or computed, are considered semi-fixed, and are not intended to be changed. Other data/calculations presented on the **Parms** sheet are listed in Table C-2.

Table C-2. Parms Sheet - Computed Additional Global Cost Data

Parameter	Units	Cell/Row	Comments/Source
Total Volume	ft^3	N6	Range Name: TVOLUME Calculation: TOTALAREA*THICKNESS/12 Comment: The total volume of concrete following rubblizing of facility
Clean Concrete Volume	ft^3	N7	Range Name: CONVOLUME Calculation: TVOLUME-(AREA*THICKNESS/12) Comment: It is the remaining clean volume of concrete the remains after the cleaning operation.
Inflation Rate after Year 1993	%	O13	Range Name: inflate1 Calculation: (1.03)^(N13-1993) Comment: Inflates costs from base year of 1993.
Inflation Rate after Year 1997	%	O14	Range Name: inflate2 Calculation: (1.03)^(N14-1997) Comment: Inflates costs from base year of 1997.

Sheet: Scenario 1

Twenty different technologies to execute the surface removal are considered, and these are selected at random during the simulation. The Scenario 1 sheet estimates the cost per ft² of floor space if contaminated surface areas were to be removed prior to rubblizing and crushing the concrete. Credits for the reclaimed aggregate and rebar are used to offset the overall cost for this scenario.

For each simulation, the technology to be used is selected at random using the @risk discrete function. The appropriate costs, efficiencies, and secondary waste streams are incorporated based on the selected technology. The technology selection and associated calculations are performed in an area titled "REMOVALTECH" Costs are determined based on project duration, distance to the LLW disposal facility, contaminant concentration, and other factors.

Table C-5. Scenario 1 Cost Table Calculations

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Trailer	F6	Units: Calculation: Comment:	$/trailer 5*D6*2 Default is 5 trailers mobilized and demobilized at $2000/trailer
Mobilization & Demobilization of Equipment	F7	Units: Calculation: Comment:	$/piece of equipment 6*D7*2 Default is 6 pieces of equipment mobilized and demobilized at $300/piece of equipment
Mobilization & Demobilization of 4 member Crew	F8	Units: Calculation: Comment	$/person/mile 4*D8*2*Parms!$D$19 4 member crew mobilized @ $0.32 (D8)/person/ mile (Parms!$D$19).
Rough grade 3 Acres	F9	Units: Calculation: Comment	$/yd2 3*43560/9*D9*inflate1 3 acres of land rough graded @$1.13/yd2*inflate1
Install chain Link Fence around Perimeter	F10	Units: Calculation: Comment:	$/ft SQRT(3*43560)*4*D10*inflate1 Fence the perimeter at $2.78/linear foot

Item	Row /Cell	Calculation/ Details	Comments/Source
Construct Decontamination Pad	F11	Units: Calculation: Comment:	$/pad D11*inflate2 $13000 (D11) to construct each equipment decontamination pad
Construct Access Road – 100 x 14 ft2	F12	Units: Calculation: Comment:	$ / ft^2 100*14*D12*inflate1 Construction of access road (100x14 ft2) to the site @ $4.04/ft2
Utilities – Water and Telephone	F13	Units: Calculation: Comment:	$/month D13*I42*infalte2 Water at $300/month; Telephone at $225/month
Utilities – Electricity	F14	Units: Calculation: Comment:	$/month D14*I42*6*inflate2 Electricity at $200/month/trailer
Utilities – Sanitation	F15	Units: Calculation: Comment:	$/month D15*I42*4*inflate2 4 port-a-johns at $80/month/port-a-john
Initial Characterization	F20	Units: Calculation: Comment:	$/sample (TOTALAREA/1000*(D20+25/2)*inflate1) Conduct sampling every 1,000 ft^2 at $370/analysis; labor at $25/hour.
Specific Sampling & Final Characterization	F21	Units: Calculation: Comment	$/sample AREA/100*(D21+25/2)*inflate1) Conduct sampling every 100 ft^2 of the contaminated area at $1000/analysis; labor at $25/hour.
Rebar Screening--@1/4 hr/load	F22	Units: Calculation: Comment	$/load TVOLUME*CONCDENSITY/2000/18*D22/4*inflate1 Rebar is tested once per truckload using hand-held scanner @ $25/hour.
Aggregate Screening--@1/4 hr/load	F23	Units: Calculation: Comment	$/hr CONVOLUME/15*0.25*D23*(1+EXPANSION/100)*inflate1 Recycled aggregate is tested once per truckload using hand-held scanner @ $25/hour.

Item	Row /Cell	Calculation/ Details	Comments/Source
Decontamination	F24	Units:	$/ft2
		Calculation:	{cost per ft^2}*AREA
		Comment	Concrete is decontaminated by selected technology
Demolish Structure	F25	Units:	Regression Equation
		Calculation:	(TOTALAREA*0.95+814)*inflate2
		Comment	Cost for demolition of the structure.
Crush and Screen Concrete	F26	Units:	$/ton
		Calculation:	CONVOLUME*CONCDENSITY/2000*COSTCRUSH*inflate2
		Comment	Cost to crush and screen concrete rubble.
Drum Waste	F27	Units:	$/drum
		Calculation:	ROUNDUP(AREA/1000,0)*(D27+25/4)*inflate1
		Comment	One drum per 1,000 ft^2 (or fraction thereof) is required, as well as any additional drums to house secondary wastes.
Collect Waste from Removal Technology and Load on Truck	F28	Units:	$/yd3
		Calculation:	AREA*DEPTH/12/27*D28*inflate1
		Comment	Cost to collect and load any surface material removed during decontamination.
Load fines	F29	Units:	$/yd3
		Calculation:	CONVOLUME/27*FINES/100*D29*(1+EXPANSION/100)*inflate1
		Comment	Cost to load fines generated.
Haul Waste to Railway Platform	F30	Units:	$/yd3/mile
		Calculation:	(AREA*DEPTH/12/27+AREA/1000*7.3/27)*(Parms!D20*0.414+1.74)*inflate1
		Comment	Cost to haul waste to the railhead.
Haul Waste to Envirocare	F31	Units:	$/ton/mile
		Calculation:	(AREA*DEPTH/12*CONCDENSITY/2000+AREA/1000*230/2000)*D31*Parms!D21*inflate2
		Comment	Cost to haul waste to Envirocare by rail.

Item	Row /Cell	Calculation/ Details	Comments/Source
Haul Rebar	F32	Units:	$/ton/mile
		Calculation:	TVOLUME*0.07*CONCDENSITY/2000*D32*Parms!D22*inflate2
		Comment	Cost to haul rebar to scrap yard.
Haul Fines	F33	Units:	$/yd3/mile
		Calculation:	(CONVOLUME/27*FINES/100*(1+EXPANSION/100)*0.414+1.74)*Parms!D23*inflate1
		Comment	Cost to haul fines to a C&D Landfill site.
Disposal Fee @ Envirocare	F34	Units:	$\$/\text{ft}^3$
		Calculation:	(AREA*DEPTH/12+AREA/1000*7.3)*D34*inflate2
		Comment	Disposal cost of LLW at Envirocare @
Disposal Fee @ C&D Landfill	F35	Units:	$\$/\text{yd}^3$
		Calculation:	CONVOLUME*(1+EXPANSION/100)*FINES/100/27*D35*inflate2
		Comment:	Disposal cost of fines at C&D landfill .
Site Clean-up	F36	Units:	Regression Equation
		Calculation:	1300+(TAREAACRES*870+53)*inflate1
		Comment:	Cost of cleanup after the completion of the project.
Decontamination of Personnel	F37	Units:	$/hr
		Calculation:	0.25*21*30*I42*D37*inflate2
		Comment:	Cost of daily personal decontamination activities.
Decontamination of Equipment	F39	Units:	$/equipment
		Calculation:	6*D39*inflate1
		Comment:	decontamination of equipment @ $180 / piece of equipment
Credit for Rebar	F40	Units:	$/ton
		Calculation:	TVOLUME*0.07*CONCDENSITY/2000*D40
		Comment:	Credit from the resale of rebar.
Credit for Aggregate	F41	Units:	$/ton
		Calculation:	TVOLUME*CONCDENSITY*0.7/2000*D41
		Comment:	Credit for sale of recycled aggregate .

Table C-6. Scenario 1 Cost Table Supplementary Calculations

Item	Row/ Cell	Calculation/ Details	Comments/Source
Technology Output Rate	C67	Units: Calculation: Comment:	ft²/hr HLOOKUP(2,REMOVALTEC,H45+1) Decontamination technology selected.
Technology Cost	D67	Units: Calculation: Comment:	$/ft2 HLOOKUP(3,REMOVALTEC,H45+1) Decontamination technology selected.
Technology Duration	E67	Units: Calculation: Comment	man-hours HLOOKUP(4,REMOVALTEC,H45+1) Duration of decontamination activities.
Selection of Technology	H45	Calculation: Comment:	Discrete({1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20},{50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50}) Each technology has an equivalent chance of being selected per iteration

Sheet: Scenario 2

The Scenario 2 sheet estimates the cost per ft² of floor space if contaminated surface areas were to be treated to free release levels prior to rubblizing and crushing the concrete. Nine different technologies to accomplish the surface treatment are considered. Credits for the reclaimed aggregate and rebar are also used to offset the overall cost for this scenario.

The Scenario 2 calculations are very similar to the calculations described previously for Scenario 1. The calculations for each technology are identical in format. Differing costs, efficiencies, and secondary waste streams are incorporated. The calculations are carried out as summarized in Tables C-5-6.

Table C-11. Scenario 2 Cost Table Calculations

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Trailer	F6	Units: Calculation: Comment:	$/trailer 5*D6*2 Default is 5 trailers mobilized and demobilized at $2000/trailer

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Equipment	F7	Units: Calculation: Comment:	\$/piece of equipment 6*D7*2 Default is 6 pieces of equipment mobilized and demobilized at \$300/piece of equipment
Rough grade 3 Acres of land	F9	Units: Calculation: Comment	\$/yd2 3*43560/9*D9*inflate1 3 acres of land rough graded @\$1.13/yd2*inflate1
Install chain Link Fence around Perimeter	F10	Units: Calculation: Comment:	\$/ft SQRT(3*43560)*4*D10*inflate1 Fence the perimeter at \$2.78/linear foot
Construct Decontamination Pad	F11	Units: Calculation: Comment:	\$/pad D11*inflate2 \$13000 (D11) to construct each equipment decontamination pad
Construct Access Road - 100 x 14 ft2	F12	Units: Calculation: Comment:	\$ / ft^2 100*14*D12*inflate1 Construction of access road (100x14 ft2) to the site @ \$4.04/ft2
Utilities – Water and Telephone	F13	Units: Calculation: Comment:	\$/month D13*I42*infalte2 Water at \$300/month; Telephone at \$225/month
Utilities – Electricity	F14	Units: Calculation: Comment:	\$/month D14*I42*6*inflate2 Electricity at \$200/month/trailer
Utilities - Sanitation	F15	Units: Calculation: Comment:	\$/month D15*I42*4*inflate2 4 port-a-johns at \$80/month/port-a-john
Initial Characterization	F20	Units: Calculation: Comment:	\$/sample (TOTALAREA/1000*(D20+25/2)*inflate 1) Conduct sampling every 1,000 ft^2 at \$370/analysis; labor at \$25/hour.
Specific Sampling & Final Characterization	F21	Units: Calculation: Comment	\$/sample AREA/100*(D21+25/2)*inflate1) Conduct sampling every 100 ft^2 of the contaminated area at \$1000/analysis; labor at \$25/hour.

Item	Row /Cell	Calculation/ Details	Comments/Source
Rebar Screening--@1/4 hr/load	F22	Units: Calculation: Comment	$/load TVOLUME*CONCDENSITY/2000/18*D22/4*inflate1 Rebar is tested once per truck-load using hand-held scanner @ $25/hour.
Aggregate Screening--@1/4 hr/load	F23	Units: Calculation: Comment	$/hr CONVOLUME/15*0.25*D23*(1+EXPANSION/100)*inflate1 Recycled aggregate is tested once per truck-load using hand-held scanner @ $25/hour.
Decontamination	F24	Units: Calculation: Comment	$/ft2 {cost per ft²}*AREA Concrete is decontaminated by selected technology
Demolish Structure	F25	Units: Calculation: Comment	Regression Equation (TOTALAREA*0.95+814)*inflate2 Cost for demolition of the structure.
Crush and Screen Concrete	F26	Units: Calculation: Comment	$/ton CONVOLUME*CONCDENSITY/2000*COSTCRUSH*inflate2 Cost to crush and screen concrete rubble.
Drum Waste	F27	Units: Calculation: Comment	$/drum ROUNDUP(AREA/1000,0)*(D27+25/4)*inflate1 One drum per 1,000 ft² (or fraction thereof) is required, as well as any additional drums to house secondary wastes.
Collect Waste from Removal Technology and Load on Truck	F28	Units: Calculation: Comment	$/yd3 AREA*DEPTH/12/27*D28*inflate1 Cost to collect and load any surface material removed during decontamination.
Load fines	F29	Units: Calculation: Comment	$/yd3 CONVOLUME/27*FINES/100*D29*(1+EXPANSION/100)*inflate1 Cost to load fines generated.

Item	Row /Cell	Calculation/ Details	Comments/Source
Haul Waste to Railway Platform	F30	Units: Calculation: Comment	$/yd3/mile (AREA*DEPTH/12/27+AREA/1000*7.3/27)*(Parms!D20*0.414+1.74)*inflate1 Cost to haul waste to the railhead.
Haul Waste to Envirocare	F31	Units: Calculation: Comment	$/ton/mile (AREA*DEPTH/12*CONCDENSITY/2000+AREA/1000*230/2000)*D31*Parms!D21*inflate2 Cost to haul waste to Envirocare by rail.
Haul Rebar	F32	Units: Calculation: Comment	$/ton/mile TVOLUME*0.07*CONCDENSITY/2000*D32*Parms!D22*inflate2 Cost to haul rebar to scrap yard.
Haul Fines	F33	Units: Calculation: Comment	$/yd3/mile (CONVOLUME/27*FINES/100*(1+EXPANSION/100)*0.414+1.74)*Parms!D23*inflate1 Cost to haul fines to a C&D Landfill site.
Disposal Fee @ Envirocare	F34	Units: Calculation: Comment	\$/ft^3 (AREA*DEPTH/12+AREA/1000*7.3)*D34*inflate2 Disposal cost of LLW at Envirocare @
Site Clean-up	F36	Units: Calculation: Comment:	Regression Equation 1300+(TAREAACRES*870+53)*inflate1 Cost of cleanup after the completion of the project.
Decontamination of Equipment	F39	Units: Calculation: Comment:	$/equipment 6*D39*inflate1 decontamination of equipment @ $180 / piece of equipment
Credit for Rebar	F40	Units: Calculation: Comment:	$/ton TVOLUME*0.07*CONCDENSITY/2000*D40 Credit from the resale of rebar.
Credit for Aggregate	F41	Units: Calculation: Comment:	$/ton TVOLUME*CONCDENSITY*0.7/2000*D41 Credit for sale of recycled aggregate.

Table C-12. Scenario 2 Cost Table Supplementary Calculations

Item	Row/ Cell	Calculation/ Details	Comments/Source
Technology Output Rate	K64	Units: Calculation: Comment:	ft²/hr VLOOKUP(4,TREATMENTTECH,K67+1) Decontamination technology selected.
Technology Cost	K66	Units: Calculation: Comment:	$/ft2 VLOOKUP(5,TREATMENTTECH,K67+1) Decontamination technology selected.
Technology Duration	K65	Units: Calculation: Comment	man-hours VLOOKUP(3,TREATMENTTECH,K67+1) Duration of decontamination activities.
Selection of Technology	K63	Units: Calculation: Comment:	NA VLOOKUP(1,TREATMENTTECH,K67+1) Each technology has an equivalent chance of being selected.

Sheet: Scenario 3

The Scenario 3 sheet estimates the costs if contaminated surface areas are to be decontaminated to free-release levels prior to demolishing the structure. The resulting rubble is capped in-place.

The calculations for each technology are identical in format, and similar to Scenario 1, and 2. Steps necessary to reduce the concrete rubble into aggregate are omitted. No credit is included for the aggregate and rebar. Also additional cost for the capping activity are included. The calculations are carried out as summarized in Tables C-7-8.

Table C-19. Scenario 3 Cost Table Calculations

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Trailer	F6	Units: Calculation: Comment:	$/trailer 5*D6*2 Default is 5 trailers mobilized and demobilized at $2000/trailer

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Equipment	F7	Units: Calculation: Comment:	$/piece of equipment 6*D7*2 Default is 6 pieces of equipment mobilized and demobilized at $300/piece of equipment
Rough Grade 3 Acres of land	F9	Units: Calculation: Comment	$/yd2 3*43560/9*D9*inflate1 3 acres of land rough graded @$1.13/yd2*inflate1
Install chain Link Fence around Perimeter	F10	Units: Calculation: Comment:	$/ft SQRT(3*43560)*4*D10*inflate1 Fence the perimeter at $2.78/linear foot
Construct Decontamination Pad	F11	Units: Calculation: Comment:	$/pad D11*inflate2 $13000 (D11) to construct each equipment decontamination pad
Construct Access Road - 100 x 14 ft2	F12	Units: Calculation: Comment:	$ / ft^2 100*14*D12*inflate1 Construction of access road (100x14 ft2) to the site @ $4.04/ft2
Utilities – Water and Telephone	F13	Units: Calculation: Comment:	$/month D13*I42*infalte2 Water at $300/month; Telephone at $225/month
Utilities – Electricity	F14	Units: Calculation: Comment:	$/month D14*I42*6*inflate2 Electricity at $200/month/trailer
Utilities - Sanitation	F15	Units: Calculation: Comment:	$/month D15*I42*4*inflate2 4 port-a-johns at $80/month/port-a-john
Initial Characterization	F20	Units: Calculation: Comment:	$/sample (TOTALAREA/1000*(D20+25/2)*inflate1) Conduct sampling every 1,000 ft^2 at $370/analysis; labor at $25/hour.
Specific Sampling & Final Characterization	F21	Units: Calculation: Comment	$/sample AREA/100*(D21+25/2)*inflate1) Conduct sampling every 100 ft^2 of the contaminated area at $1000/analysis; labor at $25/hour.

Item	Row /Cell	Calculation/ Details	Comments/Source
Decontamination	F22	Units: Calculation: Comment	$/ft2 {cost per ft^2}*AREA Concrete is decontaminated by selected technology
Demolish Structure	F23	Units: Calculation: Comment	Regression Equation (TOTALAREA*0.95+814)*inflate2 Cost for demolition of the structure.
Consolidate waste	F24	Units: Calculation: Comment	$/yd3 TOTALAREA*THICKNESS/12/27*D26*inflate1 The waste is consolidated prior to capping.
Drum Waste	F25	Units: Calculation: Comment	$/drum ROUNDUP(AREA/1000,0)*(D27+25/4)*inflate1 One drum per 1,000 ft^2 (or fraction thereof) is required, as well as any additional drums to house secondary wastes.
Collect Waste from Removal Technology and Load on Truck	F26	Units: Calculation: Comment	$/yd3 AREA*DEPTH/12/27*D28*inflate1 Cost to collect and load any surface material removed during decontamination.
Haul Waste to Railway Platform	F27	Units: Calculation: Comment	$/yd3/mile (AREA*DEPTH/12/27+AREA/1000*7.3/27)*(Parms!D20*0.414+1.74)*inflate1 Cost to haul waste to the railhead.
Haul Waste to Envirocare	F28	Units: Calculation: Comment	$/ton/mile (AREA*DEPTH/12*CONCDENSITY/2000+AREA/1000*230/2000)*D31*Parms!D21*inflate2 Cost to haul waste to Envirocare by rail.
Disposal Fee @ Envirocare	F29	Units: Calculation: Comment	$/ft^3 (AREA*DEPTH/12+AREA/1000*7.3)*D34*inflate2 Disposal cost of LLW at Envirocare @

Item	Row /Cell	Calculation/ Details	Comments/Source
Excavate Cap Material	F30	Units:	\$/yd^3
		Calculation:	TOTALAREA*1.5*1.5/27*1.4*inflate1
		Comment	Cap material is excavated
Haul cap material	F31	Units:	\$/yd^3/mile
		Calculation:	(TOTALAREA*1.5*1.5/27*Parms!D24*0.414+1.74)*inflate1
		Comment	Capping material (clay or other similar material) is hauled from the nearest point from the site.
Construct Cap	F32	Units:	\$/acre
		Calculation:	IF(TAREAACRES<=5,(TAREAACRES*43327+7836)*inflate1,IF(TAREAACRES<=10,(TAREAACRES*43346+9743)*inflate1,IF(TAREAACRES<=100,(TAREAACRES*41312+27477)*inflate1,(TAREAACRES*40972+59754)*inflate1)))
		Comment	Different cost are considered based on the size of the cap, the range of size considered are cap of size <=5, 10, and >=100.
Install Monitoring Wells	F33	Units:	\$/well
		Calculation:	(M6*2304+1264)*inflate1
		Comment:	50ft deep wells are constructed and are monitored once every year for 100 years. No. of wells are calculated in cell M6.
Monitor Groundwater	F34	Units:	\$
		Calculation:	M6*D34
		Comment:	Monitor groundwater for 30 years.
Site Clean-up	F35	Units:	\$
		Calculation:	1300+(TAREAACRES*870+53)*inflate1
		Comment:	Cost of cleanup after the completion of the project.
Decontamination of Equipment	F38	Units:	\$/equipment
		Calculation:	6*D39*inflate1
		Comment:	decontamination of equipment @ \$180 / piece of equipment

Item	Row /Cell	Calculation/ Details	Comments/Source
Seeding and fine Grading after Installation of Cap	F39	Units: Calculation: Comment:	$/yd2 M5*43560*D41/9 Cap area is covered with vegetation to protect from washouts. The cap area is calculated in cell M5
Mowing and reseeding	F40	Units: Calculation: Comment:	$/man-hr D42*I42 Vegetation is maintained for *** years.

Table C-20. Scenario 3 Cost Table Supplementary Calculations

Item	Row/ Cell	Calculation/ Details	Comments/Source
Cap Area	M5	Units: Calculation: Comment	Acres TOTALAREA*THICKNESS/12/6/43560 Cap area in acres is calculated for a depth of 6 ft of consolidated fill.
No. of Wells Required	M6	Units: Calculation: Comment	wells IF(M5<=5,4,ROUNDUP((M5/5)-1,0)+4) 4 wells are provided for every 5 acres area of cap. A min. of 4 wells are provided.
Technology Output Rate	AF52	Units: Calculation: Comment:	ft^2/hr VLOOKUP(3,BOTHTECH,AF55+1) Decontamination technology selected.
Technology Cost	AF54	Units: Calculation: Comment:	$/ft2 VLOOKUP(4,BOTHTECH,AF55+1) Decontamination technology selected.
Technology Duration	AF53	Units: Calculation: Comment	man-hours VLOOKUP(2,BOTHTECH,AF55+1) Duration of decontamination activities.
Selection of Technology	AF51	Units: Calculation: Comment:	NA VLOOKUP(1,BOTHTECH,AF55+1) Each technology has an equivalent chance of being selected per iteration

Sheet: Scenario 4

The Scenario 4 sheet estimates the cost if the facility is demolished, and the site capped in-place. In this scenario no removal or treatment of waste takes place. The calculations are carried out as summarized in Tables C-9 -10.

Table C-29. Scenario 4 Cost Table Calculations

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Trailer	F6	Units: Calculation: Comment:	$/trailer 5*D6*2 Default is 5 trailers mobilized and demobilized at $2000/trailer
Mobilization & Demobilization of Equipment	F7	Units: Calculation: Comment:	$/piece of equipment 6*D7*2 Default is 6 pieces of equipment mobilized and demobilized at $300/piece of equipment
Rough Grade 3 Acres of Land	F9	Units: Calculation: Comment	$/yd2 3*43560/9*D9*inflate1 3 acres of land rough graded @$1.13/yd2*inflate1
Install Chain Link Fence around Perimeter	F10	Units: Calculation: Comment:	$/ft SQRT(3*43560)*4*D10*inflate1 Fence the perimeter at $2.78/linear foot
Construct Decontamination Pad	F11	Units: Calculation: Comment:	$/pad D11*inflate2 $13000 (D11) to construct each equipment decontamination pad
Construct Access Road - 100 x 14 ft2	F12	Units: Calculation: Comment:	$ / ft^2 100*14*D12*inflate1 Construction of access road (100x14 ft2) to the site @ $4.04/ft2
Utilities – Water and Telephone	F13	Units: Calculation: Comment:	$/month D13*I35*infalte2 Water at $300/month; Telephone at $225/month
Utilities – Electricity	F14	Units: Calculation: Comment:	$/month D14*I35*6*inflate2 Electricity at $200/month/trailer

Item	Row /Cell	Calculation/ Details	Comments/Source
Utilities - Sanitation	F15	Units: Calculation: Comment:	\$/month D15*I35*4*inflate2 4 port-a-johns at \$80/month/port-a-john
Initial Characterization	F20	Units: Calculation: Comment:	\$/sample (TOTALAREA/1000*(D20+25/2)*inflate 1) Conduct sampling every 1,000 ft² at \$370/analysis; labor at \$25/hour.
Specific Sampling & Final Characterization	F21	Units: Calculation: Comment	\$/sample AREA/100*(D21+25/2)*inflate1) Conduct sampling every 100 ft² of the contaminated area at \$1000/analysis; labor at \$25/hour.
Demolish Structure	F22	Units: Calculation: Comment	Regression Equation (TOTALAREA*0.95+814)*inflate2 Cost for demolition of the structure.
Consolidate Waste	F23	Units: Calculation: Comment	\$/yd³ TOTALAREA*THICKNESS/12/27*D26*inflate1 The waste is consolidated prior to capping.
Excavate Cap Material	F24	Units: Calculation: Comment	\$/yd³ TOTALAREA*1*6/27*D24*inflate1 Ground is excavated for the capping activity.
Haul Cap Material	F25	Units: Calculation: Comment	\$/yd³/mile (TOTALAREA*1.5*6/27*Parms!D24*0.414+1.74)*inflate1 Capping material (clay or other similar material) is hauled from the nearest point from the site.

Item	Row /Cell	Calculation/ Details	Comments/Source
Construct Cap	F26	Units:	$/acre
		Calculation:	IF(TAREAACRES<=5,(TAREAACRES*132658+35972)*inflate1,IF(TAREAACRES<=10,(TAREAACRES*135892+22090)*inflate1,IF(TAREAACRES<=100,(TAREAACRES*133286+52840)*inflate1,(TAREAACRES*132480+127115)*inflate1)))
		Comment	Different cost are considered based on the size of the cap, the range of size considered are cap of size <=5, 10, and >=100.
Install Monitoring Wells	F27	Units:	$/well
		Calculation:	(M6*2304+1264)*inflate1
		Comment:	50ft deep wells are constructed and are monitored once every year for 100 years. No. of wells are calculated in cell M6.
Monitor Groundwater	F28	Units:	$/well
		Calculation:	M6*D28
		Comment:	Monitor groundwater for 30 years.
Site Clean-up	F29	Units:	$/acre
		Calculation:	1300+(TAREAACRES*870+53)*inflate1
		Comment:	Cost of cleanup after the completion of the project.
Decontamination of Equipment	F32	Units:	$/equipment
		Calculation:	6*D32*inflate1
		Comment:	Decontamination of equipment.
Seeding and Fine Grading after Installation of Cap	F38	Units:	$/yd2
		Calculation:	M5*43560*D33/9
		Comment:	Cap area is covered with vegetation to protect from washouts.
Mowing and Reseeding	F49	Units:	$/man-hr
		Calculation:	D34*I34
		Comment:	Vegetation is maintained for *** years.

Table C-30. Scenario 4 Cost Table Supplementary Calculations

Item	Row/ Cell	Calculation/ Details	Comments/Source
Cap Area	M5	Units: Calculation: Comment	Acres TOTALAREA*THICKNESS/12/6/43560 Cap area in acres is calculated for a depth of 6 ft of consolidated fill.
No. of Wells Required	M6	Units: Calculation: Comment	wells IF(M5<=5,4,ROUNDUP((M5/5)-1,0)+4) 4 wells are provided for every 5 acres area of cap. A min. of 4 wells are provided.

Sheet: Scenario 5

Scenario 5 involves the construction of an on-site RCRA cap with membrane liner and other specification. No surface decontamination/removal activity is conducted. Fines are disposed of in the new facility, and four monitoring wells are installed per 5 acres of cap and monitored for a period of 100 years. Calculations and spreadsheets are detailed in Tables C-11 -12.

Table C-41. Scenario 5 Cost Table Calculations

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Trailer	F6	Units: Calculation: Comment:	$/trailer 5*D6*2 Default is 5 trailers mobilized and demobilized at $2000/trailer
Mobilization & Demobilization of Equipment	F7	Units: Calculation: Comment:	$/piece of equipment 6*D7*2 Default is 6 pieces of equipment mobilized and demobilized at $300/piece of equipment
Rough Grade 3 Acres of Land	F9	Units: Calculation: Comment	$/yd^2 3*43560/9*D9*inflate1 3 acres of land rough graded @$1.13/yd2*inflate1
Install Chain Link Fence around Perimeter	F10	Units: Calculation: Comment:	$/ft SQRT(3*43560)*4*D10*inflate1 Fence the perimeter at $2.78/linear foot
Construct Decontamination Pad	F11	Units: Calculation: Comment:	$/pad D11*inflate2 $13000 (D11) to construct each equipment decontamination pad
Construct Access Road - 100 x 14 ft2	F12	Units: Calculation: Comment:	$/ft^2 100*14*D12*inflate1 Construction of access road (100x14 ft2) to the site @ $4.04/ft2
Utilities – Water and Telephone	F13	Units: Calculation: Comment:	$/month D13*I44*inflate2 Water at $300/month; Telephone at $225/month

Item	Row /Cell	Calculation/ Details	Comments/Source
Utilities – Electricity	F14	Units: Calculation: Comment:	$/month D14*I44*6*inflate2 Electricity at $200/month/trailer
Utilities - Sanitation	F15	Units: Calculation: Comment:	$/month D15*I44*4*inflate2 4 port-a-johns at $80/month/port-a-john
Initial Characterization	F20	Units: Calculation: Comment:	$/sample (TOTALAREA/1000*(D20+25/2)*inflate1) Conduct sampling every 1,000 ft² at $370/analysis; labor at $25/hour.
Specific Sampling & Final Characterization	F21	Units: Calculation: Comment	$/sample AREA/100*(D21+25/2)*inflate1) Conduct sampling every 100 ft² of the contaminated area at $1000/analysis; labor at $25/hour.
Demolish Structure	F22	Units: Calculation: Comment:	$/floor area (TOTALAREA*0.95+814)*inflate2 Cost for demolition of the structure.
Crush and Screen Rubble	F23	Units: Calculation: Comment:	$/ton CONVOLUME*CONCDENSITY/2000*COSTCRUSH*inflate2 Crush rubble prior to disposal.
Excavate LLW - Cell	F24	Units: Calculation: Comment	$/yd³ TOTALAREA*15.5*1/8*D24/27*inflate1 A hole of 15.5 ft is dug into the ground, based on the calculation of the amount of waste + lift material.
Haul Excavated Cell Material from the Site	F25	Units: Calculation: Comment	$/yd³/mile 15.5*(TOTALAREA*1*0.414/8/27+1.74)*Parms!D24*inflate1 Excavation waste is hauled from the site.
Excavate Liner and Lift Material	F26	Units: Calculation: Comment	$/yd³ TOTALAREA*1/8/27*(5.5+2+6)*D26*inflate1 Liner material is excavated.

Item	Row /Cell	Calculation/ Details	Comments/Source
Haul Liner Material	F27	Units: Calculation: Comment	$\$/\text{yd}^3/\text{mile}$ (TOTALAREA*1/8*5.5/27*0.414+1.74)*inflate1*Parms!D24 Liner material is hauled to the site.
Place Soil Liner	F28	Units: Calculation: Comment	$\$/\text{yd}^3$ TOTALAREA*1/8*5.5/27*D28*inflate1 A 5.5-ft deep liner is placed.
Place synthetic liner	F29	Units: Calculation: Comment	$\$/\text{ft}^2$ TOTALAREA*1/8*D29*inflate2 A Geo-membrane liner is place at the bottom of the cap.
Haul Intermediate Lifts	F30	Units: Calculation: Comment	$\$/\text{yd}^3/\text{mile}$ (TOTALAREA*1*2*0.414/8/27+1.74)*inflate1*Parms!D24 Lift material is hauled to site.
Place Intermediate Lifts	F31	Units: Calculation: Comment	$\$/\text{yd}^3$ TOTALAREA*1/8/27*2*D31*inflate1 Two feet lifts are placed in-between the waste.
Place Waste	F32	Units: Calculation: Comment	$\$/\text{yd}^3$ TOTALAREA*1/27*D32*inflate1 Waste is placed at the lifts of 2 ft, sandwiched between 2ft deep layers of lift material.
Excavate Cap Material	F33	Units: Calculation: Comment	$\$/\text{yd}^3$ (1.5*TOTALAREA*1*6/8/27*D33*inflate1) Ground is excavated for the capping activity.
Haul Cap Material	F34	Units: Calculation: Comment	$\$/\text{yd}^3/\text{mile}$ (1.5*TOTALAREA*1*6*0.414/8/27+1.74)*inflate1*Parms!D24 Capping material (clay or other similar material) is hauled from the nearest point from the site.

Item	Row /Cell	Calculation/ Details	Comments/Source
Construct Cap	F35	Units: Calculation: Comment	$/acre IF(TAREAACRES<=5,(TAREAACRES*132658+35972)*inflate1,IF(TAREAACRES<=10,(TAREAACRES*135892+22090)*inflate1,IF(TAREAACRES<=100,(TAREAACRES*133286+52840)*inflate1,(TAREAACRES*132480+127115)*inflate1))) Different cost are considered based on the size of the cap, the range of size considered are cap of size <=5, 10, and >=100.
Install Monitoring Wells	F36	Units: Calculation: Comment:	$/well (M6*2304+1264)*inflate1 50ft deep wells are constructed and are monitored once every year for 100 years. No. of wells are calculated in cell M6.
Monitor Groundwater	F37	Units: Calculation: Comment:	$/well M6*D37 Monitor groundwater for 30 years.
Site Clean-up	F38	Units: Calculation: Comment:	$/acre 1300+(TAREAACRES*870+53)*inflate1 Cost of cleanup after the completion of the project.
Decontamination of Equipment	F41	Units: Calculation: Comment:	$/equipment 6*D41*inflate1 Decontamination of equipment.
Seeding and Fine Grading after Installation of Cap	F42	Units: Calculation: Comment:	$/yd2 M5*43560*D42/9 Cap area is covered with vegetation to protect from washouts.
Mowing and Reseeding	F43	Units: Calculation: Comment:	$/man-hr D43*I43 Vegetation is maintained for *** years.

Table C-42. Scenario 5 Cost Table Supplementary Calculations

Item	Row/ Cell	Calculation/ Details	Comments/Source
Cap Area	M5	Units: Calculation: Comment	Acres TOTALAREA*THICKNESS/12/6/43560 Cap area in acres is calculated for a depth of 6 ft of consolidated fill.
No. of Wells Required	M6	Units: Calculation: Comment	wells IF(M5<=5,4,ROUNDUP((M5/5)-1,0)+4) 4 wells are provided for every 5 acres area of cap. A min. of 4 wells are provided.

Sheet: Scenario 6

The Scenario 6 sheet estimates the cost per ft² of floor space if contaminated surface areas are to be removed to free-release levels prior to demolishing the concrete. It represents the current DOE, the concrete debris is disposed of in a C&D landfill. Twenty-nine different technologies to accomplish the surface removal/treatment are considered.

The calculations for each technology are identical in format, and similar to Scenario 1 and 2 for removal and treatment, respectively. Steps necessary to reduce the concrete rubble into aggregate are omitted. The calculations are carried out as summarized in Tables C-13-14.

Table C-55. Scenario 6 Cost Table Calculations

Item	Row /Cell	Calculation/ Details	Comments/Source
Mobilization & Demobilization of Trailer	F6	Units: Calculation: Comment:	$/trailer 5*D6*2 Default is 5 trailers mobilized and demobilized at $2000/trailer
Mobilization & Demobilization of Equipment	F7	Units: Calculation: Comment:	$/piece of equipment 6*D7*2 Default is 6 pieces of equipment mobilized and demobilized at $300/piece of equipment
Rough Grade 3 Acres of Land	F9	Units: Calculation: Comment	$/yd2 3*43560/9*D9*inflate1 3 acres of land rough graded @$1.13/yd2*inflate1
Install Chain Link Fence around Perimeter	F10	Units: Calculation: Comment:	$/ft SQRT(3*43560)*4*D10*inflate1 Fence the perimeter at $2.78/linear foot
Construct Decontamination Pad	F11	Units: Calculation: Comment:	$/pad D11*inflate2 $13000 (D11) to construct each equipment decontamination pad
Construct Access Road - 100 x 14 ft2	F12	Units: Calculation: Comment:	$ / ft² 100*14*D12*inflate1 Construction of access road (100x14 ft2) to the site @ $4.04/ft2

Utilities – Water and Telephone	F13	Units:	$/month
		Calculation:	D13*I36*inflate2
		Comment:	Water at $300/month; Telephone at $225/month
Utilities – Electricity	F14	Units:	$/month
		Calculation:	D14*I36*6*inflate2
		Comment:	Electricity at $200/month/trailer
Utilities - Sanitation	F15	Units:	$/month
		Calculation:	D15*I36*4*inflate2
		Comment:	4 port-a-johns at $80/month/port-a-john
Initial Characterization	F20	Units:	$/sample
		Calculation:	(TOTALAREA/1000*(D20+25/2)*inflate 1)
		Comment:	Conduct sampling every 1,000 ft² at $370/analysis; labor at $25/hour.
Specific Sampling & Final Characterization	F21	Units:	$/sample
		Calculation:	AREA/100*(D21+25/2)*inflate1)
		Comment	Conduct sampling every 100 ft² of the contaminated area at $1000/analysis; labor at $25/hour.
Aggregate Screening--@1/4 hr/load	F22	Units:	$/hr
		Calculation:	CONVOLUME/15*0.25*D22*(1+EXPANSION/100)*inflate1
		Comment	Recycled aggregate is tested once per truck-load using hand-held scanner @ $25/hour.
Decontamination	F23	Units:	$/ft2
		Calculation:	{cost per ft²}*AREA
		Comment	Concrete is decontaminated by selected technology
Demolish Structure	F24	Units:	$/ft²
		Calculation:	(TOTALAREA*0.95+814)*inflate2
		Comment	Cost for demolition of the structure.
Drum Waste	F25	Units:	$/drum
		Calculation:	ROUNDUP(AREA/1000,0)*(D25+25/4)*inflate1
		Comment	One drum per 1,000 ft² (or fraction thereof) is required, as well as any additional drums to house secondary wastes.

Collect Waste from Removal Technology and Load on Truck	F26	Units: Calculation: Comment	$/yd3 AREA*DEPTH/12/27*D26*inflate1 Cost to collect and load any surface material removed during decontamination.
Haul Waste to Railway Platform	F27	Units: Calculation: Comment	$/yd3/mile (AREA*DEPTH/12/27+AREA/1000*7.3/27)*(Parms!D20*0.414+1.74)*inflate1 Cost to haul waste to the railhead.
Haul Waste to Envirocare	F28	Units: Calculation: Comment	$/ton/mile (AREA*DEPTH/12*CONCDENSITY/2000+AREA/1000*230/2000)*D28*Parms!D21*inflate2 Cost to haul waste to Envirocare by rail.
Haul Waste to C&D landfill	F29	Units: Calculation: Comment	$/yd3/mile (CONVOLUME/27)*(1+EXPANSION/100)*(Parms!D23*0.414+1.74)*inflate1 Cost to haul fines to a C&D Landfill site.
Disposal Fee @ Envirocare	F30	Units: Calculation: Comment	$\$/\mathrm{ft}^3$ (AREA*DEPTH/12+AREA/1000*7.3)*D30*inflate2 Disposal cost of LLW at Envirocare @
Disposal Fee @ C&D Landfill	F31	Units: Calculation: Comment:	$\$/\mathrm{yd}^3$ CONVOLUME/27*(1+EXPANSION/100)*D31*inflate2 Disposal cost of fines at C&D landfill .
Site Clean-up	F32	Units: Calculation: Comment:	Regression Equation 1300+(TAREAACRES*870+53)*inflate1 Cost of cleanup after the completion of the project.
Decontamination of Equipment	F35	Units: Calculation: Comment:	$/equipment 6*D35*inflate1 Decontamination of equipment

Table C-69. Scenario 6 Cost Table Supplementary Calculations

Item	Row/ Cell	Calculation/ Details	Comments/Source
Technology Output Rate	C67	Units: Calculation: Comment:	ft^2/hr HLOOKUP(2,REMOVALTEC,H45+1) Decontamination technology selected.
Technology Cost	D67	Units: Calculation: Comment:	$/ft2 HLOOKUP(3,REMOVALTEC,H45+1) Decontamination technology selected.
Technology Duration	E67	Units: Calculation: Comment	man-hours HLOOKUP(4,REMOVALTEC,H45+1) Duration of decontamination activities.
Selection of Technology	H45	Calculation: Comment:	Discrete({1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20},{50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50,50}) Each technology has an equivalent chance of being selected per iteration

Sheet: Cost Summary

The results of each scenario analysis are summarized on one sheet for ease of comparison and archiving. The formulae are self-explanatory, and no computation occurs on this sheet. It is strictly informational.

APPENDIX D – COST MODEL SCREENS

Title: Scenario Cost Estimate Table -- Scenario 1 (Surface Removal, Demolition, Recycle)
Description: Costs for Various Scenario 1 Components/Technologies
Date: Nov-97

			COST CALCULATION			PROJECT DURATION		
No.	Task Description	Comment	Rates	Units	Cost in $	Rate	Units	Total time
1	Mobilization & Demobilization	Trailer	2000	$/trailer	20,000.00			
2		Equipment	300	$/equipment	3,600.00	N	N	64
3		Travel of 4 men crew to site	0.32	$/person/mile	490.67	NA	NA	NA
4	Site Prep & Support	Rough grade 3 acres	1.13	$/yd2	18,466.90	0.02	man-hr/ft2	290.4
5		Install chain link fence around perimeter of 3 acers	2.75	$/ft	4,475.55	0.16	man-hr/ft	231.4
6		Construct decontamination Pad	13000	$	13,000 00	NA	NA	NA
7		Construct access road - 100 x 14 ft2	4.04	$/ft2	6,365.88	0.078	man-hr/ft2	109.2
8	Utilities	Water supply($300) + Telephone connection($225)	535	$/month	782.08	NA	NA	NA
9		Electricity supply	200	$/month/trailor	1,754.20	NA	NA	NA
10		Sanitation Port-a-john	80	$/month/toilet	467.79	NA	NA	NA
11	Salary & Per Diem	Project Manager	50	$/hr	12,279.41	NA	NA	NA
12		I H + Plant Engineer	35	$/hr	17,191.16	NA	NA	NA
13		Forman	40	$/hr	9,823.53	NA	NA	NA
14		*Per Diem*	75	$/month	9,209 56	NA	NA	NA
15	Characterization	Initial characterization - 1 sample/1000 ft2	370	$/sample	55,965.93	0.0022, 6.86E-6	man-hr/ft2	748 6
16		Specific sampling & Final characterization - 1 sample/ 100 ft2	1000	$/sample	444,103.79			
17		Final rebar screening - at 1/4 hr/load	25	$/load	3,810 32			
18		Final aggregate screening - at 1/4 hr/load	25	$/hr	79,254 58			
19	Decontamination - Surface Removal	Mechanical Scabbling	10	$/ft2	194,854.55	35	man-hr/ft2	4453 8
20	Demolition	Demolish structure	Regression Equation		124,314.00	0 035	man-hr/yd2	505.6
21		Crush & screen concrete,seprate rebar	3.12	$/ton	30,420 00	200	T/hr with 3 men crew	146.3
22	Package and Load	Drum Waste - @ 1 drum/1000ft2	36.45	$/drum	981.18	NA	NA	0 4
23		Collect waste (from removal technology) - load on truck	1.39	$/yd3	94.09			
24		Fines	1.39	$/yd3	2,937.70	NA	NA	10
25	Haul	Waste to Railhead	Regression Equation		432.87	NA	NA	NA
26		Waste to ENVIROCARE	0.04	$/ton/mile	12,234.51	NA	NA	NA
27		Rebar	0 078	$/ton/mile	3,529.10	NA	NA	0 6
28		Fines	Regression Equation		52,615.74	Considered @128		
29	Disposal Fees	LLW @ EnviroCare	60.00	$/ft3	105,981.90	NA	NA	NA
30		C & D Landfill	27.47	$/yd3	51,586.57	NA	NA	NA
31	Site Clean-up & Decontamination	Landscape/clean-up	Regression Equation		4,281.94	0.008	man-hr/yd2	231.7
32		Decontaminate personel	25	$/hr	5,755.97		NA	NA
33		PPE	10	$/person	9,209.56		NA	NA
34		Decontaminate equipment	180	$/equipment	1,215.55		NA	NA
35	Credit for Resale	Rebar	58.33	$/Ton	39,812.50		NA	NA
36		Aggregrate	4.72	$/Ton	32,214.00		NA	NA

Total months, assuming 30 men crew working 8 hrs per manday @21 mandays/month 1.5
No. of years 0.1

Risk Discrete : 10.5

	Removal Technology	Rate	Cost	Man-Days Calculation
	1	2	3	4
1	CO₂ Blasting	50	175	195
2	Compressed air CO₂	60	26	162
3	Centrifugal CO₂	60	26	162
4	Strippable Coating	100	14	97
5	Explosive	100	5	24
6	Grinding	100	2	97
7	High pressure Water	40	2	244
8	Ice Blasting	100	1	97
9	Laser Heating	150	1	65
10	Mechanical Scabbling	35	10	557
11	Milling	150	0 75	16
12	Microwave Scabbling	40	2	30
13	Plastic Pellet Blasting	140	2.15	70
14	Sand Blasting	50	10	195
15	Electro hydraulic Scabbling	30	1.85	325
16	Shot Blasting	150	5.02	65
17	Soft Media Blasting	80	12	244
18	Soda Blasting	180	7	54
19	Drill and Spall	6	3	406
20	Ultra high Pressure Water	60	2	162
	Mechanical Scabbling	35	10	557

TOTAL COST CALCULATIONS

Project Duration		0 Years	Costs in million $	
1	Direct Costs		1.30	76%
2	Contingences @10%		0 13	8%
3	Engineering Cost @10%		0 13	8%
4	Overhead And Profit @14%		0 22	13%
5	Credit for Recycling		-0.1	4%
TOTAL PROJECT COST			*1.71*	$
Cost /Square ft.			*13.141*	$/ft2

Split up cost

Mob and Site Prep	0 07	5.10%
Utilities & Site Management	0.05	4%
Characterization	0.58	45%
Decontamination and Demolition	0.35	27%
Load, Haul and Disposal	0 23	18%
Site Clean-up & Decontamination	0.02	2%
Total Project Cost	1.30	

reatment, Demolition, Recycle
2

		COST CALCULATION			PROJECT DURATION		
Task Description	**Comment**	**Rates**	**Units**	**Cost in $**	**Rate**	**Units**	**Total time**
bilization & Demobilization	Trailer	2000	$/trailer	20,000 00			
	Equipment	300	$/equipment	3,600 00	N	N	64
	Travel of 4 men crew to site	0.32	$/person/mile	490 67	NA	NA	NA
e Prep & Support	Rough grade 3 acres	1.13	$/yd2	18,466.90	0.02	man-hr/ft2	290.4
	Install chain link fence around perimeter of 3 acers	2.76	$/ft	4,476 65	0.16	man-hr/ft	231.4
	Construct decontamination Pad	13000	$	13,000 00	NA	NA	NA
	Construct access road - 100 x 14 ft2	4.04	$/ft2	6,365.88	0.078	man-hr/ft2	109.2
[illegible]	Water supply($300) + Telephone connection($225)	535	$/month	433 41	NA	NA	NA
	Electricity supply	200	$/month/trailor	972.13	NA	NA	NA
	Sanitation Port-a-john	80	$/month/toilet	259.24	NA	NA	NA
ary & Per Diem	Project Manager	50	$/hr	6,804 93	NA	NA	NA
	IH + Plant Engineer	35	$/hr	9,526 90	NA	NA	NA
	Forman	40	$/hr	6,443.94	NA	NA	NA
	Per Diem	76	$/month	5,103.70	NA	NA	NA
aracterization	Initial characterization - 1 sample/1000 ft2	370	$/sample	55,965.93	0.0022, 6.86E-6	man-hr/ft2	749
	Specific sampling & Final characterization - 1 sample/ 100	1000	$/sample	444,103.79			
	Final rebar screening - at 1/4 hr/load	25	$/load	3,810.32			
	Final aggregate screening - at 1/4 hr/load	25	$/hr	79,254 68			
contamination - Surface Treatment molition	Chemical Gel	2	$/ft2	38,970.91	100	man-hr/ft2	1169
	Demolish structure	Regression Equation		124,314 00	0 035	man-hr/yd2	506
	Crush & screen concrete,seprate rebar	3 12	$/ton	30,420 00	200	T/hr with 3 men crew	146
ste and Load	Drum Waste - @ 1 drum/1000ft2	36.45	$/drum	951.18	NA	NA	0
	Collect waste (from removal technology) - load on truck	1.39	$/yd3	94 09			
	Fines	1.39	$/yd3	2,937.70	NA	NA	.10
ul	Waste to Railhead	Regression Equation		432 87	NA	NA	NA
	Waste to ENVIROCARE	0.04	$/ton/mile	12,234.61	NA	NA	NA
	Rebar	0 078	$/ton/mile	3,629.10	NA	NA	0.6
	Fines	Regression Equation		52,616.74	Considered @126		
sposal Cost	LLW @ EnviroCare	60.00	$/ft3	105,961.90	NA	NA	NA
	C & D Landfill	27.47	$/yd3	61,686.67	NA	NA	NA
e Cleanup & Decontamination	Landscape/clean-up	Regression Equation		4,281.94	0 008	man-hr/yd2	231.7
	Decontaminate personel	25	$/hr	3,189 61		NA	NA
	PPE	10	$/person	5,103.70		NA	NA
	Decontaminate equipment	180	$/equipment	1,216 55		NA	NA
edit for Recycle	Rebar	58.33	$/Ton	39,812.50		NA	NA
	Aggregrate	4.72	$/Ton	32,214.00		NA	NA

Total months, assuming 30 men crew working 8 hrs per manday @21 mandays/month 0.8
No. of years 0

TOTAL COST CALCULATIONS

Project Duration 0 Years

		Costs in million $	
1	Direct Costs	1.12	77%
2	Contingences @10%	0 11	8%
3	Engineering Cost @10%	0.11	8%
4	Overhead And Profit @14%	0.19	13%
5	Credit for Recycling	-0 07	5%
TOTAL PROJECT COST		*1.45*	$
Cost /Square ft.		*11.189*	$/ft2

Split up cost

Mob and Site Prep	0 07	5 93%
Utilities & Site Management	0 03	3%
Characterization	0 58	52%
Decontamination and Demolition	0 19	17%
Load, Haul and Disposal	0 23	21%
Site Clean-up & Decontamination	0 01	1%
Total Project Cost	1.12	

Chelation	Chemical Extraction	Chemical Foam	Chemical Gel	Electrokinetic	Flashlamp Cleaning	Laser Ablation	Sponge Blasting
90	90	82 5	82 5	77.5	90	90	90
999	999	999	999	999	999	999	999
999	999	999	999	999	999	999	999
999	999	999	999	999	999	999	999
999	999	999	999	999	999	999	999
5	5	999	999	999	5	5	5
6	6	6	6	999	6	6	6
7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10
5	5	6	6	7	5	5	5
121.7840936	121.7840936	146.1409124	146 1409124	170 4977311	101 4867447	143 2754043	202 9734894
100	100	100	100	100	120	85	60
1	2	2	2	0.42	1 25	1	1

Removal Tec	Chemical Gel
Rate.	100
Man-days	*146.1409*
Cost	2
Rsik Discrete:	4 5
No. of passes	6

Scenario 3 - Surface Removal, Demolish, Cap, Monitor
Table Name: Scenario_3

Cap Area, acres 0 99
No of wells required 4

No.	Task Description	Comment	COST CALCULATION Rates	Units	Cost in $	PROJECT DURATION Rate	Units	Total time
1	Mobilization & Demobilization	Trailer	2000	$/trailer	20 000 00			
2		Equipment	300	$/equipment	3 600 00	N	N	64
3		Travel of 4 men crew to site	0 32	$/person/mile	490 67	NA	NA	NA
4	Site Prep & Support	Rough grade 3 acres	1 13	$/yd2	18,466 90	0 02	man-hr/ft2	290 4
5		Install chain link fence around perimeter of 3 acres	2 73	$/ft	4,475 55	0 16	man-hr/ft	231 4
6		Construct decontamination Pad	13000	$	13 000 00	NA	NA	NA
7		Construct access road - 100 x 14 ft2	4 04	$/ft2	6,365 88	0 078	man-hr/ft2	109 2
8	Utilities	Water supply($300) + Telephone connection($225)	535	$/month	550 52	NA	NA	NA
9		Electricity supply	200	$/month/trailor	1,234 81	NA	NA	NA
10		Sanitation Port a John	80	$/month/toilet	329 28	NA	NA	NA
11	Salary & Per Diem	Project Manager	50	$/hr	8 643 65	NA	NA	NA
12		1H + Plant Engineer	35	$/hr	12,101 12	NA	NA	NA
13		Forman	40	$/hr	6,914 92	NA	NA	NA
14		Per Diem	75	$/month	6,487 74	NA	NA	NA
15	Characterization	Initial characterization - 1 sample/1000 ft2	370	$/sample	55,965 93	0022, 6 86E 6	man hr/ft2	748 6
16		Specific sampling & Final characterization - 1 sample/ 100	1000	$/sample	444,103 79			
17	[illegible]	Microwave Scabbling	2	$/ft2	9,747 73	40	man hr/ft2	243 6
18	Demolition	Demolish structure	Regression Equation		124,314 00	0 035	man hr/yd2	505 6
19		Consolidate concrete rubble	1 4	$/yd3	7,586 76	0 0006	man hr/yd3	2 9
20	[illegible]	Drum Waste - @ 1 drum/1000ft2	36 45	$/drum	961 18	NA	NA	0 4
21		Collect waste (from removal technology) - load on truck	1 39	$/yd3	94 09			
22	[illegible]	Waste to Hanford	Regression Equation		437 87	NA	NA	NA
23		Waste to ENVIROCARE	0 04	$/ton/mile	12,234 91	NA	NA	NA
24	[illegible]	LLW @ EnviroCare	60 00	$/ft3	105,961 90	NA	NA	NA
29	[illegible]	Excavate cap material	8 76	$/yd3	213,671 57			
30		Haul cap material	Regression Equation		353,335 45			
31		Construct cap	Regression Equation		154,353 00	520	man-hr/acres	2327 8
32		Install monitoring wells 50ft deep	Regression Equation		11,785 33	0 432	man hr/well	86 4
33		Monitor groundwater	80678 well for 30 yrs		322,912 00			
25	Site Clean up & Decontamination	Landscape/clean up	Regression Equation		4,281 94	0 008	man hr/yd2	231 7
26		Decontaminate personel	25	$/hr	4,051 71			
27		PPE	10	$/person	6,487 74			
28		Decontaminate equipment	180	$/equipment	1,215 55			
34	[illegible]	Seeding and fine fingrading for initial stage	1 73	$/yd2	8,018 57	0 048	man-hr/yd2	231
35		Mowing and reseeding	25	$/man-hr	6,777 78	0 048	man hr/yd2	231

Total months, assuming 30 men crew working 8 hrs per manday @21 mandays/month 1 0
No Years 0

TOTAL COST CALCULATIONS

Project Duration 0 Years

		Costs in million $	
1	Direct Costs	1 95	73%
2	Contingences @10%	0 19	7%
3	Engineering @10%	0 19	7%
4	Overhead And Profit @15%	0 33	12%
TOTAL PROJECT COST		2 66	$
Cost /Square ft.		28 494	$/ft2

Split up cost

Mob and Site Prep	0 07	3 41%
Utilities & Site Management	0 04	2%
Characterization	0 50	26%
Decontamination and Demolition	0 14	7%
Load, Haul and Disposal	0 12	6%
Site Clean up & Decontamination	0 03	1%
Capping	1 04	54%
Total Project Cost	1 93	

64975 80634 92714 80678

	Ice Blasting	[illegible]	[illegible]	[illegible]	CO2 [illegible]	(CO2) [illegible]	(CO2) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Milling	[illegible]	[illegible]	[illegible]	[illegible]
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	64 55152	[illegible]	[illegible]
3	100 00	130 00	50 00	90 00	60 00	60 00	50 00	6 00	35 00	100 00	100 00	40 00	60 00	150 00	40 00	3 00	55 00	150 00	180 00	100 00
4	1	2 55	10	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	2	2	1	2	0 75	10	[illegible]	2	[illegible]

Chelation	Chemical Extraction	Chemical Foam	Chemical Gel	Electrokinetic	Flashlamp Cleaning	Laser Ablation	Sponge Blasting
90	90	87 5	87 5	77 5	90	90	90
999	999	999	999	999	999	999	999
999	999	999	999	999	999	999	999
999	999	999	999	999	999	999	999
999	999	999	999	999	999	999	999
5	5	999	999	999	5	5	5
6	6	6	6	999	6	6	6
7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10
5	5	6	6	7	5	5	5
121 7840936	121 7841	146 1409	146 1409	170 4977311	101 486745	143 2754	202 9735
100	100	100	100	100	120	85	60
1	2	2	2	0 42	1 25	1	1

Scenario 4 - Demolish In place, Cap, Monitor
Table Name: Scenario_4

No.	Task Description	Comment	COST CALCULATION Rates	Units	Cost	PROJECT DURATION Rate	Units	Total time
1	Mobilization & Demobilization	Trailer	2000	$/trailer	20 000 00		NA	
2		Equipment	300	$/equipment	3 600 00	NA	NA	64
3		Travel of 4 men crew to site	0 32	$/person/mile	490 87	NA	NA	NA
4	Site Prep & Support	Rough grade 3 acres	1 13	$/yd2	18,468 80	0 02	man-hr/ft2	290 4
5		Install chain link fence around perimeter of 3 acers	2 75	$/ft	4,475 55	0 18	man-hr/ft	231 4
6		Construct decontamination Pad	13000	$	13 000 00	NA	NA	NA
7		Construct access road - 100 x 14 ft2	4 04	$/ft2	8,365 88	0 078	man-hr/ft2	109 2
8	Utilities	Water supply($300) + Telephone connection($275)	535	$/month	524 36	NA	NA	NA
9		Electricity supply	200	$/month/trailor	1,178 13	NA	NA	NA
10		Sanitation Port a john	80	$/month/toilet	313 63	NA	NA	NA
11	Salary & Per Diem	Project Manager	50	$/hr	8 232 89	NA	NA	NA
12		IH + Plant Engineer	35	$/hr	11,526 05	NA	NA	NA
13		Forman	40	$/hr	6,588 31	NA	NA	NA
14		Per Diem	75	$/month	8,174 67	NA	NA	NA
15	Characterization	Initial characterization - 1 sample/1000 ft2	370	$/sample	55 985 93	7 886E 8	man hr/ft2	748 6
		Specific sampling & Final characterization - 1 sample/ 100 ft2	1000	$/sample	222,051 89			
16	Demolition	Demolish structure	Regression Equation		124 314 00	0 035	man-hr/yd2	505 6
17		Consolidate concrete rubble	1 4	$/yd3	7,588 78	NA	NA	0 4
22	Capping Activities	Excavate cap material	8 78	$/yd3	284,878 78			
23		Haul cap material	Regression Equation		708,708 94			
24		Construct RCRA cap	Regression Equation		488 078 75	520	man hr/acres	2327 8
25		Install monitoring wells 50ft deep	Regression Equation		11,785 33	0 432	man hr/well	86 4
26		Monitor groundwater	80628	/well for 30 yrs	322,512 00			
18	Site Clean-up & Decontamination	Landscape/clean-up	Regression Equation		4,281 91	0 008	man-hr/yd2	231 7
19		Decontaminate personel	25	$/hr	3 859 17			
20		PPE	10	$/person	6,174 67			
21		Decontaminate equipment	180	$/equipment	1,215 55			
26	Cap Maintenance	Seeding and fine fingrading for initial stage	1 25	$/yd2	3 009 26	0 048	man-hr/yd2	116
27		Mowing and reseeding	25	$/man hr	2,888 89	0 048	man-hr/yd2	116

Total months, assuming 30 men crew working 8 hrs per manday @21 manda 1 0
No Years 0

Cap Area, acres	0 50
No of wells requred	4

TOTAL COST CALCULATIONS

Project Duration		~ 0 Years	Costs in million $	
	1	Direct Costs	2 34	73%
	2	Contingences @10%	0 23	7%
	3	Engineering @10%	0 23	7%
	4	Overhead And Profit @14%	0 39	12%
TOTAL PROJECT COST			3 21	$
Cost /Square ft.			24 668	$/ft2

Split up cost

Mob and Site Prep	0 07	2 83%
Utilities & Site Management	0 03	1%
Characterization	0 28	12%
Decontamination and Demolition	0 13	5 63%
Load, Haul and Disposal	0 02	1%
Site Clean-up & Decontamination	1 83	77%
Capping	2 34	

Scenario 5 - On-site disposal facility
Table Name: Scenario_5

Cap Area, acres: 0.58
No. of wells required 4

			COST CALCULATION			PROJECT DURATION		
No.	Task Description	Comment	COST	Units	Cost in $	Rate	Unites	Total time
1	Mobilization & Demobilization	Trailer	2000	$/trailer	20,000.00			
2		Equipment	300	$/equipment	3,600.00	N	N	64
3		Travel of 4 men crew to site	0.32	$/person/mile	490.67	NA	NA	NA
4	Site Prep & Support	Rough grade 3 acres	1.13	$/yd2	18,466.90	0.02	man-hr/ft2	290.4
5		Install chain link fence around perimeter of 3 acers	2.75	$/ft	4,475.55	0.16	man-hr/ft	231.4
6		Construct decontamination Pad	13000	$	13,000.00	NA	NA	NA
7		Construct access road - 100 x 14 ft2	4.04	$/ft2	6,365.88	0.078	man-hr/ft2	109.2
8	Utilities	Water supply($300) + Telephone connection($225)	535	$/month	539.84	NA	NA	NA
9		Electricity supply	200	$/month/trailor	1,210.86	NA	NA	NA
10		Sanitation Port-a-john	80	$/month/toilet	322.90	NA	NA	NA
11	Salary & Per Diem	Project Manager	50	$/hr	8,476.04	NA	NA	NA
12		I H + Plant Engineer	35	$/hr	11,866.46	NA	NA	NA
13		Forman	40	$/hr	6,780.83	NA	NA	NA
14		*Per Diem*	75	$/month	6,357.03	NA	NA	NA
15	Characterization	Initial characterization - 1 sample/1000 ft2	370	$/sample	55,965.93	0.0022, 6 86E-6	man-hr/ft2	746.6
16		Specific Sampling - 1 sample/ 100 ft2	1000	$/sample	222,051.89			
17	Demolition	Demolish structure	NA	NA	124,314.00	0.035	man-hr/yd2	505.6
18		Crush & screen concrete	3.12	$/ton	30,420 00	200	3 men crew	146.3
19	Capping	Excavate LLW cell	8.76	$/yd3	91,975.95			
20		Haul excavated cell material from site	Regression Equation		153,200.73			
21		Excavate liner and lift material	8.76	$/yd3	80,108.09			
22		Haul liner material	Regression Equation		54,053.10			
23		Place soil liner	14.77	$/yd3	55,027.74			
24		Place synthetic liner	5	$/ft2	81,250.00			
25		Haul intermediate lifts	Regression Equation		19,699.29			
26		Place intermediate lifts	14.77	$/yd3	20,010.09			
27		Place waste	14.77	$/yd3	80,040.35			
28		Haul cap material	Regression Equation		88,400 92			
29		Construct RCRA cap	Regression Equation		486,079.25	520	man-hr/acre	2327.8
30		Install monitoring wells 50ft deep	Regression Equation		11,705.33	0.432	man-hr/well	86.4
31		Monitor groundwater	92714	all for 100 yrs.	370,856.00			
32	Site Clean-up & Decontamination	Landscape/clean-up	Regression Equation		4,281.94	0.008	man-hr/yd2	231.7
33		Decontaminate personel	25	$/hr	3,973.14			
34		PPE	10	$/person	6,357.03			
35		Decontaminate equipment	180	$/equipment	1,215 55			
36	Cap Maintenance	Seeding and fine fingrading for initial stage	1.25	$/yd2	3,385.42	0.048	man-hr/yd2	130
37		Mowing and reseeding	25	$/man-hr	3,250.00	0.048	man-hr/yd2	130

TOTAL COST CALCULATIONS

Project Duration 130 Years

			Costs in million $	
1	Direct Costs		2.15	73%
2	Contingences @10%		0.21	7%
3	Engineering @10%		0.21	7%
4	Overhead And Profit @14%		0.36	12%
TOTAL PROJECT COST			*2.94*	$
Cost /Square ft.			*22.621*	$/ft2

Split up cost

Mob and Site Prep	0 07	3.09%
Utilities & Site Management	0.04	2%
Characterization	0 28	13%
Decontamination and Demolition	0 15	7%
Load, Haul and Disposal	0 02	1%
Site Clean-up & Decontamination	1.59	74%
Capping	2 15	

Scenario 6 - Surface Removal, Demolition, C&D Disposal
Table Name: Scenario_6
Date: 23 Jan '98

			COST CALCULATION			PROJECT DURATION		
No.	**Task Description**	**Comment**	**Rates**	**Units**	**Cost in $**	**Rate**	**Units**	**Total time**
1	Mobilization & Demobilization	Trailer	2000	$/trailer	20,000.00			
2		Equipment	300	$/equipment	3,600.00	N	N	64
3		Travel of 4 men crew to site	0.32	$/person/mile	490.67	NA	NA	NA
4	Site Prep & Support	Rough grade 3 acres	1.13	$/yd2	16,466.90	0.02	man-hr/ft2	280 4
5		Install chain link fence around perimeter of 3 acers	2.75	$/ft	4,475.55	0.16	man-hr/ft	231.4
6		Construct decontamination Pad	13000	$	13,000.00	NA	NA	NA
7		Construct access road - 100 x 14 ft2	4.04	$/ft2	6,365.88	0.078	man-hr/ft2	109.2
8	Utilities	Water supply($300) + Telephone connection($225)	535	$/month	176.64	NA	NA	NA
9		Electricity supply	200	$/month/trailor	396.21	NA	NA	NA
10		Sanitation Port-a-John	80	$/month/toilet	105.66	NA	NA	NA
11	Salary & Per Diem	Project Manager	50	$/hr	2,773.48	NA	NA	NA
12		I H + Plant Engineer	35	$/hr	3,882.87	NA	NA	NA
13		Forman	40	$/hr	2,218.78	NA	NA	NA
14		*Per Diem*	75	$/month	2,080.11	NA	NA	NA
15	Characterization	Initial characterization - 1 sample/1000 ft2	370	$/sample	55,965.93	0.0022, 6.86E-6	man-hr/ft2	748.6
16		Specific sampling & Final characterization - 1 sample/ 100 ft2	1000	$/sample	444,103.79			
17		Final rubble screening--@1/4 hr/load	25	$/hr	79,254.58			
18	Decontamination - Surface Re	Mechanical Scabbling	10	$/ft2	184,854.55	35	man-hr/ft2	4453.8
19	Demolition	Demolish structure	Regression Equation		124,314.00	0 035	man-hr/yd2	505.6
20	Package and Load	Drum Waste - @ 1 drum/1000ft2	38.45	$/drum	981.18	NA	NA	0.4
21		Collect waste (from removal technology) - load on truck	1.39	$/yd3	94 09			
22	Haul	Waste to Railhead	Regression Equation		432.87	NA	NA	NA
23		Waste to ENVIROCARE	0 04	$/ton/mile	12,234.51	NA	NA	NA
24		Waste to C&D landfill	Regression Equation		187,252.15			
25	Disposal Fees	LLW @ EnviroCare	60.00	$/ft3	105,981.90	NA	NA	NA
26		C & D Landfill	27.47	$/yd3	171,955.22	NA	NA	NA
27	Site Clean-up & Decontaminat	Landscape/clean-up	Regression Equation		4,281.94	0 008	man-hr/yd2	231.7
28		Decontaminate personel	25	$/hr	1,300.07			
29		PPE	10	$/person	2,080.11			
30		Decontaminate equipment	180	$/equipment	1,215 55			

TOTAL COST CALCULATIONS

Project Duration 0 Years

		Costs in million $	
1	Direct Costs	1.46	73%
2	Contingences @10%	0 15	7%
3	Engineering @10%	0.15	7%
4	Overhead And Profit @14%	0.25	12%
TOTAL PROJECT COST		*2.00*	$
Cost /Square ft.		*15.409*	$/ft2

Split up cost

Mob and Site Prep	0 07	4 53%
Utilities & Site Management	0 01	1%
Characterization	0.58	40%
Decontamination and Demolition	0.32	22%
Load, Haul and Disposal	0 48	33%
Site Clean-up & Decontamination	0 01	1%
Actual Project Cost	1 46	

Site BNL
Area 130000
Distance 2,466

Summary Costs

Project Cost Summary		Scenario 1	Scenario2	Scenario3	Scenario4	Scenario5	Scenario6
1	Direct Costs	1.30	1.12	1.95	2.34	2.15	1.46
2	Contingences @10%	0.13	0.11	0.19	0.23	0.21	0.15
3	Engineering @10%	0.13	0.11	0.19	0.23	0.21	0.15
4	Overhead And Profit @14%	0.22	0.19	0.33	0.39	0.36	0.25
5	Credit for Recycling	-0.07	-0.07	NA	NA	NA	NA
TOTAL PROJECT COST		1.71	1.45	2.66	3.21	2.94	2.00
Cost /Square ft.		13.14	11.19	20.49	24.67	22.62	15.41

Cost Breakdown

Mob and Site Prep	0.07	0.07	0.07	0.07	0.07	0.07
Utilities & Site Management	0.05	0.03	0.04	0.03	0.04	0.01
Characterization	0.58	0.58	0.50	0.28	0.28	0.58
Decontamination and Demolition	0.35	0.19	0.14	0.13	0.15	0.32
Load, Haul and Disposal	0.23	0.23	0.12	NA	NA	0.48
Site Clean-up & Decontamination	0.02	0.01	0.03	0.02	0.02	0.01
Capping	NA	NA	1.06	1.81	1.59	NA
Indirect Costs	0.48	0.41	0.72	0.86	0.79	0.54
Credit for Rcycling	-0.07	-0.07	NA	NA	NA	NA
Total Project Costs	1.71	1.45	2.66	3.21	2.94	2.00

Title:	Scenario Cost Estimate Table -- Common Parameters
Description:	Parameter values common to all scenarios - ANLW
Date:	July 1996

	Parameter	Units	Value	Value
Physical	Total Area	ft²	130,000	3.0 in acres
	Facility	Brookhaven NL		BNL
	% Contaminated	%	14.98881	
	Contaminated Area	ft²	19,485	
	Thickness	in	12	
	Depth of Contamination	in	1.0	
	Concrete Density	lbs/cuf	150	
	Fines	%	30	
	Rubble Expansion Factor	%	30	
Demolition/Disposal	Crushing	$/ton	3.12	
	Rebar Salvage Value	$/ton	58.33	
	Aggregate Sale Value	$/ton	4.72	
	C&D Disposal	$/yd3	27.47	
	LLW Disposal	$/ft3	60.00	
Distances	Mobilization	mi	192	mile1
	In site rail platform	mi	10	mile2
	LLW Disposal Facility	mi	2,466.14	mile3
	Rebar Scrap Yard	mi	60	mile4
	C&D Landfill	mi	60	mile5
	Cap material	mi	35	mile6
Characterization	Prior to Release	test/yd3	0.025	
	Surface Contamination	dpm/100 cm²	158,027	
	Required Level of Contamination	dpm/100 cm² DL	10	

	Point of Origin			Route Length (miles)	Total Area ft2	Selection
1	ANLE	Argonne NL East		1541	440,000	
2	ANLW	Argonne NL west		1541	2,839,000	
3	BNL	Brookhaven NL		2466	130,000	X
4	ETEC	Energy Tech. Engr. Ctr.		793	2,861,000	
5	HANFORD	Hanford		811	110,452,000	
6	INEL	Idaho National Laboratory		327	84,024,000	
7	K25	K-25 GDP		811	10,900,000	
8	LANL	Los Alamos NL		942	4,853,000	
9	LBL	Lawrence Berkeley Lab		743	1,463,000	
10	LLNL	Lawrence Livermore NL		751	2,000,000	
11	METC	Morgantown Energy Tech		2046	49,000	
12	NTS	Nevada Test Site		469	8,577,000	
13	ORR	Oak Ridge Reservation		2024	8,410,000	
14	PP	Pantex Plant		974	3,748,000	
15	RFP	Rocky Flats Plant		600	5,313,000	
16	RESL	R & E Science Lab		1196	1,500,000	
17	SNL	Sandia NL		994	60,710,000	
18	SRS	Savannah River Site		2204	55,246,000	
19	PAD	Paducah Gas. Diff. Site		1689	960,000	
20	PORT	Portsmouth Gas Diff. Site		1898	1,230,000	

Volume Calculation

Total Volume	130000	ft3
Clean Concrete vomule	130000	ft3

% Inflation Rates

Comment	Current year	Infaltion
Inflation Rates for the Years after 1993	1997	1.12551
Inflation Rates for the Years after 1997	1997	1.0000

ratios:	158,027	104,756	34,220	19,051			
		^{60}Co	^{137}Cs	^{235}U	^{238}U		
	dpm/100 cm²:	104,756	34,220	572	18,479	pCi/m²·	7.12E+06
	pCi/g surface	77.2485946	25.2345539	0.421448116	13.62682242	116.531419	
	pCi/g homog.	0.964887187	0.315196644	0.005264172	0 170208227	1.455556231	

3

APPENDIX E – RISK MODEL RESULTS

Argonne National Laboratory - East (ANLE)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0083	0.0041	0.0230	0.0269	0.0301	0.0210
Construction	0.0029	0.0017	0.0036	0.0028	0.0043	0.0031
Delayed	0.0035	0.0017	0.0035	6.8E-05	9.12E-05	0.0039
Total	0.0147	0.0074	0.0302	0.0299	0.0345	0.0281
Lost Workdays						
Transportation	1	1	3	5	5	3
Construction	12	7	15	12	19	12
Total	13	8	18	17	24	15

Argonne National Laboratory - West (ANLW)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0532	0.0255	0.1382	0.1147	0.1345	0.1348
Construction	0.0197	0.0105	0.0225	0.0123	0.0206	0.0192
Delayed	0.0283	0.0139	0.0275	0.0005	0.0007	0.0269
Total	0.1012	0.0499	0.1882	0.1275	0.1559	0.1808
Lost Workdays						
Transportation	4	4	18	19	23	18
Construction	80	45	93	53	89	81
Total	84	49	111	73	112	99

Brookhaven National Laboratory (BNL)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0034	0.0013	0.0090	0.0154	0.0163	0.0071
Construction	0.0009	0.0005	0.0011	0.0017	0.0022	0.0009
Delayed	0.0009	0.0004	0.0008	0.00002	0.00003	0.0009
Total	0.0051	0.0023	0.0110	0.0172	0.0185	0.0089
Lost Workdays						
Transportation	0	0	1	3	3	1
Construction	4	2	5	8	10	4
Total	4	3	6	10	12	5

Energy Technology Engineering Center (ETEC)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0396	0.0250	0.1262	0.1184	0.1389	0.1225
Construction	0.0175	0.0108	0.0220	0.0125	0.0211	0.0194
Delayed	0.0253	0.0137	0.0266	0.0005	0.0007	0.0279
Total	0.0823	0.0495	0.1748	0.1315	0.1608	0.1699
Lost Workdays						
Transportation	4	4	19	20	24	18
Construction	71	46	91	55	93	79
Total	75	51	110	76	117	98

Hanford

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	1.5182	0.9468	4.7373	4.0998	4.8787	4.6945
Construction	0.7224	0.3996	0.8879	0.4333	0.7567	0.6937
Delayed	1.4038	0.6915	1.4604	0.0215	0.0268	1.4005
Total	3.6445	2.0380	7.0856	4.5546	5.6622	6.7887
Lost Workdays						
Transportation	151	152	691	693	824	690
Construction	3069	1743	3734	1924	3360	3067
Total	3220	1895	4426	2617	4184	3757

Idaho National Engineering Laboratory

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.8742	0.6953	3.3220	3.1332	3.7281	3.2900
Construction	0.5665	0.3075	0.6974	0.3368	0.5881	0.5675
Delayed	1.2011	0.5522	1.1158	0.0170	0.0212	1.1823
Total	2.6418	1.5549	5.1352	3.4870	4.3374	5.0398
Lost Workdays						
Transportation	115	116	528	530	631	525
Construction	2420	1342	2958	1467	2562	2370
Total	2535	1458	3486	1997	3193	2895

Los Alamos National Laboratory

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0722	0.0426	0.2177	0.1927	0.2274	0.2131
Construction	0.0285	0.0181	0.0383	0.0208	0.0351	0.0346
Delayed	0.0449	0.0238	0.0532	0.0009	0.0011	0.0537
Total	0.1456	0.0845	0.3092	0.2145	0.2637	0.3013
Lost Workdays						
Transportation	7	7	31	33	39	31
Construction	124	79	167	92	156	135
Total	131	85	199	125	194	165

Lawrence Berkely National Laboratory (LBL)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0204	0.0129	0.0657	0.0664	0.0770	0.0632
Construction	0.0114	0.0057	0.0113	0.0072	0.0116	0.0103
Delayed	0.0150	0.0067	0.0123	0.0003	0.0004	0.0151
Total	0.0468	0.0252	0.0894	0.0738	0.0889	0.0887
Lost Workdays						
Transportation	2	2	10	11	13	10
Construction	44	24	48	31	50	44
Total	46	26	58	43	63	54

Lawrence Livermore National Laboratory (LLNL)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0272	0.0172	0.0870	0.0849	0.0991	0.0848
Construction	0.0128	0.0074	0.0159	0.0093	0.0153	0.0122
Delayed	0.0189	0.0092	0.0184	0.0004	0.0005	0.018
Total	0.0588	0.0338	0.1212	0.0946	0.1149	0.1149
Lost Workdays						
Transportation	3	3	13	14	17	13
Construction	55	32	67	40	67	56
Total	58	35	80	55	83	69

Morgantown Energy Technology Center (METC)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0012	0.0005	0.0045	0.0124	0.0128	0.0026
Construction	0.0003	0.0002	0.0006	0.0014	0.0016	0.0004
Delayed	0.0003	0.0001	0.0003	0.000007	0.00001	0.0003
Total	0.0018	0.0009	0.0053	0.0139	0.0144	0.0033
Lost Workdays						
Transportation	0	0	1	2	2	0
Construction	1	1	2	6	7	2
Total	2	1	3	9	9	2

Nevada Test Site (NTS)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0975	0.0719	0.3507	0.3303	0.3912	0.3452
Construction	0.0507	0.0317	0.0711	0.0358	0.0612	0.0601
Delayed	0.0831	0.0432	0.0992	0.0016	0.0020	0.0963
Total	0.2314	0.1468	0.5211	0.3677	0.4545	0.5016
Lost Workdays						
Transportation	12	12	54	56	66	54
Construction	221	135	302	155	265	249
Total	233	146	356	211	331	303

Oak Ridge Reservation (ORR)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.1884	0.0794	0.4363	0.3232	0.3828	0.4307
Construction	0.0579	0.0314	0.0686	0.0345	0.0594	0.0525
Delayed	0.0900	0.0460	0.0899	0.00168	0.00213	0.0854
Total	0.3362	0.1568	0.5948	0.3594	0.4443	0.5686
Lost Workdays						
Transportation	12	12	54	56	66	54
Construction	234	134	270	151	261	218
Total	245	145	325	207	327	272

Pantex (PAN)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0561	0.0322	0.1644	0.1481	0.1743	0.1617
Construction	0.0268	0.0136	0.0287	0.0158	0.0267	0.0251
Delayed	0.0432	0.0191	0.0360	0.0007	0.0009	0.0381
Total	0.1261	0.0649	0.2291	0.1647	0.2019	0.2248
Lost Workdays						
Transportation	5	5	24	25	30	23
Construction	104	59	122	70	118	106
Total	109	64	146	95	148	130

Rocky Flats Plant (RFP)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0658	0.0449	0.2225	0.2076	0.2451	0.2177
Construction	0.0328	0.0200	0.0443	0.0225	0.0387	0.0353
Delayed	0.0543	0.0263	0.0553	0.0010	0.0013	0.0560
Total	0.1529	0.0911	0.3222	0.2311	0.2851	0.3090
Lost Workdays						
Transportation	7	8	34	36	42	34
Construction	140	86	193	97	167	152
Total	148	93	227	133	209	186

Radiological and Environmental Sciences Laboratory (RSL)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.0338	0.0142	0.0793	0.0664	0.0770	0.0769
Construction	0.0101	0.0056	0.0125	0.0071	0.0114	0.0104
Delayed	0.0145	0.0069	0.0127	0.0003	0.0003	0.0144
Total	0.0584	0.0267	0.1045	0.0737	0.0887	0.1016
Lost Workdays						
Transportation	2	2	10	11	13	10
Construction	43	24	51	32	51	44
Total	45	26	61	43	64	53

Sandia National Laboratory (SNL)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.9301	0.5328	2.7073	2.2782	2.7102	2.6667
Construction	0.4042	0.2236	0.5081	0.2446	0.4265	0.4205
Delayed	0.7838	0.3865	0.7962	0.0120	0.0154	0.8117
Total	2.1181	1.1429	4.0115	2.5348	3.1521	3.8989
Lost Workdays						
Transportation	86	87	394	395	470	391
Construction	1619	982	2134	1082	1884	1741
Total	1705	1069	2528	1478	2354	2132

Savannah River Site (SRS)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	1.2800	0.5243	2.9271	2.0552	2.4447	2.8911
Construction	0.3569	0.2022	0.4727	0.2177	0.3799	0.3790
Delayed	0.7309	0.3371	0.6855	0.0109	0.0135	0.7696
Total	2.3678	1.0636	4.0854	2.2837	2.8381	4.0397
Lost Workdays						
Transportation	76	77	350	350	416	348
Construction	1567	861	2020	967	1685	1608
Total	1643	938	2369	1317	2101	1955

K25

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.2460	0.1034	0.5663	0.4195	0.4974	0.5600
Construction	0.0767	0.0406	0.0895	0.0458	0.0788	0.0771
Delayed	0.1216	0.0543	0.1228	0.0020	0.0025	0.1210
Total	0.4444	0.1983	0.7786	0.4673	0.5787	0.7581
Lost Workdays						
Transportation	15	15	69	71	84	69
Construction	317	173	383	195	335	310
Total	333	188	452	265	419	379

Paducah GDP (PAD)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.1283	0.0589	0.3170	0.2485	0.2938	0.3140
Construction	0.0484	0.0241	0.0517	0.0267	0.0457	0.0430
Delayed	0.0751	0.0326	0.0694	0.0012	0.0016	0.0693
Total	0.2517	0.1156	0.4381	0.2765	0.3411	0.4263
Lost Workdays						
Transportation	9	9	41	43	50	41
Construction	195	102	229	116	199	194
Total	204	111	270	159	249	235

Portsmouth GDP (PORT)

	Scenarios					
Fatalities	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Transportation	0.1789	0.0763	0.4174	0.3154	0.3735	0.4139
Construction	0.0522	0.0294	0.0662	0.0339	0.0582	0.0584
Delayed	0.0865	0.0418	0.0894	0.0015	0.0019	0.0976
Total	0.3175	0.1475	0.5731	0.3509	0.4336	0.5699
Lost Workdays						
Transportation	12	12	54	55	65	53
Construction	220	130	271	148	254	245
Total	231	142	324	203	319	298

APPENDIX F – COST MODEL RESULTS

Argonne National Laboratory - East (ANLE) - Cost Summary

Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	2.49	2.17	4.14	2.87	3.04	2.81
Project Management @ 10%	0.25	0.22	0.41	0.29	0.30	0.28
Contingencies @10%	0.25	0.22	0.41	0.29	0.30	0.28
Engineering @6%	0.15	0.13	0.25	0.17	0.18	0.17
Overhead And Profit @14%	0.44	0.38	0.73	0.51	0.54	0.50
Credit for Recycling	-0.65	-0.65	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	2.93	2.47	5.95	4.12	4.37	4.03
Cost /Square ft.	6.10	5.61	13.52	9.36	9.94	9.16

Argonne National Laboratory - East (ANLE) - Cost Breakdown

Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
MOB and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	0.80	0.81	0.38	0.38	0.38	0.77
Decontamination and Demolition	0.98	0.66	0.53	0.52	0.49	0.85
Load, Haul and Disposal	0.48	0.47	0.05	0.00	0.00	0.95
Site Clean-up & Decontamination	0.01	0.01	0.03	0.09	0.01	0.01
Capping	0.00	0.00	2.93	1.65	1.93	0.00

Argonne National Laboratory - West (ANLW) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	14.89	12.86	23.82	15.32	16.37	16.76
Project Management @ 10%	1.49	1.29	2.38	1.53	1.64	1.68
Contingencies @10%	1.49	1.29	2.38	1.53	1.64	1.68
Engineering @6%	0.89	0.77	1.43	0.92	0.98	1.01
Overhead And Profit @14%	2.63	2.27	4.20	2.70	2.89	2.96
Credit for Recycling	-4.17	-4.17	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	17.21	14.30	34.21	22.00	23.52	24.07
Cost /Square ft.	5.54	5.04	12.05	7.75	8.28	8.48

Argonne National Laboratory - West (ANLW) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	5.16	5.29	2.49	2.49	2.49	5.01
Decontamination and Demolition	6.27	4.24	3.39	3.36	3.17	5.44
Load, Haul and Disposal	3.17	3.05	0.34	0.00	0.00	6.02
Site Clean-up & Decontamination	0.07	0.07	0.17	0.57	0.09	0.07
Capping	0.00	0.00	17.21	8.67	10.40	0.00

Brookhaven National Laboratory (BNL) - Cost Summary

Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	0.89	0.80	1.61	1.29	1.35	0.98
Project Management @ 10%	0.09	0.08	0.16	0.13	0.13	0.10
Contingencies @10%	0.09	0.08	0.16	0.13	0.13	0.10
Engineering @6%	0.05	0.05	0.10	0.08	0.08	0.06
Overhead And Profit @14%	0.16	0.14	0.28	0.23	0.24	0.17
Credit for Recycling	-0.19	-0.19	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	1.09	0.96	2.31	1.86	1.94	1.41
Cost /Square ft.	7.72	7.38	17.81	14.31	14.89	10.81

Brookhaven National Laboratory (BNL) - Cost Breakdown

Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
MOB and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	0.24	0.24	0.11	0.11	0.11	0.23
Decontamination and Demolition	0.28	0.19	0.16	0.15	0.15	0.25
Load, Haul and Disposal	0.15	0.14	0.02	0.00	0.00	0.28
Site Clean-up & Decontamination	0.00	0.00	0.01	0.03	0.01	0.00
Capping	0.00	0.00	1.10	0.78	0.86	0.00

Energy Technology Engineering Center (ETEC) - Cost Summary

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	14.86	12.85	24.31	15.53	16.54	16.82
Project Management @ 10%	1.49	1.29	2.43	1.55	1.65	1.68
Contingencies @10%	1.49	1.29	2.43	1.55	1.65	1.68
Engineering @6%	0.89	0.77	1.46	0.93	0.99	1.01
Overhead And Profit @14%	2.62	2.27	4.29	2.74	2.92	2.97
Credit for Recycling	-4.21	-4.21	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	17.14	14.25	34.92	22.31	23.75	24.16
Cost /Square ft.	5.47	4.98	12.21	7.80	8.30	8.44

Hanford - Cost Summary

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	573	491	915	575	615	646
Project Management @ 10%	57	49	91	57	62	65
Contingencies @10%	57	49	91	57	62	65
Engineering @6%	34	29	55	34	37	39
Overhead And Profit @14%	101	87	161	101	108	114
Credit for Recycling	-163	-163	0	0	0	0
TOTAL PROJECT COST	660	542	1314	826	883	928
Cost /Square ft.	5.45	4.91	11.89	7.48	8.00	8.40

Idaho National Engineering Laboratory (INEL) - Cost Summary

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	432	372	697	438	468	488
Project Management @ 10%	43	37	70	44	47	49
Contingencies @10%	43	37	70	44	47	49
Engineering @6%	26	22	42	26	28	29
Overhead And Profit @14%	76	66	123	77	83	86
Credit for Recycling	-123	-123	0	0	0	0
TOTAL PROJECT COST	497	411	1001	629	672	701
Cost /Square ft.	5.40	4.89	11.91	7.48	8.00	8.34

Energy Technology Engineering Center (ETEC) - Cost Breakdown

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	5.16	5.28	2.49	2.49	2.49	5.01
Decontamination and Demolition	6.34	4.28	3.42	3.39	3.21	5.50
Load, Haul and Disposal	3.07	3.00	0.33	0.00	0.00	6.02
Site Clean-up & Decontamination	0.07	0.07	0.17	0.58	0.09	0.07
Capping	0.00	0.00	17.69	8.86	10.53	0.00

Hanford - Cost Breakdown

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	201	206	97	97	97	195
Decontamination and Demolition	249	165	132	131	123	217
Load, Haul and Disposal	120	118	13	0	0	232
Site Clean-up & Decontamination	2.5	2.5	6.6	22.1	3.3	2.5
Capping	0	0	666	325	391	0

Idaho National Engineering Laboratory (INEL) - Cost Breakdown

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	152	156	73	73	73	148
Decontamination and Demolition	189	126	100	99	94	164
Load, Haul and Disposal	89	88	10	0	0	174
Site Clean-up & Decontamination	1.9	1.9	5.0	16.8	2.5	1.9
Capping	0	0	508	248	298	0

Los Alamos National Laboratory (LANL) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	25.24	21.74	41.13	26.00	27.71	28.51
Project Management @ 10%	2.52	2.17	4.11	2.60	2.77	2.85
Contingencies @10%	2.52	2.17	4.11	2.60	2.77	2.85
Engineering @6%	1.51	1.30	2.47	1.56	1.66	1.71
Overhead And Profit @14%	4.45	3.84	7.26	4.59	4.89	5.03
Credit for Recycling	-7.15	-7.15	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	29.10	24.08	59.08	37.34	39.81	40.95
Cost /Square ft.	5.48	4.96	12.17	7.69	8.20	8.44

Lawrence Berkely National Laboratory (LBL) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	7.74	6.67	12.59	8.17	8.74	8.72
Project Management @ 10%	0.77	0.67	1.26	0.82	0.87	0.87
Contingencies @10%	0.77	0.67	1.26	0.82	0.87	0.87
Engineering @6%	0.46	0.40	0.76	0.49	0.52	0.52
Overhead And Profit @14%	1.36	1.18	2.22	1.44	1.54	1.54
Credit for Recycling	-2.16	-2.16	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	8.95	7.43	18.08	11.74	12.56	12.53
Cost /Square ft.	5.59	5.08	12.36	8.02	8.58	8.56

Lawrence Livermore National Laboratory (LLNL) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	10.36	9.04	17.09	11.02	11.69	11.72
Project Management @ 10%	1.04	0.90	1.71	1.10	1.17	1.17
Contingencies @10%	1.04	0.90	1.71	1.10	1.17	1.17
Engineering @6%	0.62	0.54	1.03	0.66	0.70	0.70
Overhead And Profit @14%	1.83	1.59	3.01	1.94	2.06	2.07
Credit for Recycling	-2.95	-2.95	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	11.93	10.04	24.54	15.82	16.80	16.84
Cost /Square ft.	5.45	5.02	12.27	7.91	8.40	8.42

Los Alamos National Laboratory (LANL) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	8.80	9.00	4.24	4.24	4.24	8.54
Decontamination and Demolition	10.84	7.27	5.79	5.75	5.44	9.41
Load, Haul and Disposal	5.27	5.14	0.57	0.00	0.00	10.23
Site Clean-up & Decontamination	0.11	0.11	0.29	0.98	0.15	0.11
Capping	0.00	0.00	30.02	14.81	17.67	0.00

Lawrence Berkely National Laboratory (LBL) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	2.64	2.70	1.27	1.27	1.27	2.56
Decontamination and Demolition	3.28	2.18	1.75	1.73	1.64	2.85
Load, Haul and Disposal	1.56	1.53	0.17	0.00	0.00	3.06
Site Clean-up & Decontamination	0.03	0.03	0.09	0.30	0.05	0.03
Capping	0.00	0.00	9.09	4.65	5.57	0.00

Lawrence Livermore National Laboratory (LLNL) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	3.60	3.69	1.73	1.73	1.73	3.50
Decontamination and Demolition	4.35	2.99	2.39	2.37	2.24	3.76
Load, Haul and Disposal	2.14	2.09	0.22	0.00	0.00	4.20
Site Clean-up & Decontamination	0.05	0.05	0.12	0.40	0.06	0.05
Capping	0.00	0.00	12.40	6.29	7.44	0.00

Morgantown Energy Technology Center (METC) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	0.48	0.44	0.96	0.89	0.91	0.51
Project Management @ 10%	0.05	0.04	0.10	0.09	0.09	0.05
Contingencies @10%	0.05	0.04	0.10	0.09	0.09	0.05
Engineering @6%	0.03	0.03	0.06	0.05	0.05	0.03
Overhead And Profit @14%	0.08	0.08	0.17	0.16	0.16	0.09
Credit for Recycling	-0.07	-0.07	0.00	0.00	0.00	0.00
Total Scenario Costs	0.61	0.56	1.38	1.27	1.30	0.73
Cost /Square ft.	11.52	11.42	28.15	26.01	26.54	14.93

Morgantown Energy Technology Center (METC) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
MOB and Site Prep	0.0959	0.0959	0.0959	0.0959	0.0959	0.0959
Utilities & Site Management	0.1249	0.1249	0.1249	0.1249	0.1249	0.1249
Characterization	0.0887	0.0908	0.0428	0.0428	0.0428	0.0861
Decontamination and Demolition	0.1093	0.0732	0.0586	0.0580	0.0556	0.0949
Load, Haul and Disposal	0.0553	0.0525	0.0060	0.0000	0.0000	0.1051
Site Clean-up & Decontamination	0.0023	0.0023	0.0041	0.0124	0.0027	0.0023
Capping	0.0000	0.0000	0.6281	0.5533	0.5834	0.0000

Nevada Test Site (NTS) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	44.17	38.21	71.15	45.07	48.30	49.74
Project Management @ 10%	4.42	3.82	7.12	4.51	4.83	4.97
Contingencies @10%	4.42	3.82	7.12	4.51	4.83	4.97
Engineering @6%	2.65	2.29	4.27	2.70	2.90	2.98
Overhead And Profit @14%	7.79	6.74	12.55	7.95	8.52	8.77
Credit for Recycling	-12.57	-12.57	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	50.87	42.32	102.21	64.74	69.37	71.45
Cost /Square ft.	5.42	4.93	11.92	7.55	8.09	8.33

Nevada Test Site (NTS) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	15.56	15.92	7.51	7.51	7.51	15.10
Decontamination and Demolition	19.03	12.83	10.23	10.15	9.60	16.50
Load, Haul and Disposal	9.17	9.05	0.97	0.00	0.00	17.72
Site Clean-up & Decontamination	0.19	0.19	0.51	1.72	0.26	0.19
Capping	0.00	0.00	51.72	25.47	30.71	0.00

Oak Ridge Reservation (ORR) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	52.25	44.76	82.66	52.38	56.15	58.84
Project Management @ 10%	5.23	4.48	8.27	5.24	5.62	5.88
Contingencies @10%	5.23	4.48	8.27	5.24	5.62	5.88
Engineering @6%	3.14	2.69	4.96	3.14	3.37	3.53
Overhead And Profit @14%	9.22	7.90	14.58	9.24	9.90	10.38
Credit for Recycling	-14.76	-14.76	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	60.30	49.54	118.73	75.24	80.65	84.52
Cost /Square ft.	5.51	4.95	11.87	7.52	8.07	8.45

Oak Ridge Reservation (ORR) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	18.17	18.59	8.77	8.77	8.77	17.64
Decontamination and Demolition	22.34	14.98	11.93	11.84	11.20	19.38
Load, Haul and Disposal	11.30	10.73	1.22	0.00	0.00	21.37
Site Clean-up & Decontamination	0.23	0.23	0.60	2.01	0.30	0.23
Capping	0.00	0.00	59.92	29.54	35.66	0.00

Pantex (PAN) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	19.57	16.87	31.47	20.09	21.48	22.03
Project Management @ 10%	1.96	1.69	3.15	2.01	2.15	2.20
Contingencies @10%	1.96	1.69	3.15	2.01	2.15	2.20
Engineering @6%	1.17	1.01	1.89	1.21	1.29	1.32
Overhead And Profit @14%	3.45	2.98	5.55	3.54	3.79	3.89
Credit for Recycling	-5.54	-5.54	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	22.57	18.70	45.21	28.86	30.85	31.64
Cost /Square ft.	5.50	4.99	12.06	7.70	8.23	8.44

Pantex (PAN) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	6.81	6.97	3.29	3.29	3.29	6.61
Decontamination and Demolition	8.37	5.62	4.47	4.44	4.20	7.26
Load, Haul and Disposal	4.08	3.98	0.44	0.00	0.00	7.85
Site Clean-up & Decontamination	0.09	0.09	0.22	0.75	0.11	0.09
Capping	0.00	0.00	22.84	11.39	13.66	0.00

Rocky Flats Plant (RFP) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	27.55	23.79	44.28	28.19	30.14	30.96
Project Management @ 10%	2.76	2.38	4.43	2.82	3.01	3.10
Contingencies @10%	2.76	2.38	4.43	2.82	3.01	3.10
Engineering @6%	1.65	1.43	2.66	1.69	1.81	1.86
Overhead And Profit @14%	4.86	4.20	7.81	4.97	5.32	5.46
Credit for Recycling	-7.86	-7.86	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	31.71	26.32	63.61	40.49	43.29	44.47
Cost /Square ft.	5.45	4.95	11.97	7.62	8.15	8.37

Rocky Flats Plant (RFP) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	9.65	9.88	4.66	4.66	4.66	9.37
Decontamination and Demolition	11.84	7.94	6.34	6.29	5.95	10.26
Load, Haul and Disposal	5.72	5.63	0.62	0.00	0.00	10.99
Site Clean-up & Decontamination	0.12	0.12	0.32	1.07	0.16	0.12
Capping	0.00	0.00	32.12	15.95	19.14	0.00

Radiological and Environmental Sciences Laboratory (RSL) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	7.92	6.88	12.88	8.36	8.95	8.93
Project Management @ 10%	0.79	0.69	1.29	0.84	0.89	0.89
Contingencies @10%	0.79	0.69	1.29	0.84	0.89	0.89
Engineering @6%	0.48	0.41	0.77	0.50	0.54	0.54
Overhead And Profit @14%	1.40	1.21	2.27	1.47	1.58	1.57
Credit for Recycling	-2.21	-2.21	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	9.17	7.67	18.50	12.01	12.85	12.82
Cost /Square ft.	5.59	5.11	12.33	8.01	8.57	8.55

Radiological and Environmental Sciences Laboratory (RSL) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	2.72	2.79	1.31	1.31	1.31	2.64
Decontamination and Demolition	3.30	2.24	1.79	1.78	1.68	2.86
Load, Haul and Disposal	1.65	1.60	0.18	0.00	0.00	3.17
Site Clean-up & Decontamination	0.03	0.03	0.09	0.30	0.05	0.03
Capping	0.00	0.00	9.29	4.75	5.69	0.00

Sandia National Laboratory (SNL) - Cost Summary

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	310	269	501	315	338	349
Project Management @ 10%	31	27	50	32	34	35
Contingencies @10%	31	27	50	32	34	35
Engineering @6%	19	16	30	19	20	21
Overhead And Profit @14%	55	48	88	56	60	62
Credit for Recycling	-90	-90	0	0	0	0
TOTAL PROJECT COST	356	297	720	453	485	501
Cost /Square ft.	5.35	4.89	11.85	7.46	7.99	8.26

Sandia National Laboratory (SNL) - Cost Breakdown

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	110	113	53	53	53	107
Decontamination and Demolition	133	91	72	72	68	115
Load, Haul and Disposal	66	64	7	0	0	126
Site Clean-up & Decontamination	1.4	1.4	3.6	12.2	1.8	1.4
Capping	0	0	365	178	215	0

Savannah River Site (SRS) - Cost Summary

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	283	245	458	288	308	320
Project Management @ 10%	28	24	46	29	31	32
Contingencies @10%	28	24	46	29	31	32
Engineering @6%	17	15	28	17	18	19
Overhead And Profit @14%	50	43	81	51	54	56
Credit for Recycling	-81	-81	0	0	0	0
TOTAL PROJECT COST	325	271	659	413	442	460
Cost /Square ft.	5.38	4.90	11.92	7.48	8.00	8.33

Savannah River Site (SRS) - Cost Breakdown

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	100	102	48	48	48	97
Decontamination and Demolition	120	83	66	65	62	103
Load, Haul and Disposal	62	59	7	0	0	119
Site Clean-up & Decontamination	1.2	1.2	3.3	11.1	1.7	1.2
Capping	0	0	334	163	196	0

K-25 - Cost Summary

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	56	49	91	57	61	63
Project Management @ 10%	6	5	9	6	6	6
Contingencies @10%	6	5	9	6	6	6
Engineering @6%	3	3	5	3	4	4
Overhead And Profit @14%	10	9	16	10	11	11
Credit for Recycling	-16	-16	0	0	0	0
TOTAL PROJECT COST	64	54	130	82	88	91
Cost /Square ft.	5.37	4.93	11.95	7.55	8.07	8.31

K-25 - Cost Breakdown

Costs	Scenarios					
	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	20	20	10	10	10	19
Decontamination and Demolition	24	16	13	13	12	21
Load, Haul and Disposal	12	12	1	0	0	23
Site Clean-up & Decontamination	0.25	0.25	0.65	2.19	0.33	0.25
Capping	0	0	66	32	39	0

Paducah GDP (PAD) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	5.22	4.50	8.50	5.62	5.90	5.87
Project Management @ 10%	0.52	0.45	0.85	0.56	0.59	0.59
Contingencies @10%	0.52	0.45	0.85	0.56	0.59	0.59
Engineering @6%	0.31	0.27	0.51	0.34	0.35	0.35
Overhead And Profit @14%	0.92	0.79	1.50	0.99	1.04	1.03
Credit for Recycling	-1.42	-1.42	0.00	0.00	0.00	0.00
TOTAL PROJECT COST	6.08	5.04	12.20	8.07	8.47	8.43
Cost /Square ft.	5.79	5.25	12.71	8.41	8.83	8.78

Paducah GDP (PAD) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Mob and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	1.75	1.79	0.84	0.84	0.84	1.70
Decontamination and Demolition	2.16	1.44	1.14	1.14	1.08	1.87
Load, Haul and Disposal	1.07	1.03	0.12	0.00	0.00	2.06
Site Clean-up & Decontamination	0.02	0.02	0.06	0.19	0.03	0.02
Capping	0.00	0.00	6.11	3.22	3.73	0.00

Portsmouth GDP (PORT) - Cost Summary

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
Direct Costs	6.60	5.67	10.78	7.02	7.48	7.40
Project Management @ 10%	0.66	0.57	1.08	0.70	0.75	0.74
Contingencies @10%	0.66	0.57	1.08	0.70	0.75	0.74
Engineering @6%	0.40	0.34	0.65	0.42	0.45	0.44
Overhead And Profit @14%	1.16	1.00	1.90	1.24	1.32	1.31
Credit for Recycling	-1.81	-1.81	0.00	0.00	0.00	0.00
Total Scenario Costs	7.67	6.33	15.49	10.08	10.75	10.63
Cost /Square ft.	5.70	5.14	12.59	8.19	8.74	8.64

Portsmouth GDP (PORT) - Cost Breakdown

	Scenarios					
Costs	Remove & Recycle	Treat & Recycle	Decon, Rubblize, & Cap	Rubblize & Cap	Crush & On-Site Disposal	Decon & C&D Disposal
MOB and Site Prep	0.10	0.10	0.10	0.10	0.10	0.10
Utilities & Site Management	0.12	0.12	0.12	0.12	0.12	0.12
Characterization	2.22	2.28	1.07	1.07	1.07	2.16
Decontamination and Demolition	2.76	1.84	1.47	1.46	1.38	2.39
Load, Haul and Disposal	1.37	1.31	0.15	0.00	0.00	2.60
Site Clean-up & Decontamination	0.03	0.03	0.07	0.25	0.04	0.03
Capping	0.00	0.00	7.80	4.02	4.77	0.00

APPENDIX G – CASE LAW SEARCH RESULTS

1. Envirosource, Inc. v. Horsehead Resource Development Co., Inc., 1996 WL 363091, 1996-2 Trade Cases P 71,4.D.N.Y., Jul 01, 1996) (NO. 95 CIV. 5106 (AGS))
2. U.S. v. Marine Shale Processors, 81 F.3d 1329, 42 ERC 1481, 26 Envtl. L. Rep. 21,012 (5th Cir.(La.), Apr 18, 1996) (NO. 94-30664)
3. American Mut. Liability Ins. Co. v. Beatrice Companies, Inc., 924 F.Supp. 861 (N.D.Ill., Apr 02, 1996) (NO. 86 C 1874)
4. Idylwoods Associates v. Mader Capital, Inc., 915 F.Supp. 1290, 64 USLW 2580, 42 ERC 1232, 26 Envtl. L. Rep. 21,027 (W.D.N.Y., Feb 16, 1996) (NO. 91-CV-364S)
5. Marriott Corp. v. Simkins Industries, Inc., 929 F.Supp. 396, 26 Envtl. L. Rep. 21,577 (S.D.Fla., Jan 24, 1996) (NO. 92-2541-CIV)
6. Bourque v. Nan Ya Plastics Corp., America, 906 F.Supp. 348 (M.D.La., Nov 28, 1995) (NO. CIV.A. 95-715-A)
7. BP Exploration & Oil, Inc.(93-3310) v. U.S. E.P.A., 66 F.3d 784, 41 ERC 1225, 26 Envtl. L. Rep. 20,037 (6th Cir., Sep 28, 1995) (NO. 93-3473, 93-3888, 93-3761, 93-3587, 93-3489, 93-3310)
8. River Springs Ltd. Liability Co. v. Board of County Com'rs of County of Teton, 899 P.2d 1329 (Wyo., Jul 19, 1995) (NO. 94-23, 94-38)
9. U.S. v. Johnson, 886 F.Supp. 1057, 26 Envtl. L. Rep. 20,148 (W.D.N.Y., May 26, 1995) (NO. 92-CR-39A)
10. U.S. v. Davis, 882 F.Supp. 1217, 25 Envtl. L. Rep. 21,315 (D.R.I., Apr 06, 1995) (NO. 90-0484P)
11. USS Cabot/Dedalo Museum Foundation v. U.S. Customs Service, 1995 WL 143542, 41 ERC 1020 (E.D.La., Mar 30, 1995) (NO. CIV. A. 94-2277, CIV. A. 94-3631)
12. Diverse Real Estate Holdings Ltd. Partnership v. International Mineral and Chemical Corp., 1995 WL 110138, 40 ERC 2102 (N.D.Ill., Mar 13, 1995) (NO. 91 C 8090)

13. Douglas County, Neb. v. Gould, Inc., 871 F.Supp. 1242, 41 ERC 2078, 25 Envtl. L. Rep. 20,727 (D.Neb., Dec 19, 1994) (NO. 8:CV90-00395)

14. Leather Industries of America, Inc. v. E.P.A., 40 F.3d 392, 39 ERC 1865, 309 U.S.App.D.C. 136, 25 Envtl. L. Rep. 20,158 (D.C.Cir., Nov 15, 1994) (NO. 93-1187, 93-1376, 93-1404, 93-1555)

15. Price v. U.S. Navy, 39 F.3d 1011, 63 USLW 2317, 39 ERC 1673, 30 Fed.R.Serv.3d 854, 25 Envtl. L. Rep. 20,177 (9th Cir.(Cal.), Nov 07, 1994) (NO. 93-55447)

16. Akzo Coatings, Inc. v. Aigner Corp., 881 F.Supp. 1202, 25 Envtl. L. Rep. 21,339, 41 Fed. R. Evid. Serv. 1186 (N.D.Ind., Oct 19, 1994) (NO. S91-570M)

17. Owen Elec. Steel Co. of South Carolina, Inc. v. Browner, 37 F.3d 146, 63 USLW 2291, 39 ERC 1609, 25 Envtl. L. Rep. 20,156 (4th Cir., Oct 12, 1994) (NO. 93-2195)

18. Murray v. Bath Iron Works Corp., 867 F.Supp. 33, 39 ERC 1997, 25 Envtl. L. Rep. 20,547 (D.Me., Aug 17, 1994) (NO. CIV. 93-188-P-DMC)

19. G.J. Leasing Co., Inc. v. Union Elec. Co., 854 F.Supp. 539, 38 ERC 1996, 25 Envtl. L. Rep. 20,408 (S.D.Ill., Jun 06, 1994) (NO. 91-158-JPG)

20. Waste Management of Desert, Inc. v. Palm Springs Recycling Center, Inc. 7 Cal.4th 478, 869 P.2d 440, 28 Cal.Rptr.2d 461 (Cal., Mar 31, 1994) (NO. S029150)

21. Waste Resource Technologies v. Department of Public Health of City and County of San Francisco, 23 Cal.App.4th 299, 28 Cal.Rptr.2d 422 (Cal.App. 1 Dist., Mar 16, 1994) (NO. A060784)

22. U.S. v. Atlas Minerals and Chemicals, Inc., 851 F.Supp. 639, 25 Envtl. L. Rep. 20,103 (E.D.Pa., Mar 01, 1994) (NO. CIV. A. 91-5118)

23. U.S. v. Stringfellow, 1993 WL 565393 (C.D.Cal., Nov 30, 1993) (NO. CV 83-2501 JMI)

24. Bituminous Cas. Corp. v. Tonka Corp., 9 F.3d 51, 24 Envtl. L. Rep. 20,456 (8th Cir.(Minn.), Nov 12, 1993) (NO. 92-3187)

25. McGuire v. Sigma Coatings, Inc., 1993 WL 329982 (E.D.La., Aug 19, 1993) (NO. CIV. A. 91-2076, CIV. A. 91-3098, CIV. A. 92-3187)

26. U.S. v. ILCO, Inc., 996 F.2d 1126, 62 USLW 2131, 37 ERC 1105, 23 Envtl. L. Rep. 21,437 (11th Cir.(Ala.), Aug 04, 1993) (NO. 91-1004)

27. Catellus Development Corp. v. U.S., 828 F.Supp. 764, 62 USLW 2151, 37 ERC 2058 (N.D.Cal., Aug 03, 1993) (NO. C-91-2531 EFL)

28. Reading Co. v. City of Philadelphia, 823 F.Supp. 1218 (E.D.Pa., May 11, 1993) (NO. CIV. A. 91-2377)

29. Sierra Club v. U.S. E.P.A., 992 F.2d 337, 61 USLW 2707, 36 ERC 1819, 301 U.S.App.D.C. 175, 23 Envtl. L. Rep. 20,827 (D.C.Cir., May 07, 1993) (NO. 92-1003, 92-1005)

30. Hawaii's Thousand Friends v. City and County of Honolulu, 821 F.Supp. 1368, 37 ERC 1398, 23 Envtl. L. Rep. 21,380 (D.Hawai'i, Apr 27, 1993) (NO. CIV. 90-00218 HMF, CIV. 91-00739 ACK)

31. Gussin Enterprises, Inc. v. Rockola, 1993 WL 114643, 36 ERC 1903 (N.D.Ill., Apr 13, 1993) (NO. 89 C 4742)

32. State of Cal. on Behalf of State Dept. of Toxic Substances Control v. Verticare, Inc., 1993 WL 245544 (N.D.Cal., Mar 01, 1993) (NO. C-92-1006 MHP)

33. LaFarge Corp. v. Campbell, 813 F.Supp. 501, 36 ERC 1343, 23 Envtl. L. Rep. 20,896 (W.D.Tex., Feb 03, 1993) (NO. CIV. A-92-CA-079)

34. Griffin Industries, Inc. v. U.S., 27 Fed.Cl. 183, 71 A.F.T.R.2d 93-474, 92-2 USTC P 50,606 (Fed.Cl., Dec 01, 1992) (NO. 622-83T)

35. Government Suppliers Consolidating Services, Inc. v. Bayh, 975 F.2d 1267, 61 USLW 2181, 35 ERC 1622, 23 Envtl. L. Rep. 20,042 (7th Cir.(Ind.), Sep 17, 1992) (NO. 92-1318, 92-1515)

36. U.S. Steel Supply Inc. v. Alco Standard Corp., 1992 WL 229252, 36 ERC 1330 (N.D.Ill., Sep 09, 1992) (NO. 89 C 20241)

37. Waste Management of the Desert, Inc. v. Palm Springs Recycling Center, Inc., 11 Cal.Rptr.2d 676, Previously published at 9 Cal.App.4th 239, 15 Cal.App.4th 368, 20 Cal.App.4th 586, (See Rules 976, 977, 979 Cal. Rules of Ct.) (Cal.App. 4 Dist., Sep 01, 1992) (NO. E009910)

38. Rhodes v. County of Darlington, S.C., 833 F.Supp. 1163, 24 Envtl. L. Rep. 20,379 (D.S.C., Aug 24, 1992) (NO. CIV. A. 4:91-0179-21)

39. U.S. v. Summit Equipment & Supplies, Inc., 805 F.Supp. 1422, 36 ERC 1880, 26 Envtl. L. Rep. 20,082, 36 Fed. R. Evid. Serv. 1102 (N.D.Ohio, Jul 21, 1992) (NO. 5:90CV1704)

40. Wisconsin Dept. of Revenue v. Parks-Pioneer Corp., 170 Wis.2d 44, 487 N.W.2d 63 (Wis.App., Jun 25, 1992) (NO. 91-0810)

41. K.J. Quinn & Co., Inc. v. Continental Cas., 806 F.Supp. 1037 (D.N.H., Jun 22, 1992) (NO. C-90-369-L)

42. City of Chicago v. Asphalt Recovery Systems, Inc., 231 Ill.App.3d 77, 596 N.E.2d 74, 172 Ill.Dec. 795 (Ill.App. 1 Dist., Jun 17, 1992) (NO. 1-91-2434)

43. Liberty Mut. Ins. Co. v. SCA Services, Inc., 412 Mass. 330, 588 N.E.2d 1346 (Mass., Mar 26, 1992) (NO. S-5775)

44. Baumgardner Oil Co. v. Com., 146 Pa.Cmwlth. 530, 606 A.2d 617 (Pa.Cmwlth., Mar 24, 1992) (NO. 2038 C.D. 1991)

45. Matter of Dougherty, 482 N.W.2d 485 (Minn.App., Mar 17, 1992) (NO. C8-91-1134)

46. State ex rel. Webster v. Missouri Resource Recovery, Inc., 825 S.W.2d 916 (Mo.App. S.D., Feb 14, 1992) (NO. 17271)

47. U.S. v. City of New York, 799 F.Supp. 1308 (E.D.N.Y., Jan 31, 1992) (NO. CV 89-2571 (JM))

48. Solite Corp. v. U.S. E.P.A., 952 F.2d 473, 60 USLW 2451, 34 ERC 1537, 293 U.S.App.D.C. 117, 22 Envtl. L. Rep. 20,376 (D.C.Cir., Dec 31, 1991) (NO. 89-1629, 89-1724, 89-1729, 89-1665, 89-1727, 89-1731, 89-1696, 89-1728, 89-1732)

49. Shell Oil Co. v. E.P.A., 950 F.2d 741, 34 ERC 1049, 292 U.S.App.D.C. 332, 22 Envtl. L. Rep. 20,305 (D.C.Cir., Dec 06, 1991) (NO. 80-1532, 80-1570, 80-1572, 80-1869, 80-1881A, 80-1888, 80-1890, 80-1909A, 80-1938)

50. Arizona Water Co. v. City of Bisbee, 172 Ariz. 176, 836 P.2d 389, 128 P.U.R.4th 95, Util. L. Rep. P 26,136 (Ariz.App. Div. 2, Oct 24, 1991) (NO. 2 CA-CV 91-0027)

51. Connecticut Coastal Fishermen's Ass'n v. Remington Arms Co., Inc., 777 F.Supp. 173, 34 ERC 1244, 22 Envtl. L. Rep. 20,483 (D.Conn., Sep 11, 1991) (NO. CIV. B-87-250 (EBB))

52. Stephen D. DeVito, Jr. Trucking, Inc. v. Rhode Island Solid Waste Management Corp., 770 F.Supp. 775, 33 ERC 2068 (D.R.I., Jul 22, 1991) (NO. CIV A 91-0307-T)

53. Lumbermens Mut. Cas. Co. v. Belleville Industries, Inc., 938 F.2d 1423, 33 ERC 1536, 22 Envtl. L. Rep. 20,101 (1st Cir.(Mass.), Jul 16, 1991) (NO. 91-1129, 91-1130)

54. Town of Norfolk v. U.S. E.P.A., 761 F.Supp. 867, 22 Envtl. L. Rep. 20,264 (D.Mass., Apr 05, 1991) (NO. CIV A 90-11086-MA, CIV A 90-11286-MA)

55. U.S. v. Western Processing Co., Inc., 761 F.Supp. 713, 32 ERC 2029, 21 Envtl. L. Rep. 20,976 (W.D.Wash., Mar 22, 1991) (NO. C89-214M, C83-252M, C89-224M)

56. Liquid Chemical Corp. v. Department of Health Services, 227 Cal.App.3d 1682, 279 Cal.Rptr. 103 (Cal.App. 5 Dist., Jan 30, 1991) (NO. F012645)

57. State of N.Y. v. SCA Services, Inc., 754 F.Supp. 995, 21 Envtl. L. Rep. 21,021 (S.D.N.Y., Jan 09, 1991) (NO. 83 CIV. 6402 (RPP))

58. Ambrogi v. Gould, Inc., 750 F.Supp. 1233, 21 Envtl. L. Rep. 20,415 (M.D.Pa., Nov 13, 1990) (NO. CIV. 88-1205, CIV. 89-0576)

59. Fireman's Fund Ins. Companies v. Ex-Cell-O Corp., 750 F.Supp. 1340, 21 Envtl. L. Rep. 20,574 (E.D.Mich., Aug 30, 1990) (NO. 85-CV-71371)

60. U.S. v. Hardage, 750 F.Supp. 1460, 21 Envtl. L. Rep. 20,721 (W.D.Okla., Aug 09, 1990) (NO. CIV-86-1401-P)

61. Carlyle Piermont Corp. v. Federal Paper Bd. Co., Inc., 742 F.Supp. 814 (S.D.N.Y., Jul 11, 1990) (NO. 89 CIV. 6302(MEL))

62. American Min. Congress v. U.S. E.P.A., 907 F.2d 1179, 31 ERC 1935, 285 U.S.App.D.C. 173, 20 Envtl. L. Rep. 21,415 (D.C.Cir., Jul 10, 1990) (NO. 88-1835, 88-1837, 88-1869, 88-1838, 88-1839, 88-1843)

63. American Petroleum Institute v. U.S. E.P.A., 906 F.2d 729, 31 ERC 1667, 285 U.S.App.D.C. 35, 20 Envtl. L. Rep. 21,091 (D.C.Cir., Jun 26, 1990) (NO. 88-1606, 89-1055-89-1059, 89-1061-89-1064, 88-1654, 89-1053, 89-1054, 88-1763, 88-1781, 88-1801)

64. Carothers v. Capozziello, 215 Conn. 82, 574 A.2d 1268 (Conn., May 22, 1990) (NO. 13745, 13746, 13747, 13748, 13749)

65. Rybachek v. U.S. E.P.A., 904 F.2d 1276, 58 USLW 2735, 31 ERC 1585, 20 Envtl. L. Rep. 20,973 (9th Cir., May 16, 1990) (NO. 88-7393, 88-7403)

66. O'Dell v. Hercules, Inc., 904 F.2d 1194, 30 Fed. R. Evid. Serv. 1124 (8th Cir.(Ark.), May 10, 1990) (NO. 88-1958, 88-2123)

67. Sierra Club v. U.S. Dept. of Energy, 734 F.Supp. 946, 58 USLW 2651, 31 ERC 1335, 20 Envtl. L. Rep. 21,044 (D.Colo., Apr 12, 1990) (NO. CIV. A. 89-B-181)

68. Pollution Control Financing Authority of Warren County v. New Jersey Dept. of Environmental Protection, 237 N.J.Super. 163, 567 A.2d 243 (N.J.Super.A.D., Dec 05, 1989) (NO. A-34-88T3)

69. U.S. v. Conservation Chemical Co. of Illinois, 733 F.Supp. 1215, 30 ERC 1856, 20 Envtl. L. Rep. 21,036 (N.D.Ind., Nov 06, 1989) (NO. CIV. H 86-9)

70. Com., Dept. of Environmental Resources v. O'Hara Sanitation Co., 128 Pa.Cmwlth. 47, 562 A.2d 973 (Pa.Cmwlth., Aug 04, 1989) (NO. 1595 C.D. 1986)

71. People v. Martin, 211 Cal.App.3d 699, 259 Cal.Rptr. 770, 86 A.L.R.4th 383 (Cal.App. 2 Dist., Jun 20, 1989) (NO. CRIM. B024374)

72. Triangle Publications, Inc. v. Liberty Mut. Ins. Co., 703 F.Supp. 367 (E.D.Pa., Jan 04, 1989) (NO. CIV. A. 85-7075)

73. Elam v. Alcolac, Inc., 765 S.W.2d 42, 57 USLW 2319 (Mo.App. W.D., Nov 01, 1988) (NO. WD.38,105)

74. Environmental Defense Fund v. E.P.A., 852 F.2d 1316, 28 ERC 1089, 271 U.S.App.D.C. 349, 18 Envtl. L. Rep. 21,169 (D.C.Cir., Jul 29, 1988) (NO. 86-1584)

75. U.S. v. Rainbow Family, 695 F.Supp. 314 (E.D.Tex., Jun 23, 1988) (NO. CIV. A. L-88-68-CA)

76. Versatile Metals, Inc. v. Union Corp., 693 F.Supp. 1563, 19 Envtl. L. Rep. 20,472 (E.D.Pa., Jun 15, 1988) (NO. CIV. A. 85-4085)

77. Public Interest Research Group of New Jersey v. U.S. Metals Refining Co. 681 F.Supp. 237, 26 ERC 2004, 18 Envtl. L. Rep. 21,253 (D.N.J., Sep 22, 1987) (NO. CIV A 86-2041)

78. American Min. Congress v. U.S. E.P.A., 824 F.2d 1177, 56 USLW 2089, 26 ERC 1345, 263 U.S.App.D.C. 197, 17 Envtl. L. Rep. 21,064 (D.C.Cir., Jul 31, 1987) (NO. 85-1206, 85-1208)

79. Ocean County Utilities Authority v. Planning Bd. of Berkeley, Tp., Ocean County, 221 N.J.Super. 621, 535 A.2d 550 (N.J.Super.L., May 13, 1987) (NO. L-047803-87 PW)

80. Artesian Water Co. v. Government of New Castle County, 659 F.Supp. 1269, 27 ERC 2039, 18 Envtl. L. Rep. 20,785 (D.Del., Apr 24, 1987) (NO. CIV. A. 83-854 MMS)

81. Natural Resources Defense Council, Inc. v. U.S. E.P.A., 790 F.2d 289, 54 USLW 2599, 24 ERC 1313, 16 Envtl. L. Rep. 20,693 (3rd Cir., Apr 30, 1986) (NO. 84-3530, 85-3012)

82. Kennecott v. U.S.E.P.A., 780 F.2d 445, 54 USLW 2391, 23 ERC 1793, 16 Envtl. L. Rep. 20,435 (4th Cir., Dec 26, 1985) (NO. 84-1288(L), 84-1479, 84-1487, 84-1659, 84-1694)

83. State of N.Y. v. Shore Realty Corp., 759 F.2d 1032, 22 ERC 1625, 15 Envtl. L. Rep. 20,358 (2nd Cir.(N.Y.), Apr 04, 1985) (NO. 84-7925, 606)

84. People v. J.R. Cooperage Co., Inc., 127 Misc.2d 161, 485 N.Y.S.2d 438 (N.Y.Sup., Jan 11, 1985) (NO. 4511/84)

85. Mardan Corp. v. C.G.C. Music, Ltd., 600 F.Supp. 1049, 22 ERC 1223, 15 Envtl. L. Rep. 20,370 (D.C.Ariz., Dec 06, 1984) (NO. CIV 83-707-TUC-WDB)

86. Glass Packaging Institute v. Regan, 737 F.2d 1083, 21 ERC 1337, 237 U.S.App.D.C. 378 (D.C.Cir., Jun 08, 1984) (NO. 83-1390)

87. Amersham Corp. v. U.S., 728 F.2d 1453, 5 ITRD 1888, 2 Fed. Cir. (T) 33 (Fed.Cir., Mar 02, 1984) (NO. 83-956)

88. Hybud Equipment Corp. v. City of Akron, 1983 WL 1814, 19 ERC 1578, 1983-1 Trade Cases P 65,356 (N.D.Ohio, Apr 06, 1983) (NO. C78-1733A, C78-65A)

A. A. Mastrangelo, Inc. v. Commissioner of Dept. of Environmental Protection, 90 N.J. 666, 449 A.2d 516, 18 ERC 1229, 13 Envtl. L. Rep. 20,376 (N.J., Aug 11, 1982) (NO. A-75, A-76, A-77, A-78)

89. Hybud Equipment Corp. v. City of Akron, Ohio, 654 F.2d 1187, 16 ERC 1320, 1981-2 Trade Cases P 64,161, 11 Envtl. L. Rep. 20,894 (6th Cir.(Ohio), Jul 17, 1981) (NO. 80-3121)

90. Field v. Area Plan Commission of Grant County, Ind., 421 N.E.2d 1132 (Ind.App. 4 Dist., Jun 17, 1981) (NO. 2-180A11)

91. Mid-State Distributing Co. v. City of Columbia, 617 S.W.2d 419, 15 ERC 1833 (Mo.App. W.D., Mar 30, 1981) (NO. WD 31226)

92. Montgomery Environmental Coalition v. Costle, 646 F.2d 568, 15 ERC 1118, 207 U.S.App.D.C. 233, 11 Envtl. L. Rep. 20,211 (D.C.Cir., Oct 08, 1980) (NO. 79-1183, 79-1576)

93. U. S. v. Solvents Recovery Service of New England, 496 F.Supp. 1127, 14 ERC 2010, 10 Envtl. L. Rep. 20,796 (D.C.Conn., Aug 20, 1980) (NO. CIV. H 79-704)

94. Burbank Anti-Noise Group v. Goldschmidt, 623 F.2d 115, 14 ERC 1842, 10 Envtl. L. Rep. 20,681 (9th Cir.(Cal.), Jul 14, 1980) (NO. 78-2629)

95. Ramos v. Lamm, 485 F.Supp. 122 (D.C.Colo., Dec 20, 1979) (NO. 77-K-1093)

96. Glenwillow Landfill, Inc. v. City of Akron, Ohio, 485 F.Supp. 671, 14 ERC 1013, 1980-1 Trade Cases P 63,200 (N.D.Ohio, Dec 19, 1979) (NO. CIV C78-65A, CIV C78-1733A)

97. Can Mfrs. Institute, Inc. v. State, 289 N.W.2d 416, 13 ERC 1689, 9 Envtl. L. Rep. 20,744 (Minn., Sep 07, 1979) (NO. 48349)

98. Environmental Defense Fund, Inc. v. Costle, 439 F.Supp. 980, 12 ERC 1929, 8 Envtl. L. Rep. 20,145 (E.D.N.Y., Sep 16, 1977) (NO. 74-C-1698)

99. American Paper Institute v. Train, 543 F.2d 328, 9 ERC 1065, 177 U.S.App.D.C. 181, 6 Envtl. L. Rep. 20,729 (D.C.Cir., Aug 06, 1976) (NO. 74-1480, 74-1516, 74-1544, 74-1814 TO 74-1821, 74-1967)

100. Omaha Pollution Control Corp. v. Carver-Greenfield Corp., 413 F.Supp. 1069 (D.C.Neb., Apr 01, 1976) (NO. CIV 03693)

101. Chemical Leaman Tank Lines, Inc. v. U. S., 368 F.Supp. 925, 6 ERC 1129 (D.C.Del., Dec 19, 1973) (NO. CIV. A. 4419)

102. U. S. v. Students Challenging Regulatory Agency Procedures (SCRAP), 412 U.S. 669, 93 S.Ct. 2405, 37 L.Ed.2d 254, 5 ERC 1449, 3 Envtl. L. Rep. 20,536 (U.S.Dist.Col., Jun 18, 1973) (NO. 72-535, 72-562)

103. Sittner v. City of Seattle, 62 Wash.2d 834, 384 P.2d 859 (Wash., Aug 29, 1963) (NO. 36614)

APPENDIX H – LIST OF INTERVIEWEES

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APPENDIX I – SURVEY QUESTIONNAIRE

GENERAL QUESTIONS

1. DOE characterizes its PAST culture as one with little or no interaction with the public. Do you recall this past culture? If so, what was your experience?

2. With respect to your personal experiences, has DOE's public involvement strategies changed over the years? If so, how?

3. Do you find DOE's decision makers are open and accessible public comment? If so, what DOE actions demonstrate this commitment? If not, why not?

4. Do you believe that NEPA as a public involvement tool adequately involves the public in DOE projects? If so, how? If not, why not?

5. In general, what specific strategies might the agency include to strengthen its public involvement processes? Why are these strategies better than those the agency currently uses?

CONCRETE RECYCLING QUESTIONS

Background: Current decontamination and decommissioning (D&D) practices within the DOE entail decontaminating the concrete surfaces, disposing of the decontamination waste streams, demolishing the structure, and disposing of the concrete rubble and rebar at a construction and demolition (C&D) landfill. This practice is often expensive and emphasizes land disposal as the single waste management option. By decontaminating and recycling this concrete, the DOE may save both disposal costs and capacity. In addition, recycling may be a more socially acceptable form of waste management than is disposal.

6. DOE is considering decontaminating nuclear contaminated waste and reusing it in benign compounds such as cement. What opinions you have about alternative nuclear waste management strategies such as recycling or reuse? Do you believe they may be viable alternatives to storage?

7. Often times it is difficult to engage diverse groups of citizens in dialogue. Are there any groups that you can identify that DOE should make a special effort to include in the decision making process that would not typically participate otherwise? How might DOE account for these citizens' views?

8. There are numerous means to convey information. Traditional sources include newspaper announcements or newsletters. What types of strategies do you believe would be most helpful to convey information about a proposed policy? Why are these suggestions better than others?

9. With respect to the decontaminated concrete recycling project, what specific public involvement strategies might the agency implement that you believe would most encourage dialogue? Why are these strategies better than others?

10. In your opinion, what stakeholders would be most affected by decontaminated concrete recycling? Why?

11. In your opinion, what stakeholders would be most supportive of decontaminated concrete recycling? What stakeholders would be most concerned?

12. Are there any other comments you would like to provide about DOE public involvement or concrete recycling that you have not already addressed?

APPENDIX J – DEMOGRAPHICS OF DOE FACILITIES

Table J-1. Demographics of DOE Facilities

Site Name	Distance	Median HH Income	Population	Caucasian	African American	Hispanic	American Indian
Argonne Nat'l. Lab East	10 miles	$49,936	469,601	421,236	22,378	17,254	679
	25 miles	$31,700	4,977,198	3,199,064	1,289,442	628,928	8,726
Argonne Nat'l. Lab West	10 miles	$24,374	932	828	1	97	25
	25 miles	$24,374	5,347	4,773	6	571	112
Brookhaven Nat'l. Lab	10 miles	$45,997	309,950	288,939	13,029	17,232	976
	25 miles	$49,229	1,023,578	936,780	48,789	69,174	2,450
Energy Tech. Engr. Ctr	10 miles	$52,215	871,266	667,422	29,008	188,953	3,613
	25 miles	$39,628	4,411,694	2,646,645	528,620	1,404,768	18,199
Hanford Site	10 miles	$36,101	5,877	5,532	24	344	89
	25 miles	$29,756	144,186	120,439	1,959	24,114	1,083
Lawrence Berkeley Lab	10 miles	$33,743	897,306	456,999	216,349	93,971	4,971
	25 miles	$40,023	3,222,082	2,029,506	421,334	410,408	18,102
Lawrence Livermore Nat'l Lab	10 miles	$58,773	138,879	122,126	4,179	11,918	792
	25 miles	$42,317	1,666,178	1,135,304	152,883	291,554	11,289
Los Alamos Nat'l. Lab	10 miles	$40,107	23,953	21,092	79	5,403	1,479
	25 miles	$30,274	95,801	73,529	333	47,857	8,509
Morgantown Energy Tech. Ctr	10 miles	$22,160	75,852	72,204	1,709	725	227
	25 miles	$20,588	275,727	265,412	7,408	1,714	571
Nevada Test Site	10 miles	$0	83	63	16	4	2
	25 miles	$22,021	2,887	2,677	75	186	71
Oak Ridge	10 miles	$31,986	134,529	127,150	5,106	1,016	366
	25 miles	$24,803	555,779	513,084	36,046	3,232	1,645

Site Name	Distance	Median HH Income	Population	Caucasian	African American	Hispanic	American Indian
Pantex Plant	10 miles	$25,394	164,344	137,101	9,148	23,174	1,395
	25 miles	$25,661	188,218	159,413	9,470	25,063	1,530
Paducah Gas. Diffusion Site	10 miles	$20,321	69,560	62,347	6,824	421	111
	25 miles	$21,374	139,993	130,983	8,334	664	297
Portsmouth Gas. Diffusion Site	10 miles	$17,451	62,410	59,945	2,000	213	295
	25 miles	$17,927	167,326	162,652	3,798	360	554
Rocky Flats Plant	10 miles	$36,872	228,607	215,573	1,534	13,617	1,043
	25 miles	$28,220	1,591,662	1,368,015	84,040	214,096	12,408
Sandia Nat'l. Lab	10 miles	$28,826	457,696	354,957	12,499	168,986	12,602
	25 miles	$28,802	548,106	425,508	14,166	200,384	19,265
Savannah River Site	10 miles	$22,054	1,896	933	898	65	0
	25 miles	$21,107	219,244	131,737	84,535	2,445	528

APPENDIX K – GOVERNMENTAL CONCRETE RECYCLING EFFORTS

Department of Energy
FUSRAP

In 1974, DOE began the Formerly Utilized Sites Remedial Action Program (FUSRAP) to cleanup old abandoned sites from the nation's early atomic energy program. These sites were created by the predecessor agencies of the DOE, the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC). The majority of sites had been decontaminated to meet the guidelines in effect at that time. Some sites not associated with MED or AEC, such as commercial industrial sites, have also been added to FUSRAP at the direction of Congress (FUSRAP, 1996).

To date, FUSRAP has completed remediation at 24 sites and released them for commercial reuse (Darby, et al. 1997). One of FUSRAP's innovative approaches to beneficially reusing concrete rubble is the use of a rock crusher to reduce the waste volumes slated for disposal. The rock crusher is used to reduce rubble and building debris to a soil-like material. This soil-like material has been beneficially reused or disposed at a reduced cost. FUSRAP reports a savings of over $4 million by using the rock crusher at four project sites (Seay, 1996).

While not recycling in the truest sense, the FUSRAP team found success with their rock crusher. They have found the crushing process to (a) effectively reduce the volume of their construction debris, (b) reduce the contamination levels in some cases and allow it to now be measured in a volumetric manner, and (c) change the classification of the material from debris to "soil", hence qualifying for less expensive disposal fees and/or meeting established soil volumetric release criteria. The FUSRAP team has worked with State regulatory agencies at three locations (Aliquippa Forge Site, PA; C.H. Schnoor Site, PA; and Colonie Site, NY), to establish acceptable release criteria for the low level contaminated material. The final average volumetric contamination levels for the sites ranged from 7.5 pCi/g to 15.5 pCi/g, which were well below the soil free release levels of 35 to 50 pCi/g which had been established for the sites (Seay, 1996). FUSRAP is currently considering contracting out further crushing to reduce their transportation costs for the crusher and to eliminate their involvement with decontaminating the crusher (McDaniel, 1997).

A few of the larger DOE facilities have been active in the D&D process and have recently found it beneficial to recycle concrete. These sites have moved past the FUSRAP utilization, which was mainly volume reduction, to reuse of the concrete rubble as general fill, saving the natural resources of aggregate rock. They demonstrate the success of recycling concrete structures and are discussed below.

Idaho National Environmental Engineering Laboratory

Idaho National Environmental Engineering Laboratory (INEL) has crushed and recycled non-contaminated concrete since 1994. They conducted a preliminary cost/benefit study and found it economically beneficial to purchase their own crusher. INEL has used their crusher mainly to process material from building slabs and some walls. The crushed material is used as fill material after the building has been demolished, restoring the land to the original grade (Sanow, 1997). Avoided disposal fees, transportation costs, and avoided virgin aggregate backfill costs have saved INEL an estimated $370,000 and proposed project savings are close to an additional $300,000. INEL's capital expense for their crushing system was $300,000 (Thiel, 1997).

Los Alamos National Laboratory

The Los Alamos National Laboratory (LANL) Environmental Restoration Project (ER) efforts have included the recycling of concrete material generated in their D&D activities. The DOE Equipment Sharing System allowed LANL to borrow INEL's crusher. In 1996, LANL recycled 4,900 metric tonnes of concrete rubble at a reported costs savings of more that 1.2 million dollars (LANL, 1997). At LANL, the crushed concrete was reused as fill material on-site as INEL did, and the Los Alamos county landfill has used some of the crushed concrete as material for a land bridge spanning a canyon. LANL has used the concrete recycling methodology for both contaminated and non-contaminated concrete..

Other DOE sites have recycled concrete rubble, although detailed information has not been obtained. The Annual Report of Waste Generation and Pollution Prevention Progress 1996 shows the following sites and the volume of concrete recycled: Argonne National Laboratory-East, 245 metric tons (mt); Brookhaven National Laboratory, 761 mt (mixed concrete, wood, and other construction debris); East Tennessee Technology Park (formerly Oak Ridge K-25 Site), 5,045 mt; Hanford Site, 6,333 mt; Kansas City Plant, 129 mt; Los Alamos National Laboratory, 6,410 mt; and Western Area Power Administration, 291 mt (Haupt, 1997).

Fernald Environmental Management Project

The DOE Fernald site has conducted a "Contaminated Concrete Recycling System Value Engineering Study" in conjunction with the Miamisburg Environmental Management Project (ICF Kaiser, 1997). Their study identified the same problem of large concrete waste volumes being produced from DOE D&D practices as the Vanderbilt work did. They proposed a contaminated recycling system to solve the DOE's problem, based on feasibility and value engineering studies. They estimate that Fernald can recover 50% to 90% of their concrete rubble at a costs savings ranging from $4.4 million to $11 million

(ICF Kaiser, 1997). The Fernald study recommends that concrete recycling should be pursued for implementation at their site and other DOE sites.

Savannah River Site Study of Concrete Reuse

The DOE Savannah River Site (SRS) study has found that the current concrete recycling industry in the United States has proven that recycling concrete is technologically feasible and competition in this industry has made recycling an affordable process. The SRS study recognizes that the greatest risk to workers is caused by the industrial accidents and not from the occupational exposure to the residual amounts of radioactivity in the concrete. However, this work with radioactive material still requires the use of radiation monitoring and engineering controls to protect the health and safety of the workers and the public.

Savings by concrete recycling is the primary benefit identified by SRS. They examined three scenarios: (1) disposal on-site (the traditional procedure), (2) recycling for reuse on-site, and (3) recycling for reuse off-site. The SRS study identified the following applications as candidates for reuse of the concrete on-site: TRU (transuranic waste) storage pads; E-Area vaults (consisting of a Low-Activity Waste Vault, an Intermediate-Level Non-Tritium Vault, and an Intermediate Tritium Vault); concrete waste boxes, casks, and silos; fill grout for filling void spaces in waste packages; TRU waste culverts; and other applications such as construction of buildings, roadbed aggregate, and bridge construction material.

The SRS study was based on processing 337,000 tons of concrete over a three-year period, and shows a total cost saving of $9 million when implementing a recycling process with either on-site or off-site reuse. Their disposal on-site scenario resulted in a total cost of $24.2 million, reuse on-site was $14.9 million, and reuse off-site was $14.5 million. The recycling scenarios still included some concrete that could not be recycled and requires disposal in a LLW facility. The SRS cost analysis assumes that 90% of the concrete volume being processed will be below the expected volumetric release criteria. The remaining 10% will exceed allowable criteria and must be disposed of as LLW.

Department of Defense

Within the DOD, the various departments have instituted their own recycling requirements and programs as part of their pollution prevention activities. The United States Air Force routinely replaces World War II- and Korean War-era buildings with modern buildings which generates large volumes of construction and demolition (C&D) waste. The Air Force's pollution prevention policy, AFI 32-7080, calls for the reduction of the amount of waste sent to landfills, and their concrete recycling efforts are just one of the ways they are striving to meet this reduction in waste. The Air Force reports that concrete can potentially be reused as crushed and screened aggregate in road sub-base, cement blocks, asphaltic cement, and as fill (PRO-ACT, 1995).

The United Stated Army also actively engages in construction, renovation, and demolition projects that produce large amounts of C&D debris that is sent to landfills across the nation. The Army recognizes that this disposal process results in a large loss of natural resources and is becoming an increasing expense in project budgets. The U.S. Army Construction Engineering Research Laboratories (USACERL) is investigating various concepts for reutilization of C&D waste material.

The DOD has reported ongoing concrete recycling efforts at the following sites:

Naval Station San Diego, CA

The Naval Station at San Diego owns and operates a C&D landfill for debris disposal. The do not charge themselves a tipping fee to dispose of their construction waste and this has made it hard to see the cost effectiveness in some recycling projects. The concrete recycling program coordinator reported that they have had success with contractors using mobile grinders on small projects (Hood, 1997). She discussed two main recycling projects at the Naval Station. The first one is the demolition and rebuilding of an old public works building that is mostly office space. 8,000 tons of concrete was recycled on-site at no visible extra cost. The rebar was separated and sold as scrap, and the concrete was crushed and used as Class 2 base under the new building slab.

The second Naval Station concrete recycling project mentioned was the demolition of an old fire-fighting school. The building contained metal, wood, and concrete that was all recycled in the project. The concrete turned out to be expensive to recycle due to the construction techniques employed. The concrete slab, built decades ago by Seabees, contained approximately 5 times the current requirement of steel rebar. The crushing of the slab was more difficult than expected. It is possible that some of the old DOE buildings might have been built in similar fashions, which could make recycling them more challenging than first thought.

Vandenberg Air Force Base, CA

Vandenberg Air Force Base has three projects dealing with concrete and construction debris recycling (Faulkner, 1997). The first project evolved from recent possible charges of "speculative accumulation" of a 500,000 ton stockpile of concrete and asphalt from past base construction work. This pile was created for use in future recycling efforts, but these efforts have never been defined into any actual projects. In order to avoid these potential charges now, they are currently setting up a project for FY'98 that would turn the waste pile into a crushed product pile for use as future road base coarse material and general fill.

This $200,000 project includes the establishment of a concrete pad with water and utility hookups so contractors and their equipment can be brought in to do the crushing. The base will then buy back the crushed aggregate for use by future construction contractors. New concrete use will require contractors to obtain the recycled aggregate for use in the new mix. This new concrete will use 100% recycled aggregate. This project will allow Vandenberg to avoid the regulations of stockpiling a waste because they are converting their waste into a sellable product to be bought by themselves in all future construction projects.

The second Vandenberg recycling project comes from a military family housing demolition project. As each family housing unit was demolished, debris was created that could not be added to the already "speculative" stockpile of concrete and asphalt on base. This project avoids stockpiling the waste from the concrete slabs under each housing unit by requiring the contractor to fully recycle the old slab into aggregate and use it in the construction of the new housing unit. This project successfully reuses 100% of the old concrete as fill under each new slab.

The third reported concrete recycling project at Vandenberg Air Force Base deals with the issue of operating their own landfill on base. A new senate bill requires that 50% of the waste going into landfills must be diverted. Therefore, this recycling project combines this requirement with the military family housing demolition project. The proposed project, for FY'98, will include the demolition of the houses, removal of the metals, and then the grinding of the structure debris by a special $200,000 Maxigrinder. The housing debris will now have been turned into a soil substance that is suitable for use as an alternate day cover at the landfill. This will effectively use the debris in a non-waste stream and save other soil from being used everyday as cover. The concrete slabs will continue to be used in the new construction. This project is currently dependant upon the funding of the Maxigrinder.

Cape Canaveral Air Station, FL

Past construction and demolition at Cape Canaveral Air Station has generated a concrete rubble pile that they are now faced with deciding what to do with it. Cape Canaveral however, is not under the same problems of "speculative accumulation" that Vandenberg Air Force Base is dealing with in California. They are currently making an economic analysis into the costs of having a contractor come in and crush the material to determine if this will be plausible and profitable. Any metal in the pile will be recovered and sold. They have the option of hiring a contractor and crushing the concrete for future use as aggregate, or they can bury the pile in place (above ground) after they grade the pile to meet Florida's dimensional requirements. The economic decision will be made at Cape Canaveral. No economic data was available at this time (Faulkner, 1997).

Spangdahlem Air Base, Germany

The Readiness Flight Commander at Spangdahlem Air Base, Germany, reports that they have done a good job with their concrete recycling efforts (Shankland, 1997). Germany is extremely concerned with all types of recycling, including concrete. "We recycle nearly all concrete removed during demolition of roads, sidewalks, buildings, airfield pavements, etc." (Shankland,1997) In the past two years, Spangdahelm has prepared 300 to 400 yd^3 of concrete for recycling. The broken concrete is stored in a designated storage area and every few years a contractor is hired to crush the concrete chunks and convert them into useable aggregate. The reinforcing bars are removed from the concrete and are also recycled. The crushed concrete is typically too angular for use as good aggregate in new concrete, so it is primarily used for base material in road and building construction. Spangdahlem requires the construction contractors to recycle the concrete they remove from their projects.

Department of Transportation

Many Department of Transportation office's around the country are allowing and encouraging concrete recycling in their projects. A survey of concrete recycling activities at DOT offices was conducted in the fall of 1996. All fifty (50) states were contacted for participation in the survey and 43 states (86%) responded. The table K-1 shows the distribution of the responses from each state:

Table K-1. State DOT Offices Involvement with Concrete Recycling

States Actively Recycling Concrete	***States Recycling Concrete, <5 projects***	***States Not Recycling Concrete***	***States Not Returning Info.***
California	Alabama	Alaska	Louisiana
Connecticut	Arkansas	Arizona	Mississippi
Florida	Colorado	Hawaii	Montana
Illinois	Delaware	Maine	Nebraska
Iowa	Georgia	Nevada	New Jersey
Michigan	Idaho	New Hampshire	North Carolina
New York	Indiana	New Mexico	Vermont
North Dakota	Kansas	Rhode Island	
Pennsylvania	Kentucky	Tennessee	
Texas	Maryland	Utah	
Wisconsin	Massachusetts	West Virginia	
	Minnesota		
	Missouri		
	Ohio		
	Oklahoma		
	Oregon		
	South Carolina		

States Actively Recycling Concrete	***States Recycling Concrete, <5 projects***	***States Not Recycling Concrete***	***States Not Returning Info.***
	South Dakota Virginia Washington Wyoming		

Results show that 64% of the state DOT offices are recycling concrete or are allowing it to be used in some projects. Of these states allowing concrete recycling, 11 are actively researching concrete recycling, encouraging its use through modifying their policies, or have completed greater than 10 projects involving concrete reuse. Some DOT offices were able to provide limited data on selected projects. This data showed that between 15% and 25% of the material in a project was generally not recycled due to process losses or the material was too fine (dust). All of the states that allow concrete recycling require that recycled material meet the project specifications. The allowed uses, reported by the state DOT offices, for recycled concrete are:

Allowed Uses of Recycled Concrete by States:

- embankments
- free-draining material
- granular fill
- pervious structure backfill
- dirt road aggregate
- riprap
- fine aggregate in trench backfill
- subbase and shoulder course
- membrane water proofing
- blotter
- broken concrete for erosion protection, sedimentation control, and rockfill
- aggregate and stabilization aggregate base
- backfill
- French drains
- curb and gutters
- valley gutters
- sidewalks
- concrete barriers
- driveways
- temporary shoulders
- interchange ramps (ADT <250)
- base course below asphalt base, ACHM binder, and surface course
- aggregate base and subbase for concrete pavement projects

- coarse aggregate in Portland cement concrete pavement

Most of the states that recycle concrete allow the contractor to decide when to recycle, although some are also required to request permission to use recycled material and then prove that it meets the specifications. Contractors' decisions are economically based, and not under the control of DOT agencies.