TABLE OF CONTENTS

Volume 1

Volume 1A

Volume 2

Volume 9

Volume 9A

Volume 9B

Volumes 10 and 11

miles of the proposed disposal site. These "dry wells" provide evidence that significant oil and gas reserves are unlikely in the area.

Sand and gravel are being produced for aggregate at an area approximately one-half mile west of the WCS Site. The operation includes crushing of caliche as well as screening and crushing of sands, gravels, and paleo-channel deposits. Subsurface exploration in the immediate vicinity of the proposed disposal site has not identified any economically viable deposits of sand and gravel. Caliche is widely available over the entire Southern Plains Region, and there is no economic incentive for caliche mining at the Site.

No other natural resources or other incentives for resource exploration are known to exist at the Site. In addition, the lack of exploitable surface water and groundwater resources in the area also serves as a disincentive for additional resource exploration.

2.8.2 *Failure to Meet Performance Objectives*

Demonstrate that the selected disposal site avoids areas that have known natural resources which, if exploited, would result in failure to meet the performance objectives of 30 TAC §336.723. [30 TAC §336.728(c)]

As discussed in Section 2.8.1, the proposed disposal site is located in an area that has been extensively investigated for oil and gas resources. Additional information has been evaluated for other natural resources including groundwater, caprock, and sand and gravel exploitation. The results of the assessment of the resource availability and economics associated with obtaining these resources at the proposed disposal site have been demonstrated to be non-beneficial, both from a resource and economic perspective. There are currently no incentives, nor are there expected to be in the future, for the exploitation of groundwater, oil and gas, or sand and gravel at the Site. Since the proposed disposal site is not attractive from a resource perspective, it is not likely that an inadvertent intruder (e.g., well driller) would disturb either the surface or subsurface to exploit potential resources. Thus, while the proposed WCS disposal Site is located in an area of known natural resources, the presence of these resources is not likely to result in failure of the proposed disposal facilities to meet the performance objectives, including the protection against inadvertent intruders and the protection of long-term site stability.

2.9 Ecology

2.9.1 *Description of Site Ecology*

Describe and quantify area and site characteristics including ecology [THSC §401.233(b)] & [30 TAC §336.708(a)(3)]

This text below includes a summary of the ecological assessment reported in the Section 2.2 of the Environmental Report (Appendix 11.1.1). The complete ecological assessment, including March and October 2004 survey updates are included in Appendix 2.9.1 and summarized in section 2.2 of Appendix 11.1.1.

5.0 OPERATION

5.1 Waste Receipt, Inspection, and Acceptance

5.1.1 Types of Radioactive Material

Describe the types, chemical and physical forms, quantities, classification, and specifications of the radioactive material proposed to be received, possessed, processed, and disposed of at the land disposal facility. The description shall include any prior disposal containing radioactive material at the site. The description shall include performance criteria for form and packaging of the waste or radioactive material that has been previously received and will be received. [THSC §401.112(a)(8)] & [30 TAC §§336.707(6), 305.45(a)(8)(B)(ii)]

Waste to be received at the facility is described in Section 8.2 of this Application, including physical and chemical forms, waste classification (i.e., Class A, B, or C), and generator profile information.

LLRW is generated from various commercial, industrial, utility, and government operations. Waste forms are similar to industrial solid waste, and range from heterogeneous debris streams, (e.g., decontamination wipes, protective sheeting, contaminated tools) to more homogenous wastes (e.g., specialty sorbents, ion exchange resins, contaminated soil, construction rubble, contaminated structural items).

LLRW is classified by federal and state regulations based on activity of various radioisotopes. The major volume of waste produced by generators is designated Class A, and represents 75% to 90% of the overall volume expected at each proposed facility.

The Compact Waste Facility (CWF) will accept commercial radioactive materials from within Texas and other compact states, and will not accept mixed waste (LLRW with hazardous characteristics or constituents regulated under RCRA). Waste receipts over the facility lifetime are estimated to be 2,800,000 cubic feet (100,000 cu. yd.). Historical trending and generator forecasting suggests that approximately 90% of the Compact facility waste volume will be Class A, 9% will be Class B, and approximately 1% will be Class C. All waste will be stabilized prior to placement in the Compact disposal cell using concrete canisters and grout, which translates to a disposal placement efficiency of about 30%.

The Federal Waste Facility (FWF) will accept radioactive materials from government facilities and actions, and is expected to accept a combination of LLRW and mixed waste. Federal facility waste volumes are expected to be significantly greater than the compact facility, and the overall disposal cell volume is limited to 6M cu. yds. (4.6M cu. meters.) in two phases based on 30 TAC 336.905. The design of the federal facility is intended to satisfy requirements for all disposals in one cell.

Approximately 99% of the Federal waste will have nuclides with half lives greater than 35 years and therefore will require structural stability to Class B requirements according to 30 TAC 336.362. A

8.0-1 TEXAS COMPACT INVENTORY

8.0-1.1 Introduction

This Appendix describes the waste to be disposed of at the Texas Compact facility. The waste is described in terms of its physical and chemical form, quantity, packaging, and classification. The waste inventory is the basis of the performance assessment calculations for the Compact disposal facility, including the calculations of radionuclide release, transport in the environment, and potential exposures to humans.

8.0-1.2 Waste Generators and Volumes

The Texas Compact facility will receive low-level radioactive waste (LLRW) from states in the Texas Compact. The Texas Compact Commission has the authority to enter into contracts with other states or Compacts and admit other states to the Texas Compact. Past waste projections have assumed the Texas Compact consists of Texas, Maine, and Vermont. In this analysis, waste volume and activities are based on past projections for the Texas Compact, except that all wastes from the Maine Yankee reactor have been excluded. Other generators in Maine are included, but their effect on the total waste volume and activity is minimal.

The Texas Compact facility was assumed to have a 35-year operational life. Waste generators in the Texas Compact will produce an estimated volume of 2.8 million cubic feet of LLRW over a period of 35 years. The total activity is estimated at 4.7 million curies. The Texas Compact facility will dispose of only LLRW; no mixed LLRW will be accepted. Waste from operations of nuclear electric utilities and all other identified generators in the Texas Compact is estimated at 870,000 cubic feet. Waste from the decommissioning of nuclear power plants is estimated at 1.9 million cubic feet. The decommissioning volume includes the decommissioning of the Vermont Yankee reactor, the two reactors of the South Texas Project, and the two Comanche Peak reactors. Vermont Yankee was assumed to operate until 2012. The South Texas Project reactors were assumed to operate until 2027 (Unit 1) and 2028 (Unit 2). The Comanche Peak reactors were assumed to operate until 2030 (Unit 1) and 2033 (Unit 2).

Waste volume projections for the Texas Compact facility are based on generator surveys documented in the report "Texas Compact Low-Level Radioactive Waste Generation Trends and Management Alternatives Study," August 2000. The waste volume projections are based on a time span of 35 years for two reasons. First, information is readily available for that time period and, second, 35 years is long enough to reasonably allow the inclusion of all reactor decommissioning waste from the Texas Compact. A shorter time period would have ignored significant volumes of reactor decommissioning waste, much of which will be generated after 2030. Alternatively, a time span longer than 35 years introduces greater uncertainty in the waste estimates without adding any waste types that differ from those currently being generated. Estimates of waste generated beyond 35 years would necessarily be simple extrapolations of current waste generation practices.

Both operational and decommissioning wastes are included in the Texas Compact inventory. Operational wastes are generated by nuclear utilities, hospitals, research and educational institutions, industries, and the military. Some waste generated by the military would be appropriate for disposal at the Federal Facility. The Texas Compact facility would receive waste from military generators only if they are NRC licensees. Decommissioning wastes are generated by the three nuclear utilities in the Texas Compact when the power reactors have reached the end of their operating licenses.

The potential waste generators in the Texas Compact have been identified and are listed in Table 8.0-1-1. The generators are in five general categories: electric power utilities, academic institutions, military, medical, and industrial facilities.

Table 8.0-1-1. Waste generators in the Texas Compact.

GENERATOR TYPE	GENERATOR NAME	STATE
Electric Utility	South Texas Project Electric Generating Station	Texas
	Comanche Peak Steam Electric Station	Texas
	Vermont Yankee Nuclear Power Station	Vermont
	Maine Yankee Nuclear Power Station	Maine
Medical	Baylor College of Medicine	Texas
	University of Texas Health Science Center at Houston	Texas
	University of Texas Health Science Center at San Antonio	Texas
	Veterans' Affairs Medical Center of Houston	Texas
	University of Texas Health Science Center at Tyler	Texas
	Texas Department of Health	Texas
	Veterans' Affairs Medical & Regional Center of White River Junction	Vermont
	Vermont Department of Health	Vermont
	University of Texas Medical Branch of Galveston	Texas
	Texas Tech University Health Science Center	Texas
	University of Texas, M.D. Anderson Cancer Center	Texas
Academic	Colby College	Maine
	Middlebury College	Vermont
	Texas A & M University in College Station	Texas
	University of Texas at Austin	Texas
	University of Texas at Arlington	Texas
	University of Texas at San Antonio	Texas
	Texas A & M University – Nuclear Science Center	Texas
	University of Vermont	Vermont
	University of Houston	Texas
Military	U.S. Navy Portsmouth Naval Shipyard	Maine
	All other military installations in Texas Compact member states	TX, VT, ME
Industrial	Rhodia, Inc.	Texas
	Mount Desert Island Biological Laboratory	Maine
	Southwest Research Institute	Texas
	Radiation Technology	Texas
	Texas Instruments	Texas
	IDEXX Laboratories	Maine
	TN Technologies	Texas
	Baker Atlas	Texas
	Jackson Laboratory	Maine
	International Isotopes	Texas

Table 8.0-1-7. Total radionuclide inventory at the Texas Compact facility.

Radionuclide	Total Inventory (Ci)
H-3	1.11E+04
Be-7	4.51E+01
C-14	1.66E+03
Na-22	2.30E-01
P-32	1.21E+01
S-35	6.93E+00
Cl-36	7.76E-02
Ca-45	9.85E-02
Sc-46	4.43E-01
Cr-51	4.70E+02
Mn-54	4.12E+04
Fe-55	5.41E+05
Fe-59	1.41E+01
Co-56	1.59E-04
Co-57	2.39E+02
Co-58	1.73E+04
Co-60	3.67E+06
Ni-59	2.70E+03
Ni-63	3.68E+05
Zn-65	7.85E+02
Ge-68	2.14E-04
Se-75	4.96E-03
Kr-85	1.46E+02
Rb-86	8.75E-02
Sr-85	7.04E-02
Sr-89	0.00E+00
Sr-90	2.63E+02
Y-88	3.17E-06
Zr-95	1.08E+03
Nb-94	1.26E+01
Nb-95	1.30E+03
Tc-99	3.37E-01
Ru-103	8.81E-02
Ru-106	0.00E+00
Ag-110m	1.29E+00
Cd-109	1.21E+01
In-111	1.25E-01
Sn-113	3.85E-02
Sb-124	4.32E+00
Sb-125	2.46E+02
I-125	8.77E+01
I-129	2.78E-04
I-131	5.65E+01
Cs-134	5.54E+02
Cs-135	0.00E+00
Cs-137	4.27E+04
Cs-139	1.94E-08
Ba-133	7.15E-03
Ba/La-140	1.03E+01
Ce-141	1.40E-01
Ce-144	9.47E+02
Pm-147	3.41E+01
Eu-152	6.34E-06
Gd-153	4.86E-03
Hf-175	3.88E-03
W-178	1.33E-03
Ta-182	3.88E-03
Re-187	3.88E-03
Ir-192	4.77E+00
Au-198	3.96E+00
Hg-208	1.67E-08
Ra-226	9.65E+03
Ra-228	8.69E-03
Th-230	1.41E-01
Th-232	1.28E+00
U-232	4.32E-06
U-233	3.31E-09
U-234	2.17E-02
U-235	4.29E-05
U-236	1.93E-05
U-238	2.02E-01
Np-237	3.31E-07
Pu-238	1.21E+01
Pu-239	6.06E-01
Pu-241	3.43E+02
Pu-242	1.00E-01
Am-241	5.31E+01
Am-243	5.08E-09
Cm-242	1.77E-02
Cm-243/244	4.58E-02

Table 8.0-2-4. Radionuclide concentrations by waste stream.

	WM Waste Streams																		
Concentration (Ci/m³)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Waste type:	Mixed	LLRW	Mixed	Mixed	LLRW	Mixed	Mixed	Mixed	LLRW	Mixed	Mixed	Mixed	LLRW	LLRW	Mixed	Mixed	LLRW	Mixed	Mixed
Class:	A	A	A	A	A	A	A	A	C	A	A	B	B	A	C	A	B	A	A
Al-26											8.50E-09								
Am-241		1.03E-03	1.11E-02	1.11E-02	8.00E-06			3.45E-05	1.91E-04	5.12E-06	2.11E-03	2.83E-05	2.83E-05	2 68E-05	1.35E-02		3.10E-05	6 86E-07	6 86E-07
Am-243		5.97E-05	4.81E-05	4.81E-05				1.21E-07	4.28E-07		1.38E-07	1.46E-08	1.46E-08				4.45E-05		
Ba-133		1.47E-06							3.91E-06		5.32E-09						4.55E-04		
C-14		1.75E-08	4.75E-07	4.75E-07		4.99E-06		8.26E-05	2.06E-01	3.49E-04	4.20E-05	1.68E-04	1.68E-04		1.08E-05	9.00E-05	2.83E-04		
C-14(act met)																			
Cd-113m					9.00E-07				3.57E-03	1.22E-05	2.56E-07			1.85E-07	4.32E-04				
Cl-36									1.69E-04										
Cm-243		1.01E-04	1.74E-05	1.74E-05					1.11E-07										
Cm-244		7.80E-06			2.50E-07				1.46E-05	2.43E-08							1.69E-04		
Co-60		1.66E-02	3.08E-03	3.08E-03	9.50E-04	1.17E-05		6.97E-01	4.87E+02	1.21E-02	4.26E-04			2.44E-07	2.15E-04		2.12E-01	1.70E-07	1.70E-07
Cs-135																			
Cs-137		4.18E-03	1.83E-03	1.83E-03	1.00E-03	7.60E-02		4.81E-02	2.79E+00	1.08E-01	2.23E-04	3.34E-03	3.34E-03	7.56E-05	1.65E-01		1.43E+00	9 07E-06	9.07E-06
Eu-152		3.53E-08	5.78E-07	5.78E-07					5.35E-01	3.42E-04	6.73E-04			2.93E-08	6.64E-03		1.16E-01		
Eu-154		1.96E-05	7.53E-07	7.53E-07	2.00E-05				5.34E-01	9.85E-04	8.76E-05			5.12E-07	1.20E-03		3.81E-03		
H-3		3.05E-01	7.86E-04	7.86E-04	8.00E-06	4.66E-01		1.26E-03	1.67E+02	8.71E-06	6.31E+02	8.51E+01	8.51E+01	6.83E-06	2.40E-02	9.00E-04	2.40E+01	2.55E-04	2.55E-04
I-129								1.57E-06	9.81E-06		9.45E-10						6.47E-08		
K-40			9.18E-05	9.18E-05					1.29E-03	3.53E-04	2.89E-07				1.12E-04		1.26E-05		
Nb-93m									1.94E-02										
Nb-94									8.63E-04		2.70E-08								
Ni-59					8.00E-06				2.61E+00		4.50E-05						9 32E-07		
Ni-63		1.64E-01	3.60E-04	3.60E-04	3.50E-04			1.29E+00	9.25E+01	6.68E-06							3 80E+00		
Np-237		2.79E-05	2.30E-05	2.30E-05				1.47E-06	1.11E-05	2.54E-06	4.73E-07	6.30E-07	6.30E-07				1.17E-05	9.98E-04	9 98E-04
Pa-231														4.39E-05				1.17E-07	1.17E-07
Pu-238		1.64E-04	1.65E-04	1.65E-04	2.00E-06			5.67E-06	5.87E-05	8.77E-07	1.57E-03	1.52E-05	1.52E-05	5.37E-05			1.01E-05	3.04E-07	3 04E-07
Pu-239		9.12E-04	6.73E-04	6.73E-04	4.50E-05			8.51E-05	1.61E-04	7.03E-07	3.13E-03	1.19E-05	1.19E-05	4.63E-04	1.67E-01		1.10E-05	3.27E-05	3.27E-05
Pu-240		1.51E-03	4.64E-04	4.64E-04	5.00E-05			1.47E-05	1.33E-05		4.46E-06			6.34E-07			6 61E-05		
Pu-241		2.32E-03	5.58E-02	5.58E-02	8.50E-04			1.92E-03	4.96E-04		6.62E-05						6.32E-09		
Pu-242		1.96E-06	3.08E-07	3.08E-07				1.62E-09	1.06E-08		2.81E-10						1.68E-08		
Pu-244			1.12E-05	1.12E-05															
Ra-226		4.30E-06	9.55E-06	9.55E-06					1.26E-03	1.26E-03	1.16E-08			9.27E-03	3.63E-04		1.49E-04		
Ra-228											7.77E-07			5.61E-06	3.26E-05		1.01E-05		
Se-79																			

Table 8.0-2-4. Radionuclide concentrations by waste stream (continued).

	ER WASTE STREAMS															
[illegible] CONCENTRATION (Ci/m³)	[illegible] ANL LLRW RUBBLE/DEBRIS [illegible]	[illegible] ANL MLLRW LA-4 PROFILE [illegible]	[illegible] LAWRENCE BERKELEY (DEFAULT NTS) [illegible]	[illegible] OAK RIDGE MLLRW [illegible]	[illegible] OAK RIDGE LLRW [illegible]	[illegible] PADUCAH DEBRIS COMMERCIAL [illegible]	[illegible] PADUCAH LLRW COMMERCIAL [illegible]	[illegible] PADUCAH MLLRW DEBRIS TBD [illegible]	[illegible] PANTEX LLRW [illegible]	[illegible] PORTSMOUTH SLUDGE COMMERCIAL [illegible]	[illegible] PORTSMOUTH SLUDGE TBD [illegible]	[illegible] ROCKY FLATS MLLRW SOLIDS [illegible]	[illegible] MOUND LAB [illegible]	[illegible] SALMON SITE (DEFAULT NTS) [illegible]	[illegible] SANDIA MLLRW (DEFAULT NTS) [illegible]	[illegible] SPRU SOIL/RUBBLE (DEFAULT NTS) [illegible]
Waste type:	LLRW	Mixed	Mixed	Mixed	LLRW	Mixed	LLRW	Mixed	LLRW	Mixed	Mixed	Mixed	LLRW	Mixed	Mixed	LLRW
Class:	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Am-241			2.68E-05			7.75E-05	7.75E-05	7.75E-05	1.88E-09			1.05E-05	5.02E-04	2.68E-05	2.68E-05	2.68E-05
Cd-113m			1.85E-07											1.85E-07	1.85E-07	1.85E-07
Co-60			2.44E-07			2.66E-06	2.66E-06	2.66E-06						2.44E-07	2.44E-07	2.44E-07
Cs-137			7.56E-05	3.74E-05	3.74E-05	7.58E-06	7.58E-06	7.58E-06	1.13E-08			8.26E-08	9.01E-08	7.56E-05	7.56E-05	7.56E-05
Eu-152			2.93E-06											2.93E-06	2.93E-06	2.93E-06
Eu-154			5.12E-07											5.12E-07	5.12E-07	5.12E-07
H-3			6.83E-06						1.06E-02			1.71E-03	1.31E-04	6.83E-06	6.83E-06	6.83E-06
K-40									1.66E-06							
Np-237						1.13E-04	1.13E-04	1.13E-04								
Pa-231			4.39E-05											4.39E-05	4.39E-05	4.39E-05
Pu-238			5.37E-05			2.71E-06	2.71E-06	2.71E-06						5.37E-05	5.37E-05	5.37E-05
Pu-239			4.63E-04			4.75E-05	4.75E-05	4.75E-05	4.72E-09			4.40E-03	1.23E-05	4.63E-04	4.63E-04	4.63E-04
Pu-240			6.34E-07									1.13E-05	1.23E-05	6.34E-07	6.34E-07	6.34E-07
Ra-226			9.27E-03						1.90E-07			2.99E-09	3.26E-09	9.27E-03	9.27E-03	9.27E-03
Ra-228			5.61E-06						2.10E-07					5.61E-06	5.61E-06	5.61E-06
Sm-151			2.00E-06											2.00E-06	2.00E-06	2.00E-06
Sr-90			6.83E-05	3.74E-05	3.74E-05							2.30E-10	2.51E-10	6.83E-05	6.83E-05	6.83E-05
Tc-99			4.15E-05			4.94E-03	4.94E-03	4.94E-03		4.98E-05	4.98E-05			4.15E-05	4.15E-05	4.15E-05
Th-229						1.23E-04	1.23E-04	1.23E-04								
Th-230			2.68E-03			5.08E-06	5.08E-06	5.08E-06	3.75E-08					2.68E-03	2.68E-03	2.68E-03
Th-232			3.90E-04						5.91E-06					3.90E-04	3.90E-04	3.90E-04
U-233			8.78E-08									1.54E-06	1.67E-06	8.78E-08	8.78E-08	8.78E-08
U-234	7.56E-05	1.10E-07	4.63E-03	4.96E-05	4.96E-05	2.40E-01	2.40E-01	2.40E-01	5.18E-08			7.70E-05	4.26E-03	4.63E-03	4.63E-03	4.63E-03
U-235	3.72E-06	5.42E-09	2.10E-04	2.22E-06	2.22E-06	2.21E-01	2.21E-01	2.21E-01	5.43E-09	1.61E-07	1.61E-07	3.71E-06	5.02E-05	2.10E-04	2.10E-04	2.10E-04
U-236						7.19E-07	7.19E-07	7.19E-07								
U-238	8.07E-05	1.18E-07	4.63E-03	4.82E-05	4.82E-05	2.33E-01	2.33E-01	2.33E-01	1.31E-06	6.81E-04	6.81E-04	6.48E-05	1.42E-06	4.63E-03	4.63E-03	4.63E-03
Volume disposed (m³):	**560**	**3,370**	**10**	**44,000**	**20,300**	**180**	**6,100**	**8**	**610**	**870**	**156**	**60,800**	**100,000**	**790**	**190**	**8,220**

Table 8.0-2-6. Total radionuclide inventory at the Federal Facility.

RADIONUCLIDE	TOTAL INVENTORY (Ci)
Al-26	3.77E-06
Am-241	1.27E+02
Am-243	1.08E+01
Ba-133	1.15E+02
C-14	5.00E+03
Cd-113m	8.61E+01
Cl-36	4.04E+00
Cm-243	1.71E-01
Cm-244	4.85E+01
Co-60	1.17E+07
Cs-135	7.83E-04
Cs-137	7.62E+05
Eu-152	4.08E+04
Eu-154	1.37E+04
H-3	1.04E+07
I-129	1.28E+01
K-40	3.56E+01
Nb-93m	4.64E+02
Nb-94	2.07E+01
Ni-59	6.25E+04
Ni-63	3.13E+06
Np-237	8.96E+01
Pa-231	1.51E+00
Pu-238	1.48E+01
Pu-239	6.05E+02
Pu-240	2.59E+01
Pu-241	3.03E+01
Pu-242	7.91E-03
Pu-244	1.00E-03
Ra-226	3.87E+02
Ra-228	2.67E+00
Se-79	6.00E-04
Sm-151	1.05E+03
Sn-121m	1.40E+02
Sn-126	8.01E-05
Sr-90	4.40E+05
Tc-99	7.99E+02
Th-229	1.65E+00

RADIONUCLIDE	TOTAL INVENTORY (Ci)
Th-230	1.12E+02
Th-232	2.00E+01
U-232	6.64E-02
U-233	5.74E+00
U-234	2.33E+04
U-235	3.12E+04
U-236	2.91E-01
U-238	2.17E+04
Zr-93	1.78E+01
Total	2.67E+07

The results of the assessment were provided for evaluation to Dr. James Bruseth, Deputy State Historic Preservation Officer of the Texas Historical Commission. Dr. Bruseth (Bruseth, 1994) issued a determination of "no effect," indicating that the currently permitted and operating Resource Conservation and Recovery Act (RCRA)/ Toxic Substances Control Act (TSCA) landfill could proceed without affecting significant cultural resources. The cover letter, stamped and signed by Dr. Bruseth, is provided in Appendix 2.2.1 on page 3. Because the location of the proposed facility was included in the previous study, the "no effect" determination also applies to the proposed Site. An updated stamped letter (Denton, 2004) was received from the Texas Historical Commission to confirm this status, and is included in Appendix 2.2.1 on page 2. A discussion of parks and landmarks that may be of cultural importance is provided in Section 3.1.3 of Appendix 11.1.1.

<u>Current Land Use</u> - The proposed Site is situated within Andrews County, about one mile north of Texas Highway 176, and adjacent to the Texas/New Mexico state line. The WCS property consists of approximately 16,000 acres of land. Figure 2.2.1-1 in the License Application shows the location of the proposed facilities and land use within a five-mile radius surrounding the property.

The area was heavily exploited for oil and gas reserves over the last 30 years. Two producing oil wells are located approximately 1.5 miles north of the proposed disposal site on WCS property. One non-producing well is located about one-half mile southwest of the proposed Site. Livestock grazing is a seasonal activity that depends on current range conditions. The majority of the land within five miles of the Site is used for grazing and ranching activities. Other businesses in proximity to the WCS property include Wallach Quarry, Sundance, Inc., and DD Landfarm located about one mile northwest and west of the Site. The Lea County Landfill occupies approximately 40 acres and is located about one mile southwest of the proposed disposal site, adjacent to WCS-owned property. Several oil and gas wells are located to the north and west in New Mexico. The remaining land in the vicinity of the Site is used for livestock grazing or is barren, rocky, unused land.

There is a current proposal to construct a uranium enrichment facility approximately 1.5 miles to the west of the proposed facilities in Lea County, NM. The proposal was developed by Louisiana Enrichment Services and was submitted to the U.S. Nuclear Regulatory Commission (NRC) in December 2003.

Demographic, social, and economic baseline data and impact analyses for facility construction and operation phases are included in Attachment A of the Environmental Report, provided as Appendix 11.1.1. This report includes the results of a limited field investigation involving 50 interviews with residents in the Region of Interest.

Meteorology and Climatology Data - Meteorological data have been collected on the WCS Site to meet two primary goals. First, precipitation and evaporation data have been collected as required for determining a water balance for the proposed disposal site. Second, air quality data have been collected for monitoring for potential air releases.

Data were used to estimate the potential groundwater transport pathways and airborne transport routes used to estimate the dispersion of emissions from the proposed facilities and to support the performance assessment as discussed in Section 8.0. The atmospheric transport and deposition models are presented and referenced in Appendix 8.0-5, section 8.0-5.3. Data have been collected from the on-site meteorological station operated by WCS since January 2000. In addition to the on-site station, data were reviewed from four additional stations in the area to conduct a comparative analysis. The data collected from the on-site station for the period January 2000 through December 2003 are summarized in conjunction with data collected by four regional weather stations located in Andrews and Midland, Texas, and Hobbs and Jal, New Mexico in Appendix 2.3.1. The data are summarized below for precipitation, temperature and humidity, wind and atmospheric stability, and storm and natural hazard activity. These data will continue to be monitored throughout the pre-operational and operational monitoring programs.

Precipitation - The average annual rainfall for the Site recorded from January 2000 through December 2003 at the on-site station is 12.2 inches. The maximum on-site rainfall amount recorded for a 24-hour period was 2.8 inches. Snow and freezing rain data were not collected at the on-site station. Table 2.3.1-1 presents a comparison of the on-site data to Midland data for the same 3-year period.

Averages for 30 years of rainfall data for the Andrews, Hobbs, Midland, and Jal meteorological stations range from 13.6 inches (Jal) to 18.1 inches (Hobbs). Thus, all 30-year averages as well as the data collected from the on-site station show an annual rainfall less than 20 inches, a State regulatory requirement for siting the proposed facility. The maximum 24-hour rainfall recorded at the four stations over a 30-year period ranged from 3.6 inches (Jal) to 7.5 inches (Hobbs). By comparison, the 24-hour, 100-year storm event for the region calculated by NOAA is 6.1 inches (Miller et al., 1973).

Regression of WCS on-site precipitation data recorded in 15-minute intervals has provided duration (minutes) and intensity (inches) per event. An event is defined as measurable precipitation. The duration begins when rainfall is measured and ends when no rain is measured. This data was then broken into monthly frequencies for duration, intensity, and occurrences (# of events). The average annual duration was 33 minutes, with a maximum duration of 255 minutes in December. The average event intensity was .09 inches, with a maximum 2.79 inches in August. The average annual occurrences was 118 with a maximum # of events in March (44). The annual maximum occurrences are 161 and the minimum occurrences are 79.

Duration, intensity, and occurrences are summarized in Table 26a in Appendix 2.3.1.

Temperature and Humidity - The highest and lowest temperatures recorded on-site between January of 2000 and December of 2003 was 107.9 degrees F and 9.1 degrees F, respectively. The mean

2.4 Surface Water Hydrology

2.4.1 Description of Surface Hydrology

Describe and quantify area and site characteristics, including surface hydrology. [THSC §401.233(b)] & [30 TAC §336.708(a)(3)]

The WCS Site is located in a semi-arid region. There are no perennial streams flowing through or adjacent to the Site nor are there any sustainable surface water bodies within 5 miles of the Site (Figure 2.2.1-1 and Appendix 2.4.2, Wetlands Inventory Map). The principal surface water drainage area on the Site consists of a draw that crosses the southern portion of the Site. This draw crosses the WCS property about ½-mile south of the proposed disposal site and flows from east to west. The draw crosses under the access road to the southwest of the proposed site through six 29-inch by 18-inch culverts and crosses under State Highway 176 through two 43-inch by 27-inch culverts. After crossing the highway the draw continues southwest and ultimately drains into Monument Draw in New Mexico.

The surface water drainage for the entire WCS facility was evaluated. Most of the stormwater drainage that leaves the facility flows to the south and then west in the draw described above. A small portion the stormwater that drains from the facility in the northwestern and western areas flows to the west. Drainage from a large area of the northern portion of the facility flows into a playa and does not discharge via a surface route from a 100-year storm event. Figure II.F.I in the report in Appendix 2.4.1 describes the drainage areas of the facility. The report provides the methodology for determining the developed flood plain. Figure II.F.4 in the report demonstrates that the flood plain from a 100-year return frequency storm does not encroach on the site. Thus the land disposal facility will not be located in the 100-year flood plain.

Water quality analytes for Baker Springs and ephemeral on-site playas are addressed in Appendix 2.10.2-2, "Non-Radiological Environment Monitoring Plan."

2.4.2 Drainage and Flooding

Demonstrate that the disposal site is generally well drained and free of areas of flooding or frequent ponding. Waste disposal shall not take place in a 100-year flood plain, coastal high-hazard area, or wetland, as defined in Executive Order 11988, "Floodplain Management Guidelines." [THSC §401.217(4)]& [30 TAC §336.728(d)]

Surface hydrology is discussed in Section 2.4.1 and drainage for the Site is shown in Attachment F and Figure II.F.1 in Appendix 2.4.1. There are no permanent surface-water bodies or groundwater discharge areas on the Site. The combination of the low annual precipitation, permeable surface soils, high evapotranspiration, and topography results in a well-drained site. The proposed disposal site is free from areas of flooding or frequent ponding as determined by the floodplain analysis report (included as Appendix 2.4.1). The location of the disposal facility along the crest of the topographic ridge minimizes the upstream drainage area and decreases the likelihood of stormwater run-on that could erode or inundate disposal units.

There are no coastal high-hazard areas, surface water bodies, or wetlands present on the Site, or within five miles of the Site as indicated on the Wetlands Inventory Map (Appendix 2.4.2). Figure II.F.4 in Appendix

apparent offsets in local drainage, and no interruptions in the gradient of erosional terraces above Baker Spring (if, as it may be conservatively assumed, Baker Spring comprises part of the lineament). In summary, the lineaments in the vicinity of the proposed Site are considered to be erosional features.

Erosion and Mass Wasting – Two processes and potential rates of erosion were evaluated by Lehman (2000) that could lead to erosion at the Site and within the area. The first includes processes on the Southern High Plains surface, and the second involves headword erosion along the escarpment bordering the Southern High Plains. Present-day erosion features within the WCS permitted area were identified using aerial photographs and topographic maps and field reconnaissance of the area. Erosional features developed within the WCS property include several subtle surface water drainage features located to the southeast of the proposed Site. These drainage features developed along the flanks of Windmill Hill and gather surface water runoff from Windmill Hill and the ranch house area. Drainage in these features is to the west-southwest.

Other erosional features identified within the WCS property include a topographic bench and several small depressions or playas. The bench developed as an erosional feature along the preferred jointing direction in the Southern High Plains. Four small depressions or playas are located to the north of the proposed Site. The largest of these has a diameter of 1200 feet along its long axis, while the smallest is approximately 200 feet in diameter. These features were evaluated using stereoscopically paired aerial photographs from 1938 and 1981 as well as National High Altitude Photography (NHAP) color infrared aerial photographs from 1983 and 1986. The objective of this photo-geologic analysis was to determine where and how any possible changes in landforms had occurred due to erosion by examining the characteristics between different sets of aerial photographs, including shapes and sizes of drainage ways and depressions or playas and observable change in location or direction of these features. The assessment concluded that landforms on the WCS property have remained virtually static for at least the last 70 years.

There have been no observable changes in the location, direction, size, or configuration of the drainages, playas, and surface depressions at or in close proximity to the Site. As is typical of these arid climates, it is generally interpreted that active erosion processes have a minimal impact in the area. Lehman (2000) suggests that the present landscape of the Southern High Plains is in dynamic equilibrium; erosion by overland flow is balanced by deposition through runoff, and wind erosion is balanced by sediment deposition from upwind source areas. Lehman (2000) concludes that, not only is the area not subject to significant long-term erosion, the area is more likely subject to slow depositional buildup due to addition of wind-blown sand and sediments.

With respect to headword erosion, Monument Draw, New Mexico and Monument Draw, Texas is typical of the draws that cross the Southern High Plains surface. The most recent episode of incision and widening of these valleys began 20,000 years ago and ceased 12,000 years ago when sediment began aggrading in the valleys (Holliday, 1995). If in the future the draws were to begin a renewed episode of incision and widening, it would take over 160,000 years for eastward retreat of the flank of Monument Draw to approach the WCS facility. This estimate is based on the rate of erosion of about 1.18 in/yr in draws on the Southern High Plains (Lehman, 2000).

Hydrogeologic Conceptual Model – The basic geologic and hydrologic system components affecting groundwater transport including communication between water-bearing zones and recharge/discharge potential from the transmissive zones identified at the proposed disposal site are detailed in Figure 2.5.1-1. A Site Conceptual Model is included in Appendix 2.5.1.

Recharge through the ground surface will take place through precipitation in the form of rain and snow. Precipitation averaging about 14 inches per year at the Site is available to infiltrate into the subsurface. It is assumed that a relatively small percentage is removed from the surface due to run off. Surface evaporation will occur to a limited extent relative to evapotranspiration from the surface soils. The estimated annual evapotranspiration rate for the area based on the results of the calculation using the standard water balance method recommended by EPA was 36 inches. Thus, the potential water loss from the top few feet of soil down to the bottom of the root zone will be significant at the Site. The water balance estimate using the HELP model for the proposed Site is provided in the Appendix 8.0-6.

Water that penetrates through the surface sand deposits and into the root zone must then travel through the capillary fringe before entering the OAG Unit (see Figure 2.5.1-1). The OAG Unit consists of a series of undifferentiated sands, gravels, and sandstone with interbedded areas of Caprock caliche. The OAG Unit has been associated with three different geologic formations (Ogallala, Antlers, and Gatuna) that behave as a single hydrostratigraphic unit. Estimated hydraulic conductivities (K) associated with the OAG Unit range from 10^{-3} to 10^{-6} cm/sec. Water entering the OAG unit may temporarily accumulate on the Caprock caliche zones in areas where it outcrops near the ground surface before penetrating further into the red bed clays. The OAG unit is described in detail in Section 2.5.1.

Conductivities in the layers of red bed clay are in the range of 10^{-9} cm/sec. The red bed layers are continuous in the vicinity of the proposed Site from approximately 30 feet below grade to a depth of approximately 500 to 600 feet. Thus, transport in these layers is more than two orders of magnitude less than the OAG Unit. Data from the multiple subsurface investigations conducted at the WCS property, including the proposed Site, indicate that a series of discontinuous siltstone and sandstone lenses are interbedded within the red bed clays at depths ranging between 80 feet to 225 feet below the surface. Samples collected from several of these sandstone lenses indicate a range of moisture contents from dry to saturated.

The uppermost water-bearing zone that is continuous across the Site has been defined at a depth of approximately 225 feet. The groundwater monitoring system for the proposed disposal site will be completed in this zone. Water yields in the 225-foot zone are minimal as indicated by groundwater measurements and the lack of water available for routine semi-annual sampling in the wells included in the existing WCS monitoring program for the RCRA facility operations. The conductivity of the 225-foot zone based on both in-situ and laboratory measurement is estimated at 10^{-8} cm/sec. Conservative estimates of the travel time required for water to reach the 225-foot zone are more than 45,000 years as discussed in Appendix 8.0-6 of this LA.

Sole source aquifers are shown in Figure 2.4.4-1. The closest aquifer designated by the U.S. EPA as a sole source aquifer is the Edwards aquifer located in the San Antonio (40 FR 58344) and Austin (53 FR 20897) areas in Texas. As demonstrated by both the proximity of the Site and the hydrogeologic conditions at the facility including the discussion in Section 2.7.1, the WCS Site is not considered to be located in a recharge area of these or any other potential sole-source aquifer.

2.7.4 Discharge of Groundwater to the Surface

Demonstrate that the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site. [30 TAC §336.728(h)]

Surface discharge of groundwater within the WCS Site or the proposed disposal site does not occur naturally. In addition, the design elements discussed below will ensure that surface discharge of groundwater will not occur from the proposed facilities.

Upward hydraulic gradients can arise in arid climates in response to a strong evapotranspirative flux. The process by which uniform upward unsaturated flow and transport persist requires prolonged periods of little or no precipitation, soils that dry rapidly, a high evapotranspiration demand, and a finite value for the unsaturated hydraulic conductivity. In order for a significant upward flux of contaminants to develop, the upward hydraulic gradient must extend through the entire cover system, backfill, and into the waste material. The hydraulic conductivity of the porous materials within the profile must also be non-negligible. For the proposed cover design that incorporates a capillary break, the unsaturated hydraulic conductivity of the coarse capillary and biointrusion barriers will be sufficiently low so as to prevent significant downward and upward unsaturated flow. The capillary barrier will function in both directions. Furthermore, the cobble-rich biointrusion barrier will limit the upward hydraulic gradient that might develop during the dry season.

2.8 Natural Resources

2.8.1 Inadvertent Intrusion

Identify the known natural resources at the disposal site, whose exploitation could result in inadvertent intrusion into the wastes after removal of active institutional control. [30 TAC §336.708(a)(4)]

Subsurface petroleum product exploration, development, and production have been conducted in the area for over 75 years. Most of the oil wells in the vicinity of the Site have been abandoned or are in the process of secondary or tertiary recovery. The absence of oil wells on or near the proposed disposal Site supports the absence of favorable conditions for oil production. A single, non-operational oil well exists several hundred yards southwest of the proposed disposal site and is the nearest well to the Site that has produced oil. The status of this well, combined with the exploration and production history in the immediate area, make any future secondary recovery or other well activity unlikely. Several oil wells that did not produce were drilled within several

estimates of salt dissolution rates, indicate that salt dissolution and retreat of the Caprock Escarpment are related (Gustavson and Simpkins, 1989). This peripheral belt of subsurface salt dissolution underlies the Canadian and Pecos River Valleys. Structural and stratigraphic data indicate that salt dissolution occurred *before*, *during*, and *after* deposition of the Ogallala Formation in the Canadian River Valley and the correlative "Cenozoic Basin Fill" (Gatuna Formation) of the Pecos River Valley (Figure 7). Hence, retreat of the Caprock Escarpment did not occur exclusively *after* deposition of the Ogallala and correlative strata. A curvilinear belt of subsurface salt dissolution also coincides with the buried Permian Capitan Reef trend surrounding the Delaware Basin. Subsidence over the reef trend resulted in a depression now filled with "Cenozoic Basin Fill" referred to as the Monument Draw Trough. This belt lies 25 to 30 km west-southwest of the WCS facility (Figures 9, 10).

The original extent of the Ogallala Formation east of the High Plains was as much as 2 to 3 times greater (200 to 400 km) than its original extent west of the present High Plains escarpment (150 km: see Figure 6). If, as is generally assumed, both western and eastern escarpments of the High Plains retreated simultaneously, then the eastern escarpment must have retreated at least 2 to 3 times faster than the western escarpment. Osterkamp and Wood (1984) estimated that the western escarpment has retreated at a rate only one-sixth as fast as the eastern escarpment. Therefore, estimates for the rate of retreat of the Caprock Escarpment based on the eastern side must be viewed as absolute maximum rates if employed here to evaluate retreat of the western side.

The position of the Caprock Escarpment in the vicinity of the WCS facility is very difficult to determine because, unlike along the eastern and northern border of the High Plains, there is no prominent topographic expression. This is owing in part to disruption of the High Plains surface by subsidence of the San Simon Swale and Monument Draw Trough, and in part to burial of the escarpment by younger eolian sediment in this area. Northwest of the WCS facility, in Lea County New Mexico, the position of the Caprock Escarpment is readily delineated by Mescalero Ridge. The escarpment rises again in Winkler and Ector Counties, Texas, southeast of the WCS facility where it is again easily located. Various authors have projected the position of the escarpment in the intervening area of western Andrews County at different locations (see Figure 1). Some of these projections do not correspond with any topographic expression. If the border of the High

occurred prior to 600,000 years ago. If the present eastern limit of the Gatuna Formation marks the former position of the Caprock Escarpment 600,000 years ago, then retreat of the escarpment for the past 600,000 years has been a maximum of 20 to 30 km, and as little as 5 to 10 km in other areas (based on Gatuna distribution shown by Kelley, 1980; shown here as Figure 7). This yields an estimated maximum retreat rate of 0.03 km/1000 yr to 0.05 km/1000 yr (for retreat of 20 and 30 km, respectively); or annual retreat rates of 3 cm/yr to 5 cm/yr. A comparable estimated retreat rate of 4 cm/yr was determined for widening of the Canadian River Valley, which is also incised into the High Plains surface along a belt of dissolution-induced subsidence active before, during, and after Ogallala deposition (Gustavson, 1980; Table 1). The Canadian and Pecos Rivers are thought to have been affected by the same processes, and hence retreat rates may have been similar in both valleys.

A number of authors have produced similar estimates for the rate of retreat of the eastern escarpment of the High Plains based on geomorphic history (see Table 1). These estimates range from 4 cm/yr to a maximum of 19 cm/yr, and were summarized by Gustavson and Simpson (1989) who regarded a range of 6 to 18 cm/yr as realistic. The authors regard these estimates as maximum rates of retreat, and as previously discussed, the eastern escarpment of the High Plains must have retreated at least 2 to 3 times faster, and perhaps as much as 6 times faster, than the western escarpment. Hence, a reasonable geomorphic estimate for the rate of retreat of the western escarpment of the High Plains would be 1 to 3 cm/yr, up to a maximum of 3 to 9 cm/yr.

Estimates of Retreat Rate based on Modern Measurements

A number of authors have determined quantitative modern (short-term) erosion rate measurements for the eastern escarpment of the High Plains (Table 1). These estimates are based on 2 to 4 years monitoring of erosion pins emplaced on varied slopes and soil types bordering the High Plains escarpment, suspended sediment loads of streams draining the escarpment, and reservoir sedimentation rates. The erosion rate measurements range from a low of 0.01 cm/yr to a maximum of 8.7 cm/yr. The highest short-term erosion rate found in these studies is 72.4 cm/yr for headcut erosion of a vertical scarp in completely unconsolidated modern alluvium. All of these data were summarized by Gustavson and Simpkins (1989), who regarded a range of 1 to 2 cm/yr as reasonable for modern erosion rates. It should be noted that annual rainfall in the region where

these studies were conducted (northeastern border of the High Plains) is 18" to 20", rather than the 12" to 14" received in western Andrews County. Hence, these erosion rate measurements are probably higher than would be expected in the vicinity of the WCS facility.

The long-term estimates based on geomorphic history (6 to 18 cm/yr) are about an order of magnitude larger than those based on actual short-term measurements (1 to 2 cm/yr), but are in general comparable to those determined here. The discrepancy between long and short-term estimates may suggest that Pleistocene erosion rates were substantially higher than those measured today, and so the modern rates may only be applicable for the time since onset of relatively "modern" climatic conditions (past ca. 8,000 years).

Assuming that the present closest position of the Caprock Escarpment is approximately 35 km to the west-southwest of the WCS facility (near Jal, New Mexico), and further assuming an average rate for erosional retreat of the escarpment estimated above (5 cm/yr), would require 700,000 years for eastward retreat of the escarpment to reach the WCS facility. Assuming an unrealistic maximum rate determined by previous authors for the eastern border of the High Plains (20 cm/yr), would require 175,000 years for the same 35 km retreat of the escarpment. Even assuming an absurd erosion rate value of 70 cm/yr (measured for retreat of a vertical scarp in unconsolidated alluvium), would require 50,000 years for retreat of the High Plains escarpment to reach the WCS facility. Alternatively, in the event that retreat of the escarpment were instead to occur along the eastern flank of Monument Draw (NM) 5 km west of the WCS facility, (isolating the area to the southwest as an outlier of the High Plains surface; e.g., as delineated by Hawley, 1984, 1993) it would require 100,000 years (at a reasonable average rate of 5 cm/yr) to 25,000 years (at the unrealistic absolute maximum rate of 20 cm/yr) for escarpment retreat to compromise the WCS facility.

Conclusions

The Caprock Escarpment surrounding the High Plains is slowly retreating by erosion. Measured rates of modern erosion suggest that the escarpment may now be retreating 1 to 2 cm/year. Geomorphic estimates suggest that the escarpment bordering the Canadian and Pecos Rivers may have retreated as rapidly as 5 cm/year in the past. The eastern Caprock Escarpment may have retreated as rapidly as 20 cm/year, two to six times faster than the western escarpment.

active erosional processes have a relatively low impact in the permitted area, which is typical of this type of arid climate. This interpretation is consistent with Lehman (Appendix 6.4-1) who concludes that the present landscape of the Southern High Plains is in dynamic equilibrium. Local erosion by overland flow is balanced by local deposition when surface water runoff ponds in depressions and playas, and local wind erosion is balanced by local sediment deposition transported from upwind source areas. Lehman (Appendix 6.4-1) also concludes that the area is not subject to significant long-term erosion, but if anything, to slow aggradation due to addition of eolian sediment.

southwest toward Monument Draw, New Mexico at approximately 50 feet per mile. Soils developed across the permitted area are typically shallow fine sandy loams with moderate to rapid permeability. The hazard of soil blowing is noted as moderate (Conner et al., 1974).

Erosional features developed within the permitted area include several subtle surface water drainage features located in the southeastern corner of the permitted area. These drainage features developed along the flanks of Windmill Hill and gather surface water runoff from Windmill Hill and the ranch house area. Drainage in these features is to the west-southwest.

Other erosional features identified within the permitted area include a topographic bench and several small depressions or playas. The bench runs through the center of the permitted area at an alignment of 300° to 320° and with a relief of approximately 20 feet. The bench developed as an erosional feature along the preferred jointing direction in the Southern High Plains. Four small depressions or playas are located on the northern half of the permitted area. The largest of these has a diameter of 1200 feet along its long axis, while the smallest is approximately 200 feet in diameter.

Terra Dynamics (1993) identified a subtle surface water drainage feature and five additional small depressions within the boundary of the landfill. These erosional features were removed during construction of the landfill and are no longer present within the permitted area.

The landforms within the WCS permitted area were evaluated using stereoscopically-paired aerial photographs from the 1938 and 1981 as well as NHAP color infrared aerial photographs from 1983 and 1986. The objective of this photo-geologic analysis was to determine where and how any possible changes in landforms had occurred due to erosion. The vertical exaggeration of the stereoscopic images was exploited to help detect any erosional changes in topography. Other characteristics compared between different sets of aerial photographs were shapes and sizes of drainageways and depressions or playas and observable changes in location or direction of these features.

Landforms on the WCS permitted area have remained virtually static for at least the last 70 years. No observable changes were detected in drainageway location, direction, shape or size or in the location, shape or size of the depressions or playas. The geologic interpretation is that

A number of authors have determined modern erosion rates for the eastern escarpment of the High Plains (Table 6.4-2). These estimates are based on 2 to 4 years monitoring of erosion pins emplaced on varied slopes and soil types bordering the Southern High Plains escarpment, suspended sediment loads of streams draining the escarpment, and reservoir sedimentation rates. The erosion rates measured in these studies range from a low of 0.004 in/yr to a maximum of 28.5 in/yr. The maximum short-term erosion rate found in these studies (28.5 in/yr) was for headcut erosion of a vertical scarp in completely unconsolidated modern alluvium. Gustavson and Simpkins (1989) regarded a range of 0.4 to 0.8 in/yr as reasonable for modern erosion rates. Annual rainfall in the region where these studies were conducted (northeastern border of the Southern High Plains) is 18 to 20 in/yr, rather than the 12 to 14 in/yr received in western Andrews County, therefore the erosion rate measurements are higher than would be expected in the vicinity of the WCS facility.

As indicated in the opening paragraph of this discussion, erosional retreat of the Caprock escarpment does not appear to be occurring in the direction of the WCS area. However, assuming that conditions could physiographically lead, at some future time, to escarpment retreat toward the WCS area, Lehman (Appendix 6.4-1) estimates the time for escarpment retreat to approach the WCS area. Assuming the present closest position of the Caprock escarpment is approximately 22 miles to the west-southwest of the WCS facility (near Jal, New Mexico), and further assuming an average rate for erosional retreat of the escarpment estimated above (about 2 in/yr), it would require about 700,000 years for eastward retreat of the escarpment to reach the WCS vicinity. Alternatively, assuming escarpment retreat were to occur along the eastern flank of Monument Draw, New Mexico, it would require 100,000 years at an average rate of about 2 in/yr for escarpment retreat to approach the WCS area. Escarpment retreat is, therefore, not considered to be an issue with respect to the WCS facility.

4.3.3 Erosional Features within the Permitted Area

Present-day erosional features within the WCS permitted area were identified using aerial photographs and topographic maps and field reconnaissance of the area. Physiographically, the WCS facility is located on a gently sloping plain with a regional slope toward the southeast at 8 to 10 feet per mile (Reeves, 1966). Local slope across the permitted area is to the

Interim Cover/Clay Fill (IC/CF)
A variable thickness layer of compacted clay (red bed non-select) fill will be installed above the concrete header layer. This layer will be placed initially by operations personnel as an interim cover, but will be compacted and contoured prior to installation of subsequent cover layers. Fill material will be excavated red bed clay that has been visually separated for interspersed sandstones and siltstones at the time of removal. This fill layer will be graded to create a convex lens shape ranging from zero (0) feet at the edges up to 19 feet at the centerline of each disposal unit, providing a 3% to 4% slope toward the perimeter of the disposal excavation. Drawings C1.5 and C 2.5 present a plan view of the interim cover placement for the Compact and Federal facilities. The interim cover will be installed as the waste elevation reaches final grade. Each side of this fill layer will slope toward the OAG-red bed interface. Drawings C1.6 and C2.6 present plan and cross-section views of the cover configuration of the Compact and Federal cover system geometry.

Performance Cover Layer (PC)
A three (3) foot thick, clay-rich soil layer will be compacted above the previous fill layer, and will serve as the performance cover to reduce infiltration. This cover element will be installed in a uniform thickness so that the gradients established by the underlying fill layer are maintained. The performance cover shall have a minimum effective saturated hydraulic conductivity of 1×10^{-7} cm/sec. Due to its abundance, red bed clay material that is free from sandstone, siltstone and similar discontinuities will be used for this layer, but with additional vibratory compaction and density testing. Field placement will be verified to ensure the minimum conductivity specification for this layer. This layer and all overlying cover elements will be installed as part of the incremental expansion of each disposal unit.

Flexible Membrane Liner (FML)
For the Federal disposal unit, an 60 mil high-density polyethylene (HDPE) FML will be placed on and in direct contact with the low-permeability clay soil performance cover layer. This synthetic membrane will act in conjunction with the compacted clay cover, and is required by RCRA.

Lateral Drainage Layer (LDL)
A two (2) foot thick granular drainage layer will be installed as the next functional component. This layer is intended to intercept moisture that percolates through the upper layers (if any) and direct it away from the disposal area, contributing to satisfy Design Criterion W4. This drainage layer will also be installed with uniform thickness, maintaining the drainage gradients established by the red bed fill layer and performance cover. This layer is specified as granular sand and gravel with a minimum hydraulic conductivity of 1 cm/sec. Given the permeability, slope, and location of this layer, the sand and gravel materials are designed to convey drainage to the existing sand/gravel lens that are generally present at the lower horizon of the OAG. This relatively permeable layer will provide a lateral conduit from the Red Bed Ridge disposal area. A 10 oz. geotextile filter fabric will be installed above and below the granular drainage layer to prevent migration of fine particulates that could reduce drainage effectiveness. The geotextile fabric is a 10 oz. non-woven, needle punched, staple fiber, and polypropylene product for both the Compact and Federal disposal units.

The lower layer of geofabric in the Federal cover system also protects the HDPE FML against puncture and concentrated loads during installation.

1.0 INTRODUCTION

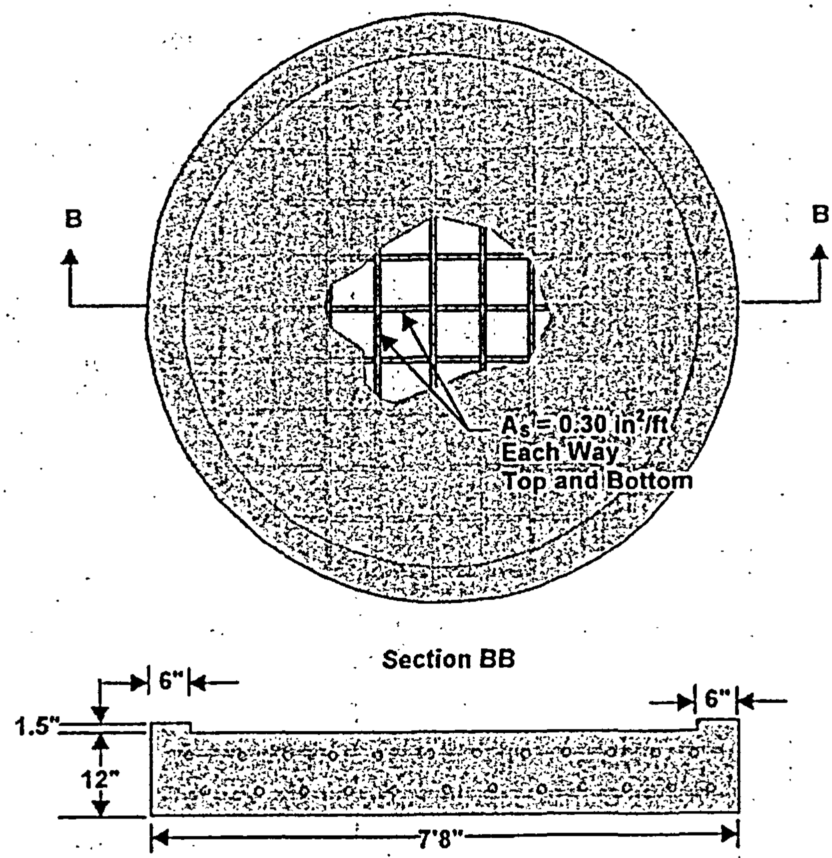
This report presents engineering design information related to design decisions for a disposal site for low-level radioactive waste (LLRW) at the Waste Control Specialists LLC (WCS) facility in Andrews County, Texas. Two separate disposal units are proposed for permanent disposal of licensed radioactive material from commercial and government generators.

The Federal Waste Facility (FWF) will encompass approximately 100 acres of previously undeveloped land at the WCS Andrews complex, and will be constructed north of the existing RCRA landfill. The FWF facility will accept LLRW from federal government facilities, which is expected to include a combination of radioactive and mixed radioactive waste over its operating lifetime. The central element of the proposed FWF disposal site is an 80-acre subsurface disposal unit that will be progressively excavated over 35 years. The FWF will be located along a topographic bench known locally as the Red Bed Ridge, where stiff and extensive natural clays lie 30 to 40 feet below the calcified carbonate (caliche) horizons of the undifferentiated Ogallala, Antlers, and Gatuna (OAG) Formation. The waste disposal unit will be established completely in the red bed clay horizon of the Dockum Group formation, and a thick multilayer cover including native clays will be installed in the 30-40 feet zone where the OAG is removed. The FWF excavation will extend approximately 80 feet into the red bed formation, making the overall depth of excavation in this unit approximately 120 feet. The maximum FWF excavation size is slightly less than 6 million cubic yards.

The Compact Waste Facility (CWF) will encompass approximately 30 acres to the east of the FWF development area, also on the Red Bed Ridge. This disposal unit will accept LLRW from Texas Compact states, but will not accept mixed radioactive waste during its operating lifetime. Many CWF engineered components and features are identical to the FWF. Like the FWF, the CWF disposal unit will be developed completely in the red bed clay formation, with a multilayer cover system installed in the 30-40 feet where OAG material is removed. Many of the cover and liner components are the same for both facilities. The CWF excavation depth differs from the FWF however, and will extend approximately 50 feet into the red bed clay. This translates to an overall CWF excavation depth of approximately 80 feet from surface grade. The CWF excavated capacity is 250,000 cubic yards (yd^3). The CWF also departs from the FWF design in that it does not include synthetic geomembranes in the cover and liner systems, although some geofabrics are incorporated. Compacted clay layers in the cover and liners are identical in both units.

The combination of arid desert climate, natural hydraulic characteristics and depth of the Dockum Group, and shallow grading of the Red Bed Ridge area combine to provide an unparalleled system of natural isolation for waste disposal. Topography and the upgradient basin that could provide run-on to the disposal site are modest in area and gentle in slope. They do not concentrate surface water run-on flows. The red bed clay host formation extends to a depth of approximately 900 feet, with hydraulic conductivities ranging from $1x10^{-8}$ to $1x10^{-9}$ centimeters per second (cm/sec). Engineered features are incorporated into each disposal unit design to preserve and complement these natural attributes, while also providing intruder protection and enhanced long-term waste form stability. Engineering drawings for LLRW disposal site development are referenced by drawing number in this report, and are available separately.

Figure 3.6-2. Precast cylindrical footing pad.



shall be deformed type and shall comply with ASTM A-615 Grade 60. Reinforcement shall be fabricated in accordance with the fabricating tolerances given in ACI SP-66.

Figure 3.6-1. Typical canister stacking configuration.

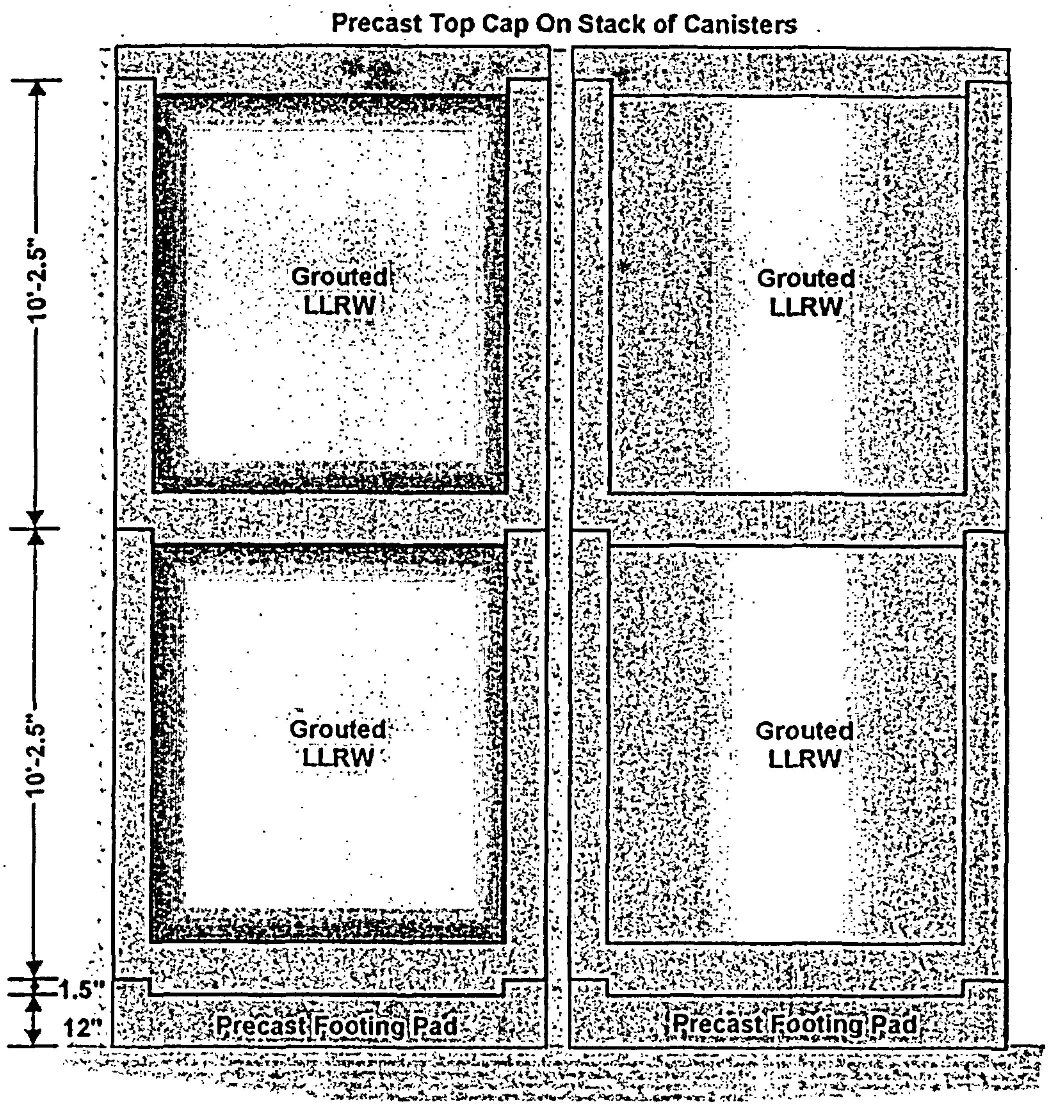
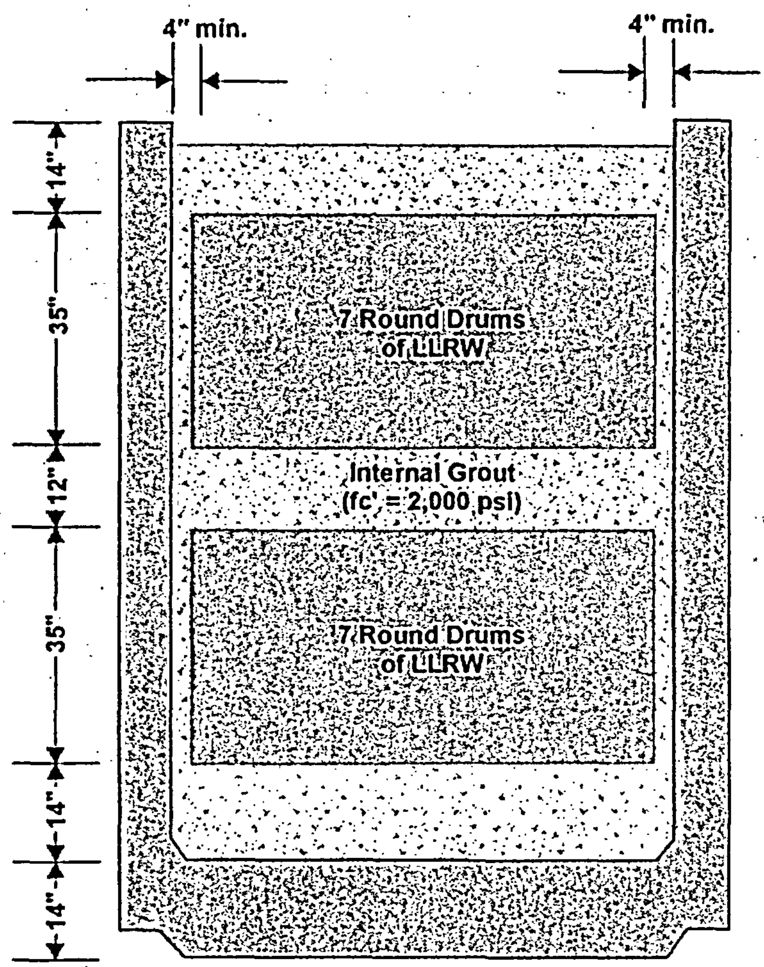
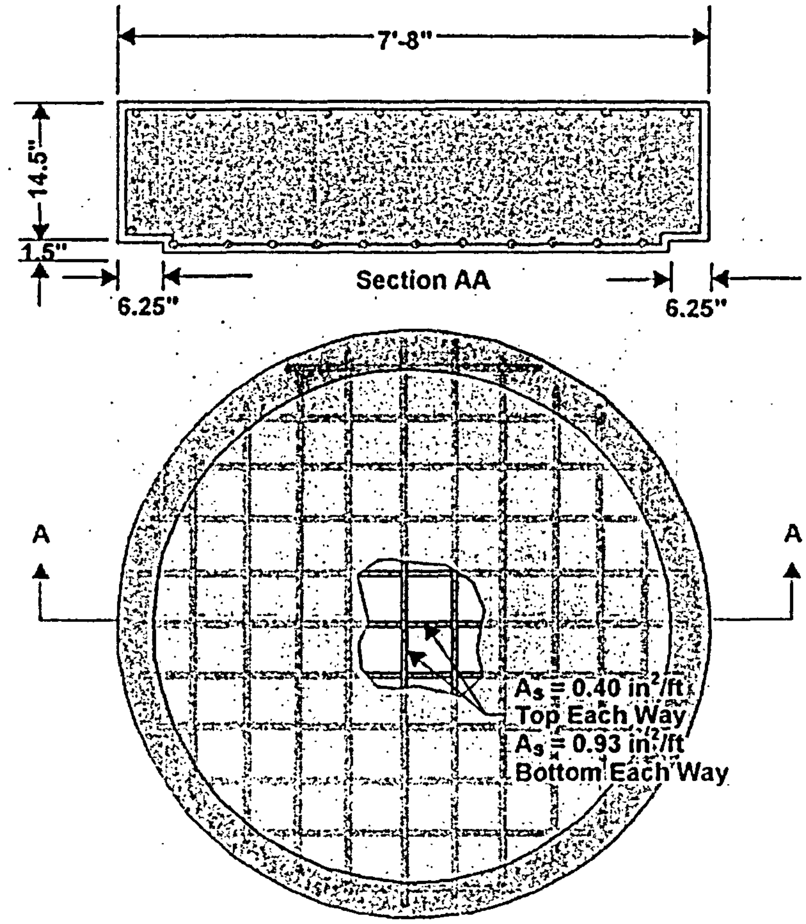


Figure 3.6-4. Cylindrical canister with grouting.



A relatively low-strength cementitious grout (200 psi at 28 days) was selected for volumetric fill between canister stacks. This flowable fill will include a mix of sand, water, and a lean cement ratio. Canisters will be separated by a minimum space of 6 inches using this backfill material, and will be placed using pumper truck or gravity feed hopper. A plan view illustration of canister spacing is provided in Figure 3.6-5. Select granular fill may be used in place of flowable grout, but may require increased clearance spacing between canisters to ensure workability and efficient compaction. This external fill media will develop microscopic cracks up to 0.15 inches between canisters, over the life of the facilities. The low-strength grout makes retrieval possible.

Figure 3.6-7. Precast cylindrical canister cover.



Gravel used for drainage layer shall be composed of hard, durable, angular pieces having a specific gravity of not less than 2.65 and conform following gradation:

U.S. STANDARD SIEVE SIZE	PERCENT BY WEIGHT PASSING
1 - 1-1/2 inch	100
3/4 inch	30-75
1/2 inch	15-55
1/4 inch	0-5

3.10.8 Long-Term Integrity of the Cover

Long-term integrity of the cover is evaluated by addressing potential concerns about the integrity of the materials isolating the waste cell from the ground surface, based exclusively on issues related to ecological changes that may occur after routine monitoring and maintenance are terminated. It is assumed that, at some point a few decades after active management of the facility ends, "natural" ecological processes will be allowed to occur. It is further assumed that an herbaceous (grass/forbs) vegetative cover will be maintained during active management.

Based on information presented in Ortega et al. (1997), it is expected that the managed herbaceous cover will establish extensive root systems down to at least the angular-rock bio-barrier within a few years. Although it is conceivable that these roots may penetrate through the barrier (Jackson et al. 1999 and references cited therein), it is highly unlikely that they would extend as far as the performance clay layer (Casper and Jackson 1997; Schenk and Jackson 2002a, b). Although maximum root depths of desert and semi-desert vegetative communities are among the deepest known, those of only a few types of these arid-land plants (certain shrubs) tend to extend beyond 2 meters (Schenk and Jackson 2002a, b).

The extent to which the main herbaceous community remains healthy, and dominates, after active management will be factor in controlling erosive processes (water and wind) at the ground surface. Based on historical experience (Buffington and Herbel 1965; Helm and Box 1970; Knopf 1994), there is a substantial likelihood that shrubs, especially mesquite (*Prosopis spp.*), will invade and ultimately dominate the cover after management is suspended. Significant colonization or dominance by shrubs will likely decrease the stability of the surface layer. This has the potential to enhance erosion that could alter the microtopography of the upper layer of the cover, but such effects would presumably not extend beyond the rock biobarrier.

ATTACHMENT 3.0-3.18: EROSION, WATER (UNIVERSAL SOIL LOSS EQUATION), AND WIND

CALCULATION SUMMARY

EROSION, WATER (UNIVERSAL SOIL LOSS EQUATION) AND WIND

This calculation summary provides calculations on long-term soil loss due to water using the universal soil loss equation. Presentation of long-term wind erosion computations using empirical methods is also included. Note that because of differing codes/ regulations, waste sources/types, and design criteria the final cover systems installed for the Compact Waste Facility (CWF) and Federal Waste Facility (FWF) differ slightly. Please refer to drawings contained in Appendix 3.0-2 (Drawing Sheets Nos. C1.1, C1.6, C2.1, and C2.6) and the Disposal Engineering Report (Appendix 3.0-1). Also, refer to calculations on erosion scour and protection and final cover erosion presented in this Appendix (3.0-3).

This document (calculation summary) and the calculation detail are from internal URS calculation WCS-004-CKA-009.

OBJECTIVES:

1. Calculate long-term soil erosion loss due to water using the universal soil loss (USL) equation.
2. Calculate long-term soil loss due to wind erosion using empirical methods as described in the assumptions section.

SOLUTIONS/CONCLUSIONS/RESULTS:

1. From the USL, the average annual soil loss by sheet and rill erosion is 7.55E-05 feet per year. A statement about the conservative nature of the estimate and discussion of time to erode the entire cover system, exposure of the performance cover, and biobarrier cobble are contained in Section 3.5.3. Specific presentation of quantitative data concerning these durations is contained in the Calculation Detail.
2. Using empirical methods, described in the assumption section, the average annual soil loss from wind is 2.81E-03 feet per year. At this rate the biobarrier cobble will not be disturbed for more than 3,500 years, which is conservative. Geological studies confirm that the area is aggrading and soil will increase in thickness with time. Specific presentation of quantitative data concerning this and other erosion durations is contained in the Calculation Detail.

CALCULATION BASIS:

Criteria:

The Texas Administrative Code (TAC) provides general direction in 30 TAC 336.729(a) and 30 TAC 336.729(d). Comparable principal design criteria, as indicated in Table

3.1.2-1 in Section 3, are specified as Criteria G2, G8, and W5; design features shall be directed toward long-term isolation, engineered features shall not require long term maintenance after closure, and cover system resists surface geologic processes.

Given Data/Inputs/Notes:

Inputs from the USL, taken from associated tables and figures, were used for equation values. The main input to the empirical average annual wind soil loss was taken from NRSC maps from four different years over a period of 15 years. Refer to the Calculation Detail for specific inputs. Other general notes and parameters follow:

1. The composite value of L*S is (from USL equation) based on a maximum slope length of about 1,600 ft and slope of 3.3% maximum (for both facilities).
2. The maximum slope at finished grade (3.3%) occurs near the middle (in plan view) south portion of the FWF, this value is assumed to be a maximum for this facility and the compact.
3. The value of P is extremely conservative based on little to no support practice after closure.
4. Wind erosion calculations and programs are mainly crafted for agrarian applications and therefore an empirical approach is utilized to calculate average annual soil loss using Natural Resource Conservation Service (NCRS) maps.
5. Based on the NRCS, the average annual soil loss ranges from 6.06 to more than 8 ton/ac/yr, because of difficultly in ascertaining the limits of the two categories nearest the WCS site, an average value was used.
6. The number 6.06 ton/ac/yr was calculated from 5% of the final facility areas (about 121 acres). This area does not include the building campus area to the west / northwest of the existing RCRA facility.

Assumptions:

1. The average bulk density of topsoil and moisture retention soil is assumed to be saturated. All soil above the cover is assumed to be topsoil (for calculation purposes) which is conservative.
2. Minimum thickness above or part of given cover layers are averages and may vary somewhat based on site contours / conditions.
3. The topsoil and moisture retention soil composition (relative to K) is assumed to be fine sandy loam or similar.
4. The actual wind erosion loss value will likely to less than that presented here because the topsoil above the facilities will not be used as cropland and, once planted and established, remain undisturbed.
5. The plant species covering the topsoil (after closure) will consist mainly of grasses with other native varieties.
6. Not all assumptions are presented here; please refer to the Calculation Detail for additional specific assumptions relative to the four main computations in this attachment.

References:

"Average Annual Soil Erosion by Wind on Cropland and CRP land, 1997, 1992, 1987, 1982," Natural Resource Conservation Service, United States Department of Agriculture, http://www.ncrs.usda.gov/technical/land/mapgif.asp?mapid=5065 or 5064 or 5063 or 5062 (last accessed 25 May 2004).

Peck, R. B., Hanson, W. E., Thornburn, T. H., "Foundation Engineering," John Wiley & Sons, Inc., New York, NY, 1974, refer to entire reference.

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., and Yoder, D.C., "Predicting Soil Loss by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)," Agricultural Handbook 703, U.S. Department of Agriculture, Agricultural Research Service, 1997., refer to entire reference.

United States Environmental Protection Agency, "Design and Construction of Covers for Solid Waste Landfills," EPA-600/2-79-165, 1979., refer to entire reference.

Form NQAP-3.3
June 2003

CALCULATION COVER SHEET

Project No.: 39400004.00300	Calc. No.: WCS-004-CKA-009
Client:	
Associated Report Title: (if applicable)	
Calc. Title (Problem Statement): Water and wind erosion calculations for the Federal and Compact facilities.	
Information Given: Spreadsheet located in G:\WCS\Calculation packs\Erosion\ Erosion Analysis Water and Wind.xls	
Assumptions: See sheets 3 and 9	
References: See sheet 2.	

REVIEW ASSIGNMENT

Assigned Checker: DHO	No Check Required ______ (PM Approved)
Type of Calculation:	Scope of Review: (P – Partial, C – Complete)
☐ Hand Calculation	☒ Math Check – P or C
☒ Spread Sheet Calculation	☒ Method of Analysis – P or C
☐ Computer Program Calculation	☒ Input Information – P or C
☐ Other______	☒ Assumptions – P or C
	☐ Compare w/Previous Calculations – P or C
	☐ Other

REVISION BLOCK

Rev.	Originator	Date	Checker	Date	PM	Date	Comments (optional)
0	CKA CKA	5/25/04	[signature]	8/18/04	[signature]	6/18/04	Reformatted (Response to
1	CKA	10/13/04	[signature]	10/14/04	[signature]	10/14/04	TCEQ ANOD #1)

CALCULATION DETAIL (ANALYSIS)

INPUTS FOR EROSION ANALYSIS DUE TO WATER AND WIND

NOT ALL INPUT VARIABLES ARE USED IN CALCULATIONS

INPUTS (Universal Soil Loss (USL); Erosion):

VARIABLE	DESCRIPTION and (REFERENCE) if applicable	VALUE	UNIT
R	Rainfall energy erosivity factor (Ref. 1, Figure 59)	90	
K	soil erodibility factor (Ref. 1, Table 27)	0.35	
L*S	slope length and steepness factor (Ref. 1, Figure/ Table 28)	0.60	
C	vegetative cover and management factor (Ref. 1, Table 29)	0.01	
P	conservation support practice factor (Ref. 1, Table 30)	1.0	
γts	unit weight of topsoil (loam or similar), moisture retention soil (Ref. 2)	115	lb/ft³
th	minimum thickness of layers from final ground to top of waste (fed. and comp.)	22	ft
thm	minimum thickness of layers from final ground to top of geomembrane or low permeability clay barrier (fed. and comp.)	16.4	ft
thb	uniform thickness near bottom level of biointrusion/barrier layer	10.0	ft

Source inputs are denoted by shading or the color yellow; other cells are used for conversions to different units or direct references to other cells. The use of shading or a light green color denotes use of information from another calculation set or internal data from another sheet (not from the main Inputs table).

INPUTS for wind erosion are contained near the end of this calculation detail.

REFERENCES:

(1) United States Environmental Protection Agency, "Design and Construction of Covers for Solid Waste Landfills," EPA-600/2-79-165, 1979., refer to entire reference.

(2) Peck, R. B., Hanson, W. E., Thornburn, T. H., "Foundation Engineering," John Wiley & Sons, Inc., New York, NY, 1974, refer to entire reference.

(3) Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., and Yoder, D.C., "Predicting Soil Loss by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)," Agricultural Handbook 703, U.S. Department of Agriculture, Agricultural Research Service, 1997., refer to entire reference.

(4) "Average Annual Soil Erosion by Wind on Cropland and CRP land, 1997, 1992, 1987, 1982," Natural Resource Conservation Service, United States Department of Agriculture, http://www.ncrs.usda.gov/technical/land/mapgif.asp?mapid=5065 or 5064 or 5063 or 5062 (last accessed 25 May 2004).

UNIVERSAL SOIL LOSS

OBJECTIVE:
Calculate soil loss from water erosion using the universal soil loss equation.

ASSUMPTIONS:
1. The average bulk density of top soil and moisture retention soil is assumed to be saturated [2]
2. The composite value of L*S is based on a maximum slope length of about 1600 ft and slope of 3.3% maximum (for both facilities).
3. The max slope at finished grade (3.3%) occurs near the middle (in plan view) south portion of the federal facility, this value is assumed to be a maximum for this facility and the compact.
4. The value of P is extremely conservative based on little to no support practice after closure.
5. Minimum thickness above the given layer are average and may vary somewhat based on site contours / conditions.
6. The topsoil and moisture retention soil composition (relative to K) is assumed to be fine sandy loam.
7. Analysis results for erosion due to water are applicable to the federal and compact facilities due to the use of the minimum composite layer thickness.

EQUATIONS:
A = R*K*(L*S)*C*P — Universal Soil Loss Equation (Ref. 1, 3)

CALCULATIONS:

VARIABLE	DESCRIPTION	VALUE	UNIT
A	average annual soil loss by sheet and rill erosion (Ref. 1)	0.189	ton/ac/yr
A	average annual soil loss by sheet and rill erosion (Ref. 1)	7.55E-05	ft/yr
t1	time to erode to top of geomembrane or low permeability clay layer	2.17E+05	yr
t2	time to erode to top of waste	2.92E+05	yr
t3	time to erode to near bottom of biointrusion/barrier layer	1.33E+05	yr

Note: Refer to the drawings (Appendix 3.0-2) for layer thicknesses.

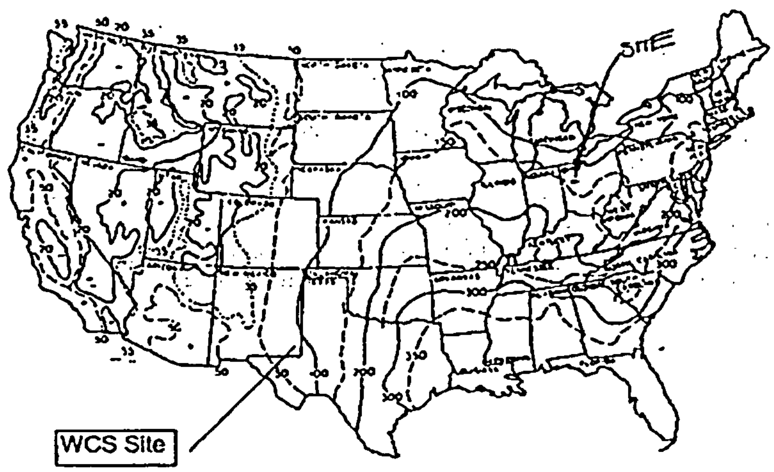


Figure 59. Average annual values of rainfall-erosivity factor R .[79]

The word 'SITE' alone in this figure is inaccurate and should be ignored. As indicated by the title WCS site, the project site is near the southeast corner New Mexico, along the north-south border with Texas and is actually within Texas. (Ref. 1)

TABLE 27. APPROXIMATE VALUES OF FACTOR K FOR USDA TEXTURAL CLASSES[79]

Texture class	Organic matter content <0.5% K	2% K	4% K
Sand	0.05	0.03	0.02
Fine sand	.16	.14	.10
Very fine sand	.42	.36	.28
Loamy sand	.12	.10	.08
Loamy fine sand	.24	.20	.16
Loamy very fine sand	.44	.38	.30
Sandy loam	.27	.24	.19
Fine sandy loam	.35	.30	.24
Very fine sandy loam	.47	.41	.33
Loam	.38	.34	.29
Silt loam	.48	.42	.33
Silt	.60	.52	.42
Sandy clay loam	.27	.25	.21
Clay loam	.28	.25	.21
Silty clay loam	.37	.32	.26
Sandy clay	.14	.13	.12
Silty clay	.25	.23	.19
Clay		0.13-0.29	

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

(Ref. 1)

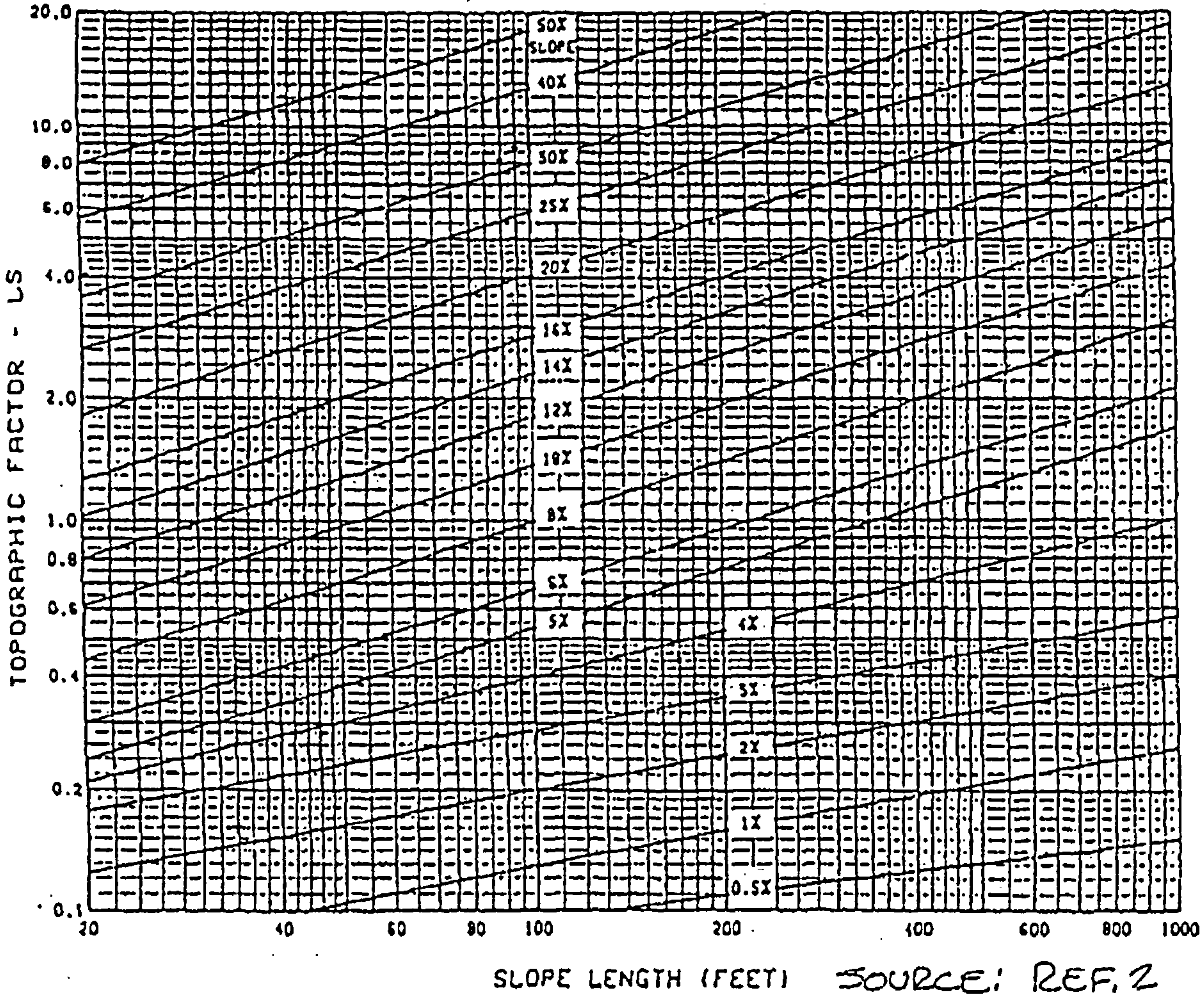


FIGURE 4.—Slope-effect chart (topographic factor, LS). LS = $(\lambda/72.6)^m (65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$ where λ = slope length in feet; θ = angle of slope; and m = 0.2 for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, and 0.5 for slopes of 5 percent or steeper.

Figure/Table 28 is actually from Ref. 1 not Ref. 2.

TABLE 29. GENERALIZED VALUES OF FACTOR C FOR STATES EAST OF THE ROCKY MOUNTAINS [79]

Crop, rotation, and management	Productivity level: High (C value)	Productivity level: Mod. (C value)
Base value: continuous fallow, tilled up and down slope	1.00	1.00
CORN		
C, RdR, fall TP, conv	0.54	0.62
C, RdR, spring TP, conv	.50	.59
C, RdL, fall TP, conv	.42	.52
C, RdR, wc seeding, spring TP, conv	.40	.49
C, RdL, standing, spring TP, conv	.38	.48
C-W-M-M, RdL, TP for C, disk for W	.039	.074
C-W-M-M-M, RdL, TP for C, disk for W	.032	.061
C, no-till pl in c-k sod, 95-80% rc	.017	.053
COTTON		
Cot, conv (Western Plains)	0.42	0.49
Cot, conv (South)	.34	.40
MEADOW		
Grass & Legume mix	0.004	0.01
Alfalfa, lespedeza or Sericea	.020	
Sweet clover	.025	
SORGHUM GRAIN (Western Plains)		
RdL, spring TP, conv	0.43	0.53
No-till pl in shredded 70-50% rc	.11	.18
SOYBEANS		
B, RdL, spring TP, conv	0.48	0.54
C-B, TP annually, conv	.43	.51
B, no-till pl	.22	.28
C-B, no-till pl, fall shred C stalks	.18	.22
WHEAT		
W-F, fall TP after W	0.38	
W-F, stubble mulch, 500 lbs rc	.32	
W-F, stubble mulch, 1000 lbs rc	.21	

Abbreviations defined:

B - soybeans
C - corn
c-k - chemically killed
conv - conventional
cot - cotton
F - fallow
M - grass & legume hay
pl - plant
W - wheat
wc - winter cover
lbs rc - pounds of crop residue per acre remaining on surface after new crop seeding
% rc - percentage of soil surface covered by residue mulch after new crop seeding
70-50% rc - 70% cover for C values in first column; 50% for second column
RdR - residues (corn stover, straw, etc.) removed or burned
RdL - all residues left on field (on surface or incorporated)
TP - turn plowed (upper 5 or more inches of soil inverted, covering residues)

SOURCE: REF 1

(Ref. 1)

TABLE 30. VALUES OF FACTOR P [79]

Practice	Land slope (percent)				
	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
	(Factor P)				
Contouring (P_c)	0.60	0.50	0.60	0.80	0.90
Contour strip cropping (P_{sc})					
R-R-M-M[1]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting (P_{cl})	0.30	0.25	0.30	0.40	0.45
Contour terracing (P_t)[2]	[3] $0.6/\sqrt{n}$	$0.5/\sqrt{n}$	$0.6/\sqrt{n}$	$0.8/\sqrt{n}$	$0.9/\sqrt{n}$
No support practice	1.0	1.0	1.0	1.0	1.0

[1] R = rowcrop, W = fall-seeded grain, O = spring-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that rowcrop strips are always separated by a meadow or winter-grain strip.

[2] These P_t values estimate the amount of soil eroded to the terrace channels and are used for conservation planning. For prediction of off-field sediment, the P_t values are multiplied by 0.2.

[3] n = number of approximately equal-length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

(Ref. 1)

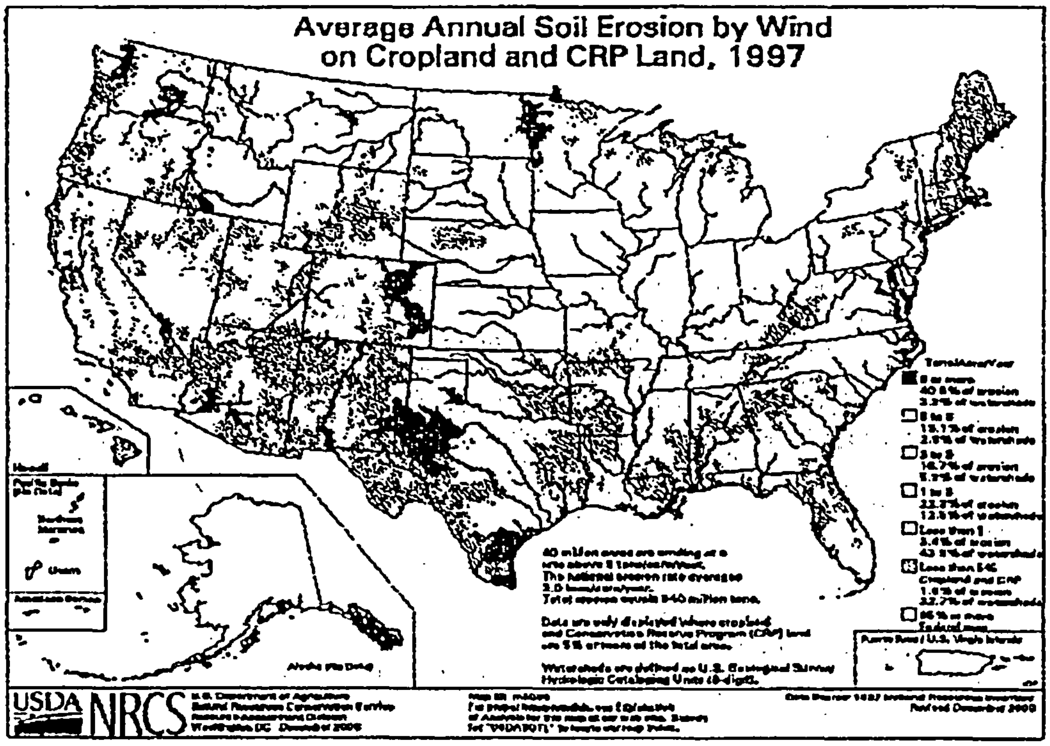
WIND EROSION ANALYSIS

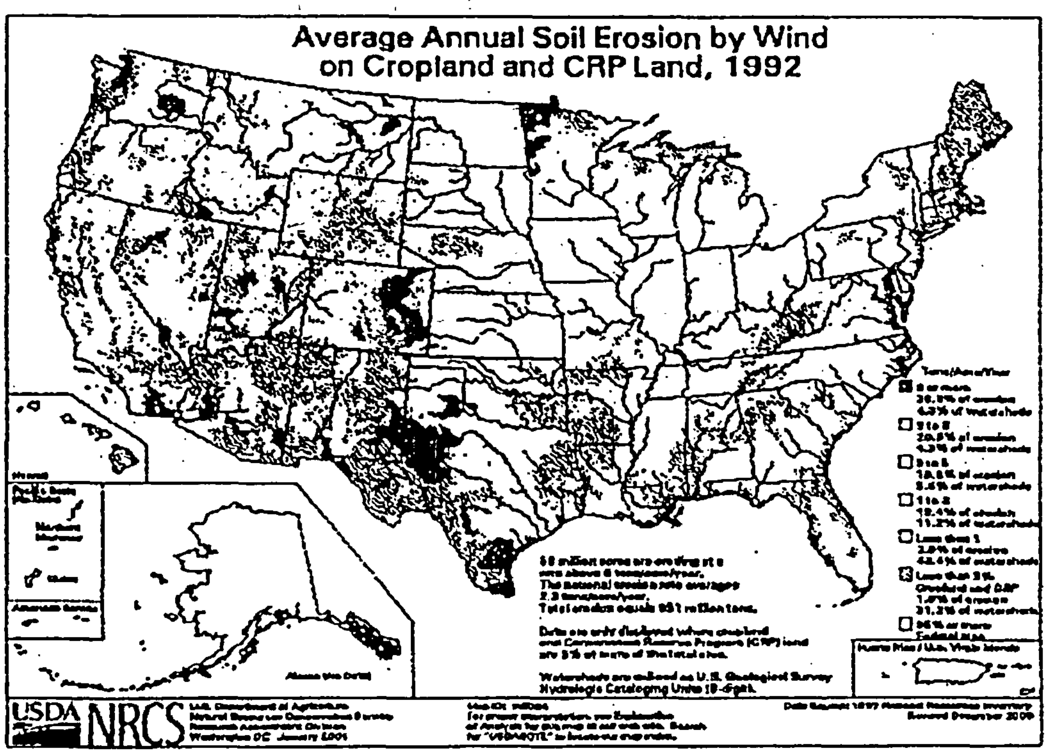
OBJECTIVE:
Calculate soil loss due to wind erosion using empirical methods as described in the assumptions section.

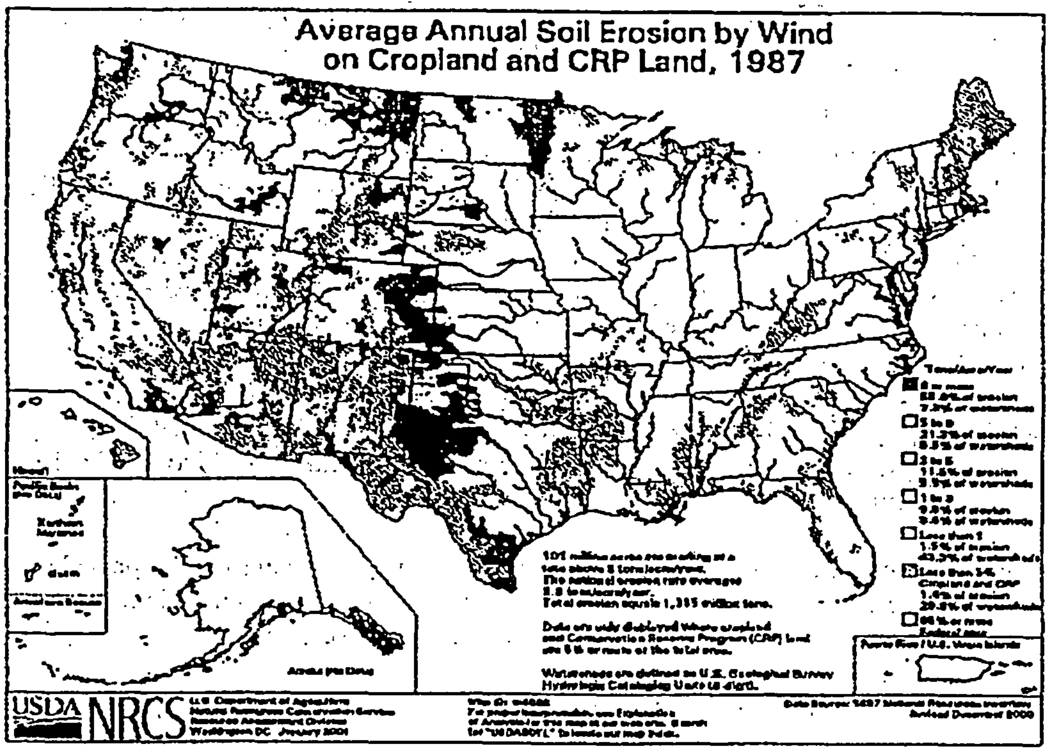
ASSUMPTIONS:
1a. Wind erosion calculations and programs are mainly crafted for agrarian applications and therefore an empirical approach is utilized to calculate average annual soil loss using NCRS maps (Ref. 4).
1b. The actual wind erosion loss value will likely to less than that presented here because the topsoil above the facilities will not be used as cropland and once planted remain undisturbed.
2. The plant species covering the topsoil (after closure) will consist maiuly of grasses with other native varieties.
3. The average bulk density of top soil and moisture retention soil is assumed to be saturated (Ref. 2)
4. The topsoil and moisture retention soil composition (relative to K) is assumed to be fine sandy loam. slope of 3.3% maximum (for both facilities).
5. Minimum thickness above the given layer are average and may vary somewhat based on site contours / conditions.
6a. Based on Refer. 4, the average annual soil loss ranges from 6.06 to more than 8 ton/ac/yr, because of difficultly in ascertaining the limits of the two categories nearest the WCS site an average value was used.
6b. The number 6.06 ton/ac/yr was calculated from 5% of the final facility areas (about 121 acres). This area does not include the building campus area to the west / northwest of the existing RCRA facility.
7. Analysis results for erosion due to wind are applicable to the federal and compact facilities due to the use of the minimum composite layer thickness.
8. Note: Other wind erosion calculations or models are not presented as part of this calculation detail.

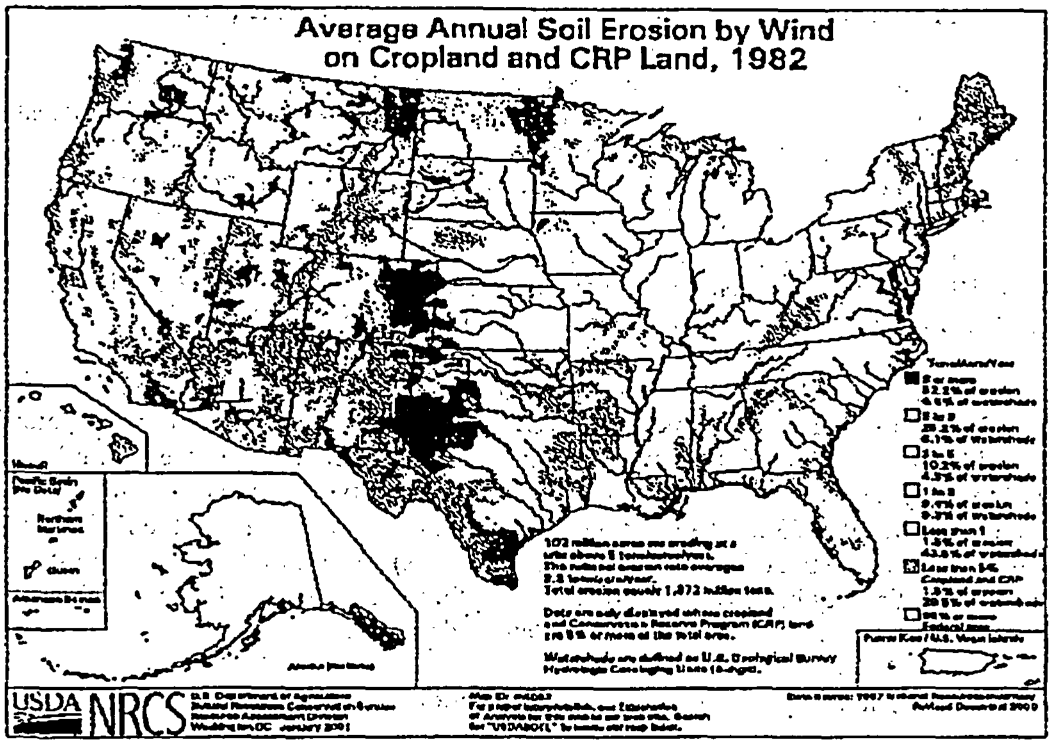
CALCULATIONS:

VARIABLE	DESCRIPTION	VALUE	UNIT
E alt	average annual soil loss for NCRS (Ref. 4).	7.03	ton/ac/yr
E alt	average annual soil loss for NCRS (Ref. 4).	2.81E-03	ft/yr
t4	time to erode to top of geomembrane or low permeability clay layer	5.84E+03	yr
t5	time to erode to top of waste	7.84E+03	yr
t6	time to erode to near bottom of biointrusion/barrier layer	3.56E+03	yr.


Average Annual Soil Erosion by Wind
on Cropland and CRP Land, 1997
USDA NRCS


Average Annual Soil Erosion by Wind
on Cropland and CRP Land, 1992
USDA NRCS


Average Annual Soil Erosion by Wind
on Cropland and CRP Land, 1987
USDA NRCS


Average Annual Soil Erosion by Wind
on Cropland and CRP Land, 1982
USDA NRCS

Below the bio-barrier is a thick layer of Redbed non-select fill material. It is material originally excavated from the Redbeds. This material will have fairly low conductivity because it is clay. However, it is not the primary barrier to water infiltration.

The next two layers are a sand drainage layer and a Redbed performance cover. The performance cover is the primary infiltration barrier and is constructed of carefully selected Redbed material with a minimum of sand and rocks. The clay will be compacted to a hydraulic conductivity of 1.0E-9 cm/s, similar to its in situ hydraulic conductivity. Under the loading conditions of the finished cover, the compacted clay layer is expected to rapidly approach and maintain the very low hydraulic conductivity that is characteristic of the undisturbed Redbed material. Placement and compaction of the material during construction will promote a low hydraulic conductivity by the exclusion of inhomogeneous material from the clay. The sand drainage layer is two feet of highly permeable material overlain by a geosynthetic textile to prevent clogging by fine particles from the layer above. In the Compact Facility, the performance cover and sand drainage layer will have a slop of 4 percent. In the Federal Facility, the slope will be 3 percent.

The bottom layer of the cover system is a fill layer of Redbed non-select material that provides a base for the performance cover. The fill is thicker at the center of the facility and thinner at the edges, in order to provide the slope necessary for the performance cover.

The cover systems for the Compact and Federal Facilities are identical except for the areas that they cover and the thicknesses of the Redbed non-select fill materials. The details of the layer properties and thicknesses are contained in the HELP computer outputs, which are attached.

The weather data from the HELP model simulations are based, as much as possible, on the meteorological conditions at the WCS Site. Recent rainfall measurements at the WCS Site indicate an annual rainfall of about 10 inches per year. However, nearby cities such as Andrews and Midland, Texas and Eunice, Hobbs, and Jal, New Mexico have annual precipitation in the range of 13 to 16 inches per year. An annual rainfall of 14 inches per year was used for the WCS Site in order to avoid underestimating the long-term average precipitation. The rainfall frequency was calculated by the HELP model based on rainfall patterns for El Paso, Texas. The solar radiation and temperature data were also generated by HELP based on conditions at El Paso.

The HELP model results show that the most important component of the cover system is the low conductivity Redbed clay in the performance cover (Layer 7, above). The total amount of water infiltration calculated to pass through the cover system is approximately equal to the hydraulic conductivity of the clay performance cover. For the Compact Facility, the predicted infiltration rate through the cover was 0.0123 inches of water per year (9.9E-10 cm/s) and for the Federal Facility, the infiltration was 0.0126 inches per year (1.0E-9 cm/s). The infiltration was slightly lower for the Compact Facility because the slope of the performance cover is greater and the slope length is shorter, both of which promote better lateral drainage.

Complete input and output data for the HELP model simulations are contained in the attached computer printouts.

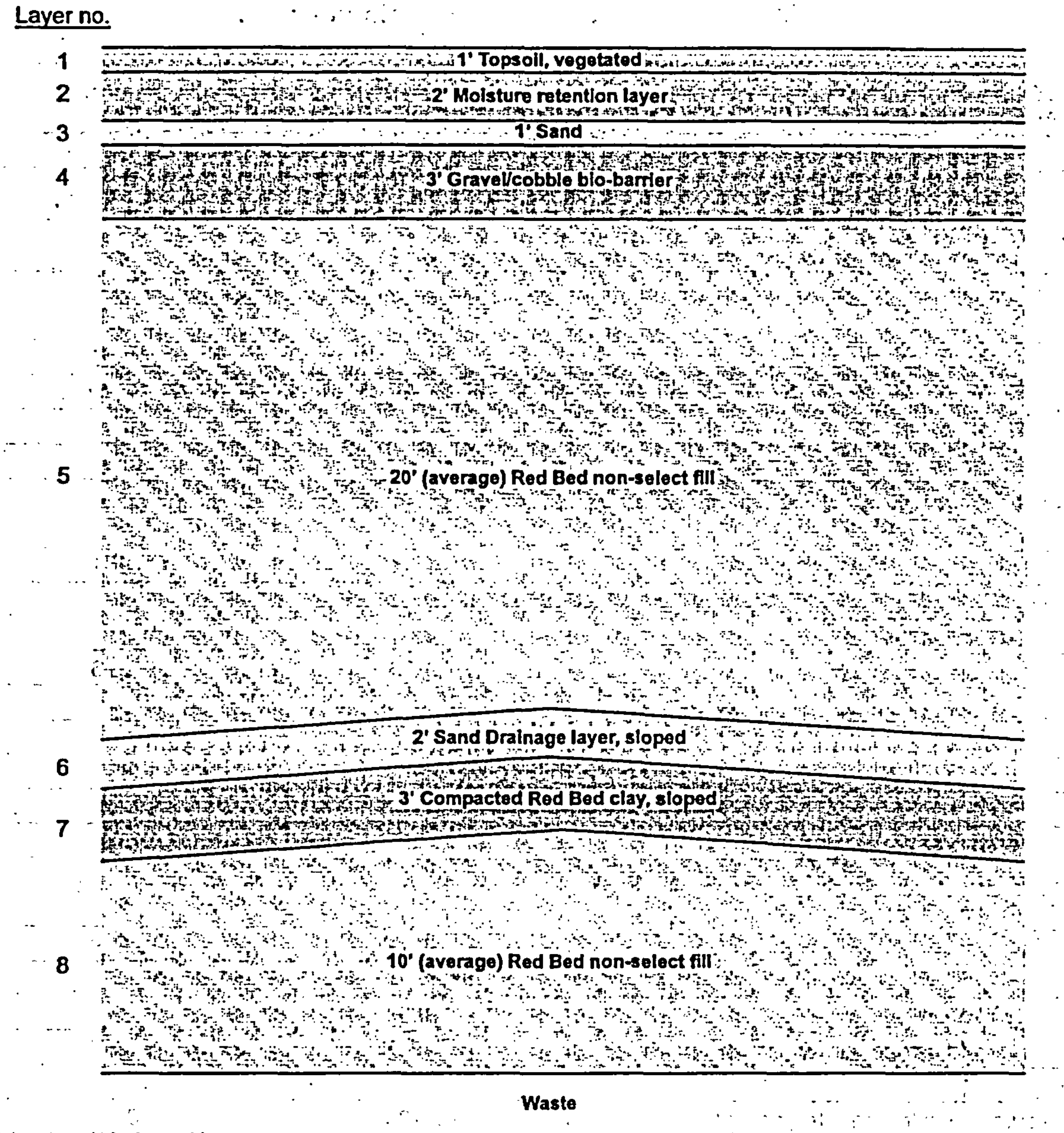


Figure 8.0-6.8-1. Cover system layers.

The next two layers in the cover system are a sand layer and a gravel bio-barrier. The gravel is designed to hold as little water as possible and remain dry, thereby preventing plant roots and burrowing animals from penetrating through the cover system. The sand layer on top of the bio-barrier serves as a transition zone to prevent the coarse gravel of the bio-barrier from becoming clogged with fine particles from the overlying moisture retention layer.

Table 8.0-6.8-2. Data for HELP simulations.

PARAMETER	COMPACT	FEDERAL
Area of cover (acres)	12	59
Precipitation (inches/year)	14	14
Layer 1 topsoil		
Thickness (ft)	1	1
Hydraulic conductivity (cm/s)	1.2E-4	1.2E-4
Layer 2 moisture retention soil		
Thickness (ft)	2	2
Hydraulic conductivity (cm/s)	2.5E-5	2.5E-5
Layer 3 sand		
Thickness (ft)	1	1
Hydraulic conductivity (cm/s)	5.8E-3	5.8E-3
Layer 4 gravel biobarrier		
Thickness (ft)	3	3
Hydraulic conductivity (cm/s)	3.0E-1	3.0E-1
Layer 5 Redbed non-select fill		
Thickness (ft)	18	20.5
Hydraulic conductivity (cm/s)	1.0E-6	1.0E-6
Layer 6 sand lateral drainage		
Thickness (ft)	2	2
Hydraulic conductivity (cm/s)	1.0E-2	1.0E-2
Slope length (ft)	365	650
Slope (%)	4	3
Layer 7 compacted Redbed		
Thickness (ft)	3	3
Hydraulic conductivity (cm/s)	1.0E-9	1.0E-9
Layer 8 Redbed non-select fill		
Thickness (ft)	10.5	9.5
Hydraulic conductivity (cm/s)	1.0E-6	1.0E-6
RESULTS		
Calculated infiltration rate (inches/year)	0.0123	0.0126

Table 8.0-6.8-4. Non-default RESRAD data for pathway G1.

PARAMETER	COMPACT	FEDERAL
Waste disposal area (m^2)	49,500	195,000
Waste thickness (m)	14.3	23.5
Waste length parallel to aquifer (m)	223	350
Cover thickness (m)	12.3	12.8
Cover density (g/cm^3)	1.6	1.6
Cover erosion rate (m/year)	0	0
Waste density (g/cm^3)	1.6	1.6
Waste erosion rate (m/year)	0	0
Evapotranspiration coefficient	0.99	0.99
Wind speed (m/s)	3.1	3.1
Precipitation (m/year)	0.36	0.36
Runoff coefficient	0.91	0.91
Horizontal flow distance through Redbeds	460	1,250
Density of unsaturated zone (g/cm^3)	1.6	1.6
Conductivity of unsat. zone (m/year)	0.001	0.001
Density of saturated zone (OAG) (g/cm^3)	1.8	1.8
Porosity of saturated zone	0.3	0.3
Conductivity of saturated zone (m/year)	500	500
Gradient in saturated zone, Redbed surface	0.001	0.001
Well pump intake depth (m)	6	6
Water table drop rate (m/year)	0	0

The meteorological data were adjusted so that the infiltration rate used by RESRAD would equal the infiltration rate calculated by the HELP model. This was done by specifying the total precipitation (0.36 m/year) and the fractions of the precipitation that were runoff and evapotranspiration. By specifying 91 percent of the precipitation as runoff and 99 percent of the remaining water as evapotranspiration, RESRAD calculated an infiltration rate of 0.032 cm/year that matched the HELP model output.

The RESRAD model was run to simulate Pathway G1 for the Compact and Federal Facilities. The initial simulations were run for a period of 10,000 years. No doses were calculated during this period. A second set of simulations was conducted using a 100,000-year period. For the entire 100,000 years, there were no doses at the well. During this time, contaminated leachate was unable to travel sufficiently far to reach an area of perched water on top of the Redbeds. The RESRAD analysis of Pathway G1 demonstrated that the shallow horizontal transport pathway was not a credible transport pathway.

The natural features of the Site provided enough containment that radionuclides were unable to reach the postulated well above the Redbeds. Engineered features of the Site, such as the waste containers and the synthetic liner system were not accounted for in the RESRAD modeling and did not contribute to radionuclide containment.

Table 8.0-6.8-3. K_d values used in RESRAD simulations.

Nuclide	Waste Kd (mL/g)	Reference	Redbeds Kd (mL/g)	Ref	Saturated Zone Kd (mL/g)	Ref
Pu-240	2,000	Default	5,100	E.3, clay	550	E.3, sand
Pu-241	2,000	Default	5,100	E.3, clay	550	E.3, sand
Pu-242	2,000	Default	5,100	E.3, clay	550	E.3, sand
Pu-244	2,000	Default	5,100	E.3, clay	550	E.3, sand
Ra-226	70	Default	9,100	E.3, clay	500	E.3, sand
Ra-228	70	Default	9,100	E.3, clay	500	E.3, sand
Sb-125	45	350.73(e)	250	E.3, clay	45	E.3, sand
Se-79	2.2	350.73(e)	740	E.3, clay	150	E.3, sand
Sm-147	245	E.3, lowest	1,300	E.3, clay	245	E.3, sand
Sm-151	245	E.3, lowest	1,300	E.3, clay	245	E.3, sand
Sr-90	30	Default	110	E.3, clay	15	E.3, sand
Tc-99	0.1	E.3, lowest	1	E.3, clay	0.1	E.3, sand
Th-228	60,000	Default	5,800	E.3, clay	3,200	E.3, sand
Th-229	60,000	Default	5,800	E.3, clay	3,200	E.3, sand
Th-230	60,000	Default	5,800	E.3, clay	3,200	E.3, sand
Th-232	60,000	Default	5,800	E.3, clay	3,200	E.3, sand
U-232	50	Default	1,600	E.3, clay	35	E.3, sand
U-233	50	Default	1,600	E.3, clay	35	E.3, sand
U-234	50	Default	1,600	E.3, clay	35	E.3, sand
U-235	50	Default	1,600	E.3, clay	35	E.3, sand
U-236	50	Default	1,600	E.3, clay	35	E.3, sand
U-238	50	Default	1,600	E.3, clay	35	E.3, sand
Zn-65	530	350.73(e)	2,400	E.3, clay	200	E.3, sand
Zr-93	600	E.3, lowest	3,300	E.3, clay	600	E.3, sand

References:
E.3, sand = RESRAD User's Manual, Table E.3, value for sand.
E.3, clay = RESRAD User's Manual, Table E.3, value for clay.
E.3, lowest = RESRAD User's Manual, Table E.3, lowest value.
E.4, NUREG = value from NUREG/CR-5512, RESRAD User's Manual Table E.4.
350.73(e) = value recommended in 30 TAC 350.73(e).
Default = Default value from RESRAD User's Manual, Table E.4.

In addition to the radionuclide inventory and K_d information, RESRAD requires information on the Site characteristics and exposure pathways. RESRAD contains a database of default parameters to characterize the exposure setting. All of the non-default parameters that were used to model Pathway G1 are listed in Table 8.0-6.8-4. These data include the waste disposal unit size, waste and cover thicknesses, meteorological data, and food and water intake data.

Table 8.0-6.9-1. Input parameters for pathway G3.

PARAMETER	COMPACT	FEDERAL
Waste disposal area (m^2)	49,500	195,000
Waste thickness (m)	14.3	23.5
Waste length parallel to aquifer (m)	223	350
Cover thickness (m)	12.3	12.8
Cover density (g/cm^3)	1.6	1.6
Cover erosion rate (m/year)	0	0
Waste density (g/cm^3)	1.6	1.6
Waste erosion rate	0	0
Evapotranspiration coefficient	0.99	0.99
Wind speed (m/s)	3.1	3.1
Precipitation (m/year)	0.36	0.36
Runoff coefficient	0.91	0.91
Thickness of unsaturated zone (m)	42	32
Density of unsaturated zone(g/cm^3)	1.6	1.6
Conductivity of unsaturated zone (m/year)	0.001 m/year min. allowed	0.001
Density of saturated zone (g/cm^3)	2.2	2.2
Porosity of saturated zone	0.14	0.14
Conductivity of saturated zone (m/year)	0.02	0.02
Gradient in saturated zone	0.016	0.016
Water table drop rate	0	0

The meteorological data were adjusted so that the infiltration rate used by RESRAD would equal the infiltration rate calculated by the HELP model. This was done by specifying the total precipitation (0.36 m/year) and the fractions of the precipitation that were runoff and evapotranspiration. By specifying 91 percent of the precipitation as runoff and 99 percent of the remaining water as evapotranspiration, RESRAD calculated an infiltration rate of 0.032 cm/year that matched the HELP model output.

The RESRAD model was run to simulate Pathway G3 for the Compact and Federal Facilities. The initial simulations were run for a period of 10,000 years. No doses were calculated during this period because the radionuclide travel times from the trench bottom to the sandstone aquifer are all greater than 10,000 years. A second set of simulations was conducted using a 100,000-year period. During this time, some radionuclides reached the groundwater and doses were calculated. The calculated doses are shown in Table 8.0-6.9-2. The primary radionuclides reaching the well were the long-lived mobile radionuclides Cl-36, Tc-99 and I-129, which accounted for 99 percent of the dose. The Compact Facility had a maximum dose from Cl-36 of 0.0017 mrem/yr calculated to occur at about 45,000 years. The maximum dose for the Federal Facility was 1.9 mrem/yr, primarily from Tc-99 and I-129, and occurred at 100,000 years.

The 100,000-year time frame for the analysis was sufficiently long to evaluate peak doses from mobile radionuclides. Doses were not calculated beyond 100,000 years because of the great

transpiration. Very little, if any, water infiltrates from the surface to the deeper layers at the level of the performance cover. The lack of water flow at depth leads to a very low infiltration rate that is largely independent of conditions at the ground surface.

The infiltration rates from the HELP model simulations were used in RESRAD to calculate the effects on doses to individuals. The RESRAD sensitivity cases are described in the next section.

8.0-7.2 RESRAD Sensitivity Analysis

The RESRAD model (DOE 2001) was used to evaluate the groundwater pathways in the performance assessment. The RESRAD sensitivity analysis evaluated three conditions that varied from the baseline analysis. These were high infiltration, enhanced nuclide leaching, and enhanced nuclide transport. The RESRAD sensitivity cases are summarized in Table 8.0-7-3. These sensitivity cases were evaluated for groundwater pathways G1 and G3, which are described in Appendix 8.0-6.

Table 8.0-7-3. Conditions evaluated in RESRAD sensitivity analysis.

CONDITION	PARAMETERS VARIED
Baseline	All parameters at baseline values
High Infiltration	Infiltration three times baseline value
Enhanced Leaching	Waste zone K_ds decreased to one tenth of baseline value
Enhanced Transport	red bed K_ds decreased to one tenth of baseline value

Based on the results of the HELP model sensitivity analysis, the infiltration rate was not expected to vary significantly from its baseline value under a variety of conditions. In the HELP sensitivity analysis, the largest increase in the infiltration rate was less than a factor of three. For the RESRAD sensitivity analysis, the infiltration rate was increased by a factor of three.

The RESRAD sensitivity analysis examined the effect of enhanced nuclide release rates. In the baseline RESRAD modeling, the release rates were based on the nuclide K_d values in the waste zone. For the sensitivity analysis, the enhanced nuclide release rates were simulated by decreasing the waste zone K_ds by a factor of ten.

Another sensitivity case was evaluated in which nuclide transport through the red beds was enhanced. The transport in the red beds was controlled by the nuclide K_ds, which were used to calculate retardation factors. For this sensitivity case, the enhanced transport was simulated by decreasing all of the red bed nuclide K_ds by a factor of ten.

The sensitivity cases were evaluated for pathways G1 and G3, which are described in Appendix 8.0-6. Pathway G1 involved horizontal transport through the red beds to a location where contaminated water may collect on the red bed surface. Pathway G3 evaluated vertical migration of nuclides from the disposal units to the saturated sandstone at about 225 feet below ground. All of the results for Pathway G1 showed no doses within 100,000 years, because of the very long horizontal distance through the red beds to reach the well location.

sloped at only 3 percent, compared to 4 percent in the Compact Facility. In addition, the slope length on the Federal Facility was longer (650 feet vs. 365 feet for the Compact). The Federal Facility's lower slope and longer slope length both served to decrease the amount of lateral drainage and, therefore, slightly increased the infiltration. For both facilities, the total infiltration was approximately equal to the hydraulic conductivity of the compacted red bed clay in the performance cover. The performance cover was assumed to have a hydraulic conductivity of 1.0E-9 cm/s. In these units, the infiltration rates were 9.0E-10 cm/s for the Compact Facility and 9.5E-10 cm/s for the Federal Facility.

Table 8.0-7-2. Infiltration sensitivity results.

Condition	Compact Facility Infiltration (cm/yr)	Federal Facility Infiltration (cm/yr)
Baseline	2.85E-2	2.98E-2
High Precipitation	3.36E-2	3.38E-2
Cover Degradation, High Conductivity	7.19E-2	8.02E-2
Cover Degradation, Reduced Lateral Drainage	3.03E-2	3.19E-2

In the first sensitivity case, the rainfall was doubled to 28 inches per year from 14 inches per year. The infiltration rates through the cover increased, but by much less than a factor of two. The Compact infiltration rate increased 18 percent to 3.36E-2 cm/yr and the Federal Facility infiltration increased 13 percent to 3.38E-2 cm/yr. Almost all of the additional rainfall was returned to the atmosphere in the form of increased evaporation and plant transpiration. The effect on the deep infiltration rate was muted, indicating that evapotranspiration in the near-surface layers was almost independent of water flow in the deeper layers of the cover system.

The next sensitivity case varied the hydraulic conductivity of the performance cover, which is the primary barrier to deep infiltration into the waste disposal units. The hydraulic conductivity of the performance cover was increased by a factor of ten to 1.0E-8 cm/s. The infiltration rates increased, but by much less than a factor of ten. The Compact Facility infiltration rate increased to 7.19E-2 cm/yr, or 2.5 times the baseline value. The Federal Facility infiltration rate increased to 8.02E-2 cm/yr, or 2.7 times the baseline value. The increase was less than a factor of ten because there was a shortage of available water in the deep cover layers. This was consistent with the earlier observation that almost all of the precipitation returned to the atmosphere from the near-surface layers of the cover system.

The final sensitivity case considered the effect of reduced lateral drainage from the performance cover. The drainage layer above the compacted clay layer served to divert water laterally from the performance cover. Over time, the drainage layer could become clogged with fine particles and fail to operate as it was designed. For this sensitivity case, the hydraulic conductivity of the drainage layer was reduced by factor of ten. Under these conditions, the Compact infiltration rate increased by 6.3 percent and the Federal infiltration rate increased by 6.8 percent. In both cases, the change in infiltration rate was very small compared to the change in hydraulic conductivity.

Considering all the sensitivity runs, a consistent picture emerged in which almost all of the precipitation at the site was returned to the atmosphere through evaporation and plant

Table 8.0-7-5. Parameters for RESRAD uncertainty analysis.

PARAMETER	RANGE	DISTRIBUTION	EFFECT
Runoff coefficient (determines infiltration rate)	0.737 – 0.91	Uniform	Varies infiltration rate from baseline value to 3x baseline
Contaminated zone K_d	0.1x baseline to 10x baseline	Log-uniform	Varies leach rate
Unsaturated zone K_d	0.1x baseline to 10x baseline	Log-uniform	Varies retardation factors in red beds

Values for the uncertainty parameters were selected from their respective probability distributions using Latin Hypercube sampling. A total of 300 values were selected for each parameter and the parameter values were grouped randomly to make 300 data sets for RESRAD. The 300 data sets were run with the RESRAD code in three groups of 100 samples each. Statistics were calculated among the three groups. The minimum, maximum, mean, and various percentile doses were calculated from among the 300 simulations. The Compact Facility and the Federal Facility were evaluated using 300 samples each. The dose results for the RESRAD uncertainty analysis are shown in Table 8.0-7-6.

Table 8.0-7-6. RESRAD uncertainty results, pathway G3.

DOSES (MREM/YR)	COMPACT FACILITY	FEDERAL FACILITY
Maximum dose in first 10,000 years	3.3E-04	2.4E-01
Maximum dose in 100,000-year simulation	9.8E-02	1.4E+01
Minimum dose in 100,000-year simulation	4.8E-04	2.2E-02
50th percentile dose, 100,000-year simulation	2.4E-03	6.1E+00
90th percentile dose, 100,000-year simulation	2.3E-02	8.9E+00
95th percentile dose, 100,000-year simulation	3.2E-02	9.9E+00

For the Compact Facility, the only dose within the first 10,000 years was from Cl-36, with a maximum dose of 3.3E-04 mrem/yr at year 10,000. From among the 300 samples, the maximum dose within the 100,000-year simulation was 0.098 mrem/yr. The minimum dose was 4.8E-04 mrem/yr. The doses at the 50th, 90th, and 95th percentiles were 0.0024, 0.023 and 0.032 mrem/yr, respectively.

For the Federal Facility, the maximum dose within the first 10,000 years was 0.24 mrem/yr at year 10,000. From among the 300 samples, the maximum dose within the 100,000-year simulation was 14 mrem/yr. The minimum dose was 0.022 mrem/yr. The doses at the 50th, 90th, and 95th percentiles were 6.1, 8.9, and 9.9 mrem/yr, respectively.

All doses within the first 100,000 years were below the 25 mrem/yr dose limit in the performance objective. The only radionuclides to reach the well within 100,000 years were C-14, Cl-36, Tc-99, and I-129.