RADIOACTIVE MATERIAL LICENSE NO. R04100
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UPDATED PERFORMANCE ASSESSMENT

FOR THE LOW-LEVEL WASTE FACILITY

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Submitted to:

Texas Commission on Environmental Quality
Office of Permitting, Remediation and Registration
Radioactive Materials Division
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TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF APPENDIXES

EXECUTIVE SUMMARY

This Performance Assessment (PA) submittal is an update to the original PA that was developed to support the licensing of the Waste Control Specialists LLC Low-Level Radioactive Waste (LLRW) disposal facility. This update includes both the Compact Waste Facility (CWF) and the Federal Waste Facility (FWF), in accordance with Radioactive Material License (RML) No. R04100, License Condition (LC) 87.

While many of the baseline assumptions supporting the initial license application PA were incorporated in this update, a new transport code, GoldSim, and new deterministic groundwater flow codes, including HYDRUS and MODFLOW-SURFACT™, were employed to demonstrate compliance with the performance objectives codified in the regulations and RML No. R04100, LC 87. A revised source term, provided by the Texas Commission on Environmental Quality staff, was used to match the 15 year initial license term. The HYDRUS code was used to evaluate infiltration rates for both current conditions and future wetter climate conditions as determined and included in the license application. The HYDRUS model showed significantly decreased infiltration rates for both current and wetter climates as compared to the model used in the application. A large-scale regional Ogallala-Antlers-Gatuña (OAG) model is also included in the report which confirms that OAG water will not intrude upon the cover drainage system under both current and future wetter conditions.

The GoldSim model runs predict radionuclide specific doses that result in dose assessments that demonstrate compliance with all of the dose-related performance objectives, specified in Title 30 of the Texas Administrative Code Sections §§336.724, 725, and 726. The performance objectives require protection of the general population (§336.724), protection of individuals from inadvertent intrusion (§336,725), and the protection of workers and the general population during facility operations (§336.727).

Based on simulations from fate and transport models, the radiation doses predicted are a small fraction of the criterion doses of 25 mrem/yr for members of the public and 5,000 mrem/yr for radiation workers. CWF and FWF peak doses, summed over all pathways, with the current climate conditions and over a 100,000-year period, were derived and are shown below for the identified receptors:

- Normal Operations, Worker average dose – CWF 220 mrem/yr, FWF 95 mrem/yr.
- Normal Operations, Site Boundary Individual, and Normal Operations, Nearest Resident (Eunice, NM) – no doses predicted. This is attributable to the fact that there was no airborne source term for the CWF or FWF for either scenario.
- Institutional Control, Worker peak dose – CWF 1.3E-5 mrem/yr, FWF 1.1E-6 mrem/yr.
- Institutional Control, Site Boundary Individual peak dose – CWF 1.3E-05 mrem/yr, FWF 8.0E-05 mrem/yr.
- Institutional Control, Nearest Resident (Eunice, NM) peak dose – CWF 6.0E-8 mrem/yr, FWF 3.6E-7 mrem/yr.
- Post-Institutional Control, Intruder Driller peak dose – CWF 5.8 mrem, FWF 1.4 mrem.
- Post-Institutional Control, Intruder Resident peak dose – CWF 3.4 mrem/yr, FWF 6.1E-1 mrem/yr.
- Post-Institutional Control, Adjacent Resident peak dose – CWF 3.7E-3 mrem/yr, FWF 1.6E-3 mrem/yr.

In a comparison between the results of the updated PA and the PA in the initial license application, calculated doses to the worker and intruder did not substantively change. The doses calculated for an assumed resident at the site boundary, due to the groundwater pathway, was substantially less in this updated PA.

This updated PA clearly confirms and demonstrates the robustness of the characteristics of the site’s geology and the advanced engineering design of the disposal units. Based on the simulations from fate and transport models, the radiation doses to members of the general public and site workers predicted in the initial and updated PA were a small fraction of the criterion doses of 25 and 5,000 mrem/yr, respectively.

1.0 INTRODUCTION

On September 10, 2009, the Texas Commission on Environmental Quality (TCEQ) issued a Radioactive Material License (RML) to Waste Control Specialists LLC (WCS) authorizing, with conditions, the construction of a new facility authorized to dispose of Class A, B and C Low-Level Radioactive Waste (LLRW) in Andrews County, Texas. The licensing, construction and opening of this facility is the first to be developed under the Low-Level Radioactive Waste Policy Act of 1980, as amended in 1985. One of the most challenging tasks of licensing this facility was preparing a Performance Assessment (PA) that addressed the potential impacts to human health and the environment not only during operations, but for tens-of-thousands of years after the 100-year institutional control period had expired. The focus of this updated PA is directed towards the efforts recently undertaken to update the original PA (WCS, 2007) that was developed to support the initial licensing of the waste disposal facility to include the Compact Waste Facility (CWF) and the Federal Waste Facility (FWF).

The purpose of preparing the updated PA was not only to comply with specific license conditions, but also to incorporate new site geological and geophysical characterization data, as well as revised distribution or partitioning coefficients (K_d). Of particular interest were the leach rates from the waste and numerical K_d values established not only for soils, but also present in the waste-matrix interfaces (e.g., radiocarbon bounded with irradiated metals and effects of concrete on mobile radionuclides).

The updated PA includes future climate changes and the peak radiation doses for the period of performance (1,000 years into the future or peak dose whichever is longer [Title 30 of the Texas Administrative Code (30 TAC) §336.724(1)]) as required under the regulations. While many of the baseline assumptions supporting the initial license were incorporated in the updated PA, new probabilistic fate and transport codes, such as GoldSim, and deterministic groundwater flow codes, including HYDRUS and MODFLOW-SURFACT™, were employed to demonstrate compliance with the performance objectives codified in the regulations.

The information and analyses provided in this update to the PA will show that the CWF and FWF satisfy the performance objectives as stated in 30 TAC §§336.724 through 727. These items are addressed as Principal Design Criteria in Section 3.1.2 of the WCS License

Application (LA) (WCS, 2007). This updated PA also meets the requirements set forth in the WCS Performance Assessment Maintenance Plan requiring that WCS submit an updated PA prior to accepting waste and by March 31st of every year thereafter (License Condition (LC) 87 of RML No. R04100). This updated PA will demonstrate compliance with dose limits for workers and members of the public as well as all performance objectives as set forth in LC 87.

2.0 BACKGROUND

2.1 RADIOACTIVE MATERIAL LICENSE NO. R04100 CONDITION 87

2.1.1 License Condition 87.A

“In demonstrating compliance with the performance objectives, the updated performance assessment shall provide for the use of a more realistic and flexible dose modeling code, such as GoldSim, and site-specific estimates of the magnitudes and the variability in the models or codes to provide a greater level of confidence in the results. The use of models or codes should be consistent with the site conceptual model and be capable of addressing the inherent complexity at the site. Any subsequent data collected at the site shall be utilized in the code as well as any other parameters required by the code that were not previously submitted.”

This condition is satisfied by the use of new computer codes that were not used in the LA. Among these computer codes are the groundwater flow codes HYDRUS and MODFLOW-SURFACT™. Radionuclide release, transport, and dose have been modeled with the GoldSim computer code. Code selection is described in Section 3 of this report.

The conceptual model of the site, also described in Section 3, has been kept the same as in the LA, as agreed to with TCEQ. Alternative conceptual models are under development and may be incorporated into future updates.

New site data obtained since the LA was submitted are described in Section 3 of this report.

2.1.2 License Condition 87.B

“The updated performance assessment shall address all plausible release and accident scenarios as they relate to the performance objectives including, but not limited to, protection of individuals from releases after closure, protection of workers and the public during normal operations and from accidents, protection of individuals from inadvertent intrusion, and long-term stability of the disposal site after closure. The accident scenarios must be submitted for review by the executive director prior to initiating revision of the performance assessment.”

The updated performance assessment addresses and satisfies these requirements as discussed in Section 6.5 and in greater detail in Appendix 4, Accident Analysis.

2.1.3 License Condition 87.C

"The updated performance assessment must evaluate the impacts or activities of nearby facilities, including any off-site surface impoundments or water management retention/detention ponds required by this license, to ensure that the performance objectives of 30 TAC §336.723 will continue to be met after closure."

This requirement is met by the discussion provided in Section 4 of this report and by the analysis in the LA, Section 8.1.2. There are no additional nearby facilities, other than those addressed in the LA Section 8.1.2. The analysis shows that the nearby facilities will not affect the ability of the CWF and FWF to meet the performance objectives, nor will they affect the radiological monitoring program or the CWF or FWF.

2.1.4 License Condition 87.D

"The updated performance assessment must evaluate the impact on the performance assessment of saturating the drainage layer in the cover in the event of future water level increases in the Ogallala-Antlers-Gatuña formation. The Licensee must provide, for review and approval, a two-dimensional infiltration model capable of simulating saturated conditions within the drainage layer of the cover. This simulation should consider future predicted conditions of a wetter climate and a degraded (i.e., more conductive) performance layer. Sensitivity analyses should be performed and submitted for review and approval."

This condition is met by the groundwater modeling described in Appendix 1, OAG Groundwater Model Update. Two-dimensional flow modeling was conducted to evaluate the potential for subsurface Ogallala-Antlers-Gatuña (OAG) water to flow into the sand drainage layer on top of the performance cover. The modeling showed that the drainage layer will remain unsaturated under all of the conditions evaluated, including future climate changes and cover degradation.

The conditions of wetter climate and degraded cover have been addressed by the HYDRUS sensitivity cases discussed in Appendix 2. The sensitivity cases include current and future climate conditions, the effects of different model boundary conditions, surface soil and evapotranspiration (ET) cover degradation, performance cover degradation, and the effects of erosion. The HYDRUS sensitivity cases each calculate a net long-term infiltration rate that is used as input to GoldSim dose assessment. A limiting case of high infiltration is described in the GoldSim sensitivity analysis in Appendix 6.

2.1.5 License Condition 87.E

"The annual performance assessment report must be prepared in accordance with the approved Performance Assessment Maintenance Plan. The annual updates must be based on changes of conditions, assumptions, received source term, or any information needed to benchmark against the original performance assessment, the collection and refinement of existing and new data, refinement of assumptions or the refinement or replacement of models in order to minimize uncertainty in the dose modeling results."

This condition has been met by the updated performance assessment described in this report. The Performance Assessment Maintenance Plan (PAMP) lists seven factors that will be evaluated and revised, if necessary, in each performance assessment update. The seven factors are:

- Radionuclide inventory
- Site characterization data
- Facility design information
- Pathways and exposure scenarios
- Conceptual model of the site
- Computer codes
- Sensitivity and uncertainty analysis

Each of these is discussed below.

Radionuclide inventory – The inventory used in this performance assessment has been updated to utilize the inventory provided by TCEQ. It differs from the inventory in the LA because it is based on only 15 years of waste receipts. The inventory provided by TCEQ is consistent with the total activity limits in LC 7.A for the CWF and LC 7.B for the FWF. The inventory is described in Section 5 of this report.

Site characterization data – This performance assessment incorporates new site data that has been gathered since the submission of the LA in 2007. New site information that affects the performance assessment is described in Section 3 of this report.

Facility design information – New facility design information has been incorporated in this performance assessment. Design information that has changed since the LA was submitted includes the area and capacity of the CWF, as well as the elevations at the bottom of the FWF. Facility design information has been provided in the response to LC 63 (WCS, 2009).

Pathways and exposure scenarios – The pathways and scenarios evaluated in this performance assessment have been reexamined and additional pathways have been added. For example, a garden irrigation pathway using water from the 225-foot zone has been added to the current model. Pathways and scenarios are described in Section 6 of this report.

Conceptual model of the site – Considerable work has been done since the LA to refine the conceptual model of the site, particularly as it relates to the groundwater pathway. It has been agreed with TCEQ that the current performance assessment will use the same conceptual model as was used in the LA. This conceptual mode is described in Section 3 of this report.

Computer codes – This performance assessment uses updated computer codes and models as requested by TCEQ. Groundwater flow and infiltration analyses have been conducted with the HYDRUS and MODFLOW-SURFACT™ models. The radionuclide release, transport, and dose analysis has been conducted with the GoldSim model at TCEQ's request.

Sensitivity and uncertainty analysis – The sensitivity and uncertainty analysis is presented in the individual modeling reports, as appropriate. Future updates of the performance assessment will include a more extensive analysis of sensitivities and a Monte Carlo uncertainty analysis using probability distributions to represent parameter uncertainties.

3.0 UPDATED SITE DATA AND MODELS

3.1 SITE CHARACTERISTICS

The site has been extensively characterized, as documented in the LA. Section 2 of the LA contains information on site characteristics, including geology, hydrology, meteorology, and climatology. Section 2 of the LA provides a concise summary of the site characteristics with additional information given in the appendices of the LA. Appendix 2.6.1 of the LA, “Geology Report”, provides much information on the subsurface conditions at the site. The Geology Report includes findings from borehole observations and laboratory tests of site samples. The results are interpreted in the context of the regional geology and provide a basis for the hydrogeological conceptual model used in the performance assessment.

Since the LA was submitted in 2007, additional site investigations have continued to gather information on site characteristics. These continuing studies are discussed in the next section.

All of the site data support the conclusion that vertical groundwater flow through the Dockum, in which the disposal units are constructed, is negligible to non-existent. The site data also support the conclusion that there is no viable hydraulic connection between the OAG unit and the underlying water-bearing units such as the 225-ft zone, where facility performance will be monitored.

3.2 DATA COLLECTION AND EVALUATION

Since the final license application was submitted to TCEQ, a variety of new data and studies have been conducted at the WCS site. These activities are identified below:

3.2.1 Hydrologic Characterization of the Dockum

Water levels in the Dockum 125-, 180-, and 225-foot zones were monitored in existing and new wells. Measurements of in situ water potential, moisture content, saturation, porosity, and electrical conductivity of a saturated paste were made on Dockum core samples from 12 boreholes (Holt et al., 2008; Holt and Hughes, 2008a, 2008b). Three borehole arrays were installed to monitor in situ water potential in the Dockum (Holt et al., 2009a, 2009b); instruments in these arrays have been monitored since their installation (Holt et al., 2010a; Griffith et al., 2010, Griffith et al., 2011a). Neutron access tubes were installed in eleven boreholes to monitor moisture content changes in the Dockum (Holt et al., 2009b; Sigda et al., 2010; Sigda et al., 2011). The hydraulic conductivity and porosity of Dockum rocks was statistically evaluated (Holt et al., 2009c). Hydraulic testing of deep Dockum and Permian formations was conducted (Pickens et al., 2008). A conceptual model accounting for Dockum hydrologic observations was developed (Holt et al., 2010b). A series of compressed-air tests were conducted in six pairs of boreholes to evaluate fracture interconnectivity in the Dockum (Beauheim et al., 2011). Additional hydraulic testing was conducted in wells in the Dockum 225-foot zone (Griffith et al., 2011b). Waters from the Trujillo and Santa Rosa Formations were age dated and geochemically analyzed (Davidson, 2008).

3.2.2 Geologic Characterization of the Dockum

A preliminary interpretation of the depositional environments of the Dockum was presented by Holt et al. (2010b). Discontinuities, including fractures, were mapped during the excavation of the Byproduct landfill (Kuszmaul et al., 2010). Dockum discontinuities were mapped during the excavation of the CWF and FWF landfills (Holt et al., 2010c); the final report on these mapping activities was submitted to TCEQ in September 2011 (Holt et al., 2011). The top of the Dockum was surveyed in the CWF and FWF excavations and preliminary data was submitted in March 2011 and May 2011 (WCS, 2011b and WCS, 2011c).

3.2.3 Dockum and OAG Borings/Wells

There are currently over 250 OAG wells and over 182 Dockum wells, including clusters of monitoring wells around the CWF and FWF landfills. The perimeter monitoring well clusters include wells in the OAG, the 125- and 225-foot zones. The boring logs and well completion information have been submitted under numerous cover letters following completion. One deep boring was drilled for the purpose of evaluating dissolution in the Permian salts (Powers, 2008).

3.2.4 Hydrologic Characterization/Modeling of the OAG

Water levels in OAG wells, including 19 continuously recording wells, were monitored and reported monthly (Grisak and Baker, 2009, 2010, 2011). A geostatistical representation of the top of the Dockum/base of the OAG was developed (Blainey et al., 2009a). An electrical resistivity study was conducted to evaluate the usefulness of electrical techniques for locating water in the OAG (Technos, 2008a,b). OAG waters were geochemically analyzed and age dated to evaluate regional interconnections in the OAG (Davidson, 2009, 2011). A groundwater model of the OAG was developed and the potential for OAG water to encroach into the CWF and FWF buffers zones was evaluated (Blainey et al., 2009b). The impact of focused recharge and anthropogenically-induced recharge to the OAG was assessed (Grisak et al., 2011a).

3.2.5 Other Activities

The locations of the nearest faults were verified (Powers, 2009a). Selected core samples from a deep borehole were petrographically examined (Powers, 2009b). Casing and cement bond logs for the Central Well at WCS were evaluated and the Central Well was plugged and abandoned (Powers, 2009c). Additional soil sampling and erosion modeling using the SWAT code was conducted (URS 2009a). Seismic stability during operations was evaluated (URS 2009b). Sorption experiments were conducted on subsurface materials from the WCS site (Serne et al., 2009). Chloride measurements were conducted on borehole soil samples to characterize recharge from the land surface (Grisak et al, 2009, Grisak et al., 2011b).

3.3 SCENARIOS AND PATHWAYS

The scenarios and pathways evaluated in this performance assessment are listed in Section 6 of this report. The exposure and radionuclide transport pathways are described in detail in Appendix 6, GoldSim Pathway Analysis.

The transport pathways consider the routes by which radionuclides may migrate from the disposal units to the accessible environment. Transport pathways generally include air, surface water, groundwater, soil and biotic pathways. The transport pathways are combined into exposure scenarios, which represent potential activities or conditions through which humans may become exposed to radionuclides. For example, an onsite resident scenario after facility closure may include exposures from inhalation of airborne radionuclides, use of groundwater, and external radiation from contamination exhumed from the disposal units by the individual. The full set of exposure scenarios is listed and evaluated in Section 6 of this report.

The scenarios and pathways evaluated in the performance assessment are the same as those evaluated in the LA. The scenarios are selected to demonstrate compliance with the facility performance objectives, which include protection of members of the general public, protection of workers at the facility, and protection of inadvertent intruders who occupy the site after institutional controls have ended. The scenarios cover the operational period, the institutional control period, and the post-institutional control period, as required by Texas regulations.

3.3.1 Waste Cells and Hydrogeologic System

The WCS CWF and FWF disposal system model comprises waste cells, at an excavated depth of about 100 feet below ground surface, contained entirely within the claystones of the Dockum Group Cooper Canyon Formation. The CWF and FWF cover designs are nearly identical, differing only in the area and slope of the compacted clay cover and drainage layers. The CWF compacted clay cover and drainage layers have a 4% slope, while the FWF has a 3% slope. There is a 3-foot thick compacted clay liner overlain by a High Density Polyethylene (HDPE) geosynthetic liner on the bottom and sides of the waste cells, as well as a 3-foot thick compacted clay performance cover overlain by a HDPE geosynthetic liner at approximately the top of the Dockum. The compacted clay performance cover is overlain by a 2-foot thick granular drainage layer. The performance cover and granular drainage layer are sloped from the center of the landfills such that the drainage layer drains to the OAG on the perimeter of the landfill. The performance cover and drainage layer are in turn overlain by about 30 feet of non-select red bed fill, comprising mostly claystone, a 3-foot thick bio-intrusion layer and an upper 4-foot thick evapotranspiration layer. The evapotranspiration layer will be covered with protective gravel mulch and the surface will be sloped to drain across the landfill from north to south.

The conceptual model of subsurface flow and transport on which this first annual performance assessment update is based is the same conceptual model that was used in the LA. The hydrogeologic conceptual model in the LA performance assessment focused on a groundwater pathway, labeled pathway G3, which consisted of downward movement of infiltration from precipitation through the cover system, the waste, and the lower compacted clay and HDPE liners, into the undisturbed Cooper Canyon Formation. Downward movement of moisture through the Cooper Canyon Formation continued under unsaturated conditions to the 225-foot sandstone, where a domestic well was located at the edge of the landfill and an onsite resident obtained part of a domestic water supply from the well. The remainder of the water supply necessary to support the hypothetical onsite resident was derived from an undefined alternate water source. The water obtained from the well by the onsite resident was not diluted within the 225-foot zone; that is, the water from the well was considered to be pure leachate derived from flow through the landfill, undiluted by any uncontaminated 225-foot zone water or by transport through the 225-foot zone.

3.4 CODES AND SUMMARY RESULTS

The codes used in this PA update are presented below.

3.4.1 GoldSim

GoldSim is used as the PA code for dose calculations. The various exposure pathways and scenarios are described in Section 3.3 above, and in Section 6. The exposure to a receptor such as a future onsite resident farmer is calculated by GoldSim as the sum of the exposures received from various interrelated exposure pathways. For instance, the exposure pathway and receptor dose resulting from drinking contaminated groundwater and eating garden vegetables watered with the same contaminated water is related to the exposure received from eating domestic animals, who have in turn been exposed by drinking contaminated groundwater. The interconnections among the exposure pathways are explicitly defined in GoldSim. GoldSim is also capable of conducting multiple runs using input variables for which multiple potential values and distributions are available, resulting in a cumulative probability distribution for the potential dose to a receptor.

GoldSim is also used to calculate transport through the geologic system from the waste cell through the landfill liner to the underlying 225-foot zone in the Dockum Group hydrogeologic system, and each radionuclide is assigned a specific K_d value. The K_d values used in the GoldSim PA serve two purposes. First, the K_d values determine the radionuclide release rates from the waste disposal unit and, second, they determine the retardation factors, which are the ratios of the pore water velocity to the radionuclide transport velocities. The K_d values used for each radionuclide are listed in Appendix 5, Distribution Coefficients. The GoldSim calculations of transport through the Dockum hydrogeologic system have been compared to both analytical and numerical solutions for flow and transport, with excellent results.

In the LA G3 pathway, an onsite resident obtained a small portion of a domestic water supply from a well located at the edge of the landfill. As calculated by RESRAD, the water obtained from the well was diluted by a factor of about 400 relative to the concentrations present in undiluted leachate derived from flow through the landfill. The GoldSim analysis in this PA update does not assume any dilution of the leachate that enters the 225-foot zone. However, additional water to meet the domestic water demand is assumed to be supplied from an uncontaminated source that is mixed with the well water after it is withdrawn from the 225-foot zone.

The water demand and well withdrawal rate in the GoldSim model serve a similar purpose, which is to calculate the mixing factor of leachate in water used for the dose calculations. Pumping rate calculations in GoldSim show the maximum sustained withdrawal rate from a well in the 225-foot zone is about 0.4 L/day. The total water demand for the intruder is set at 466 m^3/yr; this demand can't be supplied solely by the well. The radionuclide concentrations for dose calculations are obtained by combining the well pumping rate (0.4 L/day of leachate) with enough additional clean water to equal the water demand. With this simple mixing model, the radionuclide concentrations for the dose calculations depend on both the well pumping rate, which specifies how much leachate is withdrawn, and the water demand, which determines how much additional clean water is required.

The sensitivity cases described in Appendix 6 alter the mixing assumptions by changing the water demand from the baseline value of 466 m^3/yr to a much lower value of 41 m^3/yr, leading to higher concentrations in the water. The RESRAD option in GoldSim looks at an intermediate water demand of 250 m^3/yr, as in the LA, although the basis for this value is not explained in the RESRAD manual. A decrease in the water demand produces the same effect as an increase in the well pumping rate, since they both affect the concentrations.

The GoldSim model used in the updated PA can be compared to the original RESRAD analysis by activating a RESRAD switch, which turns on some of the RESRAD G3 parameters used in the LA. The RESRAD G3 parameters implemented in GoldSim include the K_ds used in the LA, a domestic well capacity of 1.7 L/d (the RESRAD default value) and an infiltration rate of 1 mm/yr. GoldSim conducts the G3 pathway analysis with the RESRAD switch on in a more realistic manner than the RESRAD analysis in the LA. In GoldSim, contaminated water enters the 225-foot zone at 1 mm/yr after traveling downward through the Dockum. GoldSim preserves mass by displacing the existing water in the 225-foot zone at the rate of 1 mm/yr. Additionally, in GoldSim the domestic well is located at the edge of the waste cell (which accounts for the sloping sides), providing approximately 20 meters of travel in the 225-foot zone, with some minor dispersion. The addition of realistic constraints and assumptions in the GoldSim G3 analysis results in a maximum CWF dose approximately one order of magnitude lower than the G3 analysis in the LA. The CWF peak dose is 0.061 mrem/yr from ^{36}Cl at about

21,000 years rather than 15,600 years as documented in the LA. For the FWF, the peak dose is more than two orders of magnitude lower. The FWF peak dose is 0.0069 mrem/yr from Tc-99 at 60,000 years, rather than 36,000 years in the LA. The reduction in dose is attributable to the Tc-99 inventory limit imposed by TCEQ, as well as the more realistic modeling with GoldSim.

The results of the GoldSim calculations show compliance with the 25 mrem/yr performance objective for members of the general public. The results also show doses to onsite individuals that are below the limits imposed by the performance objectives. The dose results for each exposure pathway are provided in Section 6.

3.4.2 HYDRUS

HYDRUS, a software package for simulating flow and transport in two- and three-dimensional variably saturated media, is used to model the infiltration of precipitation through the cover system and into the waste cells under current and future climatic conditions. A detailed discussion of the HYDRUS modeling is provided in Appendix 2, Infiltration Modeling in HYDRUS 2-D. The cover system for both the FWF and the CWF are almost identical. Hence the same infiltration model is used to estimate infiltration through the cover for both facilities. In no instance is there saturation developed in the drainage layer, therefore the difference between the slopes of 3 and 4% of the drainage layer are irrelevant.

The HYDRUS model uses daily climatic precipitation and evapotranspiration forcings based on 57 years of climatic information from the Hobbs' weather station for the current climatic conditions, and the Wichita, Kansas weather station for hypothetical future wetter conditions. Wichita is the surrogate location for the future hypothetical climate determined in a future climate study presented in the LA. Parameters for the various subsurface layers modeled with HYDRUS are based on recent laboratory analyses of samples obtained during excavation of the CWF and FWF, as well as analyses reported in the LA.

Thirteen (13) scenarios were run with the HYDRUS model, simulating various boundary conditions, atmospheric forcings, and conditions of cover naturalization, degradation and erosion. Additional sensitivity analysis was conducted to assess the impact of extending the model further downward and of including the 225-foot zone. For each scenario, the 57-year history of climatic forcings was repeated 100 times, for a total simulation time of 5,700 years, to limit the influence of boundary and initial conditions. The moisture fluxes through the waste were significantly less than the fluxes presented in the LA, due to the more detailed moisture balances and infiltration/evapotranspiration capabilities of the HYDRUS code compared to the RESRAD code used in the LA. Results indicate that the average downward flux for current climate conditions (Hobbs climate and ET forcings) range from approximately 0 to 0.02 mm/yr. Average downward flux for future-climate conditions range from less than 0.01 mm/yr (for the eroded model) to approximately 0.3 mm/yr. Additional sensitivity analysis showed that the model is relatively insensitive to the location of and prescribed pressure head at the bottom boundary as well as the inclusion of the 225-foot zone.

Both the current and future-climate conditions fluxes are much less than the 1 mm/yr flux used in the original license application. This indicates that this more realistic 2-D heterogeneous infiltration model, which directly interacts with atmospheric forcings, leads to lower flux compared to the more conservative HELP/VS2DI models used in the LA.

The moisture fluxes as well as saturation profiles through the landfill cover system are input to GoldSim as part of the array of calculated infiltration rates from the landfill into the Dockum. The range of potential fluxes to the Dockum from the landfill is used by GoldSim to calculate radionuclide concentrations entering the groundwater in the 225-foot zone.

3.4.3 MODFLOW-SURFACT™

MODFLOW-SURFACT™ is used to model the OAG groundwater system. The OAG model is presented in Appendix 1 OAG Groundwater Model Update, of the CWF Performance Assessment Update (WCS, 2011a). The updated model is significantly larger than the OAG model presented in the LA. The OAG model is approximately 8.5 by 10 miles, extending into Gaines County to the north, Lea County to the west, the southern boundary of the Flying W ranch to the south and about 4 miles east of the ranch boundary to the east. The primary objective of the OAG model is to evaluate whether water from the OAG could intrude on the CWF and FWF facilities and saturate all or part of the granular drainage layer above the compacted clay performance cover, thereby potentially increasing the downward flux of water through the waste. The model was designed to include the relatively large surface depression about 1 mile east of the eastern ranch boundary which occasionally has water in it, though currently the depression is dry. Also included in the model are small playas and other low areas which are the locations of intermittent recharge to the OAG. Studies of chloride profiles in soils on the facility indicate that there is no recharge to the subsurface in interplaya areas, consistent with the literature on recharge in arid and semi arid areas.

The boundaries of the model are: to the north, constant heads representing approximately west to east groundwater flow in the buried ancestral Monument Draw in Gaines County; to the west, a no-flow boundary; to the south, a constant head boundary representing dry conditions in the OAG that follows the ranch boundary; and to the east, constant heads that promote east/southeast groundwater flow in the OAG. The lower boundary of the model is simulated as no flow, essentially representing the top of the Dockum as impermeable compared to the sands and gravels of the OAG. In the model, the top of the Dockum is a kriged surface in the vicinity of the facilities where the data density is greatest, coupled to a geologically interpreted surface beyond the facilities area where the data are sparse.

The hydraulic conductivity distribution in the OAG was assigned based on 1) the observed texture in drill cuttings, 2) the geologic interpretation that sediments in the buried channels on the top of the Dockum will likely have higher hydraulic conductivities than elsewhere, and 3) the observations that OAG sediments in the vicinity of the top of the red bed ridge will likely have lower hydraulic conductivities because development of the caprock and younger caliches has penetrated further into the OAG sediments, occluding pore space and reducing the hydraulic conductivity. The steady state OAG model was calibrated to observations of wet and dry conditions as determined from 231 wet and dry wells on the WCS site and vicinity. Virtually all of the wells with water were used as calibration targets, eliminating only those that were clearly affected by anthropogenic activities such as infiltration from drainage ditches. Hydraulic head residuals were less than +/- 0.2 feet in the facilities area where the most head measurements were available. The normalized root mean square error was 6 percent, indicating that the target head errors constitute a small fraction of the steady-state model’s range of heads, corroborating the good quality of the calibration (Anderson and Woessner, 1992).

The calibrated model was used to simulate two transient events. The transient simulation representing the 2004 precipitation event accurately simulated heads between TP-14 and the southernmost extent of saturation north of the FWF and CWF landfills. Relatively large simulated increases in head beneath the playa at TP-14 result in modest water-level responses near the southern extent of OAG saturation. This is consistent with measured data where the response to groundwater recharge at TP-14 is at least 6 feet, a relatively large water-level increase beneath the playa, and smaller increases, on the order of 1 foot, are observed at TP-18 near the southern extent of OAG saturation.

A transient simulation representing pumping near the ranch house shows agreement with the observed data, in that the combined average pumping rate at Stock B East and PW-07 cannot be sustained over time and there is no response simulated at nearby wells consistent with observations from monthly monitoring. Pumping in this area has been discontinued.

The calibrated flow model was used to evaluate groundwater flow in the OAG under current and future climatic conditions. Under current climatic conditions the model shows, in the facilities area, wet and dry conditions similar to those observed in the field and a flow pattern consistent with observations reported in the monthly OAG groundwater reports (Grisak and Baker, 2009, 2010, 2011).

Outside the facilities area, the calibrated flow system is consistent with the regional flow regime in the High Plains/Ogallala aquifer reported in the literature and modeled in the Texas Water Development Board (TWDB) Groundwater Availability Model (GAM) reports. Under future climatic conditions, similar to those at Wichita, Kansas, the extent of the saturation in the OAG expands slightly; however, saturation in the OAG does not extend to the buffer zones of the landfills, because of their location on the topographically high axis of the buried red ridge. This is consistent with current observations in OAG wells. Under future climate conditions, the modeled elevation of the surface of the OAG water is about nine feet below the lowest elevation of the top of the red bed at the northern edge of the buffer zones. Water from the OAG cannot intrude on the facilities and saturate all or part of the granular drainage layer above the compacted clay performance cover; therefore, OAG saturation that could potentially increase the downward flux of water through the waste will not occur.

Based on a performance assessment meeting held on September 16, 2011 between TCEQ and WCS, WCS agreed to address the following points related to the OAG groundwater model: run the model with constant heads on a portion of the western boundary as an alternate representation (replacing the previous no-flow condition) and compare the no-flow and constant-head boundary simulations; provide interpreted top-of-Dockum elevations from oil/gas logs and water-level data not previously submitted (i.e., spreadsheets with water level data from wells outside of the model domain); and develop an updated hand-contour map of groundwater elevations based on water levels in OAG wells from March 2011 within the WCS site boundaries. These points are addressed in Appendix 1 and are summarized below.

WCS has provided an additional simulation that is an alternative steady-state representation of the western model boundary that includes constant-head cells on a portion of the western boundary previously simulated with a no-flow boundary. Specifically, flow to well PZ-1 is represented as a flux from constant head cells, rather than a recharge source. A comparison of the no-flow boundary simulation previously delivered and the western constant-head boundary simulation shows a minor impact on the overall water budget as a result of the boundary modification and elimination of a recharge area. As a result of the boundary modification, inflows from recharge were reduced 8%, constant-head boundary inflows increased 0.1%, and evapotranspiration losses were reduced by 1.0%. Heads from the two different simulations were compared and the head contours were found to be similar and in fact overlie each other throughout much of the model domain. The head decrease in the area of eliminated recharge is up to 3.5 feet. No change in simulated head occurs in the erosional channel on the top of Dockum north of the Compact Waste Disposal Facility (CWF) landfill.

Dr. Dennis W. Powers examined gamma logs from oil or gas wells in Texas and New Mexico at and surrounding the WCS site and determined estimates of top of Dockum elevations at 45 locations. Groundwater elevation data outside the model domain and outside of the WCS site were obtained from various sources including the TWDB groundwater database (TWDB, 2011), the United States Geological Survey (USGS) National Water Information System (NWIS) web interface (USGS, 2011), and the New Mexico Office of the State Engineer's Office (NM OSE, 2011). The well location and top of Dockum elevation data from the log interpretations, the additional water-level data, and the contour maps for top of Dockum and groundwater elevations from water levels at the WCS site in March 2011 are included in Appendix 1.

4.0 OTHER FACILITIES CONSIDERED

4.1 OTHER FACILITIES

There are five non-WCS facilities and three WCS facilities within three miles of the CWF and FWF. None of the facilities will affect the ability of the CWF or the FWF to satisfy any performance objectives or mask their environmental monitoring systems. The nearby facilities include:

- Wallach Quarry
- Lea County Landfill
- Sundance, Inc.
- DD Landfarm
- National Enrichment Facility (URENCO)
- WCS RCRA landfill
- WCS byproduct material disposal facility
- Offsite surface impoundments or water management retention/detention ponds

The retention ponds at the CWF and FWF will have no effect on meeting the performance objectives. The ponds are lined and will not release any water to the subsurface during the operational period of the facilities. At closure, the ponds will be removed and the site returned to its original condition.

For all facilities listed in the LA there have been no updates. The original detailed analysis of the five offsite facilities and the two onsite facilities can be found in section 8.1.2 of the LA.

4.2 COMPLIANCE WITH DOSE LIMITS AND PERFORMANCE OBJECTIVES

During operations, the dose limit to a member of the public is 100 mrem/yr total effective dose equivalent (30 TAC 336.313(a)). After closure, the Compact and Federal facilities are each subject to a 25-mrem/yr dose limit to a member of the public from radionuclides released from the disposal facility. The 25 mrem/yr limit is used in this assessment for members of the public during normal operations and after closure.

For the intruder scenario, a basic assumption is that only one facility is intruded upon. The intruder is not assumed to disturb multiple waste facilities sequentially. Therefore, the inadvertent intruder doses have no additive effects among multiple facilities.

The atmospheric pathway doses are limited by the 25 mrem/yr performance objective, but other regulations may also apply. An air pathway dose limit of 10 mrem/yr is commonly applied to facilities based on the EPA National Emissions Standards for Hazardous Air Pollutants rules for radionuclides. No air pathway doses are expected from the CWF or the FWF during normal operations because all of the waste will be in canisters. After facility closure, gaseous radionuclide emissions due to waste decomposition may occur. The air pathway doses after closure are a small fraction of the 10 mrem/yr limit.

An additional performance criterion is the radon gas flux emanating from the cover to the atmosphere. The radon gas flux criterion from 40 CFR 192 (20 pCi/m^2-s) was used for comparison with the calculated radon flux from the CWF and FWF. The flux calculated with the GoldSim model was a small fraction of the limit.

4.3 ENVIRONMENTAL MONITORING

The collection of site data for the PA input is described in Section 2.0 of the LA. Data was collected as part of site geological investigations, ecological studies, the annual groundwater monitoring program, and the radiological environmental monitoring program (REMP). Meteorological data was collected from weather stations onsite and in nearby communities.

The vicinity of the CWF and the FWF is monitored for direct radiation and for radioactivity in groundwater, surface water, air, soil, plants, and animals. Sampling locations have been selected to allow the monitoring systems to determine the source of any non-natural occurring radionuclides outside of trended and acceptable limits.

Direct radiation will be monitored by Thermoluminescent Dosimetry (TLD) placed in the disposal cells of each facility. The TLDs in the disposal cells will be below grade and will be unaffected by radiation from other nearby facilities. Additional TLDs will be placed at grade level on the fence at the disposal site boundaries to monitor external radiation levels. The external radiation monitoring systems in each facility will therefore not be masked by radiation from other facilities.

Monitoring of soil, plants, and animals near the disposal facilities will be less indicative of the source of the contamination. However, any radionuclides detected in the soil, plants, or animals are most likely to be detected nearest the facility from which they were released. Soil samples will be taken between facilities to minimize masking and help determine the source of any releases. Radionuclide analysis will likely indicate the source of the release by the suite of radionuclides present.

In summary, the environmental monitoring system will be capable of determining the sources of any radionuclide releases, both during operations and after closure. Any releases from the CWF or the FWF will not be masked by release or from the RCRA or byproduct material disposal facilities.

5.0 RADIONUCLIDE INVENTORY

5.1 TYPES, FORMS, AND QUANTITIES OF RADIOACTIVE WASTE FOR THE CWF

The types, forms, and quantities of waste to be received at the CWF are described in the LA in Section 8.2 and Appendix 8.0-1 of the LA. The current performance assessment uses the same 38 waste streams that were described and characterized in the LA in Section 8.2 and Appendix 8.0-1. Different volumes of each waste stream are used in this performance assessment than were used in the LA, in order to meet the requirements of LC 7.A.The CWF license authorizes the disposal of the 38 waste streams for a period of 15 years, versus 35 years considered in the LA. LC 7.A limits the aggregate disposed volume to 2.31 million cubic feet and the total disposed activity to 3.89 million curies. Consistent with these limits, TCEQ has provided a radionuclide inventory for use in the performance assessment. The inventory is shown in Table 5-1.

Table 5-1 CWF Performance Assessment Inventory

Radionuclide	Inventory (Ci)	Radionuclide	Inventory (Ci)
H-3	8.02E+03	Sb-124	1.85E+00
Be-7	1.62E+01	Sb-125	9.85E+01
Be-10	5.26E+02	I-125	3.50E+01
C-14	6.00E+02	I-129	1.23E-04
Na-22	9.85E-02	I-131	2.81E+01
P-32	5.20E+00	Cs-134	2.25E+02
S-35	2.87E+00	Cs-135	0.00E+00
Cl-36	4.61E+00	Cs-137	2.74E+04
Ca-45	2.54E-02	Cs-139	8.31E-09
Sc-46	1.90E-01	Ba-133	3.06E-03
Cr-51	1.93E+02	Ba/La-140	3.70E+00
Mn-54	1.80E+04	Ce-141	6.02E-02
Fe-55	2.39E+05	Ce-144	3.69E+02
Fe-59	1.30E+01	Pm-147	1.46E+01
Co-56	6.80E-05	Eu-152	2.72E-06
Co-57	9.64E+01	Gd-153	2.08E-03
Co-58	6.69E+03	Hf-175	1.66E-03

Radionuclide	Inventory (Ci)	Radionuclide	Inventory (Ci)
Co-60	3.24E+06	W-187	5.70E-04
Ni-59	2.37E+03	Ta-182	1.66E-03
Ni-63	3.46E+05	Re-187	1.66E-03
Zn-65	3.07E+02	Ir-192	2.04E+00
Ge-68	9.17E-05	Au-198	1.70E+00
Se-75	2.13E-03	Hg-208	7.17E-09
Kr-85	6.26E+01	Ra-226	9.67E+01
Rb-86	3.75E-02	Ra-228	0.00E+00
Sr-85	3.02E-02	Th-230	6.04E-02
Sr-89	0.00E+00	Th-232	5.47E-01
Sr-90	1.79E+02	U-232	1.91E-06
Y-88	1.36E-06	U-233	1.46E-09
Zr-95	4.05E+02	U-234	9.55E-03
Nb-93m	1.86E+03	U-235	1.69E-05
Nb-94	1.25E+01	U-236	8.54E-06
Nb-95	4.90E+02	U-238	8.64E-02
Mo-93	4.36E+00	Np-237	1.46E-07
Tc-99	3.01E+00	Pu-238	5.76E+00
Ru-103	3.78E-02	Pu-239	2.70E-01
Ru-106	0.00E+00	Pu-241	1.44E+02
Ag-108m	1.67E+02	Pu-242	3.44E-02
Ag-110m	5.69E-01	Am-241	3.44E+00
Cd-109	5.19E+00	Am-243	2.25E-09
Cd-113m	1.35E+01	Cm-242	9.79E-03
In-111	5.37E-02	Cm-243/244	2.17E-02
Sn-113	1.65E-02	**Total**	**3.89E+06**

The inventory in Table 5-1 meets the total activity limit of LC 7.A. The waste streams volumes were not provided by TCEQ, but were developed by WCS to meet the total volume limit of 2.31 million cubic feet, also stated in LC 7.A.

The waste stream volumes are shown in Table 5-2. These volumes are based on 15 years of operational waste receipts from utility and non-utility generators. The volumes are equal to the volumes given in the LA multiplied by a factor of 15/35 to adjust for 15 years of operation, compared to 35 years in the LA. The decommissioning waste streams described in the LA ware also included but their volumes were not changed from those in the LA.

Table 5-2 CWF Waste Stream Volumes

Waste Stream	**Class**	**Volume (ft^3)**
Utility Waste Streams		
1. CONDFSL Vermont	A	1.58E+04
2. CONDFSL Vermont	B	1.18E+03
3. COTRASH Texas	A	4.78E+03
4. COTRASH Vermont	A	1.73E+04
5. DECONRS Vermont	C*	5.76E+02
6. FLDRFSL Texas	A	1.41E+03
7. FPFILSL Vermont	A	9.71E+01
8. FPFILSL Vermont	C	1.96E+02
9. NCTRASH Texas	A	2.34E+05
10. NCTRASH Vermont	A	1.73E+04
11. NFRCOMP Vermont	C	1.11E+03
12. PROCFIL Texas	C	8.27E+03
13. RWCUPRS Vermont	B	7.52E+01
14. RWDMRES Texas	A	4.60E+03
15. RWDMRES Texas	B	1.05E+04
16. RWDMRES Vermont	A	3.96E+02
17. RWDMRES Vermont	B	2.95E+01
18. SSYSRES Texas	A	1.03E+04
Non-Utility Waste Streams		
19. ABSLIQD Texas	A	9.25E+03
20. ABSLIQD Vermont	A	3.57E+02
21. BIOWAST Texas	A	3.70E+03
22. BIOWAST Vermont	A	3.57E+02
23. COTRASH Texas	A	1.39E+04
24. COTRASH Vermont	A	4.48E+02
25. HIGHACT Texas	A	2.41E+03

Waste Stream	Class	Volume (ft^3)
26. LOWASTE Texas / Vt	A	2.64E+03
27. NCTRASH Texas	A	3.78E+04
28. NCTRASH Texas	B	8.72E+02
29. NCTRASH Vermont	A	1.17E+01
30. SOURCES Texas	A	4.60E+03
31. SOURCES Texas	B	8.78E+02
32. SOURCES Texas	C	1.98E+03
Decommissioning Waste Streams		
33. D&D PWR Texas	A	1.61E+06
34. D&D PWR Texas	B	2.07E+05
35. D&D PWR Texas	C	3.80E+03
36. D&D BWR Vermont	A	7.60E+04
37. D&D BWR Vermont	B	5.70E+03
38. D&D BWR Vermont	C	1.30E+03
Total Volume (ft^3)		**2.31E+06**

(*) The DECONRS Vermont Class C waste stream was incorrectly labeled as a Class A waste stream in the LA. The error originated in the Texas A&M source document used to prepare the LA.

With the exception of the volumes and activities shown in the tables, all other waste characteristics and properties are the same as those described in Section 8.2 and Appendix 8.0-1 of the LA. Those sections describe the conditions of waste receipt, waste stream chemical and physical properties, prohibited waste forms, and waste during the closure period. The inventory provided in this section serves as the input for the groundwater transport calculations in the performance assessment. The more detailed information on individual waste streams, provided in Appendix 8.0-1 of the LA, serves as the source term for the worker dose calculations, the accident analysis, and the intruder protection analysis.

5.2 TYPES, FORMS, AND QUANTITIES OF RADIOACTIVE WASTE FOR THE FWF

The types, forms, and quantities of waste to be received at the FWF are described in the LA in Section 8.2 and Appendix 8.0-2 of the LA. The current performance assessment uses the same waste streams that were described and characterized in the LA, except for waste stream 69 (depleted uranium oxide), which has been excluded from the inventory by License Condition 46.A. License Condition 7.B limits the aggregate FWF disposed volume to 26 million cubic feet and the total disposed activity to 5.6 million curies. Consistent with these limits, TCEQ has provided a radionuclide inventory for use in the performance assessment. The inventory is shown in Table 5-3.

Table 5-3 FWF Performance Assessment Inventory

Radionuclide	**Inventory (Ci)**	**Radionuclide**	**Inventory (Ci)**
Al-26	2.64E-05	Pu-238	5.17E+01
Am-241	7.41E+02	Pu-239	2.10E+03
Am-243	1.35E-01	Pu-240	2.35E+02
Ba-133	2.86E+01	Pu-241	1.43E+03
C-14	1.43E+02	Pu-242	9.11E-03
C-14 act. metal	2.59E+01	Pu-244	1.56E-03
Cd-113m	2.10E+00	Ra-226	7.41E+01
Cl-36	1.58E-01	Ra-228	5.39E-02
Cm-243	2.76E-01	Se-79	5.34E-03
Cm-244	9.10E-01	Sm-151	2.55E+01
Co-60	4.07E+05	Sn-121m	3.41E+00
Cs-135	1.06E+03	Sn-126	4.23E-04
Cs-137	1.83E+06	Sr-90	2.11E+06
Eu-152	4.07E+02	Tc-99	3.50E+01
Eu-154	5.50E+02	Th-229	5.65E+00
H-3	1.03E+06	Th-230	2.61E+01
I-129	1.50E-01	Th-232	3.45E+00
K-40	7.96E-01	U-232	5.33E-02
Nb-93m	1.14E+01	U-233	6.63E-01
Nb-94	1.96E+00	U-234	2.59E+03
Ni-59	2.76E+03	U-235	1.61E+02
Ni-63	2.12E+05	U-236	2.04E-01
Np-237	2.31E+01	U-238	9.24E+03
Pa-231	3.53E-01	Zr-93	4.36E-01
		Total	**5.60E+06**

The inventory in Table 5-3 meets the total activity limit of LC 7.B. Although waste stream volumes were not provided by TCEQ, the performance assessment update used a total waste volume of 26 million cubic feet, as generated, consistent with LC 7.B. Physical, chemical, and radiological properties of the individual waste streams are described in Appendix 8.0-2 of the LA.

6.0 COMPLIANCE WITH PERFORMANCE OBJECTIVES

6.1 PATHWAYS AND SCENARIOS

Waste disposal operations will be conducted in compliance with regulations contained in 30 TAC Chapter 336, Subchapter D and the conditions of RML No. R04100. In order to ensure compliance with regulations and the performance objectives, exposure scenarios have been developed and modeled to assess potential doses to individuals. The pathways and scenarios have been developed consistent with previous analyses conducted for the LA and consistent with performance assessment guidance documents (TCEQ, 2004; NRC, 2000).

A scenario is a set of conditions, environmental transport pathways, and a receptor individual for whom a dose is calculated. The performance assessment is based on the following four exposure scenarios:

- Normal operation
- Institutional control
- Post-institutional control
- Accidents

Normal operation covers the period during which the waste facilities are actively accepting and disposing of waste. Site access is controlled and the facility is assumed to operate as designed. This scenario includes doses to workers at both the CWF and FWF as well as doses to nearby offsite members of the public. The institutional control scenario covers the period after waste disposal operations have ceased, the facilities have been closed, but workers maintain the site and restrict access. The institutional control period is assumed to last for 100 years after closure of the facilities. The post-institutional control scenario evaluates the time period after institutional controls have ended. Access to the site is no longer assumed to be actively restricted and members of the public are postulated to visit or occupy the former waste disposal sites. Records of past waste disposal activities are assumed to be ineffective at preventing individuals from occupying the site. Finally, the accident scenario evaluates the potential consequences of waste-handling accidents, unusual conditions, or severe weather conditions at the facilities during waste disposal operations.

Each of the four exposure scenarios may cause radiological doses to different individuals. For each exposure scenario, potential human receptors are identified at various locations. Doses are evaluated for each individual receptor and the results are compared to the performance objectives. The individual receptors include the following individuals:

- Site worker
- Site boundary individual
- Adjacent resident (post-institutional control)
- Nearest resident
- On-site inadvertent intruders

The individual receptors in the dose analysis are described in detail in the appendices to this report as follows:

- Site workers, under normal operating conditions, are addressed in Appendix 3, Worker Doses.
- Site workers, under accident conditions are addressed in Appendix 4, Accident Analysis.
- The site boundary individual, adjacent resident, nearest resident, and inadvertent intruders are addressed in Appendix 6, GoldSim Pathway Analysis.

Each of the receptors described above may be exposed to radionuclides through several environmental transport pathways. The pathways to be evaluated are specified in 30 TAC §336.709(1), and include air, soil, groundwater, surface water, plant uptake, and exhumation by burrowing animals. The pathways are grouped into exposure scenarios as shown in Table 6-1. The pathways are described in detail in Appendix 8.0-3 and Table 8.3-2 of the LA. The pathways shown in Table 6-1 differ from those shown in the LA because the pathways related to airborne dust from the FWF-Non-Containerized Disposal Unit (NCDU) have been eliminated. Only the pathways applicable to the CWF and the FWF-Containerized Disposal Unit (CDU) are shown in the table.

Each exposure scenario has a dose limit associated with each individual receptor. For normal operations (i.e., no accidents) and post-closure, the dose criterion of 25 mrem/yr for a member of the public comes from the performance objective in 30 §TAC 336.724. This dose limit applies to the site boundary individual and the nearest resident. The worker dose limit of 5,000 mrem/yr comes from 30 TAC §336.305(a). The 100-mrem/yr dose criterion selected for members of the public under accident conditions is the value for normal operations stated in 30 TAC §336.313(a)(1). Although this dose criterion does not specifically apply to accident conditions, it serves as a basis to evaluate protection of the public.

Table 6-1 Scenarios for Performance Assessment

Receptor	**Pathways**		**Dose Limit (mrem/yr)**
Normal Operations Scenario			
Worker	---	External exposures as calculated in Appendix 8.0-4 “Worker Doses”	5,000
Site Boundary	---	No credible pathways for normal operations	25
Nearest Resident	---	No credible pathways for normal operations	25
Institutional Control Scenario			
Worker	A6	Radioactive gas emanation through cover	5,000
Site Boundary	A6	Radioactive gas emanation through cover	25
	G3	Groundwater transport to 225-foot sandstone	
Nearest Resident	A6	Radioactive gas emanation through cover	25
Post-Institutional Control Scenario			
Intruder Driller	A6	Radioactive gas emanation through cover	25 *
	D3	Exposure to inadvertent intruder well mud pit	
Intruder Resident	A6	Radioactive gas emanation through cover	25 *
	G3	Groundwater transport to 225-foot sandstone	
	D3	Exposure to inadvertent intruder well mud pit	
Adjacent Resident	A6	Radioactive gas emanation through cover	25
	G3	Groundwater transport to 225-foot sandstone	

Receptor	Pathways		Dose Limit (mrem/yr)
Accident Scenario			
Worker	A8	Air releases from dropped waste container	5,000
	A9	Air releases from fire	
	D1	Exposure to high activity waste package suspended by equipment failure	
Site Boundary	A8	Air releases from dropped waste canister	100
	A9	Air releases from fire	
	D1	Exposure to high activity waste package suspended by equipment failure	
Nearest Resident	A8	Air releases from dropped waste canister	100
	A9	Air releases from fire	
	D1	Exposure to high activity waste package suspended by equipment failure	

*The 25 mrem/yr dose limit was imposed by TCEQ, citing the 25 mrem/yr public dose limit specified in 30 TAC §336.72. NRC (1982) and DOE (1999) both use a 500 mrem/yr dose limit for inadvertent intruders.

6.2 NORMAL OPERATION SCENARIO

Doses to site workers during normal operation are evaluated in Appendix 3, Worker Doses. Worker doses consist entirely of external radiation from waste packages. Any unanticipated releases from waste packages are evaluated in the accident scenario.

For a member of the public at the disposal site boundary, no external or air pathway doses are anticipated. All wastes are in containers, so no airborne releases are expected. Waste disposal operations are conducted in the disposal unit below grade, so no external exposures are expected offsite. No doses are anticipated for the nearest resident for the same reasons.

6.3 INSTITUTIONAL CONTROL SCENARIO

Doses to site workers during the 100-year institutional control period are possible from decomposition gases diffusing through the cover system to the atmosphere. Maintenance workers will periodically inspect and maintain the site during the institutional control period. Decomposition gases are the only pathway through which doses could occur.

The site boundary individual, like the maintenance worker, is assumed to be exposed to gaseous radionuclides that emanate from the cover and are transported by wind. In addition, the site boundary individual may be exposed to groundwater if they drill a well adjacent to the facility.

The nearest resident may be exposed to gaseous radionuclides that are transported downwind. Groundwater exposures are not considered because the nearest resident is approximately six kilometers from the disposal facility.

6.4 POST-INSTITUTIONAL CONTROL SCENARIO

Doses are calculated for intruders and for a member of the public who resides immediately adjacent to the former disposal units. Two intruders are evaluated, using the same approach as in NRC (1986). As shown in Table 6-1, the intruder scenarios are the intruder driller and intruder resident. The intruders are exposed to gaseous radionuclides that diffuse through the cover and to contaminated drill cuttings in the driller’s mud pit, which are a source of external radiation. The driller is assumed to drill through the particular waste stream that causes the highest dose, rather than the facility average radionuclide mix. The intruder resident is exposed to the covered mud pit, radioactive gases from the disposal units, and groundwater.

The post-institutional control scenario also includes a member of the public who resides immediately adjacent to the former disposal units. This individual is not considered an inadvertent intruder because they do not disturb the buried waste. This individual resides adjacent to the waste site and is exposed to radioactive gases that may emanate through the cover and to potentially contaminated groundwater.

6.5 ACCIDENT SCENARIO

The accident scenario considers inhalation and external radiation doses to site workers during accidents or unusual conditions. The accident scenario analyzes a dropped waste container, an overturned truck, a truck fire or explosion, tornado or severe winds, flooding, brushfires, and a crane malfunction.

The accident scenarios may cause doses to an individual at the site boundary through inhalation of airborne radionuclides released during an accident or from direct radiation resulting from the crane malfunction accident.

The nearest resident is expected to have minimal exposure to accidents, due to the fact that the resident is approximately six kilometers from the facility. The only pathway for the nearest resident is atmospheric transport of airborne radionuclides. The doses to all receptors in the accident scenario are evaluated in Appendix 4, Accident Analysis.

6.6 DOSE EXPOSURE PATHWAY ANALYSIS

Many of the transport pathways and scenarios described here are evaluated using the GoldSim computer model. The pathways and scenarios modeled with GoldSim are described in Appendix 6, GoldSim Pathway Analysis. The following are the pathways contained in the GoldSim performance assessment model submitted with this report:

- Pathway A6, Gas emanation through finished cover
- Pathway G3, Leaching and groundwater transport of radionuclides to a well screened in the 225-foot water-bearing zone
- Pathway D3, Exposure to inadvertent intruder well mud pit

The accident analysis pathways have not been coded into the GoldSim platform, but are presented in Appendix 4, Accident Analysis. These pathways include:

- Pathway A8, Air releases associated with a dropped, breached waste container
- Pathway A9, Air releases associated with a truck fire
- Pathway D1, Exposure to high activity waste package suspended by equipment failure

Likewise, the external exposures to workers from normal operations have not been coded into GoldSim, but are evaluated separately in Appendix 3, Worker Doses.

6.7 PERFORMANCE ASSESSMENT RESULTS

The results of the performance assessment show that the performance objectives and regulatory dose limits are satisfied for workers and members of the public, both during operations and for the long term. The dose analysis results are summarized in Table 6-2 for a 100,000-year simulation period. The simulation was run for 100,000 years to identify any potential groundwater doses from the more mobile long-lived radionuclides. The maximum doses for a 100,000-year period, described in Appendix 6, GoldSim Pathway Analysis, all satisfy the 25-mrem/yr performance objective.

Table 6-2 Performance Assessment Dose Summary

	CWF (mrem/yr)	FWF (mrem/yr)	Appendix Reference	Criterion (mrem/yr)
Normal Operations, Worker				
External gamma (a)	2.2E+02	9.5E+01	Worker Doses	
Total	**2.2E+02**	**9.5E+01**		**5,000**
Normal Operations, Site Boundary Individual				
No credible exposure pathways	0	0		
Total	**0**	**0**		**25**
Normal Operations, Nearest Resident				
No credible exposure pathways	0	0		
Total	**0**	**0**		**25**
Institutional Control, Worker				
Pathway A6, gases	1.3E-05	1.1E-06	GoldSim Pathway Analysis	
Total	**1.3E-05**	**1.1E-06**		**5,000**
Institutional Control, Site Boundary Individual				
Pathway A6, gases	1.3E-05	8.0E-05	GoldSim Pathway Analysis	
Pathway G3, 225 zone	0	0	GoldSim Pathway Analysis	
Total	1.3E-05	**8.0E-05**		**25**
Institutional Control, Nearest Resident				
Pathway A6, gases	6.0E-08	3.6E-07	GoldSim Pathway Analysis	
Total	**6.0E-08**	**3.6E-07**		**25**
Post-Institutional Control, Intruder Driller				
Pathway A6, gases	1.1E-05	2.4E-05	GoldSim Pathway Analysis	
Pathway D3, mud pit	5.8E+00	1.4E+00	GoldSim Pathway Analysis	
Total	**5.8E+00**	**1.4E+00**		**100**
Post-Institutional Control, Intruder Resident				
Pathway A6, gases	3.0E-03	6.4E-03	GoldSim Pathway Analysis	
Pathway G3, 225 zone	3.7E-03	1.6E-03	GoldSim Pathway Analysis	

	CWF (mrem/yr)	FWF (mrem/yr)	Appendix Reference	Criterion (mrem/yr)
Pathway D3, mud pit	3.4E+00	6.1E-01	GoldSim Pathway Analysis	
Total	**3.4E+00**	**6.2E-01**		**100**
Post-Institutional Control, Adjacent Resident				
Pathway A6, gases	3.0E-03	6.4E-03	GoldSim Pathway Analysis	
Pathway G3, 225 zone	3.7E-03	1.6E-03	GoldSim Pathway Analysis	
Total	**3.7E-03(b)**	**6.4E-03(b)**		**25**
Accidents, Worker				
Pathway A8, dropped pkg	2.6E+02	7.3E+02	Accident Analysis	
Pathway A9, fire	8.6E+02	2.9E+03	Accident Analysis	
Pathway D1, ext rad	8.9E-01	8.9E-01	Accident Analysis	
Total	**8.6E+02(c)**	**2.9E+03(c)**		**5,000**
Accidents, Site Boundary Individual				
Pathway A8, dropped pkg	2.4E-01	6.7E-01	Accident Analysis	
Pathway A9, fire	2.4E+01	7.9E+01	Accident Analysis	
Pathway D1, ext rad	7.5E-03	7.5E-03	Accident Analysis	
Total	**2.4E+01(c)**	**7.9E+01(c)**		**100**
Accidents, Nearest Resident				
Pathway A8, dropped pkg	1.4E-05	3.9E-05	Accident Analysis	
Pathway A9, fire	6.2E-03	2.0E-02	Accident Analysis	
Total	**6.2E-03(c)**	**2.0E-02(c)**		**100**

a) Average over all worker types, from Appendix 3, Worker Doses.
b) Pathway doses occur at far different times and are not additive.
c) Assumes only one worst-case accident occurs.

6.8 COMPLIANCE WITH PERFORMANCE OBJECTIVES

The dose assessments summarized in Table 6-2 show compliance with all of the dose-related performance objectives, as stated in 30 TAC §§336.724, 725, and 726. The performance objectives require protection of the general population (§336.724), protection of individuals from inadvertent intrusion (§336,725), and protection of workers and the general population during facility operations (§336.727). The results in Table 6-2 show that workers, the general population, and inadvertent intruders will all be protected.

The calculated doses for the general population are all below the regulatory limit of the 25 mrem/yr. The projected doses to workers during normal operations are below the 5,000 mrem/yr regulatory limit. Although there are no regulatory limits applicable to accidents, the potential doses to workers from accidents are below the limit for normal occupational exposures. Inadvertent intruders are protected as demonstrated by the dose analysis, which meets the criterion for members of the public, even though specific dose criteria for intruders are not specified in the regulations.

7.0 SITE STABILITY

Long-term stability of the site is ensured by its siting, design, use, operation, and closure. The siting criteria in 30 TAC §336.728(i) and (j) recommend avoiding areas that exhibit severe or frequent faulting, folding, earthquakes, volcanism, slumping, landsliding, erosion, or weathering. The WCS site satisfies these criteria. The site is nearly flat, so there is little possibility of landsliding. Settling or slumping is unlikely because the geologic strata are well consolidated and surface soils have low moisture content. The semi-arid climate helps maintain low moisture content of the soils. Surface water is absent except during infrequent rainstorms. In addition, there is minimal seismic and no volcanic activity near the site. There is no evidence of tectonic or volcanic activity near the site in the recent past. Groundwater at the site is of relatively low quality and is located in greatest quantities at depths of 600 to 1,000 feet or more. The shallow groundwater is unlikely to be used for irrigation because of limited yields, so site stability is not likely to be affected by groundwater withdrawal.

Evidence suggests that over the long term, the site is aggrading (WCS 2007). However, wind and water erosion of the site have been modeled and evaluated in HYDRUS using conservative assumptions, discussed in greater detail in appendix 2 of this report. Even under the conservative assumption that erosion occurs continuously over the long term, the calculated erosion rates are very low and the site remains stable.

7.1 HEADWARD EROSION OF MONUMENT DRAW

Monument Draw, New Mexico and Monument Draw, Texas are 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 ended 12,000 years ago when sediment began aggrading in the valleys (Holliday, 1995). Filling of the valleys culminated about 3,000 years ago and little aggradation or downcutting has occurred in the past 3,000 years. Estimated rates of recent incision (downcutting) in the modern draws range from 0.06 in/yr to 0.08 in/yr (Gustavson et al., 1980; Finley and Gustavson, 1980). The valleys average about 1,542 feet in width, and the average maximum width is about 3,073 feet (Holliday, 1995). If the valleys were initially incised and widened over a time span of 8,000 years (20,000 to 12,000 years ago), then the flanks of the valleys retreated at an average rate of 1.18 in/yr to a maximum of 2.95 in/yr over that time span (assuming parallel slope retreat on either side of the valley axis). The WCS facility is about three miles east of Monument Draw, New Mexico. If, in the future, this draw were to begin a renewed episode of incision and widening, it would take more than 160,000 years (at the average rate of 1.18 in/yr) for eastward retreat of the flank of Monument Draw, New Mexico to approach the WCS facility. These drainages have not widened their valleys for the past 12,000 years; hence, retreat of the valley flanks would require renewed downcutting in the lower reaches of Monument Draw, New Mexico, and would also likely require a return to climatic conditions that prevailed during the Late Pleistocene when the draws were incised (Lehman, undated).

Site data collection efforts addressed in the LA have included the analysis of soil samples from drainage areas on the site. The soil samples were analyzed by optical luminescence to determine their ages. Ages ranged from approximately 6,000 years to slightly over 50,000 years. The results show that the drainages have been aggrading for at least the last 50,000 years. This includes the last pluvial period at the end of the last glaciation, approximately 10,000 to 15,000 years ago. Although the age dating indicates there were episodes of erosion in the past, those episodes were relatively short-lived and did not reverse the long-term trend of aggradation. Future climate studies anticipate that during the next 50,000 years, there will be periods where the average precipitation exceeds current levels but will be lower than during the last pluvial period. Therefore, it is likely that the site will continue to aggrade with windblown sediment. Measurements for the last three to five years at several stations on the WCS site indicate that aggradation has been dominant over erosion at most of the stations.

Aerial photographs of the site over the last 69 years were analyzed to identify trends related to soil erosion. The photographs, and the age dating of soil, are consistent with the conceptual model, which is that the site is aggrading and that the erosion and drainage features are very localized (WCS 2007). There is no evidence that the base level of Monument Draw, New Mexico has any effect on the site.

7.2 DESIGN, USE, AND OPERATION

The design, use, and operation of the facility will help minimize the need for long-term active maintenance. Section 3.0 of the LA presents the complete discussion of waste cell configuration. The disposal units will isolate waste under a thick earthen cover. During waste disposal operations, the waste packages and bulk wastes will be placed using compaction and backfilling procedures to minimize void spaces. All Class C, Class B, containerized Class A, and unstable Class A waste will be placed in reinforced concrete canisters. In addition, bulk waste will be placed and compacted in a manner that ensures long-term stability. Voids inside concrete canisters will be filled with grout and voids between canisters will be backfilled with sand. Waste acceptance criteria will require waste generators to fill voids inside waste packages to the extent practicable. Filling all void spaces in the disposal units to the extent practicable will minimize the potential for long-term settlement and subsidence of the disposal units.

7.3 CLOSURE

Facility closure will enhance its long-term stability. The ground surface at the disposal site will be contoured to approximate the original stable ground surface. The contours will divert surface water from the disposal units, promote runoff, and help prevent water and wind erosion. A natural vegetative cover will be established that will help stabilize and maintain the soil surface and minimize erosion. The water diversion features and the vegetated cover also serve to minimize water infiltration into the disposal units, which further promotes site stability.

Following closure of the disposal units and placement of the final cover system, the facility will be monitored for subsidence. Custodial care and minor repairs to the cover system will be made, if necessary.

Appendix 3.0-3 of the LA shows the calculations used for siting, design, and long-term stability of the LLRW facility.

8.0 CONCLUSIONS

In a comparison between the results of the updated PA against the one developed in support of the initial license, both clearly demonstrated the robustness of the characteristics of the site's geology and engineering design of the disposal units. Based on the simulations from fate and transport models, the radiation doses to members of the general public predicted in the initial and updated PA were a fraction of the allowable 25 mrem/yr (0.25 msievert/yr) dose standard for tens-of-thousands of years into the future. Draft Texas guidance on performance assessment (TCEQ, 2004) recommends a period of analysis equal to 1,000 years or until peak doses from the more mobile radionuclides occur.

The EPA National Emissions Standards for Hazardous Air Pollutants limits radionuclide doses through the air pathway to 10 mrem/yr. Gaseous radionuclide doses from the CWF and the FWF, due to decomposition gases, are a small fraction of the dose limit.

The radon flux from the CWF and FWF were compared to the flux limit of 20 pCi/m^2-s from 40 CFR 192. Because of the thick cover system, the calculated radon flux was a very small fraction of the limit.

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