TABLE I-1

Quantifiable Environmental Impacts and Cost

	Alternative 1 *Continued Tank Farm Operation*	*Alternative 2* *Subcase 1* *Glass Shipped to Offsite Repository*	*Alternative 2* *Subcase 2* *Glass in SRP Surface Storage*	*Alternative 2* *Subcase 3* *Glass in SRP Bedrock*	*Alternative 3* *Liquid in SRP Bedrock*
Occupational Radiation Exposures Based on SRP Experience, man-rem[a]	360	3,800	2,700	2,400	42
Offsite Population Dose risk, man-rem[b]	1,400	650	220	340	62,000
Offsite Population Dose Risk, man-rem[c]	24,000	-	-	-	-
Offsite Population Dose Risk, man-rem[d]	2,300	650	340	340	140,000
Non-nuclear Accidental Fatalities from Construction and Operations	17.1	6.5	6.6	6.2	2.2
Budgetary Cost, millions of 1980 dollars[e]	510	3,600	3,750	3,610	755

a. Campaign totals for all workers.

b. Consequences times probabilities, summed over all events and integrated for 300 years.

c. Assuming tanks are abandoned after 100 years, according to proposed EPA criterion.

d. Integrated for 10,000 years.

e. Includes capital and operating costs.

TABLE I-2

Summary of Difficult-to-Quantify Factors

	Alternative 1 *Continued Tank Farm Operation*	*Alternative 2* *Subcase 1* *Glass Shipped to Offsite Repository*	*Alternative 2* *Subcase 2* *Glass in SRP Surface Storage*	*Alternative 2* *Subcase 3* *Glass in SRP Bedrock*	*Alternative 3* *Liquid in SRP Bedrock*
Relative Degree of Action required by Future Generations	High	Low	Moderate	Low	Low
Relative Compliance with Public Expectations	Low	High	Moderate	High	Moderate
Conformance with Policies of S. C. and Ga. State Governments	Low	High	Moderate	Low	Low
Conformance with NRC Regulations for Commercially-Generated Waste	Low	High	Moderate	High	Low
Potential for Regrets if Future Economics or Technology Indicate a Better Method[a]	Low	High	Moderately High	High	High
Likelihood of Successful Attainment of Required Implementation Technology	Highest	High	Higher	Moderate	Moderate
Effect on Implementation Date Relative to Alternative 2	Shortens	-	None	Lengthens	Lengthens
Requires Additional Management of Decontaminated Salt	No	Yes	Yes	Yes	No

a. This factor involves both the ease of retrievability from the storage or disposal site and the ease of separating the radioactive constituents from the waste form.

TABLE IV-1

Average Chemical Composition of Fresh SRP High-Level Waste

Constituent	*Concentration* Molar	*Concentration* g/L
$NaNO_3$	3.3	281
$NaNO_2$	<0.2	<14
$NaAl(OH)_4$	0.5	59
NaOH	1	40
Na_2CO_3	0.1	11
Na_2SO_4	0.3	43
$Fe(OH)_3$	0.07	7.5
MnO_2	0.02	1.7
$Hg(OH)_2$	0.002	0.5
Other Solids	0.13[a]	7.8

a. Assuming an average molecular weight of 60.

TABLE IV-2

Average Radionuclide Composition of Fresh[a] SRP High-Level Waste

Radionuclide	*Activity, Ci/gal*	*Radionuclide*	*Activity, Ci/gal*
^{95}Nb	105	^{241}Am	1×10^{-3}
^{144}Ce-^{144}Pr	68	^{99}Tc	5×10^{-4}
^{95}Zr	60	^{239}Pu	3×10^{-4}
^{91}Y	47	^{154}Eu	1×10^{-4}
^{89}Sr	36	^{93}Zr	1×10^{-4}
^{141}Ce	12	^{240}Pu	6×10^{-5}
^{147}Pm	12	^{135}Cs	4×10^{-5}
^{103}Ru	10	^{126}Sn-^{126}Sb	1×10^{-5}
^{106}Ru-^{106}Rh	4	^{79}Se	1×10^{-5}
^{90}Sr	3	^{233}U	2×10^{-6}
^{137}Cs	3	^{129}I	1×10^{-6}
^{129}Te	2	^{238}U	6×10^{-7}
^{127}Te	2	^{107}Pd	5×10^{-7}
^{134}Cs	1	^{237}Np	4×10^{-7}
^{151}Sm	8×10^{-2}	^{152}Eu	2×10^{-7}
^{238}Pu	1×10^{-2}	^{242}Pu	6×10^{-8}
^{241}Pu	2×10^{-3}	^{158}Tb	6×10^{-8}
^{244}Cm	1×10^{-3}	^{235}U	3×10^{-8}

a. After reprocessing fuel that has been cooled six months after discharge from reactor. See Table IV-6 for the average radionuclide concentration of reconstituted SRP high-level waste in 1985.

TABLE IV-3

Average Radionuclide Composition of SRP High-Level Sludge

Time After Irradiation, years →	*Radionuclide Activity, Ci/gal* 1	5	10		*Radionuclide Activity, Ci/gal* 1	5	10
^{144}Ce-^{144}Pr	4.5×10^{2}	1.3×10^{1}	1.5×10^{-1}	^{241}Am	1.1×10^{-2}	1.1×10^{-2}	1.1×10^{-2}
^{95}Zr	9.6×10^{1}	1.8×10^{-5}	*a*	^{99}Tc	4.3×10^{-3}	4.3×10^{-3}	4.3×10^{-3}
^{94}Y	7.6×10^{1}	2.5×10^{-6}	*a*	^{239}Pu	3.5×10^{-3}	3.5×10^{-3}	3.5×10^{-3}
^{89}Sr	4.4×10^{1}	*a*	*a*	^{154}Eu	1.1×10^{-3}	8.3×10^{-4}	5.5×10^{-4}
^{95}Nb	6.0×10^{0}	*a*	*a*	^{93}Zr	8.6×10^{-4}	8.6×10^{-4}	8.6×10^{-4}
^{141}Ce	3.0×10^{0}	*a*	*a*	^{240}Pu	6.4×10^{-4}	6.4×10^{-4}	6.4×10^{-4}
^{147}Pm	1.0×10^{2}	3.6×10^{1}	9.7×10^{0}	^{135}Cs	2.2×10^{-5}	2.2×10^{-5}	2.2×10^{-5}
^{103}Ru	5.2×10^{0}	*a*	*a*	^{126}Sn-^{126}Sb	1.1×10^{-4}	1.1×10^{-4}	1.1×10^{-4}
^{106}Ru-^{105}Rh	2.4×10^{1}	1.6×10^{0}	5×10^{-2}	^{79}Se	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-4}
^{90}Sr	3.0×10^{1}	2.8×10^{1}	2.4×10^{1}	^{233}U	2.1×10^{-5}	2.1×10^{-5}	2.1×10^{-5}
^{137}Cs	1.6×10^{0}	1.5×10^{0}	1.3×10^{0}	^{129}I	9.4×10^{-6}	9.4×10^{-6}	9.4×10^{-6}
^{129}Te	9.4×10^{-1}	*a*	*a*	^{238}U	6.4×10^{-6}	6.4×10^{-6}	6.4×10^{-6}
^{127}Te	6.4×10^{0}	5.9×10^{-4}	*a*	^{107}Pd	4.4×10^{-6}	4.4×10^{-6}	4.4×10^{-6}
^{134}Cs	8.7×10^{0}	2.3×10^{0}	4.2×10^{-1}	^{237}Np	3.9×10^{-6}	3.9×10^{-6}	3.9×10^{-6}
^{151}Sm	7.5×10^{-1}	7.3×10^{-1}	7.0×10^{-1}	^{152}Eu	1.7×10^{-6}	1.3×10^{-6}	1.0×10^{-6}
^{238}Pu	1.1×10^{-1}	1.1×10^{-1}	1.1×10^{-1}	^{242}Pu	6.2×10^{-7}	6.2×10^{-7}	6.2×10^{-7}
^{241}Pu	2.4×10^{-2}	2.0×10^{-2}	1.6×10^{-2}	^{158}Tb	6.0×10^{-7}	6.0×10^{-7}	6.0×10^{-7}
^{244}Cm	1.3×10^{-2}	1.1×10^{-2}	9.5×10^{-2}	^{235}U	2.7×10^{-7}	2.7×10^{-7}	2.7×10^{-7}

a. Value <1 x 10^{-7}.

TABLE IV-4

Average Radionuclide Composition of SRP High-Level Supernate

Time After Irradiation, years →	*Radionuclide Activity, Ci/gal* 1	5	10		*Radionuclide Activity, Ci/gal* 1	5	10
^{144}Ce-^{144}Pr	2.6	7.4×10^{-2}	8.7×10^{-4}	^{241}Am	3.6×10^{-6}	3.6×10^{-6}	3.6×10^{-6}
^{95}Zr	2.7	5.0×10^{-7}	*a*	^{99}Tc	2.5×10^{-5}	2.5×10^{-5}	2.5×10^{-5}
^{91}Y	1.7×10^{-1}	5.7×10^{-9}	*a*	^{239}Pu	1.1×10^{-6}	1.1×10^{-6}	1.1×10^{-6}
^{89}Sr	1.0×10^{-1}	*a*	*a*	^{154}Eu	6.7×10^{-6}	4.8×10^{-6}	3.2×10^{-6}
^{98}Nb	1.7×10^{-1}	*a*	*a*	^{93}Zr	2.4×10^{-5}	2.4×10^{-5}	2.4×10^{-5}
^{141}Ce	1.7×10^{-1}	*a*	*a*	^{240}Pu	2.1×10^{-7}	2.1×10^{-7}	2.1×10^{-7}
^{147}Pm	6.1×10^{-1}	2.1×10^{-1}	5.7×10^{-2}	^{135}Cs	4.6×10^{-5}	4.6×10^{-5}	4.6×10^{-5}
^{103}Ru	1.4×10^{-1}	*a*	*a*	^{126}Sn-^{126}Sb	6.1×10^{-7}	6.1×10^{-7}	6.1×10^{-7}
^{106}Ru-^{106}Rh	6.7×10^{-1}	4.3×10^{-2}	1.4×10^{-3}	^{79}Se	6.0×10^{-7}	6.0×10^{-5}	6.0×10^{-7}
^{90}Sr	6.8×10^{-2}	6.2×10^{-2}	5.5×10^{-2}	^{233}U	7.1×10^{-9}	7.1×10^{-9}	7.1×10^{-9}
^{137}Cs	3.3	3.1	2.7	^{129}I	5.5×10^{-8}	5.5×10^{-8}	5.5×10^{-8}
^{129}Te	5.5×10^{-3}	*a*	*a*	^{238}U	2.1×10^{-9}	2.1×10^{-9}	2.1×10^{-9}
^{127}Tc	3.8×10^{-2}	3.4×10^{-6}	*a*	^{107}Pd	2.6×10^{-8}	2.6×10^{-8}	2.6×10^{-8}
^{134}Cs	5.1×10^{-2}	1.3×10^{-2}	2.4×10^{-3}	^{237}Np	1.3×10^{-9}	1.3×10^{-9}	1.3×10^{-9}
^{151}Sm	4.4×10^{-3}	4.3×10^{-3}	4.1×10^{-3}	^{152}Eu	1.0×10^{-8}	7.8×10^{-9}	6.0×10^{-9}
^{238}Pu	3.8×10^{-5}	3.7×10^{-5}	3.5×10^{-5}	^{242}Pu	*a*	*a*	*a*
^{241}Pu	8.1×10^{-6}	6.7×10^{-6}	5.4×10^{-6}	^{158}Tb	*a*	*a*	*a*
^{244}Cm	4.5×10^{-6}	3.8×10^{-6}	3.2×10^{-6}	^{235}U	*a*	*a*	*a*

a. Value <1 x 10^{-9}.

TABLE IV-5

Chemical Composition of Reconstituted SRP High-Level Waste

Constituent	*Concentration*	
	Molar	*g/L*
$NaNO_3$	2.2	187
$NaNO_2$	1.1	76
$NaAl(OH)_4$	0.5	59
NaOH	0.75	30
Na_2CO_3	0.3	32
Na_2SO_4	0.3	43
$Fe(OH)_3$	0.07	7.5
MnO_2	0.02	1.7
$Hg(OH)_2$	0.002	0.5
Other Solids	0.13[a]	7.8

a. Assuming an average molecular weight of 60.

TABLE IV-6

Radionuclide Content of Reconstituted SRP High-Level Waste (1985)

Radionuclide	*Activity, Ci/gal*	*Total Activity, Ci*
^{90}Sr	2.1	1.3×10^8
^{137}Cs	2.2	1.3×10^8
^{147}Pm	0.77	4.6×10^7
^{144}Ce-^{144}Pr	0.19	1.1×10^7
^{151}Sm	0.07	4.2×10^6
^{106}Ru-^{106}Rh	0.03	1.8×10^6
^{238}Pu	0.01	6.0×10^5
^{241}Am	0.001	6.0×10^4
^{244}Cm	0.001	6.0×10^4
^{239}Pu	0.0004	2.4×10^4

TABLE IV-7

Radionuclide Content of Decontaminated Salt
(10-year-old waste)

Radionuclide	*Concentration (nCi/g)* *Chemically Measured*	*Computer-Calculated*
^{3}H	NA[c]	57
^{60}Co	NA[c]	390
^{90}Sr-Y[a]	2	9
^{99}Tc	125	220
^{106}Ru-Rh[b]	287,000	100,000
^{129}I	NA[c]	0.04
^{137}Cs-Ba[a]	100	480
^{144}Ce-Pr[b]	109[d]	220[d]
^{147}Pm[b]	100[d]	5200[d]
^{151}Sm	<10[d]	116[d]
^{154}Eu	71[d]	510[d]
^{238}Pu[a]	9	0.9
^{239}Pu[a]	0.3	0.02
^{240}Pu[a]	0.3	0.02
^{241}Pu[a]	2	3.5
^{241}Am[a]	0.5	0.03

a. With decontamination factors assumed Cs 10^4, Sr 10^3, actinides 10^2 (165 for computer-calculated concentrations).

b. Decay of short-lived radionuclide may contribute to differences in computer-calculated and chemically measured concentrations.

c. Not analyzed.

d. Concentrations of rare-earth fission products should be reduced by a factor of 10^2 (165) during decontamination operations.

TABLE IV-8

Chemical Composition of Decontaminated, Crystallized Salt

Component	*Weight Fraction*
$NaNO_3$	0.458
$NaNO_2$	0.186
NaOH	0.073
$NaAlO_2$	0.100
$NaCO_3$	0.078
Na_2SO_4	0.104

(Note that the nitrate fraction decreases and the nitrite fraction increases during the early years of storage.)

Research and development have not progressed to the extent that the concentration of mercury in the decontaminated salt can be determined precisely; however, the concentration is expected to be less than 4×10^{-4} grams of mercury per gram of salt. The total amount of Hg in the 16.3 million gallons (~120,000 tons) of salt would then be less than 60 tons.

2. Alternative Storage Modes

Store in Tanks at SRP

The decontaminated salt solution is transferred to tanks outside the canyon-type solidification facility and processed through evaporators. The concentrate is transferred to decontaminated double-wall carbon steel waste tanks encased in reinforced concrete (this is the current design, or Type III, tank). The steel tanks have an expected life of 50 to 100 years, and the 2.5-ft-thick concrete encasements have an expected life of several hundred years. The concentrate is cooled to form crystallized salt. If all the solution does not crystallize when cooled, the supernate is recycled for further concentration until it does crystallize.

The tanks are monitored at the same level as the current practice for SRP waste tanks. After one hundred years when the residual ^{90}Sr and ^{137}Cs in the salt have been reduced by a factor of 10 due to radioactive decay, the access ports through the tank covers will be plugged and sealed. Other protective provisions include a confinement barrier over the tanks, such as reinforced

TABLE IV-9

International HLW Immobilization Status

Nation	*Process*	*Status/Major Milestone*
France	Borosilicate Glass - "AVM"	0.5 ton/day hot pilot plant startup 1978-1979 Production plant startup 1982-1983
Germany	Borosilicate Glass	"VERA" 0.5 ton/day cold pilot plant operation considering French "AVM" process for licensing
Eurochem	Borosilicate Glass Metal Matrix	French "AVM" selected for production plant VITRAMET - LOTES) Pilot Plant VITRAMET - PAMELA) 1981-1982
England	Borosilicate Glass	"FINGAL-HARVEST" production plant 1990 French "AVM" under consideration
Russia	Phosphate Glass	Cold pilot-plant work in progress
India	Borosilicate Glass	0.1 ton/day hot plant startup 1979-1980
Japan	Glass or Ceramic	Hot demonstration plant 1986
Sweden	Ceramic	Laboratory studies in progress

TABLE IV-10

Composition of Typical SRP Borosilicate Glass[a,b]

Calcine Composition		*Frit Composition*	
Fe_2O_3	42.0 wt %	SiO_2	52.5 wt %
Al_2O_3	8.5	B_2O_3	10.0
MnO_2	11.8	Na_2O	18.5
U_3O_8	3.9	Li_2O	4.0
NiO	5.2	CaO	4.0
SiO_2	3.8	TiO_2	10.0
Na_2O	4.7		
Zeolite	8.8		
$NaNO_3$	2.6		
$NaNO_2$	0.2		
$NaAlO_2$	0.2		
NaOH	3.9		
Na_2SO_4	1.3		

a. Glass will contain 28 wt % calcine.

b. Average density of glass will be 2.7 g/cm^3.

TABLE IV-11

High-Level Nuclear Waste Immobilization Forms — Properties Comparison

Waste Form	Devel. Status	Process Complexity	Process Flexibility	Waste Loading	Dispersion Impact Resis.	Long-Term Stability	Fire Resistance	Leachability 100°C	Leachability 350°C
Calcine	Available	Low	Excellent	High	Very Low	High	Poor	Poor	Poor
Rich Clay	Available	Low	Excellent	Low	Low	?	Poor	Medium	Poor
Normal Concrete	Available	Medium	Excellent	Medium	Medium	Medium	Poor	Medium	Poor
Hot, Pressed Concrete	5 years	High	Excellent	Medium	High	Medium	Medium	Good	Poor
Pelletized Calcine	5 years	High	Excellent	Medium	Medium	Medium	Medium	Good	Poor
Glass	Available	High	Excellent	Medium	High	High	Excellent	Excellent	Poor
Clay Ceramic	5 years	High	Poor	Medium	High	Medium	Medium	Good	Poor
Supercalcine	15 years	Very High	Poor	High	Very High	High ?	Best	Best	Poor
Synroc	15 years	High	Poor	Very Low	Very High	High ?	Best	Best	Good
Glass Ceramic	15 years	Very High	Poor	Medium	High	High	Excellent	Excellent	Poor
Pellet in Metal Matrix	5 years	Very High	Good	Low	Very High	High	Poor	Excellent	Poor
Coated Supercalcine in Metal Matrix	15 years	Highest	Poor	Medium	Very High	High ?	Excellent	Best	Poor
Cermet	10 years	Highest	Poor	Medium	High	High	Excellent	Excellent	Poor

Most Attractive   Intermediate   Least Attractive

TABLE IX-1

Summary of Long-Term and Short-Term Costs and Nuclear Risks

	Alternative 1 *Continued Tank Farm Operation*	*Alternative 2* *Subcase 1* *Glass Shipped to Offsite Repository*	*Subcase 2* *Glass in SRP Surface Storage*	*Subcase 3* *Glass in SRP Bedrock*	*Alternative 3* *Liquid in SRP Bedrock*
Short-Term Risks, man-rem	0[a]	4.60×10^3	2.57×10^3	2.57×10^3	2.19×10^2
Long-Term Risks,[b] man-rem	1.76×10^3 2.40×10^4[f]	1.30×10^2	2.91×10^2	1.30×10^2	6.2×10^4
Short-Term Costs,[c] millions of 1980 dollars	0[a]	3600	3750	3610	755
Long-Term Costs,[b,c] millions of 1980 dollars	510[d] 3060[e]	175	175	175	175

a. Short-term risks are defined to be those that are incurred from activities addition to preparing the waste as salt cake and sludge in modern tanks, because such activities are common to all alternatives. Short-term costs are treated similarly.

b. Long-term risks and costs are integrated for 300 years.

c. All costs are in undiscounted 1980 dollars. Discounting of long-term costs would reduce their magnitudes to negligible fractions of short-term costs for any alternative.

d. This is enough for one cycle of tank replacement, and is more than enough to establish a trust fund for perpetual tank replacement.

e. This is enough to replace tanks every 50 years during the 300-year period, undiscounted.

f. These are risks if tanks are abandoned after 100 years with probability of 1.0. (An EPA proposed criterion indicates that administrative control should not be relied upon for more than 100 years.)

TABLE V-1

SRP Whole Body Occupational Exposure Experience

Year	*Number of Employees Monitored*	*Total Exposure, rem*	*Average Exposure per Monitored Employee, rem*	*Maximum Individual Exposure, rem*
1965	4977	2340	0.47	2.9
1966	5032	2074	0.41	3.4
1967	5041	2604	0.52	3.0
1968	4875	2412	0.49	3.3
1969	4705	2758	0.59	3.2
1970	4626	2353	0.51	3.7
1971	4836	2401	0.50	3.3 (24.8)[a]
1972	5210	1711	0.33	3.4
1973	5005	1488	0.30	2.7
1974	5138	1367	0.27	3.1
1975	5263	1161	0.22	2.7
		Average over Period	0.42	

a. Higher value indicated by initial monitoring but not substantiated by subsequent investigation.

TABLE V-1A

SRP Reprocessing Area Whole Body Occupational Exposure Experience

Year	*Number of Employees Monitored*	*Total Exposure, rem*	*Average Exposure per Monitored Employee, rem*	*Maximum Individual Exposure, rem*
1965	1501	916	0.61	2.8
1966	1497	928	0.62	3.1
1967	1489	980	0.66	3.0
1968	1454	829	0.57	2.9
1969	1441	994	0.69	2.9
1970	1378	868	0.63	2.6
1971	1567	815	0.52	2.8
1972	1756	685	0.39	2.9
1973	1613	742	0.46	2.7
1974	1674	720	0.43	2.9
1975	1781	570	0.32	2.7
		Average over period	0.54	

TABLE V-2

Occupational Radiation Exposures Based on SRP Experience

	Operational Modules, rem/year in maximum year					
Alternative	*Removal from Tanks*	*Processing*	*Transportation*	*Storage*	*Total per Maximum Year, rem*	*Total for Campaign, rem*[a]
Alternative 1 - Continue storage in tanks	5.0[b]	Not applicable	Not applicable	7.6	1.26×10^{1}	3.56×10^{2}
Alternative 2, Subcase 1 - Process to glass; ship to offsite geologic disposal[c]	4.2	2.31×10^{2}	1.40×10^{2}	0	3.75×10^{2}	3.75×10^{3}
Alternative 2, Subcase 2 - Process to glass; surface storage at SRP[c]	4.2	2.31×10^{2}	Not applicable	6.7	2.42×10^{2}	2.64×10^{3}
Alternative 2, Subcase 3 - Process to glass; disposal in SRP bedrock cavern[c]	4.2	2.31×10^{2}	Not applicable	0	2.35×10^{2}	2.35×10^{3}
Alternative 3 - Slurry liquid waste into SRP bedrock cavern	4.2	Not applicable	Not applicable	0	4.2	4.2×10^{1}

a. See Tavle V-4 and text for campaign times.

b. This exposure occurs only when waste is reconstituted and transferred from an old tank to a new tank and during tank decontamination.

c. These numbers were developed specifically for glass waste forms, but should be quite similar for most of the other immobilization forms being investigated.

TABLE V-3

Occupational Radiation Exposures Based on DOE Standards

Alternative	*Operational Modules, rem/year* *Removal from Tanks*	*Processing*	*Transportation*	*Storage*	*Total per Year, rem*	*Total for Campaign, rem*[a]
Alternative 1 - Continue storage in tanks	5.95×10^1[b]	Not applicable	Not applicable	9.04×10^1	1.50×10^2	4.24×10^3
Alternative 2, Subcase 1 - Process to glass; ship to offsite geologic disposal[c]	5.00×10^1	2.75×10^3	1.40×10^2	0	2.94×10^3	2.94×10^4
Alternative 2, Subcase 2 - Process to glass; surface storage at SRP[c]	5.00×10^1	2.75×10^3	Not applicable	7.97×10^1	2.88×10^3	3.14×10^4
Alternative 2, Subcase 3 - Process to glass; disposal in SRP bedrock cavern[c]	5.00×10^1	2.75×10^3	Not applicable	0	2.80×10^3	2.80×10^4
Alternative 3 - Slurry liquid waste into SRP bedrock cavern	5.00×10^1	Not applicable	Not applicable	0	5.00×10^1	5.00×10^2

a. See Table V-4 and text for campaign times.

b. This exposure occurs only when waste is reconstituted and transferred from an old tank to a new tank and during tank decontamination.

c. These numbers were developed specifically for glass waste forms, but should be quite similar for most of the other immobilization forms being investigated.

TABLE V-4

Manpower and Time Requirements for Operational Modules

Operation	*No. of Employees*[a]	*Time Required*
Tank farm surveillance and monitoring	21	300 years[b]
Reconstitute, transfer from old to new tank	20	6 months[c]
Decontaminate old tank	31	6 months[c]
Remove 60 million gallons from present tanks, transfer to new processing building	10	10 years
Process 60 million gallons to glass, 10-year time[e]	550	10 years
Transport glass offsite[e]	1100[d]	10 years
Air-cooled vault surveillance and monitoring	21	300 years[b]
Offsite salt cavern or SRP bedrock surveillance and monitoring	5	300 years

a. Include direct supervision but not indirect overhead.

b. Occupational exposures would be negligible after this time. See text.

c. These operations were assumed to be required once every 50 years for each tank for 300 years. See text.

d. This case represents truck shipment of the glass form over a distance of 3000 miles from SRP. Other cases are detailed in Reference 4.

e. These numbers were developed specifically for glass waste forms, but should be quite similar for most of the other immobilization forms being investigated.

TABLE V-5

Non-Nuclear Occupational Injuries During Construction of New Facilities[a]

Alternative	*Construction of Processing Facilities*	*Fabrication of Transportation Casks and Vehicles*	*Construction of Storage Facilities*	*Total for Campaign*
Alternative 1 -				
Continue storage in tanks	Not applicable	Not applicable	1600[b] 17	1600 17
Alternative 2, Subcase 1 -				
Process to glass; ship to offsite geologic disposal[c]	460 5	39 0.5	28 0.4	530 5.9
Alternative 2, Subcase 2 -				
Process to glass; surface storage at SRP[c]	460 5	Not applicable	130 1.4	590 6.4
Alternative 2, Subcase 3 -				
Process to glass; disposal in SRP bedrock cavern[c]	460 5	Not applicable	88 1.1	550 6.1
Alternative 3 -				
Slurry liquid waste into SRP bedrock cavern	Not applicable	Not applicable	180 2.2	180 2.2

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a. Two annual numbers are given in each column for each alternative: top numbers are major injuries; bottom numbers are deaths.

b. These include construction of new tanks every 50 years during the 300-year period.

c. These numbers were developed specifically for glass waste forms, but should be quite similar for most of the other immobilization forms being investigated.

TABLE V-6

Non-Nuclear Occupational Injuries During the Operating Campaign[a]

Alternative	*Operational Modules* — *Removal from Tanks*	*Processing*	*Transportation*	*Storage*	*Total per Year*	*Total for Campaign*[b]
Alternative 1 -						
Continue storage in tanks	5.5[c] 0.0047 0.00059	Not applicable	Not applicable	3.0 0.0027 0.00034	8.6 0.0074 0.00093	1160 1.03 0.13
Alternative 2, Subcase 1 -						
Process to glass; ship to offsite geologic disposal[e]	1.5 0.0013 0.00016	80.5 0.078 0.0089	*d* 1.6 0.052	0.58 0.00051 0.00006	83 1.7 0.061	990 16 0.63
Alternative 2, Subcase 2 -						
Process to glass; surface storage at SRP[e]	1.5 0.0013 0.00016	80.5 0.078 0.0089	Not applicable	2.3 0.0021 0.00026	84 0.081 0.0093	1500 1.3 0.17
Alternative 2, Subcase 3 -						
Process to glass; disposal in SRP bedrock cavern[e]	1.5 0.0013 0.00016	80.5 0.078 0.0089	Not applicable	0.58 0.00051 0.00006	83 0.080 0.0091	990 0.87 0.11
Alternative 3 -						
Slurry liquid waste into SRP bedrock cavern	1.5 0.0013 0.00016	Not applicable	Not applicable	0.58 0.00051 0.00006	2.1 0.0018 0.00022	190 0.16 0.021

a. Three annual numbers are given in each column for each alternative: top numbers are minor injuries; middle numbers are major injuries; bottom numbers are deaths.

b. See Table V-4 and text for campaign times.

c. These include reconstituting waste and transferring to new tanks every 50 years and decontamination of old tanks.

d. Transportation accident data were taken from Reference 8.

e. These numbers were developed specifically for glass waste forms, but should be quite similar for most of the other immobilization forms being investigated.

TABLE V-7

Injury Rates During Construction of New Facilities[9]

	Occurrences per Million Man-Hours	
	Major Injuries	*Deaths*
Mining Caverns	25	0.31
Casks and Vehicles	26	0.32
All Other Construction	16	0.17

Construction Time and Manpower Estimates

Construction Operation	*Man-Hours Required (millions)*	
Processing Facilities	29	
Transportation Casks and Vehicles	1.5	
Set of 24 New Tanks	17	One set every 50 years for 300 years
Air-Cooled Surface Storage Vault	8.1	
Mining Bedrock Cavern (Liquid)	7.2	
Mining Bedrock Cavern (Glass)	3.5	
Mining Offsite Salt Cavern	1.1	

TABLE V-8

Injury Rates During Routine Operations[a]

Occurrences per Million Man-Hours		
Minor Injuries	*Major Injuries*	*Deaths*
50	0.044	0.0055

a. Based on SRP operating experience over the ten-year period 1967-1976.[9]

TABLE V-9

DOE Radiation Exposure Limits to Offsite Individuals, mrem

Type of Exposure	*Maximum Individual Exposure*[a]	*Exposure to Average Individual*
Whole Body	500	170
Gonads	500	170
Bone Marrow	500	170
G. I. Tract	1500	500
Bone	1500	500
Thyroid	1500	500
Other Organs	1500	500

a. These individuals are assumed to be at the site boundary under conditions of maximum probable exposure.

TABLE V-10

Typical State and Federal Air and Water Quality Standards[a,12,13]

Pollutant	*Limiting Concentration*	*Comment*
SO_2	80 μg/m^3	Ambient air, South Carolina
SO_2	43 μg/m^3	Ambient air, Georgia
SO_2	1300 μg/m^3	One-hour, air, South Carolina
SO_2	715 μg/m^3	One-hour, air, Georgia
SO_2	3.5 lb/10^6 Btu	Air emission, South Carolina
Particulates (Fly Ash)	0.6 lb/10^6 Btu	Air emission, South Carolina
NO_x	100 μg/m^3	Ambient air, South Carolina and Georgia
H_2S	10 ppm, 8 hr	Air, detectable effects
Non-Methane Hydrocarbons	130 μg/m^3	Three-hour, air, South Carolina
Sulfate	250 ppm	Drinking water standard, Federal
Chloride	250 ppm	Drinking water standard, Federal
Nitrate	10 ppm	Drinking water standard, Federal
Barium	1 ppm	Drinking water standard, Federal
Iron	0.3 ppm	Drinking water standard, Federal
Boron	1 ppm	Drinking water standard, Federal
Zinc	5 ppm	Drinking water standard, Federal
Chromium	0.05 ppm	Drinking water standard, Federal
Manganese	0.05 ppm	Drinking water standard, Federal
Arsenic	0.05 ppm	Drinking water standard, Federal
Mercury	0.002 ppm	Drinking water standard, Federal
Copper	1 ppm	Drinking water standard, Federal
Phenol	0.001 ppm	Drinking water standard, Federal

a. The above listing is not meant to imply that all the chemicals would be released from the waste management facilities.

TABLE V-12

Summary of Exposure Risks for Alternative 1 - Storage of Waste as Sludge and Dump Salt Cake in Onsite Waste Tanks (Present SRP Waste Management Technique)

Event	*Maximum Individual Dose, rem*	*Population Dose for Maximum Year, man-rem*	*Probability, Events/year*	*Maximum Risk, man-rem/year*
Removal from Tanks	Not applicable	Not applicable	Not applicable	Not applicable
Processing	Not applicable	Not applicable	Not applicable	Not applicable
Transportation	Not applicable	Not applicable	Not applicable	Not applicable
Storage				
Routine Releases	Negligible	1.4	1.0	1.4
Spill during Transfer	2.2×10^{-2}	5.3×10^{2}	5.0×10^{-3}	2.6
Explosion	7.8	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage by Dispersal	3.3	2.3×10^{4}	1.0×10^{-5}	2.3×10^{-1}
Sabotage by Explosion	4.1	9.8×10^{3}	1.0×10^{-5}	9.8×10^{-2}
Airplane Crash	4.1	1.1×10^{4}	1.0×10^{-5}	1.1×10^{-1}
Abandonment	3.9×10^{-1}	2.7×10^{4}	1.0×10^{-5}	2.7×10^{-1}

Time-Integrated Risk, 300 years, man-rem[a]	1.4×10^{3}
Time-Integrated Risk, 10,000 years, man-rem	2.3×10^{3}
Risk with Abandonment after 100 years[b]	2.4×10^{4}

a. Integrated annual population risk, accounting for radioactive decay and population growth by a factor of 5.

b. Population risk integrated for 300 years, if tanks are assumed to be abandoned after 100 years, in accordance with proposed EPA criterion on duration of administrative control.

TABLE V-13

Summary of Exposure Risks for Alternative 2, Subcase 1 – Glass Stored in Offsite Geologic Storage

Event	*Maximum Individual Dose, rem*[a]	*Population Dose for Maximum Year, man-rem*	*Probability, Events/year*	*Maximum Risk, man-rem/year*
Removal from Tanks				
Routine Releases	Negligible	1.4	1.0	1.4
Sludge Spill	5.0×10^{-4}	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	1.2×10^{-3}	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	2.0×10^{-3}	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	2.9×10^{-2}	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	7.8	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	1.2×10^{2}	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.5×10^{-1}	1.7×10^{5}	1.0×10^{-5}	1.7
Processing				
Routine Releases	2.2×10^{-5}	3.0	1.0	3.0
Process Incidents	$<1.0 \times 10^{-5}$	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	4.2×10^{1}	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	1.5×10^{-1}	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation				
Routine Exposures	5.0×10^{-3}	6.3×10^{1}	1.0	6.3×10^{1}
Accidents	6.9×10^{-1}	1.2×10^{2}	1.3×10^{-4}	1.6×10^{-2}
Storage				
Expected Releases	Negligible	1.3×10^{2}	1.0	1.3×10^{2}
Time-Integrated Risk, 300 years man-rem[b]		6.5×10^{2}		
Time-Integrated Risk, 10,000 years, man-rem		6.5×10^{2}		

a. Equivalent whole body dose, rem.

b. Integrated annual population risk, accounting for radioactive decay and population growth by a factor of 5.

TABLE V-14

Summary of Exposure Risks for Alternative 2, Subcase 2 — Glass Stored in Onsite Surface Storage Facility

Event	*Maximum Individual Dose, rem*	*Population Dose for Maximum Year, man-rem*	*Probability, Events/year*	*Maximum Risk, man-rem/year*
Removal from Tanks				
Routine Releases	Negligible	1.4	1.0	1.4
Sludge Spill	5.0×10^{-4}	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	1.2×10^{-3}	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	2.0×10^{-3}	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	2.9×10^{-2}	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	7.8	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	1.2×10^{2}	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.5×10^{-1}	1.7×10^{5}	1.0×10^{-5}	1.7
Processing				
Routine Releases	2.2×10^{-5}	3.0	1.0	3.0
Process Incidents	$<1.0 \times 10^{-5}$	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	4.2×10^{1}	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	1.5×10^{-1}	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation	Not applicable	Not applicable	Not applicable	Not applicable
Storage				
Sabotage	1.9	3.8×10^{3}	1.0×10^{-5}	3.8×10^{-2}
Airplane Crash	1.5×10^{-1}	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Abandonment	Negligible	0	-	0
Time-Integrated Risk, 300 years man-rem[a]	2.2×10^{2}			
Time-Integrated Risk, 10,000 years, man-rem	3.4×10^{2}			

a. Integrated annual population risk, accounting for radioactive decay and population growth by a factor of 5.

TABLE V-15

Summary of Exposure Risks for Alternative 2, Subcase 3 — Glass Stored in SRP Bedrock

Event	*Maximum Individual Dose, rem*	*Population Dose for Maximum Year, man-rem*	*Probability, /year*	*Maximum Risk, man-rem/year*
Removal from Tanks				
Routine Releases	Negligible	1.4	1.0	1.4
Sludge Spill	5.0×10^{-4}	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	1.2×10^{-3}	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	2.0×10^{-3}	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	2.9×10^{-2}	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	7.8	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	1.2×10^{-2}	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.5×10^{-1}	1.7×10^{5}	1.0×10^{-5}	1.7
Processing.				
Routine Releases	2.2×10^{5}	3.0	1.0	3.0
Process Incidents	$<1.0 \times 10^{-5}$	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	4.2×10^{1}	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	1.5×10^{-1}	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation	Not applicable	Not applicable	Not applicable	Not applicable
Storage				
Expected Releases	Negligible	1.3×10^{2}	1.0	1.3×10^{2}
Time-Integrated Risk, 300 years man-rem[a]	3.4×10^{2}			
Time-Integrated Risk, 10,000 years, man-rem	3.4×10^{2}			

a. Integrated annual population risk, accounting for radioactive decay and population growth by a factor of 5.

TABLE V-16

Summary of Exposure Risks for Alternative 3 — Unprocessed Waste Slurry Stored in SRP Bedrock

Event	*Maximum Individual Dose, rem*	*Population Dose for Maximum Year, man-rem*	*Probability, Events/year*	*Maximum Risk, man-rem/year*
Removal from Tanks				
Routine Releases	Negligible	1.4	1.0	1.4
Sludge Spill	5.0×10^{-4}	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	1.2×10^{-3}	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	2.0×10^{-3}	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	2.9×10^{-2}	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	7.8	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	1.2×10^{2}	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.5×10^{-1}	1.7×10^{5}	1.0×10^{-5}	1.7
Processing	Not applicable	Not applicable	Not applicable	Not applicable
Transportation	Not applicable	Not applicable	Not applicable	Not applicable
Storage				
Expected Releases	Negligible	1.3×10^{2}	1.0	1.3×10^{2}
Earthquake with Shaft Open	7.6×10^{3}	3.8×10^{8}	3.3×10^{-5}	1.3×10^{4}
Earthquake after Sealing	$<1.7 \times 10^{2}$	8.3×10^{6}	3.3×10^{-6}	2.8×10^{1}
Sabotage before Sealing	3.0×10^{4}	1.5×10^{9}	1.0×10^{-5}	1.5×10^{4}
Sabotage after Sealing	2.8×10^{2}	1.4×10^{7}	3.3×10^{-10}	4.6×10^{-3}
Time-Integrated Risk, 300 years, man-rem[a]	6.2×10^{4}			
Time-Integrated Risk, 10,000 years, man-rem	1.4×10^{5}			

a. Integrated annual population risk, accounting for radioactive decay and population growth by a factor of 5.

TABLE V-17

Moderate and Nondesign Basis Accidents Postulated for Repository in Salt

Accident Description	*Sequence of Events*	*Safety System*	*Release, Ci*	*Probability*
Canister drop in surface facility	Canister handling crane fails Canister breaches on impact	Positive latching grapple system and conservatively sized crane Building filter system	$3x10^{-4}$, ^{90}Sr; $3x10^{-4}$, ^{137}Cs; $1.5x10^{-6}$, ^{238}Pu; $6.0x10^{-8}$, ^{239}Pu; to building atmosphere	2×10^{-7}/yr
Canister drop down mine shaft	Canistered waste shaft hoist fails Canister breaches on impact	Failsafe wedge type braking system Mine exhaust filter system	$1.5x10^{4}$, ^{90}Sr; $1.5x10^{4}$, ^{137}Cs; $7.5x10^{1}$, ^{238}Pu; 2.9, ^{239}Pu; of small particles to mine atmosphere	1.3×10^{-8}/yr
Nuclear warfare	50-megaton nuclear weapon bursts on surface above repository Crater formed to 340 m with fracture zone to 500 m	Repository depth of 600 m	None	
Repository breach by meteor	Meteor with sufficient mass and velocity to form 2-km-dia crater impacts repository area 2-km-dia crater extends to waste horizon, dispersing 1% of waste to atmosphere	Repository depth of 600 m	$1.3x10^{6}$, ^{90}Sr; $1.3x10^{6}$, ^{137}Cs; $6x10^{3}$, ^{238}Pu; $2.4x10^{2}$, ^{239}Pu; half to stratosphere, half as local fallout	2×10^{-13}/yr
Repository breach by drilling	Societal changes lead to loss of repository records and location markers Drilling occurs 1000 yr after closure	Repository depth of 600 m Repository marked by monuments and records kept securely Site criteria - not desirable resources	$7x10^{-7}$, ^{90}Sr; $7x10^{-7}$, ^{137}Cs; $7x10^{-3}$, ^{238}Pu; 1.5, ^{239}Pu; distributed in drilling mud over 1.2 acres in the top 2 in. of soil	Not determined
Volcanism	Volcanic activity at repository carries wastes to surface	Site criteria - no history or potential for volcanic activity	Less than accident below	Not determined
Repository breach by faulting and groundwater transport	Fault intersects repository Access is created by pressure between aquifer, waste, and surface Aquifer carries waste to surface	Site criteria - low seismic risk zone Site criteria - minimal groundwater Repository depth of 600 m	$6x10^{-4}$, ^{90}Sr; $6x10^{-4}$, ^{137}Cs; 6, ^{238}Pu; $1.2x10^{3}$, ^{239}Pu; released to the groundwater 1000 yr after mine closure	2×10^{-13}/yr
Erosion	Repository overburden subject to high erosion	Site criteria - low erosion rates Repository depth of 600 m	Less than breach by a meteor	Not determined
Criticality	Criticality not feasible	—	—	—

TABLE V-17A

Possible Exposures and Risks from Geologic Repository

Accident Description	*Maximum Individual Exposure, rem (70-yr whole-body commitment)*	*Maximum Individual Risk, Probability Times Consequence, rem/year*
Canister drop down mine shaft	1.4×10^{-5}	1.8×10^{-13}
Repository breach by meteor	5.5×10^{6}	1.1×10^{-6}
Repository breach by faulting and flooding	7.4×10^{3}	3.0×10^{-11}
Repository breach by drilling	1.1×10^{4}	Probability Intermediate ($< 5 \times 10^{-3}$)

4. Offsite Land Contamination

Levels of radionuclide deposition that would require evacuation of people and restrictions on farming and milk production are discussed in more detail in Reference 8 and are given below in Table V-18. The deposition limits were derived from the dose criteria given in Table V-19, which are also discussed in Reference 8.

TABLE V-18

Radionuclide Deposition Limits for Evacuation and Restrictions on Farming, Ci/m^2

	Evacuation		*Restrictions on Farming*	
Isotope	*Direct Radiation*	*Inhalation*	*First Year*	*Long Term*
^{90}Sr	-	2×10^{-4}	4×10^{-5}	2×10^{-4}
^{137}Cs	3×10^{-5}	1×10^{-3}	2×10^{-6}	8×10^{-5}
$^{238,239}Pu$	-	1×10^{-7}	-	-

TABLE V-19

Radiation Dose Criteria

Evacuation Limits	
External Irradiation	10 rem to whole body in 30 years
Inhalation	75 rem to critical organ in 50 years
Farming Restrictions (Short Term)	
^{90}Sr	5 rem to bone marrow in first year[a]
^{137}Cs	5 rem to whole body in first year[a]
Farming Restrictions (< 1 year)	
^{90}Sr	(5 rem to bone marrow in 50 years)/year
^{137}Cs	(1 rem to whole body in 50 years)/year

---

a. The 50-year dose commitments due to these exposures in the first year are about 25 rem to the bone marrow from ^{90}Sr and 5 rem to the whole body from ^{137}Cs. (Almost all the dose from ^{137}Cs is received in the year in which it is ingested.)

Only two operational modules have potential for causing off-site land contamination for any of the abnormal events considered. These two are sabotage during removal of waste from tanks (common to all three alternative plans), and sabotage during processing waste to glass (unique to Alternative 2). The consequences, if each of these events did occur, are given in Tables V-20 and V-21, respectively, in terms of land contaminated and people evacuated.

TABLE V-20

Contamination Effects from Sabotage During Removal of Waste from Tanks

Distance from Release, km	*Acres Requiring Decontamination*	*People Moved*
15-20	8.5×10^3	2.2×10^3
20-25	1.1×10^4	3.2×10^2
25-30	1.3×10^4	0
30-35	1.6×10^4	0
35-40	1.8×10^4	0
40-45	2.1×10^4	0
45-50	2.3×10^4	0
50-55	2.5×10^4	0
55-60	0	0
Total Offsite	1.3×10^5	2.5×10^3

TABLE V-21

Contamination Effects from Sabotage During Waste Processing

Distance from Release, km	*Acres Requiring Decontamination*	*People Moved*
15-20	8.5×10^3	0
20-25	0	0
Total Offsite	8.5×10^3	0

TABLE V-22

Dose to Individual Drinking River Water and/or Eating Fish after Runoff from Decontaminated Salt Tanks Damaged by an Earthquake[a]

Nitrate-Nitrite Concentrations	0.027% EPA drinking water limit
Mercury Concentrations	0.13% EPA drinking water limit
Individual Whole Body Dose, Drinking Water	0.17 mrem/yr
Individual Bone Dose, Drinking Water	0.08 mrem/yr
Individual Whole Body Dose, Eating Fish[b]	11 mrem/yr

Population Dose Risk over 105-Year Period[c]	7.2 man-rem

a. Assumes the amount of residual radioactivity in the tanks after decontamination is equal to or less than the radionuclide content of the salt and that 10% or less of the residual activity is transferred to the salt. Also assumes 25% of the tanks containing salt are damaged and 10% of the salt and radionuclides released from the tanks reach the river.

b. Assumes this individual eats 25 pounds of fish per year. The present commercial fishing industry could supply about 200 such people.

c. Based on a probability of 10^{-3}/yr for an earthquake of intensity of MM IX which is required to damage the tanks containing salt. Assumes 25% of the tanks are damaged. Estimates show that 100 years are required for rainwater entering the tanks to dissolve the salt and empty the tanks. Also assumes the population drinking water and eating fish caught commercially increases by a factor of 5 during the period.

be used for any purpose with a restriction which would prohibit drilling, mining, or any other action that would breach the caverns.

If the alternative to continue storing high-level waste in tanks is chosen, approximately 50 acres of land will have to be committed every 50 to 100 years to build new tanks to replace the existing tanks. Presumably, however, when the tanks are emptied every 50 to 100 years, they could be decontaminated and dismantled so the site could be used for the next generation of tanks; if this can be accomplished, additional land will not have to be committed for waste tanks.

TABLE VII-1

Irreversible and Irretrievable Commitment of Resources[a]

	Continue Tank Farm Storage	*Glass Form to a Federal Repository*			*Liquid to Bedrock*
		Offsite Geological	*Onsite Surface*	*Onsite Geological*	
Land, acres	80[b]	100[c]	125	100[d]	10[d]
Concrete, cubic yards × 10^3	375[e]	100	125	125	25
Carbon steel, tons × 10^3	70	20	25	25	5
Stainless steel, tons × 10^3	5	10	10	10	1
Electricity, MW-hr × 10^3	350[e]	900	900	900	40
Coal, tons × 10^3	150[e]	600	600	600	10
Cost, billions of 1980 dollars	0.510	3.60	3.75	3.61	0.755

a. Estimates based on experience with similar facilities; assumes 10 years of glass-forming operations.

b. Assumes old tanks are dismantled after they are emptied and new tanks are built in same area.

c. Glass-forming plant only; excludes land for offsite Federal repository.

d. Excludes surface restriction prohibiting drilling or mining.

e. Assumes replacing tanks five times in the first 300 years and maintaining surveillance for 300 years.

TABLE XI-1

Radionuclide Deposition Limits for Evacuation and Restrictions on Farming, Ci/m^2

Isotope	*Evacuation* Direct Radiation	Inhalation	*Restrictions on Farming* First Year	Longer
^{90}Sr	-	2×10^{-4}	4×10^{-5}	2×10^{-4}
^{137}Cs	3×10^{-5}	1×10^{-3}	2×10^{-6}	8×10^{-5}
$^{238,239}Pu$	-	1×10^{-7}	-	-

TABLE XI-2

Radiation Dose Criteria

Evacuation Limits	
External Irradiation	10 rem to whole body in 30 years
Inhalation	75 rem to critical organ in 50 years
Farming Restrictions (Short Term)	
^{90}Sr	5 rem to bone marrow in first year[a]
^{137}Cs	5 rem to whole body in first year[a]
Farming Restrictions (>1 year)	
^{90}Sr	(5 rem to bone marrow in 50 years)/year
^{137}Cs	(1 rem to whole body in 50 years)/year

a. The 50-year dose commitments due to these exposures in the first year are about 25 rem to the bone marrow from ^{90}Sr and 5 rem to the whole body from ^{137}Cs. (Almost all the dose from ^{137}Cs is received in the year in which it is ingested.)

TABLE XI-3

Contamination Effects from Sabotage During Removal of Waste from Tanks

Distance from Release, km	*Acres Decontaminated*	*People Moved*
15-20	8.5×10^3	2.2×10^3
20-25	1.1×10^4	3.2×10^2
25-30	1.3×10^4	0
30-35	1.6×10^4	0
35-40	1.8×10^4	0
40-45	2.1×10^4	0
45-50	2.3×10^4	0
50-55	2.5×10^4	0
55-60	0	0
Total Offsite	1.3×10^5	2.5×10^3
Cost	$\$3.0 \times 10^7$	$\$1.2 \times 10^7$

TABLE XI-4

Contamination Effects from Sabotage During Waste Processing

Distance from Release, km	*Acres Decontaminated*	*People Moved*
15-20	8.5×10^3	0
20-25	0	0
Total Offsite	8.5×10^3	0
Cost	$\$2.0 \times 10^6$	

TABLE XI-5

Summary of Costs and Exposure Risks for Alternative 1:
Storage of Waste as Sludge and Damp Salt Cake in Onsite Waste Tanks
(Present SRP Waste Management Technique)

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks	Not applicable	Not applicable	Not applicable
Processing	Not applicable	Not applicable	Not applicable
Transportation	Not applicable	Not applicable	Not applicable
Storage			
Routine Releases	1.4	1.0	1.4
Spill During Transfer	5.3×10^{2}	5.0×10^{-3}	2.6
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage by Dispersal	2.3×10^{4}	1.0×10^{-5}	2.3×10^{-1}
Sabotage by Explosion	9.8×10^{3}	1.0×10^{-5}	9.8×10^{-2}
Airplane Crash	1.1×10^{4}	1.0×10^{-5}	1.1×10^{-1}
Abandonment	2.7×10^{4}	1.0×10^{-5}	2.7×10^{-1}

Time-Integrated Risk, man-rem (300 years) (with abandonment)	2.4×10^{4}
Risk Value at $1000/man-rem, millions	$24
Budgetary Cost, millions	$510
Total Cost, millions	$534
Incremental Cost-Risk, dollars/man-rem	(Base Case)
Time-Integrated Risk, man-rem (10,000 years)	2.3×10^{3}
Natural Background Exposure, man-rem (10,000 years)	1.0×10^{10}
Possible Waste Management Health Effects	0.5
Health Effects from Natural Background	2,000,000

TABLE XI-6

Summary of Costs and Exposure Risks for Alternative 2-Subcase 1: Glass Stored in Offsite Geologic Storage and Decontaminated Salt Cake Stored in Onsite Underground Waste Tanks

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0×10^{-5}	1.7
Processing			
Routine Releases	3.0	1.0	3.0
Process Incidents	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation			
Routine Exposures	6.3×10^{1}	1.3×10^{-4}	6.3×10^{1}
Accidents	1.2×10^{2}	2.1×10^{-5}	1.6×10^{-2}
Storage			
Expected Releases	1.3×10^{2}	1.0	1.3×10^{2}

Time-Integrated Risk, man-rem (300 yr)	6.5×10^{2}
Risk Value at $1000/man-rem, millions	0.65
Budgetary Cost, millions	$3600
Total Cost, millions	$3600.7
Incremental Cost-Risk, dollars/man-rem	$132,000
Time-Integrated Risk, man-rem (10,000 yr)	6.5×10^{2}
Natural Background Exposure, man-rem (10,000 yr)	1.0×10^{10}
Possible Waste Management Health Effects	0.1
Health Effects from Natural Background	2,000,000

TABLE XI-7

Summary of Costs and Exposure Risks for Alternative 2-Subcase 2: Glass Stored in Onsite Surface Storage Facility and Decontaminated Salt Cake Returned to Onsite Waste Tanks

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0×10^{-5}	1.7
Processing			
Routine Releases	3.0	1.0	3.0
Process Incidents	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation		Not Applicable	
Storage			
Sabotage	3.8×10^{3}	1.0×10^{-5}	3.8×10^{-2}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Abandonment	0	-	0

Time-Integrated Risk, man-rem (300 yr)	2.2×10^{2}
Risk Value at $1000/man-rem, millions	$0.22
Budgetary Cost, millions	$3750
Total Cost, millions	$3750.2
Incremental Cost-Risk, dollars/man-rem	$135,000
Time-Integrated Risk, man-rem (10,000 yr)	3.4×10^{2}
Natural Background Exposure, man-rem (10,000 yr)	1.0×10^{10}
Possible Waste Management Health Effects	0.07
Health Effects from Natural Background	2,000,000

TABLE XI-8

Summary of Costs and Exposure Risks for Alternative 2-Subcase 3: Glass Disposed of in SRP Bedrock and Decontaminated Salt Cake Stored in Onsite Underground Waste Tanks

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0 x 10-5	1.7
Processing			
Routine Releases	3.0	1.0	3.0
Process Incidents	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation		Not Applicable	
Storage			
Expected Releases	1.3×10^{2}	1.0	1.3×10^{2}

Time-Integrated Risk, man-rem (300 yr)	3.4×10^{2}
Risk Value of $1000/man-rem, millions	$0.34
Budgetary Cost, millions	$3610
Total Cost, millions	$3610.3
Incremental Cost-Risk, dollars/man-rem	$129,000
Time-Integrated Risk, man-rem (10,000 yr)	3.4×10^{2}
Natural Background Exposure, man-rem (10,000 yr)	1.0×10^{10}
Possible Waste Management Health Effects	0.07
Health Effects from Natural Background	2,000,000

TABLE XI-9

Summary of Costs and Exposure Risks for Alternative 3: Unprocessed Waste Slurry Disposed of in SRP Bedrock

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0×10^{-5}	1.7
Processing		Not Applicable	
Transportation		Not Applicable	
Storage			
Expected Releases	1.3×10^{2}	1.0	1.3×10^{2}
Earthquake With Shaft Open	3.8×10^{8}	3.3×10^{-5}	1.3×10^{4}
Earthquake After Sealing	8.3×10^{6}	3.3×10^{-6}	2.8×10^{1}
Sabotage Before Sealing	1.5×10^{9}	1.0×10^{-5}	1.5×10^{4}
Sabotage After Sealing	1.4×10^{7}	3.3×10^{-10}	4.6×10^{-3}
Time-Integrated Risk, man-rem (300 yr)		6.2×10^{4}	
Risk Value at $1000/man-rem, millions		$62	
Budgetary Cost, millions		$755	
Total Cost, millions		$817	
Incremental Cost-Risk		-$6500[a]	
Time-Integrated Risk, man-rem (10,000 yr)		1.4×10^{5}	
Natural Background Exposure, man-rem (10,000 yr)		1.0×10^{10}	
Possible Waste Management Health Effects		28	
Health Effects from Natural Background		2,000,000	

a. The negative value indicates this alternative is more expensive and has higher risk than Alternative 1.

TABLE XI-11

Corrective Actions for Typical Events

	Type of Corrective Action	Cost of Corrective Action, $
Air-Cooled Vault with Glass		
Sabotage with conventional explosives	A	3×10^6
Airplane crash	A	3×10^6
Tank Farm		
Abandonment	B	2×10^6
Sabotage by spraying	A & B	5×10^6
Sabotage with conventional explosives	A & B	5×10^6
Airplane crash	A & B	5×10^6
Triassic Cavern		
Expected releases	None required	---
Explosion in cavern	None required	---
Earthquake with open shaft	D	2.0×10^7
Earthquake after sealing	C	2.5×10^7
Sabotage with conventional explosives	D	2.0×10^7
Sabotage by drilling	None applicable	---

TABLE XII-1

Quantifiable Environmental Impacts

	Alternative 1	*Alternative 2*			*Alternative 3*
	Alternative 1 Continued Tank Farm Operation	*Subcase 1 Glass Shipped to Offsite Repository*	*Subcase 2 Glass in SRP Surface Storage*	*Subcase 3 Glass in SRP Bedrock*	*Alternative 3 Liquid in SRP Bedrock*
Occupational Radiation Exposures Based on SRP Experience, man-rem[a]	360	3,800	2,700	2,400	42
Occupational Radiation Exposures Based on DOE Standards, man-rem[a]	4,300	30,000	32,000	28,000	500
Offsite Population Dose Risk, man-rem[b] (300 yr)	1,400	650	220	340	62,000
Offsite Population Dose Risk, man-rem[b] (10,000 yr)	2,300	650	340	340	140,000
Offsite Population Dose, man-rem (300 years)	230,000,000	230,000,000[d]	230,000,000	230,000,000	230,000,000
From Natural Radiation, man-rem (10,000 years)[c]	7,700,000,000	7,700,000,000	7,700,000,000	7,700,000,000	7,700,000,000
Potential for Accidental Offsite Land Contamination (from Sabotage), acres	130,000	139,000	139,000	139,000	130,000
Non-Nuclear Accidental Fatalities from Construction and Operations	17.1	6.5	6.6	6.2	2.2
Budgetary Cost, millions of 1980 dollars	510	3,600	3,750	3,610	755

a. Campaign totals for all workers.

b. Consequences times probabilities, summed over all events and integrated for 300 years and 10,000 years.

c. For the same time period and population as above.

d. The natural radiation calculations assume the population distribution around the offsite repository would be the same as around the SRP site. This is conservative, because the offsite repository would probably be located in a sparsely populated region.

TABLE XII-2

Summary of Unquantifiable Factors

	Alternative 1	*Alternative 2*			*Alternative 3*
	Continued Tank Farm Operation	*Subcase 1* *Glass Shipped to Offsite Repository*	*Subcase 2* *Glass in SRP Surface Storage*	*Subcase 3* *Glass in SRP Bedrock*	*Liquid in SRP Bedrock*
Relative Degree of Action Required by Future Generations	High	Low	Moderate	Low	Low
Relative Compliance with Public Expectations[a]	Low	High	Moderate	High	Moderate
Conformance with Policies of SC and GA State Governments	Low	High	Moderate	Low	Low
Conformance with NRC Regulations for Commercially-Generated Waste	Low	High	Moderate	High	Low
Potential for Regrets if Future Economics or Technology Indicates a Better Method[b]	Low	High	Moderately High	High	High
Likelihood of Successful Attainment of Required Implementation Technology	Highest	High	Higher	Moderate	Moderate
Effect on Implementation Date Relative to Alternative 2 — Subcase 1	Shortens	-	None	Lengthens	Lengthens
Requires Additional Management of Decontaminated Salt	No	Yes	Yes	Yes	No

a. Based on pre-draft comments and proceedings of DOE and EPA meetings on public policy issues. Also documented in Reference 2.

b. This factor involves both the ease of retrievability from the storage or disposal site and the ease of separating the radioactive constituents from the waste form.

TABLE XII-3

Summary of Long-Term and Short-Term Costs and Nuclear Risks

		Alternative 2			
	Alternative 1 Continued Tank Farm Operation	Subcase 1 Glass Shipped to Offsite Repository	Subcase 2 Glass in SRP Surface Storage	Subcase 3 Glass in SRP Bedrock	Alternative 3 Liquid in SRP Bedrock
Short-Term Risks,[a] man-rem	0[a]	4.60×10^3	2.57×10^3	2.57×10^3	2.19×10^2
Long-Term Risks,[b] man-rem	1.76×10^3 2.66×10^3	1.30×10^2 1.30×10^2	2.91 1.20×10^2	1.30×10^2 1.30×10^2	6.2×10^4 1.4×10^5
Short-Term Costs,[c] millions of 1980 dollars	0[a]	3600	3750	3610	755
Long-Term Costs,[b,c] millions of 1980 dollars	510[d] 3060[e] 102,000	175	175	175	175

a. Short-term risks are defined to be those that are incurred from activities additional to preparing the waste as salt cake and sludge in modern tanks, because such activities are common to all alternatives. Short-term costs are treated similarly.

b. Long-term risks and costs are integrated for 300 years and for 10,000 years.

c. All costs are in undiscounted 1980 dollars. Discounting of long-term costs would reduce their magnitudes to negligible fractions of short-term costs for any alternative.

d. This is enough for one cycle of tank replacement, and is more than enough to establish a trust fund for perpetual tank replacement.

e. This is enough to replace tanks every 50 years during the 300-year period or the 10,000-year period, undiscounted.