

APPENDIX 7.3.2 EARLY WARNING AND CORRECTIVE ACTION PLAN

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1.0 PURPOSE AND SCOPE

This Early Warning and Corrective Action Plan has been developed based on the requirements of the Texas Administrative Code §336.731 which states:

- §336.731 (b) During the land disposal facility site construction and operation, the licensee shall maintain a monitoring program. Measurements and observations shall be made and recorded to provide data to evaluate the potential health and environmental impacts during both the construction and the operation of the facility and to enable the evaluation of long-term effects and the need for mitigative measures. The monitoring system shall be capable of providing early warning of releases of radionuclides and chemical constituents before they leave the disposal site boundary.
- §336.731 (c) After the disposal site is closed, the licensee responsible for post-operational surveillance of the disposal site shall maintain a monitoring system based on the operating history and the closure and stabilization of the disposal site. The monitoring system shall be capable of providing early warning of releases of radionuclides and chemical constituents before they leave the disposal site boundary.
- §336.731 (d) The licensee shall have a plan for taking corrective measures if migration of radionuclides and chemical constituents would indicate that the performance objectives of this subchapter may not be met.

For the purposes of this appendix the term “corrective action” refers to “corrective measures” that are addressed in 30 TAC §336.731(d). The Radiological Environmental Monitoring Plan (License Application Appendix 2.10.1-2) and Non- Radiological Environmental Monitoring Plan (License Application Appendix 2.10.2-2) and operational radiological safety programs (License Application Appendix 5.5.2-1 “Radiological Program and Procedures”) provide the inputs to this early warning and corrective action program. The environmental monitoring programs are scheduled to periodically collect and analyze various matrices that may provide a pathway for radionuclides and contaminants to man.

The respective monitoring plans, quality assurance plan (License Application Appendix 9.0 “Quality Assurance”) and radiological control manual provide for contracting, auditing and review of laboratory data that are inputs to this plan. Laboratory data verification and validation are outside the scope of this plan. As part of the environmental monitoring plans, data review against investigation and action levels trigger steps verify and/or confirm the data through reanalysis or resampling.

Operational monitoring encompasses collection and analysis of leachate from the disposal cells and day-to-day waste disposal activities.

Monitoring during the operational phase provides assurance to the site management and public regulators that the site is performing as designed. If the site does not perform as designed during the operational phase, then the monitoring system may need to be expanded to include monitoring for potential remedial actions.

The scope of this plan encompasses situations that could be present at low level radioactive waste (LLRW) facilities that may require corrective actions even though there is no immediate or obvious safety or environmental concern to the casual observer. This is because some situations, left unchecked, could result in performance degradation to an extent that the ability of the disposal facility to continue to meet performance objective could be compromised at some point in the future. Monitoring can provide early warning of degrading performance factors.

Corrective actions taken during operational, closure or post closure phases of the proposed land disposal facilities [Compact Waste Facility (CWF) and Federal Waste Facility (FWF)] will be of a scale and method appropriate to the situation.

The details of the corrective actions employed will depend upon the failures observed and the details of what actions must be taken. Based on the ways the disposal system may fail, corrective actions that might be employed have been identified and evaluated. Due to the unknown scope of a failure requiring corrective action, detailed step-by-step procedures and equipment specifications are outside the scope of this document. Radiation work permits (RWP) and specific procedures will be prepared prior to performing corrective actions. Corrective actions may be implemented on a graded approach.

The comprehensive pathway analysis is outside the scope of this appendix, but one is presented in Appendix 8.0-6 “Detailed Pathway Analysis,” which show the predominant pathway that contributes dose to man over a 100,000-year period is groundwater.

Appendix A provides a general outline for a corrective action plan.

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3.0 DEFINITIONS

- Buffer Zone – The 100-foot wide area between the disposal cell and the disposal site boundary.
- Disposal Site – Area excavated for disposal plus the buffer zone.
- Early Warning – Identification of potential contaminant migration prior to it failing to meet TAC **336.731**
- WCS Flying W Ranch – Contiguous property under the control of WCS located in Andrews County, Texas and Lea County, New Mexico

4.0 RESPONSIBILITIES

4.1 Radiation Safety Officer (RSO)

Responsible for the implementation of this program and periodic review of documentation generated in accordance with this procedure.

4.2 The Radiation Safety Technician (RST)

Responsible for the performance of this program and informing the RSO when there is non-compliance with any portion of this program.

4.3 The Environmental and Regulatory Compliance Manager (ERCM)

Responsible for reviewing the periodic cover inspections, and making required notifications to regulators.

5.0 PROCEDURE

5.1 Prerequisites

5.1.1 Facility Design

The facility is designed to reduce environmental impacts and create stable waste mass.

5.1.2 Performance Assessment – Groundwater Pathway to Man

The uppermost water-bearing zone that is continuous across the WCS ranch is defined at a depth of approximately 225 feet. The primary radionuclides reaching the well in this zone were the long-lived mobile radionuclides Cl-36, Tc-99 and I-129, which accounted for 99 percent of the dose. The CWF had a maximum dose from Cl-36 of 0.58 mrem/yr calculated to occur at about 15,000 years. The maximum dose for the Federal Facility was 3.4 mrem/yr, primarily from Tc-99 and occurred at 36,000 years.

5.1.3 Groundwater Dynamics

The hydraulic gradient in the “225-foot zone” is approximately 0.016 ft/ft based on the recent groundwater gradient maps presented in Figures 6.6-4 and 6.6-5 in Appendix 2.6.1 (Geology Report) in the LA. These gradient maps show similar direction and magnitude of the gradient with groundwater flow to the south-southwest at an average gradient of 0.016 ft/ft across the Site. The calculated groundwater velocity is 0.004 ft/year.

5.1.4 Operational Faces within the Disposal Area

At no time during disposal operations will the entire volume of the disposal area be open to the environment. The cells will be incremental opened, filled, and closed. Radiological waste and non-radiological excavation activities may occur simultaneously within either the CWF or FWF. At a minimum, there will be a 100-foot buffer zone between the disposal cell footprint and the disposal site boundary. Depending on the operational configuration at a given point in time, the distance between the outer edge of active operations and the disposal site boundary may be hundreds of feet.

5.1.5 Data Analysis and Response System

WCS is currently conducting pre-operational environmental monitoring under the Radiological Environmental Monitoring Program (REMP) presented in appendix 2.10.1-2, and in accordance with the requirements for the existing RCRA facility. Data collected as part of the current REMP and from prior radiological monitoring activities, in conjunction with the data collected under the monitoring program for the existing RCRA facility, comprise the baseline dataset for the disposal site. In support of this License Application, WCS has prepared Addendum 1 to the REMP, which is not currently being implemented at the site. Addendum 1 to the current site REMP is also contained in Appendix 2.10.1-2. The current site REMP as modified by Addendum 1 is referenced collectively in this document as “the REMP”.

WCS has also developed a Non-Radiological Environmental Monitoring Plan (NREMP) for the Federal and Compact facilities. The NREMP is presented in Appendix 2.10.2-2.

The current environmental monitoring program has been expanded prior to operation of the proposed facilities (pre-operational monitoring) as specified in the REMP and NREMP. Pre-operational monitoring will include at least one year of data collected at new and existing stations identified in the REMP. The baseline data, in combination with the pre-operational data, will constitute the background dataset. The background dataset will be used to establish background values for evaluation of environmental monitoring data collected through the operational and post-operational monitoring programs. The operational and post-operational monitoring programs are also addressed in the REMP and NREMP.

The data analysis and response system is designed to provide a reliable indication of any significant release of hazardous or radiological waste constituents. The system will be applicable to air samples, soil samples, water samples, vegetation samples, and thermoluminescent dosimetry (named hereafter, monitoring locations) as introduced in Appendix 2.10.1. The system will apply the methods described below to data for each hazardous or radiological constituent specified in Appendices 2.10.1 and 2.10.2 from each of the monitoring locations.

This data analysis and response system establishes the methods to be used to determine whether there is statistically significant evidence of contaminant migration for any parameter monitored at the WCS monitoring locations. Should such evidence of contamination be found, then the appropriate notification, investigation, and corrective action will be initiated.

5.1.5.1 Statistical Methods for Evaluation of Monitoring Data

The WCS data analysis program will use either prediction intervals or control charts, consistent with the requirements of 40 CFR 264.97(h) for groundwater detection monitoring at RCRA Subtitle C facilities, to evaluate the monitoring data for statistically significant evidence of contamination. The specific method to be used for each constituent will be determined from the results of analyses of the background data. WCS will use a minimum of eight background samples to calculate estimates of the mean and standard deviation. The recommended minimum sample size will include the percentages of non-detects cited in section 5.1.5.1.5. Inter-location comparisons are proposed for a variety of reasons as discussed in Section 5.1.5.1.1 below.

For those constituents with at least 50% detected concentrations, a combined Shewhart-cumulative sum (CUSUM) control chart method will be followed. As described in Section

5.1.5.4, all data that are within control limits will periodically be pooled with the background data, and control limits will be recomputed.

For the rarely-detected constituents (fewer than 25% detects), the combined Shewhart-CUSUM control chart method is not suitable, as the sample variance is not adequately defined (Gibbons, 1994). For these constituents, a prediction interval method will be implemented. According to McNichols and Davis (1988), a non-parametric approach is preferred for those constituents with a large percent of results reported as below the detection limit, while Gibbons (1994) and ASTM Method D6312 indicate that non-parametric or Poisson prediction limits may be used in this situation. Since the purpose of the environmental monitoring program is to detect increases in constituent concentrations that could be caused by facility operations, only the upper prediction limit will be considered. For both of the selected methods, the applicable limits are based on the background information.

For those constituents with at least 25% detected concentrations, but less than 50% detected concentrations, the combined Shewhart-CUSUM control chart method is preferred as long as acceptable false positive and false negative error rates can be achieved as discussed in Section 5.1.5.3. If acceptable error rates cannot be achieved for these constituents with the combined control chart approach, a non-parametric or Poisson prediction limit will be followed.

5.1.5.1.1 Basis for Selected Statistical Approaches

Both prediction intervals and combined control charts are accepted methodologies for evaluation of environmental monitoring data. When applied properly, both methods can minimize the probability of incorrectly concluding that a statistical exceedance exists (the false positive, or Type I error rate), as well as the probability that contamination goes undetected by the evaluation procedure (the false negative, or Type II error rate). Further, these two methods have published tables to easily control site-wide false-positive rates (SWFPRs) when testing multiple monitoring locations and constituents (Gibbons 1999; Davis and McNichols 1994a). Control of the SWFPR and the false negative rate is discussed in detail in Section 5.1.5.3 of this plan.

As noted above, inter-location comparisons are proposed, or stated more specifically, measurements of typically-detected constituents at individual monitoring locations will be compared to statistically-derived background levels established from data collected across the site. The basis for this approach, however, differs for the environmental media being sampled, as characterized below for conditions that have not been affected by site operations.

The air medium is highly dynamic, with rapid and sudden changes in the direction and rate of movement driven by variations in meteorological conditions. By contrast, groundwater is a relatively static medium, with limited and typically predictable variations in the direction and rate of movement. This is particularly true at the WCS site, where the rate of groundwater flow is extremely slow (0.004 ft/yr, as calculated in Section 6.2.4 of the Geology Report). Surface soils represent a moderately dynamic medium, since their parent chemical and radiological characteristics result from historical geologic processes, but their surface expression results in shorter-term changes due to erosional and depositional processes.

The concentrations of target analytes in vegetation samples will vary based upon the soil in which the vegetation is growing and the assimilative characteristics of the particular types of vegetation sampled. Due to the paucity of vegetation at the WCS site, the type of vegetation sampled will be limited to that which is available at the designated sampling locations, and

essentially random variability in these samples is anticipated. Similarly, fauna samples will be collected on an as-available basis, and essentially random variability in these samples is also expected due to differences in sources of food, range of foraging area, etc.

For highly dynamic media or where essentially random variability is anticipated, individual monitoring locations across the site are not anticipated to encounter discrete and discernible data populations. Rather, a single data population with inherent variability over space and time is expected. Therefore, site-wide background values are appropriate for comparison with future measurements in samples of air, vegetation, and fauna to evaluate potential impacts of site operations. Since surface soil samples are limited to a maximum depth of 5 cm, samples will be collected from the topsoil/windblown sand that overlies caliche on the red bed ridge and the Blackwater Draw sand off the flanks of the red bed ridge. As such, a single soil type will be sampled, and potential variations between locations are expected to be random. Thus, site-wide background values are also appropriate for surficial soils.

For groundwater, site-wide background values are most appropriate due to the extremely slow rate of groundwater movement. As calculated in Section 6.6.3 of the Geology Report, a sampling frequency on the order of 100 years could be required to obtain independent samples of groundwater at the WCS facility. Consequently, a background database comprised of multiple measurements over even tens of years from a group of up-gradient wells would not provide independent data, which is an inherent assumption in commonly-used statistical procedures including the combined control chart and prediction limit procedures.

Furthermore, it is likely that the sub-population sampled at a group of up-gradient wells in the WCS hydrogeologic setting would be statistically different from the sub-population that would be sampled at the down-gradient wells. Also, the use of intra-well background values, which can be desirable for evaluating groundwater monitoring data to remove the element of spatial variability, is not viable at this site. This is because all data obtained from a given well over the entire course of the monitoring program would be highly correlated.

The dataset consisting of measurements from multiple wells at various locations over the WCS site will provide the least-correlated data for establishment of background values for evaluating groundwater monitoring data. This approach will also result in conservative estimates of the true variability, which will in turn result in actual false positive rates in excess of that calculated. In the event that the actual false positive rates are unacceptable, alternate methods that provide for separate estimates of the variability components will be investigated.

5.1.5.1.2 Combined Shewhart-CUSUM Control Charts

The combined Shewhart-CUSUM control chart (Westgard et al. 1977; Lucas 1982; Starks 1989) compares sequential measurements in time against control limits. The combined Shewhart-CUSUM control chart has two control limits. The Shewhart component assesses one monitoring result at a time to detect large, sudden departures from the background levels. The CUSUM component assesses available monitoring results cumulatively to detect gradual increases from background levels.

In addition to the assumption of independent data, the combined Shewhart-CUSUM control chart procedure assumes that the data are normally distributed with a fixed mean and constant variance. If the background dataset includes data that could have been impacted by prior operations, trends may be observed that would lead to biased estimates of the mean and variance,

resulting in inflated control limits. Additionally, if outliers (inconsistently large or small values) are present in the background dataset, as may occur due to errors in the sample collection, transportation, and analytical process, and these outlying data are not removed from the computation of the background mean and standard deviation, the magnitude of the control limit will be artificially increased, resulting in an increase in the false negative rate. Consequently, prior to calculation of control limits, all data in the background database will be evaluated for the presence of outliers and the normality of the distribution, and all data obtained from locations within the existing operational areas of the site after their start-up will be evaluated for trends. After these steps have been completed, the combined control chart can be constructed.

Testing for Normality – Testing for normality is performed using the Shapiro-Wilk test, which is appropriate when the number of background values is 50 or less (Gilbert, 1987; Gibbons, 1994; EPA, 2000). If the number of background values exceeds 50, D’Agostino’s test (Gilbert, 1987; Gibbons, 1994) or the Shapiro-Francia test (Gibbons, 1994) will be used.

The purpose of testing for normality is simply to evaluate whether this assumption is met. When the assumption is not met, a common approach is to transform the data by taking the logarithm of each measurement or by raising them to a power so that the transformed data are Gaussian. However, as pointed out by Gibbons (1994), the normality assumption is less important than the independence assumption for the robust performance of the Shewhart-CUSUM method. Further, transformation of the data can lead to biased estimates when they are transformed back into original scale (Gilbert, 1987). Therefore, WCS proposes to proceed with the Shewhart-CUSUM method regardless of whether the distribution of the data is consistent with a hypothesis of normality, except that a non-parametric upper control limit is established in those cases where normality is rejected. Calculation of the non-parametric control limits is based on the median (Conover, 1999).

Identification of Linear Trends – As noted above, all data in the background dataset obtained from locations within the existing operational areas of the site after their start-up will be evaluated for trends. The existence of a linear trend may be investigated using a variety of methods; however, when irregularly-spaced measurement periods and/or non-detect values (i.e., missing data) are present in the background data, the appropriate test methods are more limited. Also, many of these tests require large datasets that cannot be realistically obtained for all media. For example, linear regression techniques are not appropriate for datasets with missing data, and the Box-Jenkins method requires 50 to 100 measurements. However, trend analysis of moderately-sized data sets with missing data can be conducted using Sen’s Test (Gilbert, 1989) or the Mann-Kendall Test (Gilbert, 1989; Gibbons, 1994). If regularly-spaced data are available, robust linear regression techniques can be used. If a trend is identified in the background data attributable to prior waste management activities at the site, the data will either be excluded from the computation of the background limits or will be adjusted to remove the bias associated with the apparently-affected measurements.

Computation of the Shewhart-CUSUM Limits – The combined Shewhart-CUSUM control chart (Westgard et al. 1977; Lucas 1982; Starks 1989) compares sequential measurements in time against control limits, and any monitoring result above a control limit will be considered an exceedance. The combined Shewhart-CUSUM control chart has two control limits. The Shewhart component assesses one monitoring result at a time to detect large, sudden departures

from the background level. The CUSUM component assesses available monitoring results cumulatively to detect gradual increases from the background level.

Two control limits are calculated for the two components of the Shewhart-CUSUM limits, as described below.

The Shewhart control limit is defined to be

$$SCL = \bar{x} + z * s$$

Where

\bar{x} = the background mean

s = the background standard deviation

z = the standard normal quantile for the chosen SWFPR.

The value for z suggested by the Environmental Protection Agency (EPA 1992a, 1992b) and based on studies by Starks (1989) is 4.5. This means that a monitoring result that is 4.5 standard deviations larger than the background mean will be considered an exceedance. The EPA-suggested value for z (i.e., 4.5) will be retained for the life of the landfill monitoring program unless a change is agreed to with the TCEQ.

The CUSUM control chart statistic for time i is defined to be

$$S_i = \max \left\{ 0, \frac{x_i - \bar{x}}{s} - k + S_{i-1} \right\}$$

where

\bar{x} = the background mean

s = the background standard deviation

k = the displacement parameter (or the minimum number of standard deviations' change between one sample to the next that is added to the CUSUM statistic).

$S_0 = 0$

The CUSUM statistic is compared to the control limit h, which is the number of standard deviations shift before a result is considered an exceedance. The EPA (EPA 1992a, 1992b), based on studies by Starks (1989), recommends values of k = 1 and h = 5. For the CUSUM, a cumulative increase of h = 5 standard deviations will be considered an exceedance.

The advantages of the combined control chart are that it is graphical and easy to read, the method is somewhat robust to the assumption of normality (Starks 1989), and it can detect both sudden large changes as well as gradual increases over time. The disadvantage is that the combined control chart and associated limits are more complicated to set up than some other methods.

5.1.5.1.3 Prediction Limits

The nonparametric prediction limit for a single future monitoring result (Davis and McNichols 1994a) makes no distribution assumptions, although observations are assumed to be independent and identically distributed. However, relatively large background datasets may be necessary to

attain acceptable false positive error rates. If sufficient data exist to establish a non-parametric prediction limit with an acceptable false positive error rate (see Section 5.1.5.3), a non-parametric prediction limit will be established. The maximum background value is used as the nonparametric prediction limit in these cases. If the background dataset is insufficient to establish a non-parametric prediction limit with an acceptable false positive error rate, but at least eight detected values are present in the background data, a Poisson prediction limit may be established, following the methodology identified by Gibbons (1994). In all other cases, the maximum quantification limit will be used as the prediction limit (ASTM D6312).

The advantages of the nonparametric prediction limit are that there are no distribution assumptions and it does not require substitutions for results reported below the detection limit. It can therefore be used for data with a large non-detect population and it easily controls the SWFPR for testing multiple monitoring locations and constituents. The disadvantages are that a larger background sample size is required to obtain a reasonably small SWFPR and it is less powerful than parametric approaches if distribution assumptions could be met.

5.1.5.1.4 Other Acceptable Methods

An alternative statistical test may be submitted for approval by TCEQ should it be required. Because the above two methods are deemed appropriate for use in the WCS data analysis program, no further statistical methods are presented here. However, if issues arise during implementation of either of the two selected methods, agency approval will be sought prior to using an alternative statistical method to evaluate the environmental monitoring data.

5.1.5.1.5 Dealing with Non-detected Results

When using the combined control chart procedure to establish background values for parameters with non-detected results, any non-detected results will be replaced by 1/2 the reported detection limit and then evaluated by the combined control chart. Studies show that this simple replacement method is reasonable for up to 50% non-detected results (McNichols and Davis 1988; Davis 1994). WCS plans on defining non-detects as samples with values below the LLD and therefore any values above the LLD will be used as reported in the statistical procedures.

For those constituents where the combined control chart procedure is not appropriate, the non-parametric or Poisson prediction interval method will be followed as described above. Neither of these prediction limits requires any substitution for results reported as below the detection limit.

5.1.5.2 Resampling to Confirm Exceedance

Verification re-sampling is an integral part of the statistical methodology (USEPA 1992 section 5) for control of the SWFPR when multiple monitoring locations and parameters are being evaluated. Gibbons (1999) has evaluated the statistical properties of combined Shewhart-CUSUM control charts, including evaluation of the false positive rate as a function of the number of background measurements, the number of future comparisons, the verification resample strategy, and alternative Shewhart control limit factors (z). Based on the evaluation performed by Gibbons, at least one re-sampling event is anticipated to be necessary to achieve an acceptable SWFPR (i.e., < 5%) with the EPA-recommended control limit factor of 4.5, assuming, of course, that the data are independent. Since the hydrogeology at the WCS site

precludes the collection of independent groundwater samples, it is critical that the calculated false positive rate for this medium be as small as possible and certainly less than 5%.

For parametric prediction limits, verification re-sampling strategies that require one of the next one or two re-samples to be in bounds result in lower upper prediction limits than would otherwise be required to obtain an SWFPR of 5%, as well as lower false negative rates. For non-parametric prediction limits, one of these verification re-sampling strategies *must* be used as a necessary component of the decision rule to reduce the false positive rate to acceptable levels. However, this verification re-sampling step does not influence the false negative rate. The only factor that reduces the false negative rate for non-parametric prediction limits is the background sample size (Gibbons, 1994). It is noted that other re-sampling strategies (e.g., requiring both of the next two re-samples to be in bounds) do not necessarily enhance the power of the parametric prediction interval test (although the false positive rate is unaffected), while it has the effect of *increasing* the false positive rate for non-parametric prediction limits.

Based on the literature cited above, a verification re-sample strategy requiring one of the next one or two re-samples to be in bounds will be incorporated into the decision rule for determining when an environmental monitoring result constitutes a significant exceedance of the established background value. With either of these verification re-sample approaches, an apparent statistically-significant exceedance cannot be confirmed or denied until the results of the re-sampling event(s) have been obtained.

If the verification re-samples do not confirm that a statistically-significant exceedance has occurred, then WCS continues its usual monitoring. If the verification re-sample(s) confirm the initial exceedance, the TCEQ will be notified and appropriate investigation and corrective action started.

5.1.5.3 Controlling Site-Wide False-Positive and False-Negative Rates

For any given medium at a site, the SWFPR is the probability that a statistical evaluation procedure will indicate possible contamination, based upon the results of a monitoring event for all parameters at all locations in that medium, when no contamination is actually present. Stated more simply, the SWFPR is the probability of falsely claiming that an environmental medium at a site is contaminated. An SWFPR encompasses all monitoring locations within a given environmental medium across a site, but it does not extend to results across various media. The false-negative rate is defined as the probability that a statistical evaluation procedure will not indicate possible contamination when contamination is actually present.

For groundwater monitoring at RCRA Subtitle C facilities, EPA recommends maintaining an SWFPR of approximately 5%, while maintaining statistical power commensurate with the EPA Reference Power Curve for a comparable number of background measurements. In general, a false negative rate of no more than 20% for an increase of three standard deviations is considered acceptable.

The SWFPR associated with either the combined control chart or the nonparametric prediction limit at the WCS facility will depend on the background sample size, the number of future comparisons (i.e., the number of monitoring locations times the number of constituents monitored in each event), and, as discussed in Section 5.1.5.2, the re-sampling scheme. The false

negative rate for the combined Shewhart-CUSUM control chart depends primarily on the background sample size and the Shewhart control chart factor, z . Gibbons (1999) concluded that variation in the CUSUM control limit, h , had minimal impact.

For each medium to be monitored and evaluated statistically, WCS will evaluate the false positive and false negative rates for the candidate evaluation procedures through simulation studies of statistical power based upon the size of the initial background dataset for each parameter (reference Sections 5.1.5 and 5.1.5.1) in accordance with ASTM D 6312 and EPA (1992b). Initial background values will be established as described in Section 5.1.5.4 to control the false positive and false negative rates as discussed above.

5.1.5.4 Establishing Limits Associated with Selected Statistical Methods

Background sampling results from all monitoring locations will be used to determine which of the selected statistical methods is appropriate for each parameter and to establish the initial background limits. The appropriate method (either the combined control chart or non-parametric prediction interval) will be determined for each parameter from each medium and limits will be calculated from the background data, as described herein. Determining the limits also involves assigning false-positive and false-negative rates required for assessing statistically significant exceedances, as discussed in Section 5.1.5.3. Results of the initial background value determinations, along with associated backup information, will be submitted to TCEQ prior to initiation of operations under the license.

As part of the ongoing monitoring, the control limits established for a given parameter/monitoring location will be evaluated on a regular basis to incorporate additional data obtained after startup as recommended by ASTM D 6312. These evaluations will be conducted annually for data collected on a monthly basis; every 2 years for data collected on a quarterly basis; and quadrennially for groundwater data, which will be collected on a staggered annual (biennial) basis. All new data that are in control will be pooled with baseline data to determine new control limits. New control limits will be incorporated into the statistical evaluation program as authorized by TCEQ. WCS may also request to switch the method for establishing the background limit for a parameter if warranted by changes in detection frequency.

If issues arise during implementation of the data analysis program with either of the two selected methods (combined control chart or non-parametric prediction interval), agency approval will be sought prior to using an alternative statistical method to evaluate the monitoring data.

5.1.6 *Corrective Action Monitoring Program*

If a constituent is confirmed to exceed the Action Limit (Section 5.3.8 of Appendix 7.3.2, Appendix 2.10.1-2, and table 8.2.7-1 of Appendix 11.1.1) corrective action investigation will be instigated. Prompt notification will be made to the TCEQ by telephone or electronically (i.e. fax or email) to the designated contact. Within 30 days of a confirmed sample result exceeding the control limit, a formal written report will be prepared evaluating the cause and describing planned corrective actions. The report will include an evaluation of the significance of the result within the context of the facility performance assessment and an evaluation of the regulatory significance. Such corrective actions may include, separately or in combination, procedural

changes and escalated data evaluations, administrative changes, engineering studies and additional investigations. Corrective actions will be based on the results of engineering studies and additional investigations.

5.2 Precautions and Limitations

Inspection and monitoring operations are to be performed in accordance with radiological and industrial safety, operations, quality assurance and additional procedures as appropriate.

If a failure occurs, this document may require revision. Corrective actions are to occur under valid and appropriate procedures.

5.3 Instructions

5.3.1 Routine Monitoring and Inspections of Site Conditions

Due to the nature of the waste, it is not expected for chemical contamination to be present without radiological contamination during disposal operations. Detection of radiological contamination may trigger analysis for commingled chemical contamination. Due to the anticipated variation in waste streams on a daily basis, this will be an operational decision. Radionuclide contamination can be detected more quickly and accurately in the field than most chemical contamination. Radioactive contamination will serve as a surrogate for chemical contamination during daily operations.

5.3.1.1 Operational Radiological Surveys

Operational radiological surveys can provide near-immediate warning of surficial contamination. As part of routine operations, periodic radiological surveys will occur for personnel, equipment and road surfaces within the disposal cell and waste handling operations areas. Based on the survey results, operations may be promptly modified and surficial contamination promptly encapsulated and removed. These surveys are intended to prevent contamination from being transported from the initially affected area or and potentially exiting the disposal site boundary.

5.3.1.2 Operational Air Monitoring

The RSO may direct the installation of air samplers, electronic dust monitors or continuous air monitors (CAM) at either fixed or mobile locations near the active operations within the disposal cell or waste handling operations areas.

CAMs provide real-time warning of airborne radionuclide releases. Filter analysis provides frequent and rapid air analysis data. Operational air monitoring will be performed through the Radiological Environmental Monitoring Program (Appendix 2.10.1-2 to the License Application) and the Radiation Safety Program (Appendix 5.5.2-1 to the License Application).

5.3.1.3 Cover Inspection

Cover design information is presented in License Application Section 3.0. The interim and final covers will be visually inspected periodically, with representative photos documenting the condition of the cover. Locations examined during the inspection will be noted in a logbook.

Widespread problems with cover integrity are unlikely. The visual inspection will focus on detecting localized problems:

- Presence of cracking
- Patterns of cracking
- Presence of slumping and/or sink holes
- Erosion
- Presence of deep-rooted plants

The cover will also be surveyed, and elevations compared and trended over time. The rate of degradation will be evaluated for consistency over time.

Visual inspection findings, with the exception of deep-rooted plants, or significant elevation changes may trigger engineering investigations and reporting requirements. In addition to the engineering investigations, the waste placement database will be reviewed to assist in understanding the mechanisms triggering any potential cover problems.

5.3.2 Physical Parameters that Could Degrade Performance of the Disposal Site

Several physical parameters and site characteristics require monitoring, either by periodic measurement or periodic direct observation. Additional information on post-closure site inspection, monitoring and maintenance is provided in License Application Sections 7.1.1 and 7.2.1.

Changes in the following parameters should be evaluated to see if the performance assessment might require an update. Environmental changes may affect the assumptions used in Appendix 8.0-6.

- Groundwater hydraulic head and gradient
- Meteorological parameters (e.g., precipitation, wind speed and direction, temperature)
- Soil moisture content
- Surface erosion
- Appearance of permanent bodies water

Changes in the following parameters will be promptly evaluated to see if timely corrective actions are necessary:

- Integrity of man-made structures, including concrete
- Groundwater hydraulic head and gradient
- Surface erosion
- Disposal unit subsidence
- Ponding of surface water above the disposal cells
- Appearance of permanent bodies water

**APPLICATION FOR LICENSE TO AUTHORIZE NEAR-SURFACE
LAND DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTE
Appendix 7.3.2: Early Warning and Corrective Action Plan**

Periodic walkover inspections and aerial topography of the facilities and the disposal units will identify changes in surface erosion, surface water bodies, ponding, integrity of man-made structures and disposal unit subsidence.

Given the topography of the site, the potential for erosion down slope of the facility would be minor and would not greatly impact the site to the extent that potential water pathways could occur within the cover system. However, erosion near the LLRW disposal site will be monitored quarterly to assess the potential impacts of erosion to the facility. The details of this monitoring activity are included in the Structural Performance Monitoring Plan (Appendix 4.4-1). Also, an in-depth, site-specific erosion analysis is provided as Appendix 2.6.1, Attachment 4-3.

Any impacts observed will be managed according to the procedures outlined in Sections 5.3.6 through 5.3.9 of this document.

Groundwater and piezometer monitoring will provide data used to evaluate if there are changes to soil moisture, groundwater hydraulic head and groundwater gradient.

Meteorological monitoring at the on-site station combined or compared to data from regional weather stations may be used to track climate changes.

Table 7.3.2-1. Post-Closure Monitoring and Maintenance

Activity	Phase I Years 1-2	Phase II Years 3-5	Phase III		Phase IV Years 16-30
			Years 6-10	Years 11-15	
Walk-over and downslope inspections	Monthly	Quarterly	Annual	Annual	Quintennial
Land surveys	Annual	Annual	Annual	Quintennial ¹	Quintennial ¹
Leakage Detection Monitoring	Monthly	Quarterly ²	Semiannual ²	Semiannual ²	Semiannual ²
Maintenance of Leakage Detection Monitoring System	As needed ³	As needed ³	As needed ³	As needed ³	As needed ³
Operation of Leachate Collection and Removal System	As needed ³	As needed ³	As needed ³	As needed ³	As needed ³
Post-Operational Monitoring Program	Annual	Annual	Annual	Annual	Annual
Maintenance of Groundwater Well Network	As needed	As needed	As needed	As needed	As needed
Interpretation of Surveillance Results and Formal Reporting	Annual	Annual	Annual	Annual	Annual
Periodic Final Cover Repair	As needed	As needed	As needed	As needed	As needed

Minimum frequency may be modified at any time if unexpected conditions are noted

1 – Until the license and permit are terminated and/or responsibility transferred to the CA.

2 – As long as liquid levels in sumps remain below pump operating levels for at least two consecutive monitoring periods. Should the pump operating level be exceeded, monitoring frequency returns to monthly. Monitoring frequency then decreases to quarterly and semiannually as long as the water level remains below the pump operating level for at least two consecutive monitoring periods.

3 – Until permit is terminated.

5.3.3 FWF Leak Detection

In the FWF, a leak detection monitoring system is required between the double-layered flexible membrane liner (FML) in the disposal cell floor. The leak detection system provides early warning in the FWF of contaminant migration. This warning occurs before liquid has left the disposal cell, as there is an additional layer of FML between the leak detection system and environment. Section 3.6.2 of the License Application provides additional information.

5.3.4 Operation of the CWF and FWF Leachate Collection System

The CWF and FWF employ leachate collection systems as part of routine operations. Changes in either the volume or leachate contaminant levels may warrant further investigation prior to implementing a decision for appropriate remedial action.

During the operational period, leachate generated in each cell can be sampled and analyzed. In order to determine the location within the disposal facility where leachate is originating several actions can be taken. First, leachate detection within the system will be tied to a specific cell within the disposal unit since the collection system is designed to isolate the contents of each cell. Second, a comparison of radionuclides or hazardous constituents in the leachate with detailed inventory records of waste streams within the cell will provide evidence as to the general location of the potential leaking or damaged canister(s). Further investigations can then be conducted from the surface to identify the problem canisters.

Leachate collected within the cells during operations will be managed as discussed in LA Section 5.4.1.4.3 “Contact Water.” LA Section 5.4.1 provides a full discussion of both leachate and water management. In summary, leachate that meets the Texas Pollutant Discharge Elimination System (TPDES) permit requirements for release to the environment may be released or reused (i.e., dust suppression, compaction) on site in accordance with the permit. Leachate that cannot be released to the environment or reused on site will be shipped to a licensed off-site facility for treatment or disposal in accordance with procedures, LL-OP-2.8 “Managing On-Site Generated Waste” and LL-OP-2.8 “Off-Site Shipment of Radioactive Waste” as appropriate (these two procedures are included in Appendix 5.5). If the leachate is removed from the disposal cell and placed in storage tanks during the operational period, the leachate will be sampled and managed in accordance with the TPDES permit.

Post-Closure Leachate Monitoring and Disposition— Leachate will be monitored as part of the Post-Closure Plan (Appendix 7.1.1) and Institutional Control Plan (Appendix 7.2.2). If contaminated leachate is discovered in the collection sumps of the disposal cells during post-closure monitoring, it will be sampled and analyzed for radionuclides to determine the disposition. The water will then be pumped into a tanker truck and disposed off-site based on the sample results. All leachate pumped after final site closure will be shipped off-site for disposal. Because of this, WCS will not need a TPDES permit after the site closure.

5.3.5 Determination of Contaminant Migration

Environmental monitoring, coordinated with updating the performance assessment, provides a means for determining potential future public doses and their significance relative to the performance objectives. During the post-operational phase, monitoring may be reduced to include only matrices that are representative of critical pathways to man (e.g., groundwater).

The guidance document DOE/LLW-13Tg identifies three concepts for monitoring where the general direction and velocity of migrating pollutants can be estimated:

1. If the direction of the pollutant can be measured or predicted to be from A toward B, a sampling station should be located on the line between A and B.
2. The position of a sampling station is determined by the desired time for pollutant detection and the speed of migration. Assuming a simplistic vadose zone model and groundwater velocity of 0.003 feet/year without accounting for other migration processes in the saturated zone, it will take over 30,000 years for the contamination to travel 100 horizontal feet.
3. The time between samplings should be equal to or less than the travel time from A to the sampling station. In the simplified case, a groundwater monitoring well 50 feet downgradient (travel time of 15,000 years) that is sampled semi-annually would meet the recommendation.

5.3.5.1 Air

Permanent air sampling stations are installed to reflect the predominant wind directions of the site and gather data from control locations. Winds predominantly approach the WCS ranch from the southwest, south, and southeast. Since the transport time of windborne contaminants to the disposal cell boundary is very short, air sampling stations operate continuously. Plume widths are a function of release height and atmospheric stability. Air monitoring during operations provides an early warning of operational issues that could release radionuclides into the environment. During operations, air monitoring data is not indicative of an early warning of subsurface failure of the disposal cell. During the post-operational period, air monitoring will not be a leading early warning indicator due to the massive volume of cover material between the air and waste.

5.3.5.2 Surface Water

Surface water is seldom a potential carrier of pollutants from a LLRW disposal facility, and surface water will not serve as an early warning of cell failure. In this arid area, there are no permanent bodies of surface water in the immediate site vicinity. Appendix 2.6.1 contains the Flood Plain Analysis, providing more detail of surficial water flow after precipitation events and local topography. Surface water monitoring is problematic due to the limited moisture in the area. Periodic monitoring of ephemeral water bodies that may have accumulated in low areas in the vicinity of the LLRW facilities may be conducted on a case-by-case basis.

5.3.5.3 Unsaturated (Vadose) Zone

The goal of unsaturated zone monitoring is to obtain an early warning of contaminant migration before it reaches the saturated zone. The vadose zone of concern is between the floor of the disposal cell and the 225-foot zone where the first contiguous groundwater zone occurs. A vadose-zone monitoring system with redundant elements will be installed under the liner system of the disposal units. The main purpose of this system is to provide early warning of a contaminant release and aid in scoping the extent of a corresponding corrective action by detecting the location of a contaminant release. These monitors will be sampled quarterly throughout the closure, post-closure, and institutional control periods. The plan for executing this monitoring is provided in the Structural Performance Monitoring Plan, Appendix 4.4-1.

5.3.5.4 Saturated (Groundwater) Zone

Groundwater is the major potential pathway to man for contaminants in the FWF and CWF. Groundwater analysis can provide early warning of contaminant migration before it reaches the disposal site boundary. Groundwater wells can be located within the disposal site boundary and may provide early warning tens of thousands of years before the groundwater could potentially exit the WCS property. Potential releases are likely to be of a sufficient duration to allow early plume detection before the groundwater could potentially migrate beyond the WCS property.

The approach for monitoring groundwater is to:

- Monitor the leachate system
- Monitor the vadose zone
- Monitor the groundwater

The leachate collection and analysis program described in Section 5.3.4 will provide data to determine the source, nature, and extent of contamination within the collection system. The specific isotopes and concentrations identified will provide a basis for reviewing waste inventory locations where inspections will be made to determine the surface locations where water is entering the disposal system.

5.3.5.5 Surface Soil/Sediment

Surface soil is not an early warning indicator of cell failure. Soil or sediment analysis is necessary to confirm any contaminants deposited from accidental spillage during operations, airborne transport and deposition, or transport by surface runoff during operations did not occur. If contamination is found, task-specific procedures will be implemented to remedy the incident. The data also provides inputs to revisions of the performance assessment.

5.3.5.6 Flora and Fauna

Flora and fauna do not provide early warning. The data supports the performance assessment. The flora pathway to man is through consumption of wildlife that fed on local vegetation.

Vegetation foodstuffs for the predominant game species of javelina, dove and rabbit will be monitored for contaminant concentrations. Deep-rooted plants found on the interim and final covers may be sampled and destroyed.

Samples of flora and fauna species will be periodically collected and compared to corresponding species.

5.3.6 *Engineering Studies*

If an engineering study is initiated, regulators will receive prompt notification. Appropriate regulatory bodies will receive a 30-Day Notification after receipt of the final engineering report.

Engineering services will be contracted following WCS procurement and quality control guidelines. Engineering studies will focus on identifying the mechanism of failure and appropriate corrective actions.

5.3.7 Additional Investigations

In addition to engineering evaluations, a three-phase investigation may be implemented. The investigation plan may address radiological and/or chemical contamination:

- Historical Data – Review of monitoring data at the location of interest, upgradient, downgradient and related control locations.
- Surface Soil/Sediment – Evaluation of surface soil or sediment contamination due to a contaminant release.
- Vadose Zone – Evaluation of soil contamination beneath and soil gases around the disposal cell that is most likely to have released contamination.
- Saturated Zone – Evaluation and additional sampling of groundwater at the location of interest.

All sampling results will be assessed to determine whether a significant release has occurred. The results may also impact final closure strategies for the site, and future operational requirements. If releases are not indicated by the investigation, the site may continue operations or be closed in accordance with license requirements, which include a closure cover and long-term groundwater monitoring. If releases are indicated by the investigation, WCS may require additional investigations and/or corrective actions.

5.3.8 Identification of Corrective Actions

Implementing procedures for corrective actions is premature at this time. If a substantive failure (e.g., liner or cover system breach) or release of material is encountered, an incident-specific Corrective Action Plan and procedures will be prepared for that deficiency. A failure or contaminant release may be revealed by the inspections, monitoring, investigations, and subsequent data analyses as discussed above in this section, or as other aspects (e.g., site surveillance activities) of the post-operational monitoring program indicate. Engineering investigations may be employed to aid in determining contaminant release or mechanism of concern or failure, and may guide selection of appropriate corrective actions. The Corrective Action Plan will establish precise actions that WCS or the custodial agency (CA) will take, if the results of monitoring indicate an exceedance, or the potential for an exceedance, of pre-established limits (e.g., action levels).

Corrective actions taken during operational, closure, or post-closure phases of the CWF and FWF will be of a scale and method appropriate to the situation. All corrective action methods are available for selection during all phases; no remediation or corrective action method is excluded based upon the current operational phase.

Depending on the scope of a contaminant release or system failure, the implementation of graded approach to address the situation based on the following items, separately or in combination, may be appropriate. Some examples of this graded approach are detailed below for selected contaminant release or system failure scenarios.

1. Cover degradation:
 - Volumetric grout injection below the cover

- Regrading of the cover
 - Spot removal of deep-rooted plants
 - Re-grading and reconstruction of the cover to remedy excessive erosion
 - Re-grading and reconstruction of the cover surface slopes to prevent ponding of water above the waste
 - Removal and reconstruction of portions of the evapotranspiration (ET) cover
 - Removal and reconstruction of portions of the ET cover and portions of the hydraulic cover
2. Surface and near-surface contamination:
- Spot removal or fixation of surface contamination.
 - Spot removal of contaminated surface soil or man made structures.
3. Waste package failure:
- Removal and reconstruction of portions of the ET cover, portions of the hydraulic cover and retrieval of waste packages in the upper waste lifts within a failed disposal cell
 - Removal and reconstruction of portions of the ET cover and portions of the hydraulic cover and retrieval of all waste packages within a failed disposal cell
 - Removal and treatment of leachate from leachate collection system for extended period of time
4. Groundwater contamination:
- More frequent monitoring of existing wells and additional analyses.
 - Install and monitor additional groundwater wells.
 - Pumping, treatment, and re-injection of contaminated groundwater.
 - Removal and treatment of leachate from leachate collection system for extended period of time

5.3.9 Schedule of Corrective Action Plan

Corrective actions should be timely as required to avert additional environmental impacts. The schedules should address tasks from investigation to site restoration following the corrective action. Depending on the scope of the action, it may take days, weeks, or years to complete. Tasks that may be included in the schedule are:

- Potential schedule uncertainties
- Cost estimation
- Review and approval of the corrective action plan
- Selection of remediation contractor and/or selection WCS remediation team

- Supplemental sampling and surveys
- Available technology evaluation
- Bench scale studies
- Mobilization activities
- Site preparation
- Corrective action steps
- Site restoration
- Waste management
- Corrective action report

6.0 RECORDS

6.1 Notifications

6.1.1 Investigation Level Responses

An internal permanent record of the evaluation will be made which may include a calculation of the estimated or actual impact to the worker or public; a summary will be included in the annual report.

6.1.2 Action Level Responses

6.1.1.1 Prompt Notification

An off-site environmental impact indicator result exceeding a prescribed AL requires prompt reporting to the responsible regulatory agency. The start of a cover integrity engineering study will also trigger a prompt notification of appropriate regulators. Prompt notification may be made by telephone or electronically (i.e. fax or email) to the designated contact at the appropriate regulatory body. A permanent record of the notification, including regulator contact names, will be retained.

6.1.1.2 Thirty-Day Notification

Within 30 days of a confirmed sample result exceeding the AL or conclusion of an engineering report prepared as part of this plan, a formal written report will be prepared evaluating the cause and describing planned corrective actions. The report will include an evaluation of the significance of the result within the context of the facility performance assessment and an evaluation of the regulatory significance. The appropriate regulatory body will be notified of the results and planned evaluation and/or corrective actions.

6.2 Corrective Action Reporting

At the conclusion of a corrective action, a report will be issued to close the corrective action. Supplemental or interim corrective action reports may also be prepared prior to the closing of the corrective action. Supplemental reports detailing additional or long-term monitoring may also be prepared as required.

6.3 Environmental Monitoring Data Reporting

Environmental monitoring data will be collected and maintained in an environmental monitoring data system. Annual environmental monitoring reports will be prepared at the conclusion of each calendar year that summarizes both the radiological and non-radiological data, evaluates trends, discusses anomalies and any elevated levels, and evaluates potential impact on the environment. The environmental monitoring program provides the data for early warning of the CWF or FWF not meeting the performance objectives of 30 TAC 336.723. Annual reports are provided to the appropriate regulatory body as required.

A summary of investigation level or action responses will be included in the annual reports.

6.4 Walkover Inspections

Walkover inspections will be documented in bound logbooks.

6.5 Radiological Performance Assessment

Periodic evaluations of the radiological performance assessment will be documented as part of each request for license renewal.

7.0 CORRECTIVE ACTION

For the WCS license application, 30TAC §336.738 requires that financial assurance be provided “. . . to address unplanned events that pose a risk to public health, safety, and the environment that may occur after the decommissioning and closure . . .” of the FWF or CWF. TCEQ requires that WCS consider a range of corrective actions and identify the corrective action configuration that bounds, in terms of potential cost, the other corrective action configurations. As used herein the each corrective action configuration has the following components:

- A means to detect that the corrective action is necessary
- A location either in the CWF or FWF
- A measurable extent so that activities and quantities involved in performing the corrective action can be measured.

The identification of a range of corrective action configurations and the selection of the bounding corrective action is the focus of the remainder of this section of this appendix. The estimated cost to conduct the bounding corrective action is provided in Appendix 7.3.3.

30TAC §336.738 does not allow the licensee to take into account the probability that an unplanned event that poses a risk to public health, safety and the environment may occur in

determining the cost for which financial assurance is to be provided. The corrective action configurations that WCS has identified therefore does not take into account the number and type of failures in disposal unit performance required to result in an event that poses a risk to public health, safety, and the environment. The WCS design, as detailed in Section 3.0, complements and enhances the characteristics of the disposal site and provides multiple design features that support the disposal facilities meeting the performance objectives of 30 TAC §336.723. The WCS site and design therefore provides multiple characteristics and features so that a single failure in any one element (i.e., site characteristic or design feature) will not result in an unplanned event for which financial assurance would be required.

For example, in order for risk to public health, safety, and the environment to occur via the groundwater pathway from the either the CWF, each of the following individual failures would have to occur concurrently and in the same proximate location:

- Evapotranspiration cover fails to return infiltrating water to the atmosphere
- Performance cover fails to shed water laterally to the sides of the cover system
- Performance cover fails to limit the amount of water coming in contact with the waste
- The red bed clay does not maintain its low permeability allowing water to move to the vadose zone monitoring system within 100 to 130 years following closure, which is many times faster than the characteristics of the natural red bed would allow

If the probability of failure of each of the above listed items were 0.01, the overall probability of failure would be 1.E-8, or 1 in 100 million.

The unplanned corrective action configuration for which financial assurance is to be provided is identified using two steps. First a qualitative assessment is made of the disposal system (site characteristics and disposal unit design). This qualitative assessment results the identification of a set of potential corrective action configurations that are quantitatively evaluated to identify the bounding corrective action configuration. It is this bounding corrective action configuration that is used to develop the cost estimate included in Appendix 7.3.3 for which WCS is required to provide financial assurance.

7.1 Qualitative Assessment of Corrective Action Configurations

The WCS site as described in Section 2.0 and Appendix 2.6.1 is stable in terms of erosion and other mass wasting processes. There is also at least 40 feet between the bottom of the FWF-CDU and FWF-NCDF (the deepest disposal units) and the water table.

As described in Section 3.0 of the LA and in Appendix 3.0-1 the WCS disposal system following the start of the institutional control period can be characterized as follows.

- Waste is disposed 25 to 45 feet below the ground surface
- Waste is disposed of in concrete canisters both the CWF and the FWF-CDU or in stable lifts within the FWF-NCDF
- Waste is isolated from the environment by a combination of cover layers, liners, concrete barriers (a concrete envelope in for the FWF-CDU and the CWF)

As described in Section 6.0 and 7.0 and their associated appendices, disposal system (site and disposal unit design) performance is monitored through a combination of groundwater wells, vadose zone monitors, settlement monitors, and visual inspections. This combination of monitoring activities will provide early warning of unplanned conditions allowing for corrective actions to be taken before the performance objectives are exceeded.

Based solely on the location of the monitoring points used to assess disposal system performance the bounding corrective action configuration must be one that includes monitoring results that exceed action levels at points below the bottom or side liners of the disposal units. Should settlement monitoring or visual inspections produce results that exceed action levels the required corrective action investigations and remediation activities would be limited to the repair of the cover system. Results that exceed action levels for these monitoring systems would not necessarily indicate that the concrete canisters had been compromised nor that there was excessive moisture moving through the red bed clay immediately below the sides or bottom of the disposal units. Therefore the remediation activities that would be included in this corrective action could be limited to only the repair of the cover system and may not require the removal of waste, the off-site disposal of waste, the repair of liners, and the backfilling of the volume created by the removal of waste.

Should the vadose zone monitoring system below the sides and bottom of the disposal units produce relative moisture content measurements that exceed action levels, these results would indicate that the cover system is not performing correctly and that the disposal unit liner layers were not performing as expected and modeled. Multiple failures of the disposal system would be required to create this situation and would require an investigation program to determine the location of each failure. Additionally the necessary corrective action would include the remediation of each failure – the one in the cover and the one in the liner system. The scope of corrective action remediation activities would include the repair of each failure and also the removal of waste required to reach the point of failure in the liner system. Therefore the magnitude of a corrective action involving the failure of both the cover system and the liner system will qualitatively require a greater level of resources on a per unit of area basis than a corrective action involving only the cover system.

Based on the above qualitative assessment of the disposal system the corrective action configurations that should undergo quantitative analysis would all involve both the repair of a defect in the cover system and in the disposal unit liner system below the waste. The qualitative evaluation will determine whether the bounding corrective action is in the FWF-CDU, the FWF-NCDU, or in the CWF. This evaluation also determines the location of the area requiring corrective action within the bounding disposal unit – whether it is over the side slope or over the bottom of the bounding unit.

7.2 Quantitative Evaluation of Corrective Action Configurations

Based on the qualitative assessment WCS defined several potential corrective action configurations for quantitative evaluation. Completion of the quantitative evaluation results in the identification of the bounding corrective action that is the basis for WCS' financial assurance.

The quantitative evaluation was designed to identify which disposal unit (FWF-CDU, FWF-NCDU, or CWF) may involve a higher remediation cost should the hypothetical failure occur in that unit. It was also designed to determine the location within a disposal unit where correction of a failure might involve a higher cost. To arrive at these determinations, the applicant evaluated the following disposal units and configurations:

- Failure at the center of the FWF-CDU
- Failure at the center of the CWF
- Failure on the side slope of the FWF-CDU
- Failure at the center of the FWF-NCDU
- Failure on the side slope of the FWF-NCDU

The characteristics and evaluation of these configurations are described below.

7.2.1 Failure at the Center of the FWF-CDU

A schematic of failure at the center of the FWF-CDU is presented in Figure 7.3.2-1. The cell and location along the length of the cell where the shotcrete barrier and clay liner are postulated to have failed is identified by the vadose zone monitoring system provided under the Clay Liner. The probable location for the failure is the trough of the cell, to which infiltrating water will drain under force of gravity.

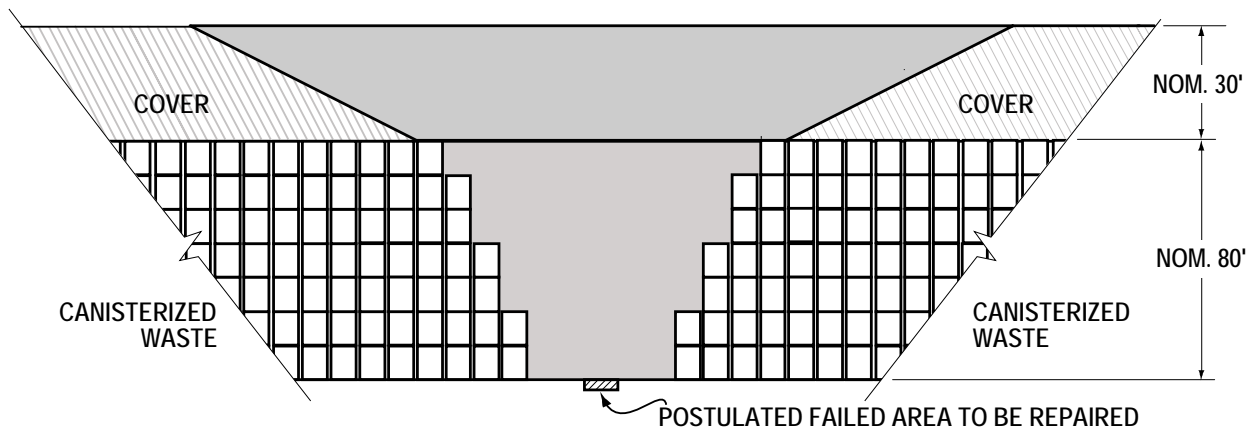


Figure 7.3.2-1. Depiction of Excavation Required to Repair Postulated Failed Area at Center of FWF-CDU

Figure 7.3.2-1 shows removal of 19 canisters from the bottom (seventh) layer of canisters in the FWF-CDU and the repair of the failed portion of the shotcrete barrier and clay liner. The area of the failed shotcrete and clay liner was taken to be 100 square feet, producing a volume of waste requiring disposal of about 11 cubic yards. In addition, seven of the canisters in the bottom layer were assumed to be damaged and to require disposal at an off-site DOE disposal facility. The total volume requiring disposal as LLRW was estimated to be about 5,000 cubic feet.

Canisters were assumed to be removed so that the exposed face goes down two layers and then in two canisters (one on either side of the excavation). Effectively this produces a “canister removal slope” of 200 percent (2 vertical to one horizontal). By this scheme a total of 325 canisters were calculated to be removed. The quantity of backfill requiring removal was estimated to be about 2,400 cubic yards.

Excavation in the 30-foot-thick cover system was limited to a slope of 50 percent (1 vertical to 2 horizontal). At the final surface of the cover system, the diameter of the area requiring excavation and reconstruction was determined to be 215 ft. The volume of cover system to be excavated and reconstructed was estimated to be about 58,000 cubic yards.

The cost to excavate and reconstruct the cover system was estimated to total about \$3.4 million. The cost to transport and dispose of waste that requires disposal at an off-site DOE disposal facility (taken to be the Nevada Testing Station at a distance of about 1,100 miles) was estimated to be \$370,000. Other costs brought the costs for this hypothetical corrective action to a total of about \$4.3 million.

7.2.2 Failure at the Center of the CWF

A schematic of failure at the center of the CWF is presented in Figure 7.3.2-2. The cell and location along the length of the cell where the shotcrete barrier and clay liner are postulated to have failed is identified by the vadose zone monitoring system provided under the clay liner. The probable location for the failure is the trough of the cell, to which infiltrating water will drain under force of gravity.

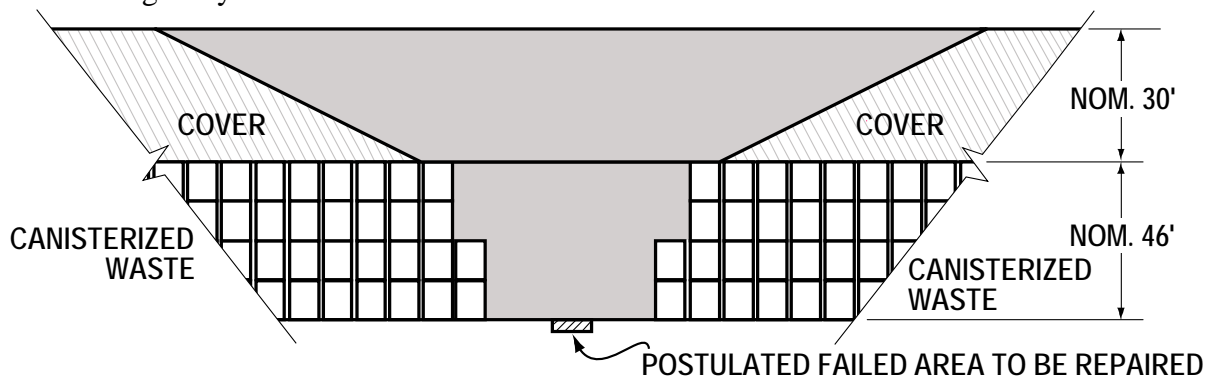


Figure 7.3.2-2. Depiction of Excavation Required to Repair Postulated Failed Area at Center of CWF

Figure 7.3.2-2 illustrates the removal of 19 canisters from the bottom (fourth) layer of canisters in the CWF and the repair of the failed portion of the shotcrete barrier and clay liner. The area of the failed shotcrete and clay liner was taken to be 100 square feet, producing a volume of waste requiring disposal of about 11 cubic yards. In addition, seven of the canisters in the bottom layer were assumed to be damaged and to require disposal at an off-site commercial LLRW disposal facility. The total volume requiring disposal as LLRW was estimated to be about 5,000 cubic feet.

Canisters were assumed to be removed so that the exposed face goes down two layers and then in two canisters (one on either side of the excavation). Effectively this produces a “canister removal slope” of 200 percent (2 vertical to one horizontal). A total of 112 canisters were calculated by this scheme to be removed. The quantity of backfill requiring removal was estimated to be about 820 cubic yards.

Excavation in the 30-foot-thick cover system was limited to a slope of 50 percent (1 vertical to 2 horizontal). At the final surface of the cover system, the diameter of the area requiring excavation and reconstruction was determined to be 180 ft. The volume of cover system to be excavated and reconstructed was estimated to be about 35,000 cubic yards.

The cost to excavate and reconstruct the cover system was estimated to total about \$2.0 million. The cost to transport and dispose of waste that requires disposal at an off-site commercial LLRW disposal facility (taken to be the Barnwell disposal facility at a distance of about 1,400 miles) was estimated to be \$3.6 million. Other cost brought the costs for this hypothetical corrective action to a total of about \$5.8 million.

7.2.3 Failure on the Side Slope of the FWF-CDU

A schematic of failure on the side slope of the FWF-CDU is presented in Figure 7.3.2-3. The cell and location along the length of the cell where the shotcrete barrier and clay liner are postulated to have failed is identified by the vadose zone monitoring system provided under the Clay Liner. The location for the failure is taken to be the side slope of the cell, to which infiltrating water will drain under force of gravity.

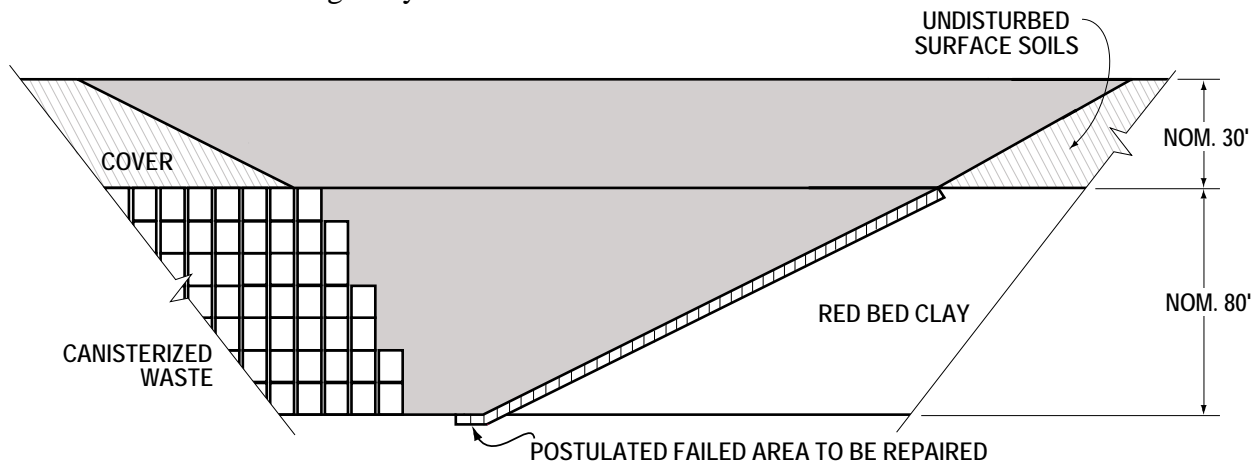


Figure 7.3.2-3. Depiction of Excavation Required to Repair Postulated Failed Area on Side Slope of FWF-CDU

Figure 7.3.2-3 shows removal of 11 canisters from the bottom (seventh) layer of canisters in the CWF and the repair of the failed portion of the shotcrete barrier, FML and clay liner. In this case the Clay Liner along the entire side slope was postulated to have failed to require repair. The area of the failed shotcrete and clay liner was estimated to be 7,100 square feet, producing a volume of waste requiring disposal of about 875 cubic yards. In addition, seven of the canisters in the bottom layer were assumed to be damaged and to require disposal at an off-site DOE disposal

facility. The total volume requiring disposal as LLRW was estimated to be about 26,000 cubic feet.

Toward the center of the FWF-CDU, canisters were assumed to be removed on a “canister removal slope” of 200 percent (2 vertical to 1 horizontal). Toward the side slope, all canisters were assumed to be removed. A total of 375 canisters were calculated by this scheme to be removed. The quantity of backfill requiring removal was estimated to be about 2,700 cubic yards.

Excavation in the 30-foot-thick cover system was limited to a slope of 50 percent (1 vertical to 2 horizontal). At the final surface of the cover system, the area requiring excavation and reconstruction was determined to be effectively 224 ft in diameter. The volume of cover system to be excavated and reconstructed was estimated to be about 59,000 cubic yards.

The cost to excavate and reconstruct the cover system was estimated to total about \$3.4 million. The cost to transport and dispose of waste that requires disposal at an off-site DOE disposal facility (taken to be the Nevada Testing Station) at a distance of about 1,100 miles) was estimated to be \$1.9 million. Other cost brought the costs for this hypothetical corrective action to a total of about \$6.6 million.

7.2.4 Failure at the Center of the FWF-NCDU

A schematic of failure at the center of the FWF-NCDU is presented in Figure 7.3.2-4. The cell and location along the length of the cell where the shotcrete barrier and clay liner are postulated to have failed is identified by the vadose zone monitoring system provided under the Clay Liner. The probable location for the failure is the trough of the cell, to which infiltrating water will drain under force of gravity.

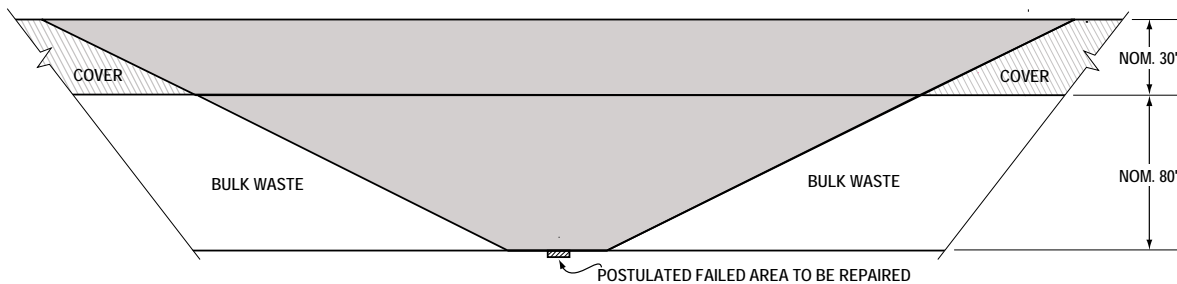


Figure 7.3.2-4. Depiction of Excavation Required to Repair Postulated Failed Area at Center of FWF-NCDU

Figure 7.3.2-4 shows removal of waste and cover system on an excavation slope of 50 percent (1 vertical to 2 horizontal) and the repair of the failed portion of the Shotcrete Barrier and Clay Liner. The area of the failed Shotcrete and Clay Liner was taken to be 100 square feet, producing a volume of waste requiring disposal of about 11 cubic yards. Twenty percent of the excavated waste (totaling about 24,000 cubic feet) was assumed to require disposal at an off-site DOE disposal facility.

The quantity of waste requiring removal was estimated to be about 120,000 cubic yards. At the final surface of the cover system, the diameter of the area requiring excavation and

reconstruction was determined to be 484 ft. The volume of cover system to be excavated and reconstructed was estimated to be about 160,000 cubic yards.

The cost to excavate and replace/reconstruct the waste and cover system was estimated to total about \$8.3 million. The cost to transport and dispose of waste that requires disposal at an off-site DOE disposal facility (taken to be the Nevada Testing Station at a distance of about 1,100 miles) was estimated to be \$1.7 million. Other cost brought the costs for this hypothetical corrective action to a total of about \$10.1 million.

7.2.5 Failure on the Side Slope of the FWF-CDU

A schematic of failure on the side slope of the FWF-CDU is presented in Figure 7.3.2-5. The cell and location along the length of the cell where the shotcrete barrier and clay liner are postulated to have failed is identified by the vadose zone monitoring system provided under the Clay Liner. The probable location for the failure is taken to be the side slope of the cell, to which infiltrating water will drain under force of gravity.

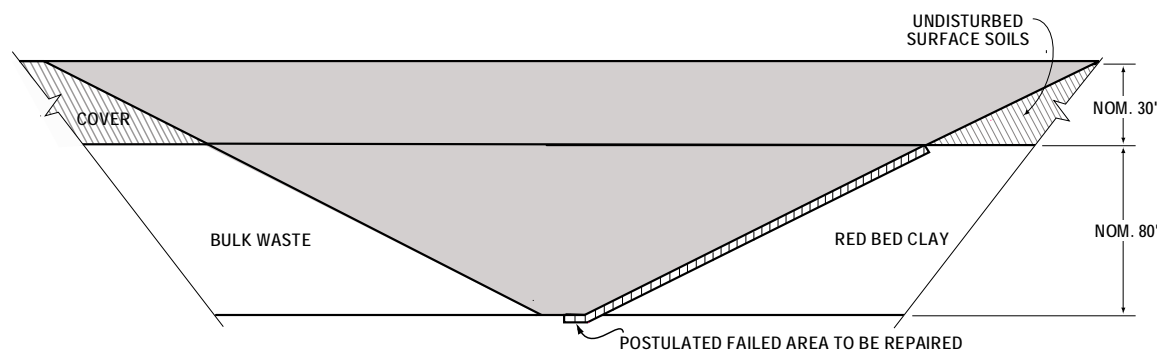


Figure 7.3.2-5. Depiction of Excavation Required to Repair Postulated Failed Area on Side Slope of FWF-NCDU

Figure 7.3.2-5 shows removal of waste and cover system on an excavation slope of 50 percent (1 vertical to 2 horizontal) and the repair of the failed portion of the Shotcrete Barrier, FML and Clay Liner. The area of the failed shotcrete, FML, and clay liner was estimated to be 7,755 square feet, producing a volume of waste requiring disposal of about 875 cubic yards. The total volume requiring disposal as LLRW was estimated to be about 24,000 cubic feet.

On both sides of the excavation (toward the center and toward the side slope) of the FWF-NCDU, waste is assumed to be removed at an excavation slope of 50 percent (1 vertical to 2 horizontal). Excavation in the 30-foot-thick cover system was limited to a slope of 50 percent (1 vertical to 2 horizontal). At the final surface of the cover system, the area requiring excavation and reconstruction was estimated to be 462 ft in diameter. The volume of cover system to be excavated and reconstructed was estimated to be about 145,000 cubic yards.

The cost to excavate and reconstruct the cover system was estimated to total less than \$7.7 million. The cost to transport and dispose of waste that requires disposal at an off-site DOE disposal facility (taken to be the Nevada Testing Station) at a distance of about 1,100 miles) was estimated to be \$1.7 million. Other cost brought the costs for this hypothetical corrective action to a total of about \$9.5 million.

7.2.6 *Summary of Quantitative Evaluation of Corrective Action Configurations*

The quantities calculated to quantitatively evaluate the above described corrective action configurations are summarized in Table 7.3.2-2. These calculations are presented in detail in Attachment 7.3.2-1 to this appendix. Based on cover volume excavated and reconstructed and waste excavated and disposed of, failure at the center of the FWF-NCDU should produce the highest cost of the disposal units and configurations considered in this section.

Table 7.3.2-2. Quantities Calculated in Scoping of Corrective Action Configurations

Scoping Quantities		FWF-CDU Center	CWF Center	FWF-CDU Side Slope	FWF- NCDU Center	FWF- NCDU Side Slope
A	Cover Excavation/Recompact Volume (bcy)	58,091	34,592	58,601	157,451	142,472
B	Bulk Waste Excavation/ Recompact Volume (bcy)	0	0	0	116,284	97,450
C	Liner Repair Volume (bcy)	11	11	873	11	873
D	Canisters Removed (ea)	325	112	375	0	0
E	Canisters Disposed of (ea)	7	7	7	0	0
F	Canisters Replaced (ea)	318	105	368	0	0
G	Bulk Waste Replaced (bcy)	0	0	0	93,027	97,450
H	New Backfill (bcy)	186	186	1,047	872	0
I	Backfill Around Canisters Removed (bcy)	2,355	812	2,717	0	0
J	Liner Volume Disposed of (cf)	300	300	23,564	300	23,564
K	Canister Volume Disposed of (cf)	3,339	3,339	3,339	0	0
L	Bulk Waste Volume Disposed of (cf)	0	0	0	23,257	0
M	Backfill Volume Disposed of (cf)	1,370	1,370	1,370	0	0
N	Total Volume Disposed of (cf)	5,009	5,009	28,273	23,557	23,564
O	Diameter at Surface (ft)	215	181	225	483	462

Based on quantities calculated and presented in Table 7.3.2-1, total bulk volumes excavated, transported, and reconstructed on-site were estimated, as were total volumes disposed of off-site

for each case. In order to compare the relative cost of on-site construction and off-site disposal activities, an effective volume was calculated for each case, based on relative volumes and cost differences involved in on-site and off-site activities. This effective volume includes the calculated volume of bulk materials that are handled on-site and adds the volume to be disposed of off-site, scaled by a relative cost multiplier. On-site volumes, off-site disposal volumes, and effective volumes are presented in Table 7.3.2-3.

The relative cost multiplier is the ratio of the costs per unit volume to transport and dispose of waste at an off-site disposal facility and unit cost to excavate, transport, and reconstruct bulk volumes on site. For disposal of federal waste (at the Nevada Test Station, for example) the relative cost multiplier is about 124¹. For disposal at a commercial LLRW disposal facility (at Barnwell, South Carolina, for example), the relative cost multiplier is about 1,200². Multiplying volumes to be disposed of off-site by the relative cost multiplier and adding the result to the volume to be handled on-site gives an effective volume that accounts for the cost of both on-site handling and off-site disposal.

Table 7.3.2-3. Summary Scoping of Corrective Action Configuration

Volume	Lines from Table 7.3.2-4 Included	FWF-CDU Center	CWF Center	FWF-CDU Side Slope	FWF-NCDU Center	FWF-NCDU Side Slope
Total Volume Excavated and Reconstructed (bcy)	2(A+C+I)+B+G+L	120,915	70,829	124,381	547,492	505,154
Total Volume of Waste Disposed of Off-Site (cf)	N	5,009	5,009	28,273	23,557	23,564
Relative Cost Multiplier	---	124	1,200	124	124	124
Effective Volume	---	144,037	293,478	256,842	632,881	592,338

The effective volume provides a means of comparing the relative costs of both on-site and off-site activities. The effective volume is greatest for the hypothetical failure in the clay liner at the center of the FWF-NCDU. In fact, the effective volume for the FWF-NCDU center case is more than twice the effective volume of the next largest case, namely CWF center. This suggests that the relative cost of the corrective action that would grow out of the hypothetical failure of the clay liner in the FWF-NCDU is expected to be roughly twice that of corrective action cases in any other disposal unit. The additional cost of repairing damaged liner on the side slope of the FWF-NCDU is more than offset by the reduced cost of excavating cover and waste when

¹ Relative Cost Multiplier at NTS; $\$74/\text{cf} * 27\text{cf} / \# \text{cy} / \$16/\# \text{cy} = 124$; Disposal at NTS is 124 time more costly than on-site handling.

² Relative Cost Multiplier at Barnwell, SC; $\$711/\# \text{cf} * 27\text{cf} / \# \text{cy} / \$16/\# \text{cy} = 1,200$; Disposal at Barnwell is 1,200 times more costly than on-site handling.

considering the failure in the center and side slope of the FWF-NCDU. Thus, the most costly of the cases considered in failure at the center of the FWF-NCDU.

WCS identified the hypothetical failure of the clay liner at the center of the FWF-NCDU and the release scenario that would produce the highest corrective action costs using the sequence of screening and scoping the possible hypothetical corrective actions..

7.3 Calculation of Bounding Corrective Action Configuration Cost

As shown above in Section 7.2.5, the highest cost corrective action will result from the hypothetical concurrent failures of the cover system and the clay liner in the center of the FWF-NCDU. WCS has selected this hypothetical bounding corrective action configuration for the sole purpose determining the magnitude of corrective action financial assurances it should provide. WCS does not accept that this, or any of the corrective action configurations evaluated in Section 7.2.5, is reasonable because of their extremely low probabilities of occurrence and their low likelihood in resulting in a situation where the performance objectives of 30 TAC §336.723 would not be met.

The following is a list of the major activities involved in the assessment and remediation of the bounding corrective action:

- Investigate the problem
- Determine appropriate corrective action
- Design the selected corrective action
- Mobilize and construct required infrastructure
- Excavate cover system
- Excavate bulk waste and contaminated materials
- Transport containerized contaminated materials to NTS for disposal
- Reconstruct the foundation of the failed area of the cell
- Replace waste and contaminated materials not disposed of off-site
- Reconstruct the cover system of the “failed” cell to meet original design and specifications
- Demolish clean infrastructure and dispose at construction and demolition waste landfill
- Demobilize
- Monitor and maintain the reconstructed failed area of the cell

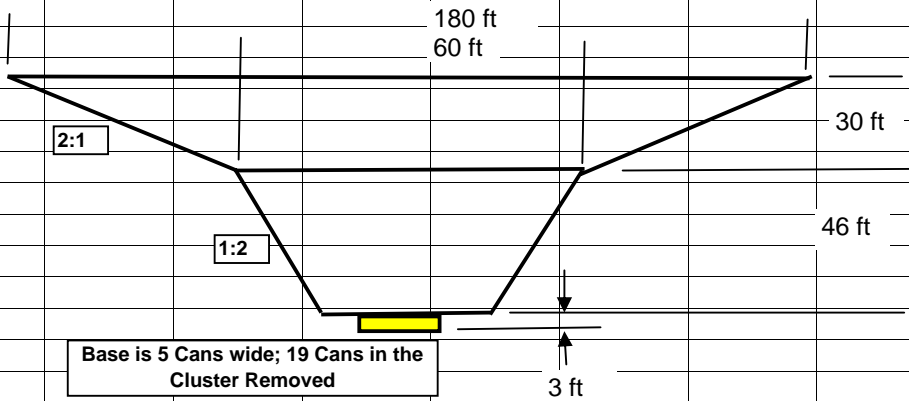
Corrective action sketches that are the basis for quantities used in preparing the cost for the hypothetical bounding corrective action configuration are included as part of Attachment 7.3.3-1.

The detailed estimates of corrective action costs for this case are presented in Appendix 7.3.3.

**ATTACHMENT 7.3.2-1 CORRECTIVE ACTION SCOPING
CALCULATIONS**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	FWF-CDU -- CENTER															
2											215 ft					
3											95 ft					
4															30 ft	
5									2:1							
6																
7																
8																
9																
10															80 ft	
11									1:2							
12																
13																
14																
15																
16																
17																
18	Bottom Area of Failed Liner System Requiring Repair:						100	sf		=INPUTS!B11						
19	Volume of Failed Liner						11	cy		=F18*INPUTS!B7/27						
20	Diameter of Failed Circle in Liner						11.3	ft		=2*SQRT(F18/PI())						
21	Diameter of Working Area on Liner (19 Cans)						43.4	ft		=INPUTS!B12						
22	Excavation Slope in Canisters						2			=INPUTS!B10						
23	Excavation Slope in Cover						0.5			=INPUTS!B8						
24	Canisters Removed						325	ea		=Sheet2!B17						
25	Canisters Disposed of Off-Site as Waste						7	ea		=7						
26	Canisters Replaced in FWF-CDU						318	ea		=F24-F25						
27	Backfill per Canister						195.7	cf		=INPUTS!B15						
28	Backfill Retrieved						2,355.1	cy		=F24*F27/27						
29	Backfill Disposed of Off-Site as Waste						1,369.6	cf		=F25*F27						
30	Depth of Waste to be excavated:						80	ft		=INPUTS!B5						
31	Radius of Top of Waste Cone						47.685	ft		=Sheet2!S7/2						
32	From Working Area Down to Cone Apex						43.35	ft		=F21/2*F22						
33	Height of Waste Cone from Apex to Top of Waste						123.35	ft		=F32+F30						
34	Volume of Minor Cone to Subtract						293,719	cf		=PI()*F31^2*F33/3						
35	Volume of Waste Cone						218,621	cf		=F24*INPUTS!B13						
36							8,097	cy		=F35/27						
37	Cover Thickness						30	ft		=INPUTS!B4						
38	Radius of Cover at Finished Grade						107.685	ft		=F31+F37/F23						
39	Height of Cover plus Cone to be Subtracted						153.35	ft		=F33+F37						
40	Volume of Cover Cone						1,568,466	cf		=PI()*F38^2*F39/3-F34						
41							58,091	cy		=F40/27						
42																
43	Volume Handled (cy)						68,555			=F41+F36+F28+F19						
44	Volume Shipped Barnwell (cy)						0			=0						
45	Volume Shipped NTS (cy)						101			=(F25*F27+F29)/27						

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	CWF -- CENTER												
2								180 ft					
3								60 ft					
4													
5											30 ft		
6													
7													
8											46 ft		
9													
10													
11													
12													
13													
14													
15	Area of Failed liner system requiring repair:						100 sf		=INPUTS!B11				
16	Volume of Failed Liner						11 cy		=F15*INPUTS!B7/27				
17	Diameter of failed circle in Liner						11.3 ft		=SQRT(F15/PI())*2				
18	Diameter of Working Area on Liner (19 Cans)						43.4 ft		=INPUTS!B12				
19	Excavation Slope in Canisters						2		=INPUTS!B10				
20	Excavation Slope in Cover						0.5		=INPUTS!B8				
21	Canisters Removed						112 ea		=Sheet2!B19				
22	Canisters Disposed of Off-Site as Waste						7 ea		=7				
23	Canisters Replaced in FWF-CDU						105 ea		=F21-F22				
24	Backfill per Canister						195.7 cf		=INPUTS!B15				
25	Backfill Retrieved						811.6 cy		=F21*F24/27				
26	Backfill Disposed of Off-Site as Waste						1,369.6 cf		=F22*F24				
27	Depth of Waste to be excavated:						46 ft		=INPUTS!B6				
28	Radius of Top of Waste Cone						30.345 ft		=Sheet2!S10/2				
29	From Working Area Down to Cone Apex						43.35 ft		=F18/2*F19				
30	Height of Waste Cone from Apex to Top of Waste						89.35 ft		=F29+F27				
31	Volume of Minor Cone to Subtract						86,158 cf		=PI()*F28^2*F30/3				
32	Volume of Waste Cone						75,340 cf		=F21*INPUTS!B13				
33							2,790 cy		=F32/27				
34	Cover Thickness						30 ft		=INPUTS!B4				
35	Radius of Cover at Finished Grade						90.345 ft		=F28+F34/F20				
36	Height of Cover plus Cone to be Subtracted						119.35 ft		=F30+F34				
37	Volume of Cover Cone						933,980 cf		=PI()*F35^2*F36/3-F31				
38							34,592 cy		=F37/27				
39													
40													
41													
42													
43	Volume Handled (cy)						76,461		=2*(F38+F33+F25+F16)+F22*F24/27				
44	Volume Shipped Barnwell (cy)						51		=F26/27		No canister failure (only 4 layer deep)		
45	Volume Shipped NTS (cy)						0		=0				



	A	B	C	D	E	F	G	H	I	J	K	L
1	FWF-CDU -- SIDE											
2						224 ft						
3						105 ft						
4												
5											30 ft	
6												
7												
8												
9												
10											80 ft	
11												
12												
13												
14												
15												
16												
17												
18	Bottom Area of Failed Liner System Requiring Repair:					100	sf		=INPUTS!B11			
19	Width of Side Liner Requiring Repair					43	ft		=5*INPUTS!B17			
20	Depth of Waste to be excavated:					80	ft		=INPUTS!B5			
21	Excavation Slope in Cover					0.5			=INPUTS!B8			
22	Length of Side Liner Requiring Repair					179	ft		=SQRT(F20^2+(F20/F21)^2)			
23	Side Area of Failed Liner System Requiring Repair					7,755	sf		=F22*F19			
24	Total Area of Liner Requiring Repair					7,855	sf		=F23+F18			
25	Volume of Failed Liner					873	cy		=F24*INPUTS!B7/27			
26	Diameter of Failed Circle in Liner					11.3	ft		=2*SQRT(F18/PI())			
27	Diameter of Working Area on Liner (4 Cans Wide)					34.7	ft		=INPUTS!B12/5*4			
28	Excavation Slope in Canisters					2			=INPUTS!B10			
29	Canisters Removed					375	ea		=Sheet4!G43			
30	Canisters Disposed of Off-Site as Waste					7	ea		=7			
31	Canisters Replaced in FWF-CDU					368	ea		=F29-F30			
32	Backfill per Canister					195.7	cf		=INPUTS!B15			
33	Backfill Retrieved					2,717.4	cy		=F29*F32/27			
34	Backfill Disposed of Off-Site as Waste					1,369.6	cf		=F30*F32			
35	Number of Canisters at Top of Waste Zone					132	ea		=Sheet4!G21			
36	Canister Area at Top of Waste Zone					8,593.0	sf		=F35*INPUTS!B16			
37	Effective Radius of Top of Waste Zone					52.3	ft		=SQRT(F36/PI())			
38	From Working Area Down to Effective Cone Apex					34.68	ft		=F27/2*F28			
39	Height of Effective Cone from Apex to Top of Waste					114.68	ft		=F38+F20			
40	Volume of Minor Cone to Subtract					328,480	cf		=PI()*F37^2*F39/3			
41	Volume of Waste Zone					252,255	cf		=F29*INPUTS!B13			
42						9,343	cy		=F41/27			
43	Cover Thickness					30	ft		=INPUTS!B4			
44	Radius of Cover at Finished Grade					112.2993	ft		112.2993			
45	Height of Cover plus Cone to be Subtracted					144.68	ft		=F39+F43			
46	Volume of Cover Cone					1,582,216	cf		=PI()*F44^2*F45/3-F40			
47						58,601	cy		=F46/27			
48												
49												
50	Volume Handled (cy)					143,168			=2*(F47+F42+F33+E25)+F30*F32/27+F34/27			
51	Volume Shipped Barnwell (cy)					0			=0			
52	Volume Shipped NTS (cy)					101			=(F30*F32+F34)/27			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
1	FWF-NCDU -- CENTER																	
2																		
3								484 ft										
4								364 ft										
5																		
6																	30 ft	
7																		
8																		
9																		
10																		
11																	80 ft	
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19	Area of Failed Liner System Requiring Repair:							100 sf		=INPUTS!B11								
20	Volume of Failed Liner							11 cy		=INPUTS!B11*INPUTS!B7/27								
21	Diameter of Failed Circle in Liner							11		=2*SQRT(INPUTS!B11/PI())								
22	Diameter of Working Area on Liner (same as CDU-Center)							43.35 ft		=INPUTS!B12								
23	Excavation Slope in Bulk Waste:							0.5		=NPUS!B9								
24	Depth of Waste to be Excavated:							80 ft		=INPUTS!B5								
25	From Working Area Down to Cone Apex							11 ft		=INPUTS!B12/2*G23								
26	Height of Waste Cone							91 ft		=G24+G25								
27	Radius of Top of WasteCone							182 ft		=G26/G23								
28	Volume of Waste Cone							3,139,671 cf		=PI()*G27^2*G26/3								
29								116,284 cy		=G28/27								
30																		
31	Cover Thickness							30 ft		=INPUTS!B4								
32	Radius of Cover at Finished Grade							242 ft		=G27+G31/G23								
33	Volume of Cover Cone							4,251,169 cf		=PI()*G32^2*(G26+G31)/3-G28								
34								157,451 cy		=G33/27								
35																		
36																		
37	Volume Handled (cy)							547,492		=2*(G34+G29+G20)								
38	Volume Shipped Barnwell (cy)							0		=0								
39	Volume Shipped NTS (cy)							0		=0								
40																		

	A	B	C	D	E	F	G	H	I
1	INPUTS								
2	FOR SCOPING POTENTIAL CORRECTIVE ACTIONS								
3		Used	Units	Actual	Comment	Basis			
4	Cover Thickness	30	ft			Engineering Dwgs			
5	FWF Waste Thickness	80	ft	72.31	Conervative	Engineering Dwgs			
6	CWF Waste Thickness	46	ft	41.32	Conervative	Engineering Dwgs			
7	Liner thickness	3	ft			Engineering Dwgs			
8	Cover Slope	0.5				Engineering Constraint			
9	Bulk Waste Slope	0.5				Engineering Constraint			
10	Can Waste Slope	2				Assumed			
11	Area of Failed Liner System Requiring Repair:	100	sf			Assumed			
12	Diameter of Working Area on Liner	43.35	ft			5 times Gross Canister Diameter			
13	Gross Canister Volume	672.7	cf			RDB Calc; "Canister Evaluation.xls"			
14	Canister Volume	477.0	cf			RDB Calc; "Canister Evaluation.xls"			
15	Backfill per Canister	195.7	cf			Subtracted			
16	Gross Canister Footprint	65.1	sf			RDB Calc; "Canister Evaluation.xls"			
17	Gross Canister Diameter	8.7	ft			RDB Calc; "Canister Evaluation.xls"			
18	Percent of Bulk Waste Disposed of Off-site	20%				Assumed			

	A	B	C	D	E	F
1	CORRECTIVE ACTION COST COMPARISON:					
2	SCOPING COSTS TO EXCAVATE, RETRIEVE, REPAIR, DISPOSE, AND RECONSTRUCT					
3	SCOPING QUANTITIES	FWF-CDU CENTER	CWF CENTER	FWF-CDU SIDE SLOPE	FWF-NCDU CENTER	
4	Cover Excavation/Recompact Volume (bcy)	58,091	34,592	58,601	157,451	
5		=CDU CENTER!F41	=CWFIF38	=CDU SIDE!F47	=NCDU CENTER!G34	
6	Bulk Waste Excavation/ Recompact Volume (bcy)	0	0	0	116,284	
7		=0	=0	=0	=NCDU CENTER!G29	
8	Liner Repair Volume (bcy)	11	11	873	11	
9		=CDU CENTER!F19	=CWFIF16	=CDU SIDE!F25	=NCDU CENTER!G20	
10	Canisters Removed (ea)	325	112	375	0	
11		=CDU CENTER!F24	=CWFIF21	=CDU SIDE!F29	=0	
12	Canisters Disposed of (ea)	7	7	7	0	
13		=CDU CENTER!F25	=CWFIF22	=CDU SIDE!F30	=0	
14	Canisters Replaced (ea)	318	105	368	0	
15		=CDU CENTER!F26	CWFIF23	=CDU SIDE!F31	=0	
16	Bulk Waste Replaced (bcy)	0	0	0	93,027	
17		=0	=0	=0	=E6-E26	
18	New Backfill (bcy)	186	186	1,047	872	
19		=B30/27	=C30/27	=D30/27	=E30/27	
20	Backfill Around Canisters Removed (bcy)	2,355	812	2,717	0	
21		=CDU CENTER!F28	=CWFIF25	=CDU SIDE!F33	=0	
22	Liner Volume Disposed of (cf)	300	300	23,564	300	
23		=B8*27	=C8*27	=D8*27	=E8*27	
24	Canister Volume Disposed of (cf)	3,339	3,339	3,339	0	
25		=B12*INPUTS!B\$14	=C12*INPUTS!B\$14	=D12*INPUTS!B\$14	=E12*INPUTS!B\$14	
26	Bulk Waste Volume Disposed of (cf)	0	0	0	23,257	20 % OF EXCAV VOL
27		=0	=0	=0	=E6*INPUTS!B18E6*INPUTS!B18	
28	Backfill Volume Disposed of (cf)	1,370	1,370	1,370	0	
29		=CDU CENTER!F29	=CWFIF26	=CDU SIDE!F34	=0	
30	Total Volume Disposed of (cf)	5,009	5,009	28,273	23,557	
31		=SUM(B22:B28)	=SUM(C22:C28)	=SUM(D22:D28)	=SUM(E22:E28)	
32						
33	TOTAL VOLUME EXCAVATED AND RECONSTRUCTED (bcy)	120,915	70,829	124,381	524,235	
34		=2*B4+B6+2*B8+B16+2*B20	=2*C4+C6+2*C8+C16+2*C20	=2*D4+D6+2*D8+D16+2*D20	=2*E4+E6+2*E8+E16+2*E20	
35	TOTAL VOLUME OF WASTE DISPOSED OF OFF-SITE (cf)	5,009	5,009	28,273	23,557	
36		=B30	=C30	=D30	=E30	
37						
38	Excavate & Reconstruct Unit Cost (\$/bcy)	\$16.00	\$16.00	\$16.00	\$16.00	
39		=On-Site Unit Cost!\$J\$44	=On-Site Unit Cost!\$J\$44	=On-Site Unit Cost!\$J\$44	=On-Site Unit Cost!\$J\$44	
40	Transportation & Disposal Unit Cost (\$/bcy)	\$1,992	\$19,202	\$1,992	\$1,992	
41		=TNOD #2 Unit Costs!\$F\$57*27	=TNOD #2 Unit Costs!\$H57*27	=TNOD #2 Unit Costs!\$F\$57*27	=TNOD #2 Unit Costs!\$F\$57*27	
42	Relative Cost Multiplier	124	1,200	124	124	
43		=B40/B38	=C40/C38	=D40/D38	=E40/E38	
44	Disposal Location	Nevada	South Carolina	Nevada	Nevada	
45						
46	EFFECTIVE VOLUME HANDLED and DISPOSED (bcy)	144,010	293,451	254,746	632,854	
47		=B33+B35/27*B42	=C33+C35/27*C42	=D33+D35/27*D42	=E33+E35/27*E42	

Description	Estimated Quantities	Units	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	RS Means Group Number	RS Means Phase Number	RS Means Item Number	Other Cost References
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**Waste Load, Haul, Load, Haul, Compact
Hypothetical Load of 1,000 bcy**

Load Waste, Haul 1 mi RT

EARTHWORK

2300.000

Excavating, bulk bank measure, backhoe, hyd, 3 CY cap = 160 CY/hr	1,000.00 bcy		421			1,578		2.00 /bcy	1,999		2315.424	300	
Hauling, off hwy haulers, 34 CY rear/bot dump, 1 MI RT, 3.5 lds/hr	1,000.00 lcy		306			1,523		1.83 /lcy	1,829		2315.490	2070	

Load Waste, Haul 1 mi RT, Compact

EARTHWORK

2300.000

Backfill, dozer backfilling, compacting, 6" 12" lifts, sheepfoot rlr	1,000.00 ecy		551			2,040		2.59 /ecy	2,591		2315.110	1700	
Excavating, bulk bank measure, backhoe, hyd, 3 CY cap = 160 CY/hr	1,000.00 bcy		421			1,578		2.00 /bcy	1,999		2315.424	300	
Hauling, off hwy haulers, 34 CY rear/bot dump, 1 MI RT, 3.5 lds/hr	1,000.00 lcy		306			1,523		1.83 /lcy	1,829		2315.490	2070	

Description	Amount	Hours
Labor	\$2,003	61.645
Equipment	\$8,244	54.48
Subtotal	\$10,247	
Labor O&P	\$1,112	55.5%
Equip O&P	\$824	10.0%
	\$12,183	
General Conditions	\$731	6.0%
	\$12,914	
S/C Admin/Engineering	\$775	6.0%
Constr Oversight	\$517	4.0%
	\$14,205	
Escalation 2008	\$341	2.4%
	\$14,546	
Contingency	\$1,455	10.0%
TOTAL	\$16,001	
Volume (bcy)		1,000

**ON-SITE EXCAVATION, TRANSPORTATION, AND
RECONSTRUCTION UNIT COST (\$/bcy) \$16.00**