City of Waco Landfill
McLennan and Limestone Counties
TCEQ Permit No. MSW-2400
Parts III and IV, Volume 4 of 4

Administratively Complete

Prepared for

City of Waco

501 Schroeder Drive
Waco, Texas 76710

Prepared by:

SCS ENGINEERS

SCS Project No. 16216088.00 | Revision 0 – May 2020 and June 2020

1901 Central Drive, Suite 550
Bedford, Texas 76021
817.571.2288

City of Waco Landfill
McLennan and Limestone Counties
TCEQ Permit No. MSW -2400

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER

5/13/2020

SCS Engineers
TBPE Reg. # F-3407

MSW Landfill Permit Application, Parts III and IV

Table of Contents

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
McLENNAN AND LIMESTONE COUNTIES, TEXAS

PART III - SITE DEVELOPMENT PLAN
ATTACHMENT 7
GROUNDWATER SAMPLING AND ANALYSIS PLAN

Prepared for:

CITY OF WACO

Solid Waste Services
501 Schroeder Drive
Waco, TX 76710

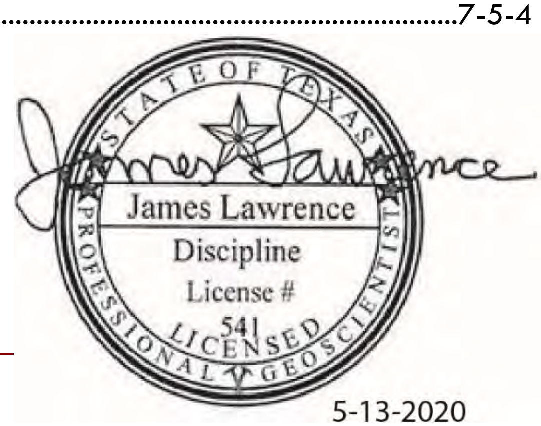
Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 – May 2020
SCS Project No. 16216088.00

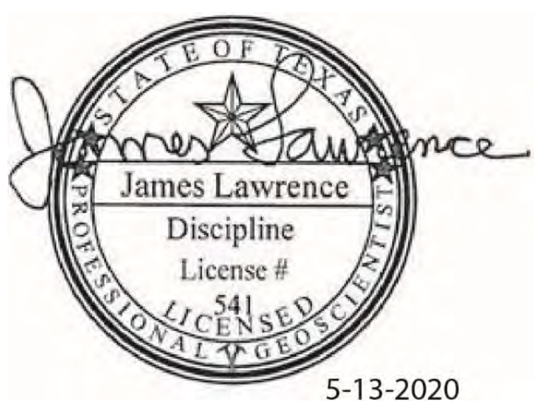
STATE OF TEXAS
James Lawrence
Discipline
License #
541
LICENSED
PROFESSIONAL GEOSCIENTIST
5-13-2020

TABLE OF CONTENTS



Tables

Appendices



1 INTRODUCTION

This Groundwater Sampling and Analysis Plan (GWSAP) has been prepared for the City of Waco Landfill (TCEQ Permit No. MSW-2400) consistent with regulations in Title 30, Texas Administrative Code (30 TAC), sections §330.63(f) and §330.405 through §330.415, which conform to federal Resource Conservation and Recovery Act, Subtitle D rules for groundwater monitoring and corrective action in Title 40, Code of Federal Regulations, Part 258, Subpart E. This GWSAP establishes appropriate methods for sampling and analysis that shall yield accurate results for evaluating groundwater conditions at this Facility.

This document is prepared in accordance with §330.405(a), and is intended to include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide an accurate representation of groundwater quality at the background and point of compliance wells, installed in compliance with §330.403(a) - (c).

There is no evidence of a plume of contamination in accordance with §330.63(f)(2). No site groundwater chemistry data are available. In accordance with §330.63(f)(3), an analysis of the most likely pathway(s) for pollutant migration is addressed in Attachment 4.

2 GROUNDWATER SAMPLING PROCEDURES

2.1 PRELIMINARY WORK

Prior to purging and sampling the well, the sampler shall adhere to the following protocol upon arrival at each well location.

2.1.1 Well Inspection

The sampler shall refrain from using organic sprays or other potential contaminants to remove any insects found on or in the casing, or organic lubricants on well components such as hinges and locks. Topical skin care products may also contain organic compounds and shall not be allowed to contaminate the area or the sample.

The components of the well and its surroundings shall be verified to be in good condition, and the well shall be clearly identified. The casing, concrete pad, protective collar, and protective barriers such as bollards shall be checked for cracks, fissures, or damage (by equipment, animals, vandalism, or other cause). The sampler shall check that the lid of the protective collar has a lock, that the lock is functional, and that the lid was locked when the sampler visited the well. The well cap shall be present and fit snugly on top of the well casing. Also, the sampler shall note the proximity of the well to potential sources of contamination, including facility roads.

2.1.2 Water Level Measurement

Before purging a well, the sampler shall measure and record the depth to water at every event and the depth to the bottom of the well at least every two years. Both measurements shall be taken to the nearest hundredth of a foot. All depth measurements shall be taken from a permanent, clearly marked and identifiable reference point, or datum. The datum is typically a notch or a point marked with permanent marker at the top of the well casing, and shall be documented on the Well Data Sheet for each well. The water level indicator probe shall be decontaminated before use in each well. The sampler shall include in the field log any indication of organic compounds that have formed a liquid separate from the groundwater. The sampler shall calculate the elevation of the water level with respect to mean sea level and reports to the nearest hundredth of a foot after water-level measurements are taken.

Water level measurements shall be collected from the highest water elevation to the lowest water elevation wells unless any constituents are detected at concentrations of concern. If the constituents are detected at concentrations of concern, then water level measurements shall be collected from the least to greatest impacted well.

2.2 WELL PURGING

The primary purging method is conventional purge as described below. Each well shall be purged prior to sampling. The purge method may vary due to specific well conditions such as recharge rate, depth to water, and volume of water to be purged. Purge water can be measured in a known-volume container such as a 5-gallon bucket. If a well goes dry during the purging process, it is deemed sufficiently purged.

In a field log the sampler shall record the following data shall include all of the following:

- Sampler's name.
- Date and time.
- Outdoor temperature and weather conditions.
- Initial depth to water, measured well depth, and calculated height and volume of the water column.
- Desired well volume to purge (for example, three casing volumes).
- Purge-discharge rate, if known, and purge duration (elapsed time).
- Volume of water actually purged from a well.
- Low-flow parameter readings, if a low-flow method is used.
- Well inspection results.
- Any other pertinent information.

2.2.1 Low-Flow Purging

Low flow purging may be appropriate for the site, depending upon initial data collected during conventional purge operations. The owner of operator may consult with TCEQ regarding low flow purging during the background monitoring period. Low flow purging is a widely used method of well purging which involves removal of well water in a manner that minimizes drawdown, turbidity, and disturbances to the aquifer. The sampler shall place the pump intake in the middle of the screened interval to avoid mixing formation water with sediments in the well bottom or overlying stagnant water within the well casing, unless water levels within the screen are low enough to warrant a lower pump intake placement. A dedicated purging and sampling device shall be used, but if non-dedicated equipment is used, it shall be decontaminated between wells to prevent cross-contamination. Measure and record water levels before pumping. Initiate purging and adjust flow to a rate that results in minimal drawdown. The minimum well-purge volume shall be at least two pump and tubing volumes.

Water quality indicator parameters shall be continuously monitored during purging, preferably with a flow-through cell. Stabilization of parameters such as pH, specific conductance, dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, and turbidity shall be used to determine when stagnant casing water has been purged and formation water is available for sampling. A minimum subset shall include pH, specific conductance, and either turbidity or DO. Measurements shall be recorded every three to five minutes. Temperature and pH are not helpful in distinguishing between formation water and stagnant casing water, but are still important for data interpretation. Stabilization is considered achieved when all the parameters are within the following ranges for three successive readings:

- ±0.1 units for pH
- ±3% for specific conductance
- ±10 millivolts for ORP
- ±10% for turbidity and DO

2.2.2 Purging with a Bailer

Purging with a bailer is an alternative method to purging with a pump. Bailers shall have a bottom-emptying device that allows the bailer to be emptied slowly with minimum aeration of the sample. When purging with a bailer, the sampler shall take extra care to avoid introducing contaminants to the water in the well, and use disposable gloves, a new pair for each well, to avoid cross-contamination. Because of the ease of stirring up accumulated sediments at the bottom of the well, purging shall be done in ways that shall minimize turbidity. Bailers shall be lowered gently, not dropped, to a foot or two above the bottom of the screen, allowed to sit for several seconds, and then pulled slowly and steadily up to the surface. Purging and recovery shall continue until at least three casing volumes have been removed or the well goes dry.

2.3 STORAGE AND DISPOSAL OF PURGE WATER AND EXCESS SAMPLE WATER

2.3.1 Storing Purge Water and Excess Sample Water

The sampler shall store purge water and excess sample water in a properly labeled drum or container until the analytical results have been received and a proper disposal method has been selected. All the disposable sampling equipment (such as tubing or bailers) and supplies (such as gloves) shall be containerized separately from the purge water.

2.3.1.1 Disposing of Uncontaminated Water

If the analytical results indicate that constituents are at or below background concentrations, purge water and excess sample water may be applied to the unsaturated soil on-site or discharged to surface water, if an authorization is not required.

2.3.1.2 Disposing of Contaminated Water

If constituents are above background concentrations, the water is considered contaminated. The following methods are allowed:

- Place in the landfill leachate collection system via storage tanks, accessible risers, evaporation ponds, or other access points, and manage in the same manner as leachate.
- Place in the landfill gas condensate storage tanks and manage in the same manner as condensate.
- Solidify at a liquid waste processing operation at the facility and dispose of in landfill.

- Transport off-site or discharge to an authorized wastewater treatment facility, or liquid waste processing facility, if the water quality is acceptable to the receiving facility.

If test results indicate levels of contaminants that cause the water to be classified as hazardous, the water shall be properly transported and disposed of at a hazardous waste facility.

2.4 SAMPLE COLLECTION

Physical or chemical changes can occur in groundwater samples if inappropriate or inadequate sampling devices, collection procedures, preservatives, temperature controls, or shipping methods are used. The sampler shall observe the following procedures when collecting samples.

2.4.1 Sample Collection Methods

2.4.1.1 Timing and Sequence of Sampling

The elapsed time between purging and sample collection shall be as short as practical, to avoid temporal variations in water levels and water chemistry. Preferably, sampling shall be done within 24 hours of purging. The sampler shall measure the water level in each well again before sampling to determine whether there is enough water for sampling, especially if the well went dry during purging. Where practicable, the water level in a well shall be allowed to recover to 90 percent of the level that existed prior to purging, before collecting a sample. To allow wells that purged dry to recover sufficiently to sample, or suspended sediments to settle, the sampler may have to wait several hours or several days between purging and sampling.

The sampler may allow up to seven days recovery time after purging a well before determining that the well is dry or has not recharged sufficiently to sample. If after seven days a slowly recharging well has not recovered sufficiently for a complete set of samples, the sampler shall collect a partial set of samples in the order specified in this GWSAP, or in another order if warranted by conditions and data needs, until no more samples for the set can be collected. If contamination is known to be present in one or more wells at an MSW landfill, the sampler shall begin the sampling at the well that is known to be the least contaminated and end with the most contaminated well. Where no contamination is known, the order shall generally be from the well with the highest water-level elevation to the one with the lowest elevation (that is, from upgradient to downgradient) for wells screened in the same water-bearing unit.

2.4.1.2 Cleaning and Decontaminating Field Equipment

If the sampler uses non-dedicated sampling devices, they shall clean and decontaminate them using appropriate procedures before sampling each well. Do not reuse sample bottles, bailer rope, rubber hoses, or disposable gloves. If a bailer is used, a bottom-emptying device is required, because it allows the bailer to be emptied slowly from the bottom, reducing turbulence and aeration, which could alter sample chemistry.

2.4.1.3 Calibrating Field Equipment

Field equipment, including devices for water quality indicator parameters, shall be calibrated in accordance with the manufacturer's instructions prior to sampling.

2.4.1.4 Water Quality Indicator Parameters

Before sample collection begins, the sampler shall measure and record water quality indicator parameters—including pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature, and turbidity—in addition to the measurements the sampler made during purging [if low-flow sampling is used].

2.4.1.5 Sample Filtering

Per 30 TAC §330.405(c), the sampler shall not filter any samples in the field.

2.4.2 Sample-Collection Procedure

Sampling with a bailer is the collection method of choice at this Facility. If for some reason a bailer is not available for use, a low-flow pump such as a Monsoon pump is an acceptable alternative.

2.4.2.1 Cleanliness

To prevent contamination, the sampler shall keep clean equipment on top of plastic sheeting and not in direct contact with the ground. The sampler shall check the area around the sampling point for possible sources of air contamination, particularly when sampling for VOCs. The sampler shall note any potential impacts in the field log. The sampler shall collect all water samples as close to the wellhead as practical. The sampler shall not allow the sampling device to touch the sampling container, but hold the two as close to each other as possible, to reduce aeration. Water removed during sampling and not utilized shall be handled in the same way as purge water.

2.4.2.2 Sample Volumes and Sampling Containers

The volume of samples and types of sample containers needed depends on the constituents to be analyzed. The sampler shall follow the following EPA recommendations:

- For volatile organic compounds (VOCs), use two [or three] 40 ml glass vials (or lab-specified alternate quantity or size) with special caps with Teflon® septa, pre-preserved by the lab. The septum shall be correctly placed, with the Teflon® side toward the sample (shiny side away from the sample).

- For semivolatile organic compounds (SVOCs), use a one-liter glass container.

- For metals, use laboratory-provided polyethylene or glass containers that already contain the necessary preservatives.

- For other inorganic constituents, use laboratory-provided polyethylene or glass containers (preservatives generally are not used, except for samples to be analyzed for ammonia).

2.4.2.3 Filling Sample Containers

The sampler shall fill sample containers in the following order, according to volatilization sensitivity (from most to least volatile):

- VOCs
- SVOCs
- Metals
- Other Inorganic Constituents

When filling containers for VOC samples, the sampler shall allow the water stream to flow down the inner wall of the vial to minimize formation of air bubbles. The sampler shall overflow the containers slightly so that the vial has a positive meniscus. The sampler shall screw the caps on carefully to avoid leaving any air space in the vials. If an air bubble forms in the bottle, the sampler shall not open the bottle to remove it, but collect an additional, separate sample. If the sampler uses bailers for sampling, the sampler shall discard the first part of the sample to remove any sludge or suspended solids, then fill both VOC vials from a single bailer to minimize differences in the samples.

2.4.2.4 Labeling Sample Containers

All sample containers shall be labeled for identification purposes. The labels shall include information such as sample number (with the well number as part of the sample number), site identification, analysis to be performed, preservatives used, date and time of sample collection, and name of sampler. The sampler shall write the information on the label with permanent ink and, if necessary, cover the label with transparent tape to protect the written data.

2.4.3 Quality Control Samples

The sampler is required to use appropriate trip blanks, field blanks, equipment blanks, and field duplicate samples for quality control (QC), as they can help determine whether samples have been contaminated from other sources. Typical collecting frequencies are as follows:

Table 7-2-1. Typical Collecting Frequencies for Blanks

Type of Blank Collection	Frequency
Trip Blanks	One for each sampling event
Field Blanks	One per day, or one for every 10 wells sampled, whichever is greater
Equipment Blanks	One per day or sampling event [if non-dedicated/non-disposable equipment is used]
Field Duplicates	One for every 20 wells sampled, with at least one per sampling event

The various types of QC samples are described below.

- Trip Blanks. A trip blank is a laboratory-prepared sample of reagent-grade or distilled water provided with a set of sample jars that is transported to and from the site in the same manner as the sample containers. The purpose of the trip blank is to determine if any of the sample bottles or collected samples have been contaminated before or during sampling, or if sample shipment, handling, and storage have had an impact on the integrity of the sample.

- Field Blanks. A field blank is prepared in the field by pouring laboratory reagent-grade or distilled water into clean sample containers opened in the field, then returned with the samples to the laboratory for analysis. It is used to check for incorrect sampling procedures or airborne contaminants at the sample-collection point. It is appropriate to collect the field blanks when sampling downgradient wells. If a well is contaminated, a field blank collected close to the contaminated well, in addition to the regular field blank, may help determine if there are other contaminant sources in the area of the well.

- Equipment Blanks. An equipment blank is a sample of laboratory reagent-grade or distilled water run through the well-sampling equipment in the same manner as the actual groundwater sample, to determine the effectiveness of the procedures for equipment decontamination. An equipment blank is not necessary if non-dedicated/non-disposable equipment is used.

- Field Duplicates. Analysis of field duplicate samples provides a check on the precision of the laboratory techniques. Field duplicates are two samples taken at the same time from the same well, and from the same bailer, if bailers are used. Field duplicates are labeled differently so that the laboratory is unaware that the samples are duplicates.

- Field duplicate samples shall be labeled as the sampler would regular samples, but with a sample name such as “Dup-1,” “Dup-2,” and so on, and with the sample time omitted, so there is no way for the laboratory to know which well the duplicate sample is from. The information about which well the duplicate is from shall be recorded in the field log book.

2.4.4 Chain-of-Custody Documentation

A suitable chain-of-custody (COC) document shall accompany the samples at every step from field to laboratory and shall be signed by each party (except commercial transporters) handling the samples, from the sampler to the laboratory representative. Usually laboratories provide their own blank COC forms with the empty sample-bottle shipment. Proper COC procedures are essential to ensure sample integrity and to provide legally and technically defensible data.

The person collecting the sample starts the COC procedure and fills in all the required information on the COC document, such as sample name, collection date and time, and requested analyses. Individuals relinquishing and receiving the samples shall sign, date, and note the time of transfer on the COC document. A completed COC document shall be placed inside a sealed plastic bag to prevent the ice or water in the cooler from damaging it. Mailed packages shall have tracking numbers to allow for locating shipments.

2.4.5 Sample Storage and Transport

All samples shall be kept cold, ideally at 4° C ± 2°, and transported to the laboratory as soon as possible, preferably within 48 hours of sampling. The samples shall be wrapped, put into resealable plastic bags, and placed in a hard-sided ice chest or other insulated container packed with sufficient ice or refreezable materials to keep them at the ideal temperature. Dry ice is not to be used to chill the samples because the samples could freeze and break their containers.

If the samples are to be shipped, they shall be kept chilled with ice in plastic bags while sampling is occurring. Then, just before shipping, the sampler shall pour out the excess melt water, and add more ice, if necessary. Coolers can also be kept cold with frozen packages of refreezable materials such as "blue ice." The samples, blanks, and COC documents need to be well packed in the insulated cooler, with as little extra air space as possible, utilizing ice bags, foam, or bubble wrap to add padding, then thoroughly sealed with shipping tape. Flimsy, expanded-foam or soft-sided ice chests are not suitable for shipping.

2.4.6 Documentation of Sampling

This GWSAP requires that all information related to a sampling event be recorded in a bound, permanent field log book or equivalent. All the entries in the log book shall be legible and made in black, permanent ink. Entry errors shall be crossed out with a single line, dated, and initialed by the person making the corrections. An essential practice is to record sufficient information so that the sampling situation can be reconstructed without relying on the sampler's memory. Location, date, time, weather conditions, name and identity of sampling personnel, all field measurements including numerical values and units, comments about the integrity of the well, and so on shall be recorded. Because the field log book may be the only acceptable record for legal purposes, it shall be protected and kept in a safe place.

3 GROUNDWATER ANALYSIS

3.1 LABORATORY ACCREDITATION

General provisions as well as accreditation and certification requirements for environmental testing laboratories are specified in 30 TAC, Chapter 25. All environmental testing laboratories shall be accredited in accordance with 30 TAC, Chapter 25 (except as provided in 30 TAC §25.6), if the laboratory provides analytical data that is used for a TCEQ decision relating to a (1) permit, (2) authorization, (3) compliance action, (4) enforcement action, (5) corrective action, (6) characterization of an environmental process or condition, or (7) assessment of an environmental process or condition.

3.2 GROUNDWATER SAMPLING AND ANALYSIS REQUIREMENTS

In accordance with 30 TAC §330.405 through §330.415, a groundwater monitoring program shall include consistent sampling and analysis procedures that are designed to ensure results that provide an accurate representation of groundwater quality at the background and point-of-compliance wells.

3.3 CONSTITUENTS REQUIRED FOR DETECTION MONITORING

In accordance with 30 TAC §330.419, the constituents listed in Appendix I to 40 CFR, Part 258, shall be sampled for in all groundwater monitoring wells (Appendix III-7.A). In certain cases, the TCEQ may delete any of the constituents listed in Appendix I, and allow facilities to establish an alternative list of inorganic indicator constituents (in place of the constituents listed in Appendix I), if the alternative list ensures a reliable indication of releases from the landfill to the groundwater. TCEQ may also add constituents to the list, if they are expected to be in or derived from the waste contained in the landfill or if they are likely to provide a useful indication of releases from the landfill.

3.4 TEST METHODS

Lab test methods shall be in accordance with the following two publications: Test Methods for Evaluating Solid Waste (a publication of the EPA; also known as SW-846; as revised), and Standard Methods for the Examination of Water and Wastewater (a joint publication of the American Public Health Association, the American Water Works Association, and the Water Environment Federation; as revised). Any alternative inorganic constituents chosen for detection monitoring can be analyzed by the methods described in either of these two references.

3.5 REPORTING ANALYTICAL RESULTS

Analytical results for groundwater samples from the Landfill groundwater monitoring wells shall be reported using a practical quantitation limit (PQL) (as defined below). Any statistical method used to evaluate groundwater monitoring data shall account for data below the limit of detection with one or more statistical procedures that are protective of human health and the environment, and any PQL that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions in accordance with 30 TAC §330.405(f)(5).

30 TAC §330.405(f)(5) defines the PQL as the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. For each constituent listed in 40 CFR, Part 258, Appendix I or Appendix II, or for each groundwater parameter that has a groundwater protection standard (GWPS), the laboratory shall demonstrate that the method and procedure used in the analysis can attain a PQL at or below the GWPS. Laboratory quality control samples shall meet the precision and accuracy data-quality objectives that are listed in the table below.

Table 7-3-1. Measurement-Quality Objectives

Chemical of Concern	Precision (% RSD)	Accuracy (% recovery)
Metals	10	70–130
Volatiles	20	50–150
Semivolatiles	30	50–150

The laboratory shall report non-detected results as less than the value of the PQL. When the limits for precision and accuracy listed in Table 7-3-1 cannot be met, the owner or operator shall submit information to support a recommendation for using alternative precision and accuracy limits.

Laboratory Case Narrative: All analytical data submitted under the requirements of this permit shall be examined by the owner or operator to ensure that the data-quality objectives are considered and met prior to submittal for the commission's review. The owner or operator shall determine if the results for a sample are accurate and complete. The quality control results, supporting data, and data review by the laboratory shall be included when the owner or operator reviews the data. The owner or operator shall report any anomalies that were identified in the laboratory case-narrative summary.

The owner or operator shall ensure that the laboratory documents and reports all problems and anomalies associated with the analysis. If analysis of the data indicates that the data fails to meet quality control goals, the owner or operator shall determine if the data is usable. If the owner or operator determines that the analytical data may be used, all problems and corrective action that the laboratory identified during the analysis shall be included in the report submitted to the TCEQ.

A Laboratory Case Narrative (LCN) for all problems and anomalies observed shall be submitted by the owner or operator. The LCN shall provide the following information:

1. The exact number of samples, constituents analyzed, and sample matrices.
2. The name of the laboratory performing analyses. If more than one laboratory is used, all laboratories shall be identified in the case narrative.
3. Explanation of each failed precision and accuracy measurement determined to be outside of the laboratory or method control limits.

4. Explanation if the failed precision and accuracy measurements cause a positive or negative bias on the results.

5. Identification and explanation of problems associated with the sample results, along with the limitations on data usability.

6. When appropriate and when requested, a statement on the estimated uncertainty of analytical results of the samples.

7. A statement of compliance or noncompliance with data-quality objectives. Holding-time exceedances and matrix interferences shall be identified. Dilutions shall be identified, and if dilutions are necessary, they shall be done to the smallest dilution possible to effectively minimize matrix interferences and bring the sample into control for analysis.

8. Identification of all applicable quality assurance and quality control samples that shall require special attention by the reviewer.

In addition to the LCN, a laboratory report shall include the following:

1. A table identifying the field-sample name with the sample identification in the laboratory report.

2. Chain of custody.

3. For each sample, a report (certificate of analysis) of the constituents analyzed, the analytical methods, and the laboratory PQLs.

4. A release statement provided by the laboratory, with the following wording: "I am responsible for the release of this laboratory data package. This data package has been reviewed by the laboratory and is complete and technically compliant with the requirements of the methods used, except where noted by the laboratory in the attached exception reports. By my signature below, I affirm to the best of my knowledge that all problems or anomalies that were observed by the laboratory as having the potential to affect the quality of the data have been identified by the laboratory in the Laboratory Review Checklist, and no information or data have been knowingly withheld that would affect the quality of the data."

5. An MSW Laboratory Review Checklist (LRC). For every "exception report"—a response of "No," "NA," or "NR"—on the checklist, the permittee shall ensure that the laboratory provides a detailed description of the exception in the summary of the LCN.

3.5.1 MSW Benchmark PQLs and Laboratory PQLs

Sample results shall be reported using laboratory MSW benchmark PQLs (listed in a letter to MSW landfill owners and operators, dated May 25, 2010); the letter is available at www.tceq.texas.gov/goto/msw-pqls. Once the method and PQL for a constituent at the Landfill is established, the equivalent or better method and PQL shall be used for future analyses. A PQL may be modified if a different test method is used for a constituent, or if the designated PQL cannot be achieved. PQLs shall be equal to or below the groundwater protection standards established for each constituent, unless an alternative PQL is approved by the TCEQ.

3.5.2 Reporting Estimated Results below the PQLs

The MSW rules do not address estimated constituent concentrations (typically flagged in laboratory reports by the letter “J”). The EPA document Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance (March 2009) (Unified Guidance) specifies that J-flagged sample results represent concentrations that are detected but not quantified, and shall be treated as valid measurements for statistical purposes only.

3.5.3 Acceptance Limits for Quality Control Samples

Quality control samples are used to determine precision (how repeatable a measurement is) and bias (how close the result is to the actual value). Each analysis has associated acceptance limits. Quality control results that are outside acceptance limits for a constituent and method shall be flagged by the laboratory, with an explanation of any problems encountered by the laboratory, including any corrective actions attempted to resolve the analytical problems. Groundwater sample results associated with quality control results that are outside acceptance limits may still be used, but shall be flagged. The owner or operator shall review all data and ensure that the laboratory has performed all required quality assurance and quality control activities, and document any problems and corrective actions associated with an analysis. The laboratory shall maintain all records in accordance with the requirements of the National Environmental Laboratory Accreditation Conference (NELAC).

4 STATISTICAL EVALUATION OF MONITORING DATA

4.1 REGULATORY REQUIREMENTS

In accordance with 30 TAC §330.405(e) and (f), statistical evaluation of analytical results from groundwater samples is required to determine if Landfill activities have affected groundwater quality. Statistical procedures provide an objective way for characterizing analytical results and making decisions, including: establishing background groundwater quality, determining if changes in groundwater quality are significant, and determining if constituents of concern are above or below groundwater protection standards and whether corrective action is needed.

Any statistical method used to evaluate data shall be appropriate for the distribution of tested constituents. It may not be possible to specify statistical methods until at least a few background samples have been taken.

The Unified Guidance offers information about selecting and using various statistical methods.

4.2 ESTABLISHING AND UPDATING BACKGROUND

The background data for a facility shall reflect groundwater quality that has not been affected by a landfill. These conditions could range from an uncontaminated aquifer to a historically contaminated site. A minimum of four background samples are needed to establish limits for any statistical test. Twelve background samples shall be obtained at each well for this Landfill.

The owner or operator may establish background limits for a well using data collected earlier from that well, and then compare detection monitoring results from that well to the earlier background (intrawell comparison), provided that the earlier data from the well represent background groundwater quality not affected by waste-management activities. If background values are not available from a well or if the well is already affected by waste-management activities, then detection monitoring results from the well shall need to be compared to background from upgradient wells (in the absence of spatial variation) or other wells that are not affected (interwell comparison).

Background limits shall be periodically reviewed and updated as necessary with valid semiannual detection monitoring results that are representative of background groundwater quality not affected by landfill activities. Intrawell background data shall be updated once every two years, when at least 4 new measurements are available.

4.2.1 Assumptions for Statistical Tests

4.2.1.1 Statistical Independence

Quarterly or semiannual sampling is commonly accepted in Texas to achieve statistical independence. Samples obtained from this Landfill shall be quarterly (for background monitoring) or semiannual (for detection monitoring), except for resampling as described below.

4.2.1.2 Normality of Data and Selecting Parametric or Nonparametric Methods

Most statistical methods used for the evaluation of groundwater monitoring results from MSW Type I landfills are based on the assumption that the population from which the data are taken is normally distributed. These methods also apply to data from a population that has been transformed by mathematical manipulations into a normal distribution. In that case, the data are treated statistically after the appropriate transformation.

If the data are not normally distributed, either raw or transformed, then nonparametric statistical methods that do not require or assume normality can be used.

4.2.2 Spatial Variation and Selecting Interwell or Intrawell Comparisons

Each monitored constituent shall be evaluated for evidence of spatial variation. When possible, results from the Landfill shall be evaluated using intrawell comparisons, to avoid statistical complications due to natural spatial variation. If background data for a well are not available, interwell comparisons shall be necessary. A mixture of statistical approaches may be used: interwell tests for some constituents and intrawell tests for others.

4.2.3 Outliers

Unusual values in a data set are considered outliers. Outliers in sample results can be due to several factors, including measurement errors, laboratory errors, clerical errors, and contaminated samples. Statistical calculations are required to determine if a sample result is a statistical outlier. The Unified Guidance recommends generally not to remove outliers unless some basis for a likely error can be identified. However, the Unified Guidance also recommends removing extreme values (unusual-looking, high magnitude measurements) in background data sets even if the reason for the extreme values is not known. Removal of statistically-identified outliers shall be based on technical information, or knowledge that can support that decision.

4.2.4 Trends

An assumption about background is that background samples come from a background population with a stable mean and variance that does not vary significantly through time. Data that show a trend of increasing or decreasing concentrations may violate this assumption. The proper handling of trends in background depends on the cause of the trend. For newly installed monitoring wells, it may be necessary to discard initially collected observations and wait for the aquifer or well construction materials to stabilize.

4.2.5 Non-Detects

Samples with values below the laboratory quantitation limit or other reporting limit (RL) are called “non-detects.” The actual concentration of a constituent reported as non-detect may be anywhere between zero and the reporting limit.

When using parametric statistical tests, one half of the RL be used in place of non-detects for calculations, in accordance with the Unified Guidance.

If the proportion of non-detects exceeds certain thresholds, nonparametric tests appropriate to the dataset shall be used.

When all data are non-detect, a nonparametric prediction limit shall be used, with the RL as the limit. If a constituent has never been detected in groundwater at a site, or has not been detected recently, it may be evaluated using the "double-quantification rule" (DQR, described later in this document).

4.3 SITE-WIDE FALSE POSITIVE RATES AND STATISTICAL POWER

False positives are results that are from the background population, but exceed the background statistical limit. Statistical power refers to the ability of a test to identify real increases above background.

The Unified Guidance recommends two statistical performance criteria that are fundamental to good design of a detection monitoring program:

- Application of an annual cumulative Site-Wide False Positive Rate (SWFPR) design target, suggested at 10 percent per year (5 percent for each of two semiannual sampling events). The owner or operator shall evaluate the SWFPR annually as a part of the annual groundwater monitoring report. The Unified Guidance recommends a power (the y axis of the power diagram) of at least 55 to 60 percent when concentration levels are 3 standard deviations (SD, the x axis of the power diagram) above the background mean, and at least 80 to 85 percent at 4 SD.

- Use of EPA power curves to gauge the cumulative annual ability of any individual test to detect contaminated groundwater when it exists. The owner or operator shall use power curves as necessary.

The SWFPR is a function of the number of constituents, number of wells, number of annual evaluations, and the type of verification resampling program. The greater the number of constituents, the greater the likelihood of false positives. Constituents not historically detected in background shall not be included in SWFPR computations.

4.4 STATISTICALLY SIGNIFICANT INCREASES DURING DETECTION MONITORING

During detection monitoring, a statistically significant increase (SSI) is declared when the concentration of a constituent increases above its background limit and, if resampling is elected by the facility, is verified by resampling. An SSI triggers assessment monitoring, unless it is demonstrated that a source other than the Landfill caused the contamination, or that the SSI resulted from error in sampling, analysis, or statistical evaluation, or from natural variation in groundwater quality [30 TAC §330.407(b)(3)].

4.5 STATISTICAL TESTS

Prediction limits, control charts, and confidence intervals are statistical tools that are commonly used to evaluate sample data from landfills. Prediction limits and control charts are used for evaluating detection monitoring results. Confidence intervals are used to evaluate results during assessment monitoring and corrective action.

An alternative method—the "double quantification rule"—is available for evaluating results for constituents that have never been detected or that have not been detected in a long time.

Verification resampling will almost always be needed to maintain adequate statistical power and minimize the overall false-positive rate for detection monitoring programs. Therefore, it is important to outline a resampling strategy prior to beginning detection monitoring.

4.5.1 Prediction Limits

Prediction limits provide an estimate of an interval that shall include values of future measurements based on previous measurements, with a given level of confidence. The previous measurements may be background data for either a group of wells (interwell comparison) or a single well (intrawell comparison). For parametric prediction limits, background data shall be either normal or normalized by using a transformation (e.g., the natural logarithm) and shall not exhibit trends and shall not include statistical outliers. All possible outliers shall be examined to determine whether a cause is known. If a transformation is used, the resulting limit shall be back-transformed to the original units. When normality cannot be justified, a nonparametric limit shall be computed. The largest or second-largest value in a background data set is usually selected as a nonparametric limit.

4.5.2 Control Charts

Combined Shewhart-CUSUM control charts are an alternative test to prediction limits in detection monitoring. This control chart assesses two statistics at one time: the Shewhart portion works somewhat like a prediction limit and compares each new measurement against a control limit, whereas the CUSUM portion tracks the cumulative sum of how much each measurement exceeds a threshold level. A statistical exceedance is declared if either the new measurement or the CUSUM exceeds the limit.

To use the Shewhart-CUSUM control chart for analysis, the original or transformed data shall be (1) normally distributed, (2) independent, (3) generally above detection limits, and (4) represent groundwater quality not affected by the Landfill.

4.5.3 Trend Tests

The Unified Guidance suggests trend tests as an alternative to prediction limits when the data are not amenable to prediction limits. Also, a trend test can be used for historically contaminated wells, where uncontaminated data cannot be collected. For most constituents, a trend test will have one of three outcomes: (1) a statistically significant decreasing trend, which indicates that water quality may be improving; (2) an insignificant trend, which indicates that water quality is staying the same;

or (3) a statistically significant increasing trend, which indicates that water quality may be getting worse.

4.5.4 Double Quantification Rule (DQR)

The Unified Guidance recommends using the Double Quantification rule (DQR) for constituents not historically detected. Constituents that have not been detected in the background samples are not subject to formal statistics and shall not be included in Site-Wide False Positive Rate (SWFPR) computations. If a constituent has been detected for two consecutive semiannual sampling events, it shall be treated as an SSI and added to SWFPR computations.

4.5.5 Verification Resampling

This Landfill detection monitoring program shall implement verification resampling where appropriate. A confirmed SSI is not declared unless the resample or resamples also exceed the background limit. The exceedance detected in the initial sample may be referred to as an "initial" or "unverified" exceedance.

Verification resampling may be conducted [at the owner or operator's discretion] to verify or disconfirm an initial exceedance. If a constituent in an original sample from a well exceeds its statistical limit, then one or more resamples are collected from that well and evaluated. A statistical test utilizing resampling is not complete until all necessary resamples have been evaluated.

Prediction limits are well suited for retesting. Typical retesting strategies are to allow for one resample for constituents evaluated using a parametric method with eight background measurements, or two resamples for constituents evaluated using a nonparametric method with eight background measurements. If the retesting strategy involves one resample, the initial exceedance is disconfirmed if the constituent concentration in the resample does not exceed the prediction limit (pass one of one resample). If the retesting strategy involves two resamples, the initial exceedance is disconfirmed if the constituent concentration in the first or second resample does not exceed the prediction limit (pass one of two resamples); if the first resample passes, the second resample does not need to be taken.

A resampling strategy ordinarily shall not be changed from event to event; however, it can be periodically reevaluated and changed as necessary during a background update, which would include new sample results since the previous background evaluation, and may include new wells or changes to the list of constituents monitored.

4.5.6 Confidence Intervals for Assessment Monitoring and Corrective Action Monitoring

Confidence intervals shall be used for evaluating results during assessment monitoring and corrective action monitoring, in accordance with The Unified Guidance. A confidence interval shall be constructed using at least four measurements. For semiannual monitoring, the four samples would include the sample from the current event and the samples from the three preceding semiannual events (spanning a period of one and a half years).

During assessment monitoring, the lower confidence limit (LCL) for each constituent is compared against its GWPS to determine if a constituent is present at a statistically significant level above its GWPS. If an LCL exceeds a GWPS, corrective action is triggered, unless it is demonstrated that the statistically significant level resulted from error in sampling, analysis, statistical evaluation, or from natural variation in groundwater quality.

During corrective action monitoring, the upper confidence limit (UCL) for each constituent is compared against its GWPS to determine if a constituent remains at a statistically significant level above its GWPS. A remedy under corrective action is considered complete when the UCLs for all assessment constituents have not exceeded GWPSs for a period of three consecutive years.

5 MONITORING FREQUENCY AND REPORTING REQUIREMENTS

5.1 BACKGROUND MONITORING [30 TAC §330.407(A)(1)]

Background refers to the data set representing groundwater quality that has not been affected by leakage from a landfill. A minimum of twelve statistically independent samples shall be collected quarterly from each upgradient and downgradient [point-of-compliance] well and analyze them for the constituents listed in Appendix I of 40 CFR, Part 258. After the facility completes background monitoring, it shall evaluate the background data to ensure that the data are representative of background groundwater constituent concentrations unaffected by waste management activities or other sources of contamination. The evaluation shall be documented in a report and submitted to the Executive Director before the next subsequent groundwater monitoring event following the updated background period.

The owner or operator may update background data sets every two years with semiannual monitoring results (at least four measurements) that are demonstrated to be representative of background groundwater quality. The owner or operator shall submit background evaluation reports (BER), as well as background updates, to the TCEQ for review and approval. The owner or operator shall provide the Site-Wide False Positive Rate and Statistical Power for a proposed background data set and statistical evaluation plan in each BER.

5.2 DETECTION MONITORING [30 TAC §330.407]

After the completion of background monitoring, all monitoring wells shall be sampled on a semiannual basis unless another sampling schedule is approved by the TCEQ. The monitoring requirements shall continue throughout the active life of the Landfill and the post-closure care period. The goal of detection monitoring is to identify changes in groundwater chemistry that may indicate a release from the landfill.

Changes in groundwater chemistry are identified by statistically comparing the detection monitoring result for each constituent in each well to the established background statistical limit for that constituent. No later than 60 days after each sampling event, the facility shall determine if there has been an initial [or unverified] exceedance over the background limit for any tested constituent. If an initial exceedance is determined at the point of compliance, the facility shall notify the TCEQ and any local pollution agency with jurisdiction that has requested to be notified, in writing within 14 days. (The term "initial [or unverified] exceedance" refers to a monitoring result that exceeds a statistical limit but has not yet been verified by resampling.)

5.2.1 Verification Resampling [30 TAC §330.407(b)]

If an initial exceedance over a background limit is determined, the owner or operator may conduct up to two verification resampling events and submit the results within 60 days of the initial exceedance determination. The verification resampling results shall confirm or disprove the initial exceedance. If an initial exceedance is verified, an SSI is declared and assessment monitoring is triggered unless an "alternate source demonstration" is submitted and approved. If a verification resample does not confirm an exceedance, routine detection monitoring may continue.

5.2.1.1 Alternate Source Demonstration [30 TAC §330.407(b)(3)]

If a statistically significant increase over a background limit of any tested constituent at any monitoring well has occurred and the owner or operator has reasonable cause to think that a source other than the Landfill caused the contamination or that the statistically significant increase resulted from error in sampling, analysis, or statistical evaluation, or from natural variation in groundwater quality, then the owner or operator may submit a report providing documentation to this effect. The report is commonly referred to as an "alternate source demonstration (ASD)," but may be a demonstration of an error or of natural variation, instead of a source other than the Landfill.

In making a demonstration under this paragraph, the owner or operator shall not filter the groundwater sample for constituents addressed by the demonstration prior to laboratory analysis. The executive director may also require the owner or operator to provide analyses of the landfill leachate to support the demonstration per 30 TAC §330.407(b)(3)(C).

The owner or operator pursuing an ASD shall first notify the executive director of the TCEQ (and any local pollution agency with jurisdiction that has requested to be notified) in writing, within 14 days of determining an SSI over a background limit, that the owner or operator intends to make the demonstration. The ASD shall be submitted within 90 days of determining an SSI.

If the ASD is satisfactory to the executive director, the facility may continue detection monitoring. If the ASD is not satisfactory, the Landfill shall proceed with assessment monitoring.

5.3 ASSESSMENT MONITORING [30 TAC §330.409]

Assessment monitoring is required if a facility determines there has been an SSI over a background limit for one or more of the constituents. Within 90 days of determining that an SSI has occurred, and not less than annually thereafter, the owner or operator shall sample and analyze each affected well and the two wells adjacent to each affected well for the full set of constituents listed in Appendix II to 40 CFR, Part 258. After sampling for the full set of Appendix II constituents, the executive director may delete any of the Appendix II constituents.

The executive director may specify an appropriate alternative frequency for repeated sampling and analysis for the full set of 40 CFR Part 258, Appendix II constituents. During alternative frequency for repeated sampling, the following shall be established:

- Background concentrations for any additional Appendix II constituents detected.
- A GWPS for all constituents in point of compliance wells detected.
  - for constituents for which a maximum contaminant level (MCL) has been promulgated under 40 CFR Part 141, Safe Drinking Water Act (MCL).
  - for constituents for which MCLs have not been promulgated.
  - for constituents for which the background level is higher than the MCL or health based levels.

During alternative frequency repeat sampling, the executive director may establish an alternative GWPS in accordance with 30 TAC §330.409(i).

If any new constituents are detected in the well as a result of the Appendix II analysis, a background limit shall be established for the additional constituents. This background level consists of four statistically independent samples from each background well.

If the concentration of any Appendix II constituent is above its respective background limit, but below its GWPS, the facility shall continue assessment monitoring. If the concentrations of all Appendix II constituents are shown to be at or below background values for two consecutive sampling events, the owner or operator may return the well to detection monitoring status, after notifying the executive director and receiving approval.

No later than 60 days after each sampling event a determination shall be made whether any Appendix II constituents were detected at statistically significant levels above the groundwater protection standard. If any Appendix II constituents were detected at statistically significant levels above the groundwater protection standard, the facility shall notify the executive director and appropriate local government officials within seven days of the determination.

The owner or operator will also need to characterize the nature and extent of the release, notify in writing all persons that own or occupy the land that directly overlies any part of the plume of contamination, and initiate an assessment of corrective measures within 90 days of the notice to the executive director.

The owner or operator may demonstrate an ASD in accordance with 30 TAC §330.409(g)(2). The executive director shall be notified within 14 days of exceedance determination an intent to submit an ASD. The ASD report shall be submitted within 90 days of exceedance determination. The owner or operator shall not filter the groundwater sample for constituents addressed by the demonstration prior to laboratory analysis. The executive director may also require the owner or operator to provide analyses of the landfill leachate to support the demonstration. The owner or operator shall continue to monitor in accordance with the assessment monitoring program. If a successful demonstration is made, the owner or operator shall continue monitoring in accordance with the assessment monitoring program.

If the owner or operator determines that the assessment monitoring program no longer satisfies the requirements of this section, the owner or operator shall, within 90 days, submit an application for a permit amendment or modification to make any appropriate changes to the program in accordance with 30 TAC §330.409(g)(4).

5.4 ASSESSMENT OF CORRECTIVE MEASURES [30 TAC §330.411]

Within 90 days of finding that any of the 40 CFR, Part 258, Appendix II constituents have been detected at a statistically significant level above a GWPS, the owner or operator shall initiate an assessment of corrective measures. This assessment shall be completed within 180 days of initiating the assessment.

The assessment shall analyze the effectiveness of potential corrective measures, including performance, reliability, ease of implementation, and potential impacts. The assessment shall also discuss the control of exposure to residual contamination, time required to begin and complete the remedy, costs of remedy implementation, and institutional requirements such as state or local permit requirements that may substantially affect implementation of the remedy or remedies.

Prior to selecting a remedy, the owner or operator shall discuss the results of the assessment of corrective measures in a public meeting with interested and affected parties. The owner or operator shall arrange the meeting and provide notice in accordance with the provisions of 30 TAC §39.501(e)(3).

5.4.1 Selection of Remedy [30 TAC §330.413]

Within 30 days of completing the assessment of corrective measures, the facility shall select a remedy and submit a report to the TCEQ for review and approval. The report shall describe the remedy or remedies proposed for selection and the way it meets the remedy standards in 30 TAC §330.413(b).

5.4.2 Implementation of the Corrective Action [30 TAC §330.415]

The facility shall implement a corrective action groundwater monitoring program following the schedule specified for the selected remedy. The corrective action is considered complete when the concentrations of all constituents are shown to be at or below GWPSs for a period of three consecutive years. The owner or operator shall also take any interim measures necessary to ensure the protection of human health and the environment. Interim measures shall, to the greatest extent practicable, be consistent with the objectives of and contribute to the performance of the approved remedy.

5.5 REPORTING REQUIREMENTS

5.5.1 Annual Detection Monitoring Report

The results from detection monitoring events shall be submitted to the TCEQ in an annual report within 90 days after the last groundwater monitoring event in a calendar year at the Landfill. The last groundwater monitoring event refers to a second semiannual event. The annual detection monitoring report shall include the following information:

- A discussion regarding SSIs during the calendar year and a summary of the statistical calculations.
- A summary of the groundwater monitoring events with the monitoring status of each well.
- Results of all groundwater monitoring, resampling, and analytical work produced during the sampling events for the year, including all of the following:
- groundwater sampling results on form TCEQ-0312
- background statistical limits and statistical analyses

- a laboratory case narrative and laboratory review checklist
- the chain of custody for the samples
- A contour map of piezometric groundwater levels and groundwater flow direction for each sampling event. The map shall include all background wells and point-of-compliance wells.
- Recommendations for any changes or updates to the background data set or the monitoring program for the facility.
- Any other items requested by the executive director.
- Submit a permit amendment or modification, if the detection monitoring program no longer satisfies 30 TAC §330.407.

The entire laboratory report, which includes the laboratory quality assurance information and quality control data, and laboratory analytical data, shall be provided electronically in a PDF file on a CD or equivalent media acceptable to TCEQ.

5.5.2 Semiannual Report

A semiannual report covering the first half of the calendar year shall be submitted within 74 days after the first semiannual event. The annual report shall not duplicate information that was provided in the semiannual report (such as TCEQ-0312, forms, results of statistical evaluations, and laboratory checklist), but shall include a summary of the semiannual report.

5.5.3 Assessment Monitoring Report

The results from assessment monitoring events shall be submitted no later than 60 days after each sampling event. In addition, an annual assessment monitoring report shall be submitted within 60 days after the second semiannual groundwater monitoring event at a facility. The report shall include a statement documenting whether any constituent was present at a statistically significant level above a GWPS during the calendar year. The annual detection monitoring report shall also include the following information:

- Results of all groundwater monitoring results, summary of background groundwater quality values, groundwater monitoring analyses, statistical calculations, graphs, and drawings.
- The groundwater flow rate and direction in the uppermost aquifer based on data from sampling events with supporting documentation.
- A contour map of piezometric water levels in the uppermost aquifer based, at a minimum, upon concurrent measurement in all monitoring wells. All data or documentation used to establish the contour map should be included in the report.
- Recommendations for any changes.

- Any other items requested by the executive director.

5.5.4 Corrective Action Report

If the Landfill is performing corrective action, an annual corrective action report shall be submitted by March 1 of each year.

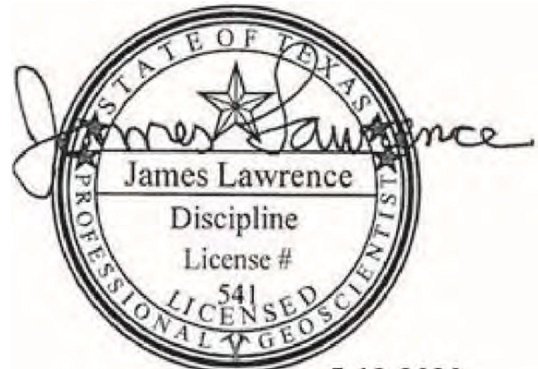
5.5.5 Additional Information about Reporting

Assessment monitoring reports may be combined with detection monitoring reports.

Further information about meeting the reporting requirements for groundwater monitoring [30 TAC §330.405 through §330.409] is provided in the document Guidelines for Groundwater Monitoring Reports, available on the TCEQ website at https://www.tceq.texas.gov/permitting/waste_permits/msw_permits/msw_gwmon_coract.html

APPENDIX III-7.A

LIST OF CONSTITUENTS FOR DETECTION MONITORING



5-13-2020

List of Constituents for Detection Monitoring

Constituent	Method *	CAS Number
Antimony	EPA 6020	7440-36-0
Arsenic	EPA 6020	7440-38-2
Barium	EPA 6020	7440-39-3
Beryllium	EPA 6020	7440-41-7
Cadmium	EPA 6020	7440-43-9
Chromium	EPA 6020	7440-47-3
Cobalt	EPA 6020	7440-48-4
Copper	EPA 6020	7440-50-8
Lead	EPA 6020	7439-92-1
Nickel	EPA 6020	7440-02-0
Selenium	EPA 6020	7782-49-2
Silver	EPA 6020	7440-22-4
Thallium	EPA 6020	7440-28-0
Vanadium	EPA 6020	7440-62-2
Zinc	EPA 6020	7440-66-6
Acetone	EPA 8260	67-64-1
Acrylonitrile	EPA 8260	107-13-1
Benzene	EPA 8260	71-43-2
Bromochloromethane	EPA 8260	74-97-5
Bromodichloromethane	EPA 8260	75-27-4
Bromoform; Tribromomethane	EPA 8260	75-25-2
Carbon disulfide	EPA 8260	75-15-0
Carbon tetrachloride	EPA 8260	56-23-5
Chlorobenzene	EPA 8260	108-90-7
Chloroethane; Ethyl chloride	EPA 8260	75-00-3
Chloroform; Trichloromethane	EPA 8260	67-66-3
Dibromochloromethane; Chlorodibromomethane	EPA 8260	124-48-1
1,2-Dibromo-3-chloropropane; DBCP	EPA 8260	96-12-8
1,2-Dibromoethane; Ethylene dibromide; EDB	EPA 8260	106-93-4
o-Dichlorobenzene; 1,2-Dichlorobenzene	EPA 8260	95-50-1
p-Dichlorobenzene; 1,4-Dichlorobenzene	EPA 8260	106-46-7
trans-1, 4-Dichloro-2-butene	EPA 8260	110-57-6
1,1-Dichlorethane; Ethylidene chloride	EPA 8260	75-34-3
1,2-Dichlorethane; Ethylene dichloride	EPA 8260	107-06-2
1,1-Dichloroethylene; 1,1-Dichloroethene; Vinylidene chloride	EPA 8260	75-35-4
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene	EPA 8260	156-59-2
trans-1, 2-Dichloroethylene; trans-1,2-Dichloroethene	EPA 8260	156-60-5
1,2-Dichloropropane; Propylene dichloride	EPA 8260	78-87-5
cis-1,3-Dichloropropene	EPA 8260	10061-01-5
trans-1,3-Dichloropropene	EPA 8260	10061-02-6
Ethylbenzene	EPA 8260	100-41-4
2-Hexanone; Methyl butyl ketone	EPA 8260	591-78-6
Methyl bromide; Bromomethane	EPA 8260	74-83-9
Methyl chloride; Chloromethane	EPA 8260	74-87-3
Methylene bromide; Dibromomethane	EPA 8260	74-95-3
Methylene chloride; Dichloromethane	EPA 8260	75-09-2

Constituent	Method *	CAS Number
Methyl ethyl ketone; MEK; 2-Butanone	EPA 8260	78-93-3
Methyl iodide; Iodomethane	EPA 8260	74-88-4
4-Methyl-2-pentanone; Methyl isobutyl ketone	EPA 8260	108-10-1
Styrene	EPA 8260	100-42-5
1,1,1,2-Tetrachloroethane	EPA 8260	630-20-6
1,1,2,2-Tetrachloroethane	EPA 8260	79-34-5
Tetrachloroethylene; Tetrachloroethene; Perchloroethylene	EPA 8260	127-18-4
Toluene	EPA 8260	108-88-3
1,1,1-Trichloroethane; Methylchloroform	EPA 8260	71-55-6
1,1,2-Trichloroethane	EPA 8260	79-00-5
Trichloroethylene; Trichloroethene	EPA 8260	79-01-6
Trichlorofluoromethane; CFC-11	EPA 8260	75-69-4
1,2,3-Trichloropropane	EPA 8260	96-18-4
Vinyl acetate	EPA 8260	108-05-4
Vinyl chloride	EPA 8260	75-01-4
Xylenes	EPA 8260	1330-20-7

* Equivalent or better methods may be substituted

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
MCLENNAN AND LIMESTONE COUNTIES, TEXAS

PART III - SITE DEVELOPMENT PLAN
ATTACHMENT 8
CLOSURE AND POST-CLOSURE COST ESTIMATES

Prepared for:

CITY OF WACO

Solid Waste Services
501 Schroeder Drive
Waco, Texas 76710

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 – April 2020
SCS Project No. 16216088.00

TABLE OF CONTENTS

SECTION **PAGE**

SCS Engineers
TBPE Reg. # F-3407

1 INTRODUCTION

These closure and post-closure cost estimates have been prepared for the City of Waco Landfill, TCEQ Permit No. MSW-2400 (landfill), consistent with the 30 TAC Chapter 330, Subchapter L of the Municipal Solid Waste [MSW] rules. These cost estimates are included in this attachment.

The City of Waco (Owner) will establish financial assurance for closure and post-closure care for the largest area requiring final cover (see Attachment 9, Section 3.2.1) in accordance with Chapter 37, Subchapter R. In accordance with §330.63(j), the Owner will submit the required documentation to demonstrate financial assurance consistent with Chapter 37, Subchapter R, no later than 60 days prior to the initial receipt of waste. In accordance with §330.503(b), the Owner will maintain continuous financial assurance coverage for closure until the landfill has officially been placed under the post-closure maintenance period and all requirements of Attachment 9 - Final Closure and Post-Closure Care Plan have been approved as evidenced in writing by the TCEQ. Additionally, in accordance with §330.507(b), the Owner will maintain continuous financial assurance coverage for post-closure care until the facility is officially released in writing by the TCEQ from the post-closure care period in accordance with all requirements of Attachment 9.

2 CLOSURE COST ESTIMATE

Consistent with 30 TAC §330.503, "The owner or operator shall provide a detailed written cost estimate, in current dollars, showing the cost of hiring a third party to close the largest waste fill area that could potentially be open in the year to follow and those areas that have not received final cover in accordance with the final closure plan. For any landfill this means the completion of the final closure requirements for active and inactive fill areas."

To comply with this rule, consistent with the Final Closure and Post-Closure Plans (Attachment 9), the Owner is providing a detailed closure cost estimate, in 2020 dollars, based on the cost of hiring a third party to close the largest waste fill area that could require closure in the year to follow closing the landfill. For the purpose of preparing the closure cost estimate, the largest area requiring closure is expected to be approximately 21.3 acres, comprised of closure of Sector 1 within the East Disposal Area.

This detailed cost estimate has been developed consistent with the Final Closure and Post-Closure Care Plan (Attachment 9). A summary of closure costs is presented in Appendix 8A – Closure Cost Estimate Form for Municipal Solid Waste Type I Landfills. Calculations and supporting data for the cost estimates are included in Appendix 8B - Closure Cost Estimate Calculations. Unit rate cost estimates provided in Appendices 8A and 8B are based on data available from similar work and/or construction projects (e.g., quotes, bid tabulations, etc.).

Consistent with 30 TAC 330.503(a), the Owner will review the facility's permit conditions on an annual basis and verify that the current active area is less than or equal to the areas (i.e., the acreage) on which the closure cost estimates were based. The Owner will increase the closure cost estimate and the amount of financial assurance provided if changes to the final closure plan or the landfill conditions increase the maximum cost of closure at any time during the active life of the unit. Increases will be submitted to the TCEQ for review and approval. In addition, the Owner will adjust the closure cost estimate to account for annual inflation, as described in Section 4, or other reasons as required by regulation.

3 POST-CLOSURE CARE COST ESTIMATE

30 TAC §330.507 states that, "The owner or operator shall provide a detailed written cost estimate, in current dollars, of the cost of hiring a third party to conduct post-closure care activities for the municipal solid waste unit, in accordance with the post-closure care plan. The post-closure care cost estimate used to demonstrate financial assurance in subsection (b) of this section shall account for the total costs of conducting post-closure care for the largest area that could possibly require post-closure care in the year to follow, including annual and periodic costs as described in the post-closure care plan over the entire post-closure care period."

Additionally, consistent with 30 TAC §330.507, the following detailed post-closure cost estimate, in current dollars, is based on the cost of hiring a third party to conduct post-closure care activities for the landfill, in accordance with the post-closure care plan. This post-closure care cost estimate will include annual and periodic costs, as described in the post-closure care plan over the entire post-closure care period. This post-closure care cost estimate accounts for the total costs of conducting post-closure care for the waste fill area as described in Section 2 of this attachment.

As noted in Section 2, consistent with 30 TAC 330.503(a), the Owner will review the facility's permit conditions on an annual basis and verify that the current active area is less than or equal to the areas (i.e., the acreage) on which the post-closure cost estimates were based. As noted in Section 2, the Owner will increase the post-closure care cost estimate and the amount of financial assurance provided if changes to the post-closure care plan or the landfill conditions increase the maximum cost of post-closure care at any time during the active life of the unit. Consistent with such revisions to the closure cost estimate, at the time that such revisions to the closure cost estimate are made, the Owner will also make appropriate revisions to the post-closure care cost estimate and the amount of financial assurance provided. Such proposed increases will be submitted to the TCEQ for review and approval. In addition, the Owner will adjust the post-closure care cost estimate to account for annual inflation adjustments, as described in Section 4, or other reasons as required by regulation.

The post-closure care period has been established by the TCEQ to be 30 years. During this period, the final cover system, including the drainage systems, will be maintained in a condition consistent with their design intent. Also, the following systems will be maintained in appropriate operating condition: monitoring systems, leachate collection system, and landfill gas management system (after installation).

The post-closure care cost estimates are based on the Final Closure and Post-Closure Care Plan (Attachment 9) and provide a cost for the routine monitoring and maintenance of the final cover system, leachate collection system, landfill gas management and monitoring system, and groundwater monitoring system. This estimate for routine monitoring and maintenance is a cumulative cost throughout the 30-year post-closure care period. This cost estimate is based on 2020 dollars. A summary of post-closure care costs is presented Appendix 8C – Post-Closure Cost Care Estimate Form for Municipal Solid Waste Type I Landfills. Calculations and supporting data for the cost estimate are included in Appendix 8D - Post-Closure Care Cost

Estimate Calculations. Unit rate cost estimates provided in Appendices 8C and 8D are based on data available from similar work and/or construction and monitoring projects.

At the time of the annual review of the post-closure care cost estimate, the Owner will also confirm that the assumptions regarding this estimate are valid and that the associated estimates are accurate in view of the landfill's operating practice since the previous estimates were made. Based on this annual review, adjustments will be made, as appropriate, subject to the approval of the TCEQ.

4 COST ESTIMATE ADJUSTMENTS

In addition to the potential changes noted in the preceding sections, during the active life of the landfill, the Owner will annually adjust the cost estimates for inflation within 60 days prior to the anniversary date of the establishment of the financial instrument(s). The adjustment may be made by recalculating the maximum costs of closure in current dollars, or by using an inflation factor derived from the most recent Implicit Price Deflator for Gross National Product published by the United States Department of Commerce in its Survey of Current Business. The inflation factor is the result of dividing the latest published annual deflator by the deflator for the previous year. The first adjustment is made by multiplying the cost estimate by the inflation factor, resulting in the adjusted cost estimate. Subsequent adjustments are made by multiplying the latest adjusted cost estimate by the latest inflation factor.

An increase in the closure or post-closure care cost estimate and the amount of financial assurance will be made if changes to the final closure or post-closure care plan or the landfill conditions increase the maximum cost, as discussed in Sections 2 and 3 of this attachment. As noted in these sections, in the event cost estimates increase, such updated cost estimates will be submitted to the TCEQ for approval along with appropriate changes to the financial assurance.

A request to reduce the closure or post-closure care cost estimate and the amount of financial assurance may be submitted to the TCEQ if the cost estimate exceeds the maximum cost of closure at any time during the remaining life of the landfill or post-closure care remaining over the post-closure care period. The Owner will submit a written request to the TCEQ of the detailed justification for the reduction of the cost estimates and the amount of financial assurance.

APPENDIX 8A

CLOSURE COST ESTIMATE FORM
FOR MUNICIPAL SOLID WASTE TYPE I LANDFILLS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED PROFESSIONAL ENGINEER

5/13/2020

SCS Engineers
TBPE Reg. # F-3407
Inclusive of pages 8A-1 to 8A-15

Texas Commission on Environmental Quality

Closure Cost Estimate Form for Municipal Solid Waste Type I Landfills

This form is for use by applicants or site operators to provide cost estimates for closure of MSW Type I landfills to meet the requirements in 30 Texas Administrative Code (TAC) Chapter 330, Section 330.63(j) and 30 TAC Chapter 330 Subchapter L. The costs to be provided herein are cost estimates for hiring a third party to close the largest waste fill area that could potentially be open in the year to follow and those areas that have not received final cover. If you need assistance in completing this form, please contact the MSW Permits Section in the Waste Permits Division at (512) 239-2335.

Facility Name: City of Waco Landfill

MSW Permit No.: 2400

Site Operator/Permittee Name and Mailing Address: City of Waco

Total Closure Cost Estimate (2020 Dollar Amount): $2,147,642

I. Professional Engineer's Statement, Seal, and Signature

I am a licensed professional engineer in the State of Texas. To the best of my knowledge, this Closure Cost Estimate has been completed in substantial conformance with the facility Closure Plan and, in my professional opinion, is in compliance with Title 30 of the Texas Administrative Code, Chapter 330.

Name: Ryan Kuntz, P.E. Title: Vice President

Date:

Company Name: SCS Engineers Firm Registration Number: F-3407

Professional Engineer's Seal

Professional Engineer's Signature

II. Annual Review of Permit Conditions, Cost Estimates, Inflation Factor, and Financial Assurance

The permittee/site operator acknowledges that he/she will:

1. Review the facility's permit conditions on an annual basis and verify that the current active and inactive waste fill areas of the landfill match the areas on which closure cost estimates are based.
2. Request in writing via a permit modification application for an increase in the closure cost estimate and the amount of financial assurance provided if changes to the closure plan or the landfill conditions increase the maximum cost of closure at any time during the remaining active life of the landfill.
3. Request in writing via a permit modification application for a reduction in the cost estimate and the amount of financial assurance provided if the cost estimate exceeds the maximum cost of closure at any time during the remaining active life of the landfill. The permit modification application will include a description of the situation and a detailed justification for the reduction of the closure cost estimate and the amount of financial assurance.
4. Establish financial assurance for closure of the unit in an amount no less than the current closure cost estimate in accordance with 30 TAC Chapter 37, Subchapter R.
5. Adjust the current cost estimate for inflation within 60 days prior to the anniversary date of the first establishment of the financial assurance mechanism.
6. Provide annual inflation adjustments to the closure costs and financial assurance during the active life of the facility, until the facility is officially placed under the post closure care period and all requirements of the final closure plan have been approved in writing by the TCEQ executive director. The adjustment will be made using an inflation factor derived from the most recent annual Implicit Price Deflator for Gross National Product published by the United States Department of Commerce in its Survey of Current Business, as specified in paragraphs (1) and (2) of 30 TAC §37.131. The inflation factor is the result of dividing the latest published annual Deflator by the Deflator for the previous year.
7. Provide continuous financial assurance coverage for closure until the facility is officially placed under the post-closure care period.

III. Description of the Closure Cost Estimates Worksheet

The following descriptions of the items on the closure cost estimates worksheet provide guidance for identifying the minimum work or cost elements and estimating the unit or lump sum cost of each item as applicable. Enter additional detail for each item in the field following the item as necessary and as site-specific condition warrants. The cost items are grouped under closure costs for engineering, construction, and storage and processing units. Include attachments to detail any additional work and associated costs necessary to close the site that is not already included as a line item on the worksheet. Reference the attachments and list the work or cost items in the fields under “Additional Engineering Cost Items Not Listed on the Worksheet,” “Additional Construction Cost Items Not Listed on the Worksheet,” or “Additional Storage and Processing Units Items Not Listed on the Worksheet” as applicable. Provide the total cost of the additional work or cost items in each cost category on the worksheet line that precedes the cost subtotal for each cost group.

1. Engineering Costs

The engineering tasks have been subdivided into seven items and are described below. Other related costs may be added as site-specific issues warrant.

1.1. Topographic Survey

A topographic survey will be required to verify the existing elevation and slopes of the landfill to ensure conformance with the final cover system, drainage system, and final grading designs.

Topographic survey applies to largest area requiring closure (See item 1.1, Appendix 8B).

1.2. Boundary Survey

The metes and bounds description is required for filing of the affidavit of closure and deed recording of any area of the site which has received waste. Other activities to be included here are publication of the public notice of closing activities.

Boundary survey applies to the entire area to be administratively closed (See Item 1.2, Appendix 8B).

1.3. Site Evaluation

The evaluation includes a site inspection to identify waste disposal areas, analyze drainage and erosion protection needs, and to determine other site operational features that are not in compliance with the permit. The site evaluation also includes verifying the need for new or relocation of existing groundwater monitoring wells and landfill gas monitoring probes, analysis of groundwater samples, and review of site operating record. The third party consultant who performed the site evaluation will prepare and submit an engineering report to the executive director to document the status of the site. The report will identify all areas of work and the associated implementation costs necessary to safely close the landfill operations with recommendations on how to fulfill these needs.

Site evaluation applies to the entire area to be administratively closed (See Item 1.3, Appendix 8B).

1.4. Development of Plans

The final closure, plan the final cover system design and specifications, grading and drainage plans, specification for revegetation, design of any other improvements to bring the site into compliance with the permit, the closure schedule, and coordination with the TCEQ and provision of closure notice to the public *(See Item 1.4, Appendix 8B).*

1.5. Contract Administration (bidding and award)

The third-party consultant will advertise the project, receive the bids, evaluate the bids, award the closure construction contract and administer the contract during construction.

Contract administration cost equal to 5 percent of the Subtotal Cost for Items 1.1 – 1.4 (See Item 1.5, Appendix 8B).

1.6. Closure Inspection and Testing

The professional of record will observe closure construction, perform cover thickness and permeability verification, and prepare an evaluation report upon completion of closure.

Closure inspection and testing applies to largest area requiring closure (See Item 1.6, Appendix 8B).

1.7. TPDES and other Permits

The third-party consultant will prepare plans, specifications, and other documents necessary for compliance with applicable federal and state laws and requirements, including the Clean Water Act, for the proper closure of the site *(See Item 1.7, Appendix 8B).*

1.8. Additional Engineering Cost Items Not Listed on the Worksheet

List the Attachment(s) detailing any additional engineering cost items necessary to close the site that is not already included as a line item on the worksheet:

This is non-applicable for this site.

1.9. Engineering Costs Subtotal

1.9.1. Enter the sum of engineering costs in Items 1.1 through 1.8.

2. Construction Costs

Closure construction costs include those for construction of the final cover system, site grading, and drainage improvements. Other costs may be added as site-specific issues warrant.

2.1. Mobilization

2.1.1. Mobilization of Personnel and Equipment

The cost of mobilizing personnel and construction heavy equipment must be included as part of the construction costs.

Mobilization costs are equal to 5 percent of construction costs of the final cover, inclusive of Items 2.2 through 2.9 (See Item 2.1, Appendix 8B).

2.2. Final Cover System

The owner or operator must install a final cover system that is designed to minimize infiltration and erosion. The final cover system is subdivided into the sideslope cover and cap cover with their associated components to facilitate cost calculations. If an alternative final cover is proposed, the closure cost estimate will still be based on a design that utilizes the conventional composite cover system.

Final cover installation materials are consistent with Attachment 6C, Drawing 6C.2.

2.2.1. Side Slope Cover

Enter information for Items 2.2.1a through 2.2.1h.

2.2.2. Top Slope Cover

Enter information for Items 2.2.2a through 2.2.2h.

2.2.3. Cells for Class 1 Nonhazardous Industrial Waste

This is non-applicable for this site.

2.3. Site Grading

Site grading includes the final grading of the site, including the landfill cap and sideslopes.

Site grading appies to the largest area requiring closure (See Item 2.3, Appendix 8B).

2.4. Site Fencing and Security

Site fencing and security must be included for the area which has received waste and have no existing approved fencing.

See Item 2.4, Appendix 8B.

2.5. Landfill Gas Monitoring and Control Systems

Enter information for Items 2.5.1 through 2.5.6.

Final installation of the landfill gas monitoring and control systems must include the installation costs of pipes and appurtenances. In the event of a forced closure, the systems may not have been completed, thus, the estimated costs to complete the landfill gas monitoring and control system must be provided.

It is anticipated that at the time of a forced closure of the largest area requiring closure, the waste mass will have an NMOC concentration below the NSPS threshold for requiring an active landfill gas collection and control system (GCCS), so an active GCCS will not be required. Additionally, it is assumed that the existing landfill gas monitoring system will be sufficient at the time of closure (See Attachment 11). As such, this item is non-applicable for this site.

2.6. Groundwater Monitoring System

2.6.1. Monitor Well Installation

Upon closure of the site, it may be necessary to relocate the compliance boundary. This requires the installation of new monitor wells.

Under a forced closure of the largest area requiring closure, it is assumed that the compliance boundary will not change, and the existing groundwater monitoring system will be sufficient at closure (See Attachment 11). As such, this item is non-applicable for this site.

2.6.2. Piezometer and Monitor Well Plugging and Abandonment

Piezometer or monitor well abandonment is the cost of abandoning (plugging) piezometers or monitor wells that are no longer needed. Determine the number of piezometers or monitor wells to be abandoned and include the total cost.

Under a forced closure of the largest area requiring closure, it is assumed that no piezometers or monitoring wells will need to be abandoned. As such, this item is non-applicable for this site.

2.7. Leachate Management

2.7.1. Completion of Existing Leachate Collection System

In the event of a forced closure, there may be circumstances where the leachate collection system has not been completed. In this event, the leachate collection system must be closed with a permanent outfalls and permanent cleanouts installed.

Under a forced closure of the largest area requiring closure, it is assumed that the leachate collection system will be installed and sufficient. As such, this item is non-applicable for this site.

2.8. Stormwater Management

2.8.1. Stormwater Drainage Management System

To reduce the potential long-term impacts of the landfill on surface water quality, drainage features must be incorporated into the final cover design to direct runoff, minimize erosion, control sediments, and avoid ponding of stormwater. The drainage system construction costs must be included.

The stormwater drainage management system includes the costs associated with construction of downchutes, drainage swales, drainage pond excavation and the pond outlet structure (See Item 2.8, Appendix 8B). As discussed in Attachment 6A, this assumes drainage swales will be constructed with a maximum horizontal spacing between swales of 130 horizontal feet. These swales will drain towards two 24-foot wide, stone filled downchutes. This also assumes that the perimeter drainage channels will be constructed at the time of cell construction. These channels will flow into a 9-foot deep, 40'x55' drainage pond that shall be excavated as part of the forced closure scenario.

2.9. Additional Construction Cost Items Not Listed on Worksheet

List the Attachments detailing any additional construction cost items necessary to close the site that is not already included as a line item on the worksheet:

This is non-applicable for this site.

2.10. Construction Costs Subtotal

2.10.1. Enter the sum of construction costs in Items 2.1 through 2.9.

3. Storage and Processing Unit Closure Costs

For landfills that incorporate storage and/or processing operations that are not separately authorized, all waste and processed and unprocessed materials associated with storage and/or processing units must be removed during the closure process.

The closure costs provided in this section are related to the closure of the Citizen's Collection Station at the landfill.

3.1. Waste Disposal

The cost of disposal of waste at an authorized facility.

Under a forced closure scenario, it is assumed that the contents of the six roll-off containers for MSW at the citizen's collection center will be disposed of at the working face of the landfill (See Item 3.1, Appendix 8B). See Item 3.3 for removal/disposal of containers.

3.2. Material Removal and Disinfection

The cost of removal, including transportation, of any remaining processed and unprocessed materials to an authorized off-site location.

Under a forced closure scenario, materials received on-site (including metals, cardboard, plastics, glass, aluminum, white goods (appliances), and tires) will be removed and disposed. It is assumed that metals and white goods materials will be disposed of at a metals scrapyard, and will include the salvaging of their four roll-off containers concurrently. Other material containers will be taken to an appropriate recycling or processing facility for disposal of their contents. This includes two roll-off containers (cardboard, plastics, etc.) and one trailer for tires. Disinfection of the MSW roll-off containers will also occur after disposal at the landfill working face (Item 3.1). Additionally, the facility pavement will be powerwashed for disinfection purposes (See Item 3.2, Appendix 8B).

3.3. Demolition and Disposal

The cost of dismantling and/or disinfection of storage and/or processing units and disposal, as applicable.

This includes disposal of eight roll-off containers at a metals salvage yard after disinfection of the six MSW containers and disposal of contents of two containers with cardboard, plastic, and other recyclable materials (See Item 3.3, Appendix 8B). As discussed in Item 3.2, roll-off containers for metals and white goods will be salvaged concurrently with the metal materials. Addtionally, it is assumed there will be no required demolition on-site.

3.4. Additional Storage and Processing Unit Closure Cost Items Not Listed in Worksheet

List the Attachments detailing any additional storage and processing unit closure cost items necessary to close the site that is not already included as a line item on the worksheet.

This is non-applicable for this site.

4. Sum of Cost Subtotals

    4.1. Enter the sum of engineering, construction, and storage and processing unit closure cost subtotals from lines 1.9.1, 2.10.1, and 3.5.1.

5. Contingency

    5.1. Add an amount equal to at least 10 percent of the sum of cost subtotals to cover unanticipated events during implementation of closure activities.

6. Contract Performance Bond

    6.1. Add an amount equal to at least 2 percent of the sum of cost subtotals for purchase of a surety bond to guarantee satisfactory completion of the closure activities.

7. Third Party Administration and Project Management Costs

    7.1. Add an amount equal to at least 2.5 percent of the sum of cost subtotals to cover the cost for a third party hired by TCEQ to administer the closure activities.

8. Total Closure Cost

    8.1. Enter the sum of the amounts on lines 4.1, 5.1, 6.1, and 7.1.

IV. Closure Cost Estimates Worksheet

A. Landfill Data

Total Permitted Waste Disposal Area: 175.7 acres

Largest Area Requiring Final Cover in the year to follow: 21.3 acres

Total Filled Area with Constructed Final Cover: 0 acres

Total Area Certified Closed: 0 acres

Number of Monitor Wells to be Installed for Closure: 0 (See Item 2.6)

Number of Gas Probes to be Installed for Closure: 0 (See Item 2.5)

Total Acreage Needing LFG Collection and Control System: 0 acres (See Item 2.5)

The unit or lump sum cost for each item is based on the work items and cost elements described in Section III of this Closure Cost Estimate document:

Yes ☒ No ☐ Partially ☐

(*if "No" or "Partially" is checked, please include attachments describing the additional work items and detailing the unit, quantities, and costs for the additional items*)

B. Facility Drawings and Financial Assurance Documentation

- Facility drawings
  - Attach facility drawings showing the closure areas to which the closure cost estimates apply.
    - *The largest area requiring final cover in the year to follow closure is associated with the area of Sector 1 within the East Disposal Area. This area is shown on Attachment 1, Drawings 1.2 and 1.3.*
- Financial assurance documentation
  - For an existing facility, attach a copy of the documentation required to demonstrate financial assurance as specified in 30 TAC Chapter 37, Subchapter R.
  - For a new facility, a copy of the required documentation shall be submitted 60 days prior to the initial receipt of waste.

C. Attachments

- Additional Engineering, Construction, and Storage and Processing Units Cost Items Details (See Appendix 8B).

D. Closure Cost Estimates Worksheet

If any item listed in this worksheet is not applicable to the subject facility, enter “NA” (Not Applicable) in the affected field.

Table 1. Closure Cost Estimates Worksheet.

Item No.	Item Description	Units[1]	Quantity	Unit Cost	Cost	Source of Unit Cost Estimate[2]
1. Engineering Costs						
1.1	Topographic Survey	Acres	21.3	$70.00	$1,491	(4)
1.2	Boundary Survey	Acres	502.5	$15.00	$7,538	(4)
1.3	Site Evaluation	Acres	502.5	$25.00	$12,563	(4)
1.4	Development of Plans	Lump Sum	1	$35,000	$35,000	(4)
1.5	Contract Administration (bidding and award)	Lump Sum	1	$2,830	$2,830	(4)
1.6	Closure Inspection and Testing	Acres	21.3	$5,000	$106,500	(4)
1.7	TPDES and other Permits	Lump Sum	1	$5,000	$5,000	(4)
1.8	Additional Engineering Cost Items (describe in attachments)	NA	NA	NA	NA	NA
1.9 Engineering Costs Subtotal						
1.9.1	Engineering Costs Subtotal	NA	NA	NA	$170,922	NA
2. Construction Costs						
2.1 Mobilization						
2.1.1	Mobilization of Personnel and Equipment	Lump Sum	1	$80,959	$80,959	(4)
2.2 Final Cover System						
2.2.1 Side Slope Cover						
2.2.1a	Infiltration Layer – Compacted Clay	CY	41,233	$2.50	$103,083	(4)
2.2.1b	Infiltration Layer – Geosynthetic Clay Liner	SF	NA	NA	NA	NA
2.2.1c	Flexible Membrane Cover – HDPE	SF	742,200	$0.55	$408,210	(4)
2.2.1d	Flexible Membrane Cover – LLDPE	SF	NA	NA	NA	NA

Closure Cost Estimate for MSW Type I Landfill

Facility Name: __City of Waco Landfill____ Revision No.: ___0_____

Permit No: ___2400_________ Date: __April 2020______

Item No.	Item Description	Units[1]	Quantity	Unit Cost	Cost	Source of Unit Cost Estimate[2]
2.2.1e	Drainage Layer – Aggregate	CY	NA	NA	NA	NA
2.2.1f	Drainage Layer – Drainage Geocomposite Material	SF	742,200	$0.60	$445,320	(4)
2.2.1g	Erosion Layer	CY	54,978	$2.75	$151,190	(4)
2.2.1h	Vegetation	Acres	17.04	$1,000	$17,040	(4)
2.2.2 Top Slope Cover						
2.2.2a	Infiltration Layer – Compacted Clay	CY	10,311	$2.50	$25,778	(4)
2.2.2b	Infiltration Layer – Geosynthetic Clay Liner	SF	NA	NA	NA	NA
2.2.2c	Flexible Membrane Cover – HDPE	SF	185,600	$0.50	$92,800	(4)
2.2.2d	Flexible Membrane Cover – LLDPE	SF	NA	NA	NA	NA
2.2.2e	Drainage Layer – Aggregate	CY	NA	NA	NA	NA
2.2.2f	Drainage Layer – Drainage Geocomposite Material	SF	NA	NA	NA	NA
2.2.2g	Erosion Layer	CY	13,748	$2.75	$37,807	(4)
2.2.2h	Vegetation	Acres	4.26	$1,000	$4,260	(4)
2.2.3 Cells for Class 1 Nonhazardous Industrial Waste						
2.2.3a	Dike Construction	NA	NA	NA	NA	NA
2.3 Site Grading						
2.3.1	Site Grading	Acres	21.3	$500	$10,650	(4)
2.4 Site Fencing and Security						
2.4.1	Site Fencing and Security	Lump Sum	1	$10,000	$10,000	(4)
2.5 Landfill Gas Monitoring and Control System						
2.5.1	Gas Control Wells	NA	NA	NA	NA	NA
2.5.2	Gas Header Piping	NA	NA	NA	NA	NA
2.5.3	Gas Lateral Piping	NA	NA	NA	NA	NA
2.5.4	Flare Station	Lump Sum			NA	NA

Item No.	Item Description	Units[1]	Quantity	Unit Cost	Cost	Source of Unit Cost Estimate[2]
2.5.5	Condensate Sumps	NA	NA	NA	NA	NA
2.5.6	Completion of LFG Monitoring System	NA	NA	NA	NA	NA
2.6 Groundwater Monitoring System						
2.6.1	Groundwater Monitoring Well Installation	Each	NA	NA	NA	NA
2.6.2	Piezometer and Monitor Well Plugging and Abandonment	Each	NA	NA	NA	NA
2.7 Leachate Management						
2.7.1	Completion of Leachate Management System	NA	NA	NA	NA	NA
2.8 Stormwater Management						
2.8.1	Stormwater Drainage Management System	Lump Sum	1	$313,050	$313,050	(3)
2.9 Other Cost Items						
2.9.1	Additional Construction Cost Items (describe in attachments)	NA	NA	NA	NA	NA
2.10 Construction Costs Subtotal						
2.10.1	Construction Costs Subtotal	NA	NA	NA	$1,700,147	NA
3. Storage and Processing Unit Closure Costs						
3.1	Waste Disposal	☐ Tons ☒ Cubic Yards	180	$1.67	$301	(4)
3.2	Material Removal and Disinfection	Lump Sum	1	$3,900	$3,900	(4)
3.3	Demolition and Disposal	Each	8	$50	$400	(4)
3.4	Additional Storage and Processing Unit Closure Cost Items (describe in attachments)	NA	NA	NA	NA	NA
3.5 Storage and Processing Unit Closure Costs Subtotal						
3.5.1	Storage and Processing Unit Closure Costs Subtotal	NA	NA	NA	$4,601	NA

Closure Cost Estimate for MSW Type I Landfill

Facility Name: __City of Waco Landfill____ Revision No.: ___0_____

Permit No: ___2400_________ Date: __April 2020______

Item No.	Item Description	Units[1]	Quantity	Unit Cost	Cost	Source of Unit Cost Estimate[2]
4. Sum of Engineering, Construction, and Storage and Processing Unit Closure Costs						
4.1	Sum of Engineering, Construction, and Storage and Processing Unit Closure Cost Subtotals	NA	NA	NA	$1,875,670	NA
5. Contingency						
5.1	Contingency (10% of Sum of Engineering, Construction, and Storage and Processing Unit Closure Cost Subtotals)	NA	NA	NA	$187,567	NA
6. Contract Performance Bond						
6.1	Contract Performance Bond (2% of Sum of Engineering, Construction, and Storage and Processing Unit Closure Cost Subtotals)	NA	NA	NA	$37,513	NA
7. Third Party Administration and Project Management Costs						
7.1	Third Party Administration and Project Management Costs (2.5% of Sum of Engineering, Construction, and Storage and Processing Unit Closure Cost Subtotals)	NA	NA	NA	$46,982	NA
8. Total Closure Costs						
8.1	Total Closure Costs (sum of amounts in Sections 4, 5, 6, and 7)	NA	NA	NA	$2,147,642	NA

[1] For items marked "specify," the responsible professional engineer will enter appropriate unit of measurement

[2] Sources of Unit Costs for Cost Estimates table may include:

(1) Published Cost Estimator Manuals (e.g., RS Means);
(2) Third Party Quotes (e.g., Environmental Field Services Contractors);
(3) Verifiable Data based on Actual Operations; or
(4) Other sources of cost acceptable to the executive director of the TCEQ.

APPENDIX 8B

CLOSURE COST ESTIMATE CALCULATIONS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER

5/13/2020

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 8B-1 to 8B-4

CITY OF WACO LANDFILL
CLOSURE COST ESTIMATE CALCULATIONS

Required: Estimate the cost to perform final closure activities on the largest portion of the landfill that could potentially be open in the year to follow closing the landfill (Refer to Appendix 8A for cost summary).

Consistent with 30 TAC §330.503 and with the Final Closure and Post-Closure Care Plans (Attachment 9), this closure cost estimate is based on 2019 dollars.

References:
1. Texas Natural Resource Conservation Commission, *Cost Estimate Handbook for Closure and Postclosure Care, Version 1, August 1993.*
2. 30 TAC 330 Subchapters K and L
3. Texas Water Commission, *Municipal Solid Waste Groundwater Protection Cost Study, November 1992.*
4. Unit rate cost estimates are based on data available from similar work and/or construction projects (e.g., quotes, bid tabulations, etc.).

Solution: The largest area that would require closure activities to begin under a forced closure scenario, including placement of final cover, as discussed in Attachment 9, is defined below.

As discussed in Attachment 8, as conditions at the site warrant a change in the closure cost estimate, notification to the TCEQ will be made.

Area requiring final cover placement =	21.3	ac **(See Note 1)**
=	927,800	sf
Sideslope Area =	742,200	sf
Top Slope Area=	185,600	sf (Assumes 20% of total Final Cover Area)
Area to be administratively closed =	502.5	ac

1.0 Engineering Costs

1.1 Topographic Survey **(See note 2)**						
	21.3	ac @	$ 70	/ ac =	$	1,491
1.2 Boundary Survey						
	502.5	ac @	$ 15.00	/ ac =	$	7,538
1.3 Site Evaluation						
	502.5	ac @	$ 25.00	/ ac =	$	12,563
1.4 Development of Plans						
				Lump Sum =	$	35,000
				Subtotal =	$	56,592
1.5 Contract Administration (bidding and award)						
	5%			of Items 1.1 through 1.4 =	$	2,830
1.6 Closure Inspection and Testing						
	21.3	acres @	$ 5,000	/ ac =	$	106,500
1.7 TPDES and Other Permits						
				Lump Sum =	$	5,000
				Engineering Costs Subtotal =	**$**	**170,922**

2.0 Construction Costs

2.1 Mobilization of Personnel and Equipment 5% of Construction Costs = $ 80,959

2.2 Final Cover System

2.2.1 Sideslope Cover

2.1.1a Infiltration Layer - Compacted Clay

1.5 ft thick
742,200 sf

41,233 cy for infiltration layer

Soil available on-site for installation

$ 2.50 / cy = $ 103,083

2.2.1c Flexible Membrane Cover - HDPE

742,200 sf
$ 0.55 / sf = $ 408,210

2.2.1f Drainage Layer - Drainage Geocomposite Material
(Sideslopes only, double-sided 200 mil)

742,200 sf
$ 0.60 / sf = $ 445,320

2.2.1g Erosion Layer

2.0 ft thick
742,200 sf
54,978 cy for erosion layer
Soil available on-site for installation
$ 2.75 / cy = $ 151,190

2.2.1h Vegetation

17.04 ac @ $ 1,000 / ac = $ 17,040

2.2.2 Top Slope Cover
2.2.2a Infiltration Layer - Compacted Clay

1.5 ft thick
185,600 sf
10,311 cy for infiltration layer
Soil available on-site for installation
$ 2.50 / cy = $ 25,778

2.2.2c Flexible Membrane Cover - HDPE

185,600 sf
$ 0.50 / sf = $ 92,800

2.2.2f Drainage Layer - Drainage Geocomposite Material
(Sideslopes only, double-sided 200 mil)

0 sf
$ 0.55 / sf = $ -

2.2.2g Erosion Layer

2.0 ft thick
185,600 sf
13,748 cy for erosion layer
Soil available on-site for installation
$ 2.75 / cy = $ 37,807

2.2.2h Vegetation

4.26 ac @ $ 1,000 / ac = $ 4,260

2.3 Site Grading

21.3 ac @ $ 500 / ac = $ 10,650

2.4 Site Fencing and Security

If the site were closed prior to entire permitted footprint being filled, site fencing and security for the entire landfill would already be in place. Nevertheless, to ensure adequacy of the fencing for access control, an allowance was included in this estimate.

Allowance = $ 10,000

2.5 Landfill Gas Monitoring and Control System **(See Note 3)**

0.0 ac @ $ - / ac = $ -

2.6 Groundwater Monitoring System **(See Note 4)**

2.6.1 Groundwater Monitoring Well Installation

0.0 per well @ $ - / well = $ -

2.6.2 Piezometer and Monitor Well Plugging and Abandonment

0.0	per well @	$ -	/ well =	$	-

2.7 Leachate Management

The forced closure scenario assumes that the LCS has been installed. No expenses are projected for this item.

2.8 Stormwater Management

Downchutes	800	lf @	$ 200.00	/ lf =	$	160,000
Drainage Swales	5,250	lf @	$ 15.00	/ lf =	$	78,750
Drainage Pond Excavation	19,800	cy @	$ 3.50	/ cy =	$	69,300
Drainage Pond Outlet Structure				Lump Sum =	$	5,000
				Stormwater Management Subtotal =	$	313,050
				Construction Costs Subtotal =	**$**	**1,700,147**

3.0 Storage and Processing Unit Closure Costs (Citizen's Collection Station)

3.1 Waste Disposal

6.0	roll-off containers (MSW)
30	cy per container
180	cy of MSW

$ 1.67	/ cy =	$	301

3.2 Material Removal and Disinfection **(See Note 5)**

Material						
Tires	1.0	Tire trailer @	$ 2,500	/ trailer =	$	2,500
Metals	3.0	Containers @	$ 50	/ container =	$	150
Cardboard/Plastics/others	2.0	Containers @	$ 50	/ container =	$	100
White Goods	1.0	Containers @	$ 50	/ container =	$	50
Disinfection (MSW Containers)	6.0	Containers @	$ 100	/ container =	$	600
Disinfection (Facility)				Lump Sum =	$	500
				Subtotal =	$	3,900

3.3 Demolition and Disposal **(See Note 6)**

8.0	Containers @	$ 50	/ container =	$	400
			Storage and Processing Unit Closure Costs Subtotal =	**$**	**4,601**

Note 1: As discussed in Section 2 of Attachment 9, this assumes approximately 21.3 acres of waste-in-place in Sector 1.

Note 2: Aerial coverage of topographic survey only required for filled, excavated, and stockpiled areas.

Note 3: Based on landfill gas emissions from landfills of similar size and characteristics, it is assumed that the estimated emissions from the landfill at this stage of development will be below regulatory thresholds that would warrant installation of a LFG control system.

Note 4: Under a forced closure scenario, it is assumed the compliance boundary will not change, and the existing groundwater monitoring system will be sufficient at closure. This also assumes that no piezometers or monitoring wells will be required to be abandoned.

Note 5: Offsite disposal costs of all materials (tires, metals, containers, white goods, etc.) are included, with exception to MSW (see Item 3.1), as well as transporation costs for offsite removal/disposal of the containers, as applicable. Both the contents and containers for metals and white goods will be disposed at a metal salvage yard, concurrently. Disinfection of the MSW containers will occur after disposal at the landfill working face (Item 3.1).

Note 6: This includes disposal of roll-off containers at a metal salvage yard, after disinfection of MSW containers and disposal of cardboard, plastic, and other recyclable materials (Item 3.2). It is also assumed there will be no demolition required on-site.

APPENDIX 8C

POST-CLOSURE CARE COST ESTIMATE FORM
FOR MUNICIPAL SOLID WASTE TYPE I LANDFILLS

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 8C-1 to 8C-10

Texas Commission on Environmental Quality

Post-Closure Care Cost Estimate Form for Municipal Solid Waste Type I Landfills

This form is for use by applicants or site operators to provide post-closure care cost estimates for post-closure care of MSW Type I landfills to meet the requirements in 30 Texas Administrative Code (TAC) Chapter 330, Section 330.63(j) and 30 TAC Chapter 330 Subchapter L. The costs to be provided herein are cost estimates for hiring a third party to conduct post-closure care of the largest waste fill area that has been certified closed in writing by the TCEQ executive director.

If you need assistance in completing this form, please contact the MSW Permits Section in the Waste Permits Division at (512) 239-2335.

I. General Information

Facility Name: City of Waco Landfill

MSW Permit No.: 2400

Date: August 2019

Revision Number: 0

Site Operator/Permittee Name and Mailing Address: City of Waco

Total Post-Closure Care Cost Estimate (2020 Dollar Amount): $2,493,420

II. Professional Engineer’s Statement, Seal, and Signature

I am a licensed professional engineer in the State of Texas. To the best of my knowledge, this Post- Closure Care Cost Estimate has been completed in substantial conformance with the facility Post-Closure Care Plan and, in my professional opinion, is in compliance with Title 30 of the Texas Administrative Code, Chapter 330.

Name: Ryan Kuntz, P.E. Title: Vice President

Date:

Company Name: SCS Engineers Firm Registration Number:

Professional Engineer’s Seal

Signature

III. Annual Review of Permit Conditions, Cost Estimates, Adjustments for Inflation, and Financial Assurance

The site operator/permittee acknowledges that he/she will:

1. Revise and increase the post-closure care cost estimate and the amount of financial assurance provided whenever changes in the post-closure care plan or the landfill conditions increase the maximum cost of post-closure care at any time during the remaining active life of the landfill and until the facility is officially released from the post-closure care period in writing by the executive director.

2. Request a reduction in the post-closure care cost estimate and the amount of financial assurance as a permit modification whenever the post-closure care cost estimate exceeds the maximum cost of post-closure care remaining over the post-closure period. The permit modification will include a detailed justification for the reduction of the post-closure care cost estimate and the amount of financial assurance.

3. Establish financial assurance for post-closure care of the unit in an amount no less than the current post-closure care cost estimate in accordance with 30 TAC Chapter 37

4. Adjust the current post-closure care cost estimate for inflation within 60 days prior to the anniversary date of the first establishment of the financial assurance mechanism.

5. Provide annual inflation adjustments to the post-closure care costs and financial assurance during the active life of the facility and during the post closure care period. The adjustment will be made using an inflation factor derived from the most recent annual Implicit Price Deflator for Gross National Product published by the United States Department of Commerce in its Survey of Current Business, as specified in 30 TAC Chapter 37. The inflation factor is the result of dividing the latest published annual Deflator by the Deflator for the previous year.

6. Provide continuous financial assurance coverage for post-closure care until the facility is officially released in writing by the executive director from the post-closure care period in accordance with all requirements of the post-closure care plan.

IV. Description of Worksheet Items of the Post-Closure Care Cost Estimates

The following descriptions of the worksheet items provide guidance for identifying the minimum work or cost elements for estimating the unit or lump sum cost of each item as applicable. Enter additional detail for each item in the field following the item as necessary and as site-specific conditions warrant. The cost items are grouped under post-closure care costs for engineering, construction, and leachate management. Include attachments to detail any additional work and associated costs necessary for the post-closure care of the unit or facility that is not already included as a line item on the worksheet. Reference the attachments and list the work or cost items in the fields under "Additional Engineering Cost Items Not Listed on the Worksheet," "Additional Construction Cost Items Not Listed on the Worksheet," or Additional Leachate Management Costs Not Listed on the Worksheet" as applicable. Provide the total cost of additional work or cost items in each cost category on the worksheet line that precedes the cost subtotal for each cost group.

1. Engineering Costs

1.1 Site Inspection and Recordkeeping

Regularly scheduled and event-driven site inspection must be performed to identify areas experiencing settlement, subsidence, erosion, or other drainage related problems, and note the conditions of the environmental control and monitoring systems, including leachate collection, groundwater monitoring, and landfill gas monitoring systems.

Site inspection and recordkeeping applies to the entire administratively closed area (See Item 1.1, Appendix 8D).

1.2 Correctional Plans and Specifications

The cost for an engineering consultant to prepare corrective measure construction plans and specifications to correct problems identified during site inspections.

Correctional plans and specifications apply to largest area requiring closure. It is assumed these correctional plans and specifications will only be required every other year. As such, the cost per event has been divided by 2-years to show the average annual cost over the 30-year post-closure period (See Item 1.2, Appendix 8D).

1.3 Site Monitoring

The cost of performing semiannual groundwater (including costs for sampling and analyzing parameters, and assessment and reporting) and quarterly landfill gas monitoring (including costs for sampling and reporting) and the monitoring of other site-specific systems at the landfill during the post-closure period.

Site monitoring includes sampling and analysis of groundwater monitoring wells (semi-annually) and gas monitoring probes (quarterly) (See Items 1.3.1a and

1.3.2a, Appendix 8D, respectively). Site monitoring also includes a one-time event of abandonment of piezometers, groundwater monitoring wells, and gas monitoring probes. This cost has been divided by 30-years to show annual cost over the 30-year post-closure period (See Items 1.3.1b and 1.3.2b, Appendix 8D).

1.4 Additional Engineering Cost Items Not Listed on the Worksheet

List the Attachments detailing additional post-closure care engineering cost items not already included as a line item on the worksheet.

This is non-applicable for this site.

2. Construction Costs

2.1 Cap and Sideslope Repairs and Revegetation

The cost of repair of the cap and cap drainage control structures due to erosion or structural integrity failures and maintaining final cover vegetation to minimize erosion.

It is assumed that corrective actions, such as cap and sidelsope repairs and revegetation, only applies to 5% of the largest area requiring closure (See Item 2.1, Appendix 8D).

2.2 Mowing and Vegetation Control

The cost of controlling vegetation growth on the final cover and other areas of the landfill.

Mowing and vegetation control applies to largest area requiring closure (See Item 2.2, Appendix 8D).

2.3 Groundwater Monitoring System Maintenance

The cost of repairs/replacement and routine maintenance.

See Item 2.3, Appendix 8D.

2.4 LFG Monitoring Probes Maintenance

The cost of repairs/replacement and routine maintenance.

See Item 2.4, Appendix 8D.

2.5 LFG Collection System Maintenance

The cost of repairs and routine maintenance.

As discussed in Appendix 8A, it is assumed an active landfill gas collection and control system will not be required. As such, this item is non-applicable for this site.

2.6 Perimeter Fence and Gates Maintenance

The cost of maintaining perimeter fence and gates to restrict unauthorized access to the closed landfill.

See Item 2.6, Appendix 8D.

2.7 Access and Rights-of-Way Maintenance

The cost of maintaining the access roads and other rights of way to the closed landfill to conduct inspections, environmental sampling, routing maintenance and other post-closure activities.

Lump sum for cost of access and rights-of-way maintenance is inclusive of costs related to a 15-foot wide road with 12-inch thick aggregate over an assumed 200-foot length (See Item 2.7, Appendix 8D).

2.8 Drainage System Cleanout and Repairs

The cost to include costs for maintaining and repairing ditches, conveyance structures, and ponds/basins.

It is assumed these corrective actions, such as ditch or conveyance structure repair, will only be required every other year. As such, the cost per event has been divided by 2-years to show the average annual cost over the 30-year post-closure period See Item 2.8, Appendix 8D.

2.9 Additional Construction and Maintenance Cost Items Not Listed on the Worksheet

List the Attachments detailing any additional construction and maintenance cost items necessary for post-closure care that are not already covered on the worksheet.

This is non-applicable for this site.

3. Leachate Management Costs

3.1 Leachate Collection and Removal System Operation and Maintenance

The cost of operation, routine maintenance and repairs.

See Item 3.1, Appendix 8D.

3.2 Leachate Disposal

The cost of leachate disposal off-site.

The leachate volume for disposal is based on the largest area requiring closure, and is consistent with the average annual leachate generation rate, calculated with HELP modeling as described in Attachment 12, Appendix 12A. See Item 3.2, Appendix 8D.

3.3 Additional leachate management cost items not listed on the worksheet. List the Attachments detailing any additional leachate management cost items necessary for post-closure care that are not already covered on the worksheet.

This is not applicable for this site.

4. Sum of Cost Subtotals

Enter the sum of engineering, construction, and storage and leachate management post-closure care cost subtotals from lines 1.5.1, 2.10.1, and 3.5.1.

5. Contingency

The cost added to cover unanticipated events during implementation of post-closure activities.

Contingency equal to 10 percent of the sum of engineering, construction and maintenance, and leachate management.

6. Third Party Administration and Project Management Costs

The cost for the third party hired by TCEQ to administer the post-closure activities.

V. Post-Closure Care Cost Estimates Worksheet

Post-Closure Care Period – 30 years

Total Permitted Acreage: 502.5 acres

Total Permitted Waste Footprint: 175.7 acres

Number of Groundwater Monitoring Wells: 8

Number of GW Monitoring Events: 2 /year

Number of Gas Probes: 7

Number of LFG Monitoring Events: 4 /year

The unit or lump sum cost for each item is based on the work items and cost elements described in Section III of this Post-Closure Cost Estimate document:

Yes ☒ No ☐ Partially ☐

If “No” or “Partially” is checked, please attach a written description of work items and cost elements which form the bases of unit or lump sum cost for the affected items.

(NOTE: If any item listed in this worksheet is not applicable to the subject facility, enter Not Applicable (N/A) in the affected fields)

Attachments

Additional Engineering, Construction, and Leachate Management Cost Items Details.

Post-Closure Care Cost Estimate for MSW Type I Landfills

Facility Name: __City of Waco Landfill___________ Revision No.: ___0_____

Permit No: ___2400_____ Date: __April 2020______

Table 1: Post-Closure Care Cost Estimates

Item No.	Item Description	Units	Annual Qty.	Unit Cost	Annual Cost	Source of Unit Cost Estimate[i]
1.0 Engineering Costs						
1.1	Site Inspection and Recordkeeping[ii]	acres	502.5	$10	$5,025	(4)
1.2	Correctional Plans and Specifications	acres	21.3	$500	$5,325	(4)
1.3 Site Monitoring						
1.3.1 Groundwater Monitoring System						
1.3.1(a)	Sampling and Analysis of GW Monitoring Wells (Quantity = 2 x Number of wells)	Wells	16	$1,400	$22,400	(4)
1.3.1(b)	Piezometers/Well Abandonment	Lump Sum	1	$267	$267	(4)
1.3.2 LFG Monitoring System						
1.3.2(a)	LFG Quarterly Monitoring (Quarterly)	Each	4	$2,500	$10,000	(4)
1.3.2(b)	LFG Probe Plugging and Abandonment	Lump Sum	1	$233	$233	(4)
1.4 Additional Engineering Cost Items (Detail in Attachments)						
1.4.1	Additional Engineering Cost Items (describe in attachments)	NA	NA	NA	NA	NA
1.5 Engineering Costs Subtotal						
1.5.1	Engineering Costs Subtotal	NA	NA	NA	$43,250	NA
2.0 Construction and Maintenance Costs						
2.1	Cap and Sideslopes Repairs and Revegetation	Acres	1.07	$1,000	$1,070	(4)
2.2	Mowing and Vegetation Management	Acres	21.3	$100	$2,130	(4)
2.3	Groundwater Monitoring System Maintenance	Lump Sum	1	$2,500	$2,500	(4)

Post-Closure Care Cost Estimate for MSW Type I Landfills

Facility Name: __City of Waco Landfill___________ Revision No.: ___0_____

Permit No: ___2400_____ Date: __April 2020______

Item No.	Item Description	Units	Annual Qty.	Unit Cost	Annual Cost	Source of Unit Cost Estimate[i]
2.4	LFG Monitoring Probes Maintenance	Lump Sum	1	$2,500	$2,500	(4)
2.5	LFG Collection System Maintenance	NA	NA	NA	NA	NA
2.6	Perimeter Fence and Gates Maintenance	Lump Sum	1	$1,500	$1,500	(4)
2.7	Access Roads Maintenance	Lump Sum	1	$7,500	$7,500	(4)
2.8	Drainage System Cleanout/Repairs	Lump Sum	1	$5,000	$5,000	(4)
2.9 Additional Construction and Maintenance Cost Items (Details in Attachments)						
2.9.1	Additional Construction and Maintenance Cost Items (details in attachments)	NA	NA	NA	NA	NA
2.10 Construction and Maintenance Costs Subtotal						
2.10.1	Construction and Maintenance Costs Subtotal	NA	NA	NA	$22,200	NA
3.0 Leachate Management						
3.1	Leachate Management System Operation and Maintenance	Lump Sum	1	$5,000	$5,000	(4)
3.2	Leachate Disposal	Gals	85,733	$0.04	$3,429	(4)
3.3 Additional Leachate Management Cost Items (Details in Attachments)						
3.4	Additional Leachate Management Cost Items (details in attachments)	NA	NA	NA	NA	NA
3.5 Leachate Management Costs Subtotal						
3.5.1	Leachate Management Costs Subtotal	NA	NA	NA	$8,429	NA

Post-Closure Care Cost Estimate for MSW Type I Landfills

Facility Name: __City of Waco Landfill___________ Revision No.: ___0_____

Permit No: ___2400_____ Date: __April 2020_____

Item No.	Item Description	Units	Annual Qty.	Unit Cost	Annual Cost	Source of Unit Cost Estimate[i]
4.0 Sum of Engineering, Construction, and Leachate Management Costs						
4.1	Sum of Engineering, Construction, and Leachate Management Cost Subtotals	NA	NA	NA	$73,879	NA
5.0 Contingency						
5.1	Contingency (10% of Sum of Engineering, Construction, and Leachate Management Cost Subtotals)	NA	NA	NA	$7,388	NA
6.0 Third Party Administration and Project Management Costs						
6.1	Third Party Administration and Project Management Costs (2.5% of Sum of Engineering, Construction, and Leachate Management Cost Subtotals)	NA	NA	NA	$1,847	NA
7. Total Post-Closure Cost						
7.1	Total Annual Post-Closure Cost (Sum of amounts in Sections 4, 5, and 6)	NA	NA	NA	$83,114	NA
7.2	30 Year Post-Closure Costs (Total Annual Post-Closure Cost x 30)	NA	NA	NA	$2,493,420	NA

[i] Sources of Unit Cost Estimates may include:
(1) Published Cost Estimator Manuals (e.g., RS Means);
(2) Third Party Quotes (e.g., Environmental Field Services Contractors); or
(3) Verifiable Data based on Actual Operations

[ii] Example Description for Item No. 1.1 – "Includes costs for site inspection performed at least annually for identification of areas experiencing settlement or subsidence, erosion or other drainage-related problems, inspection of the leachate collection system, gas monitoring system and LFG monitoring system."

APPENDIX 8D

POST-CLOSURE CARE COST ESTIMATE CALCULATIONS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED PROFESSIONAL ENGINEER

5/13/2020

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 8D-1 to 8D-3

CITY OF WACO LANDFILL
POST-CLOSURE CARE COST ESTIMATE CALCULATIONS

Required: Estimate the cost to hire a third party to conduct post-closure care activities (Refer to Appendix 8C for cost summary).

References:
1. Texas Natural Resource Conservation Commission, *Cost Estimate Handbook for Closure and Postclosure Care, Version 1, August 1993.*
2. 30 TAC 330.507
3. Texas Water Commission, *Municipal Solid Waste Groundwater Protection Cost Study, November 1992.*
4. Unit rate cost estimates are based on data available from similar work and/or construction and monitoring projects.

Solution: Costs are based on specified post-closure care period. The item numbers are from Appendix 8C - Post-Closure Care Cost Estimate Form.

Postclosure care period = 30 yr
Area to be administratively closed = 502.5 ac
Area with waste in place = 21.3 ac **(See Note 1 of Appendix 8B)**

1.0 Engineering Costs

1.1 Site Inspection and Recordkeeping
502.5 ac @ $ 10.00 / ac / yr = $ 5,025 / yr

1.2 Correctional Plans and Specifications
Assume engineering plans required to correct erosion issues every other year.
21.3 ac @ $ 500 / ac / 2-yr = $ 10,650 / 2-yr
$ 5,325 / yr

1.3 Site Monitoring

1.3.1 Groundwater Monitoring System
1.3.1a Sampling and Analysis of GW Monitoring Wells **(see Note 1)**
8 wells
$ 1,400 / well / event
2 events / yr Total = $ 22,400 / yr

1.3.1b Piezometers/Well Abandonment
8 wells @ $ 1,000 /well $ 8,000 total (one-time event)
$ 267 / yr

1.3.2 LFG Monitoring System
1.3.2a LFG Quarterly Monitoring **(see Note 2)**
$ 2,500 / event
4 events / yr Total = $ 10,000 / yr

1.3.2b LFG Probe Plugging and Abandonment
7 probes @ $ 1,000 /well $ 7,000 total (one-time event)
$ 233 / yr

Engineering Costs Subtotal = $ 43,250 / yr

2.0 Construction and Maintenance Costs

2.1 Cap and Sideslopes Repairs and Revegetation (Assumes 5% of Final Cover area each year)
1.07 ac @ $ 1,000 / ac / yr = $ 1,070 / yr

2.2 Mowing and Vegetation Management
21.3 ac @ $ 100 / ac / yr = $ 2,130 / yr

2.3 Groundwater Monitoring System Maintenance
Lump Sum = $ 2,500 / yr

2.4 LFG Monitoring Probes Maintenance
Lump Sum = $ 2,500 / yr

CITY OF WACO LANDFILL
POST-CLOSURE CARE COST ESTIMATE CALCULATIONS

2.5 LFG Collection System Maintenance

0.0	ac @	$ -	/ ac / yr =	$ -	/ yr

2.6 Perimeter Fence and Gates Maintenance

Lump Sum = $ 1,500 / yr

2.7 Access Roads Maintenance

Lump Sum = $ 7,500 / yr

2.8 Drainage System Cleanout/Repairs

Assume drainage system repairs required every other year.

Lump Sum = $ 10,000 / event

$ 5,000 / yr

Construction and Maintenance Costs Subtotal = $ 22,200 / yr

3.0 Leachate Management

3.1 Leachate Management System Operation and Maintenance

Lump Sum = $ 5,000 / yr

3.2 Leachate Disposal

4,025	gal / ac / yr generated (refer to Appendix 12A, Closed Condition)
21.3	ac with generating leachate system

85,733	gal / yr @	$ 0.04	/ gal =	$ 3,429	/ yr

Leachate Management Costs Subtotal = $ 8,429 / yr

Note 1: The number of wells is based on the extent of the landfill footprint in place at the time of closure and the phased implementation of the groundwater monitoring system as described in Attachment 4, Geology Report.
Note 2: The number of gas monitoring probes is based on the extent of the landfill footprint in place at the time of closure and the phased implementation of the landfill gas monitoring system as described in Attachment 11, Landfill Gas Management Plan.

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
McLENNAN AND LIMESTONE COUNTIES, TEXAS

PART III – SITE DEVELOPMENT PLAN
ATTACHMENT 9
FINAL CLOSURE AND POST-CLOSURE PLAN

Prepared for:

CITY OF WACO

Solid Waste Services
501 Schroeder Drive
Waco, TX 76710

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 – April 2020
SCS Project No. 16216088.00

TABLE OF CONTENTS

SECTION **PAGE**

Appendices

Figures

SCS Engineers
TBPE Reg. # F-3407

1 INTRODUCTION

These Final Closure and Post-Closure Plans have been prepared for the City of Waco Landfill (landfill) consistent with 30 TAC §330.63(h), §330.63(i), and Subchapter K. The landfill completion plan for the proposed landfill consists of final contours and drainage features for the completed landfill, as presented in Attachment 3 - Landfill Completion Plan, Drawings 3.1 through 3.3 in accordance with §330.457(e)(5).

Attachment 3 (Landfill Completion Plan, including drainage design features), Attachment 2 (Fill Cross Sections), and Attachment 8 (Cost Estimate for Closure and Post-closure Care) have not been duplicated in this attachment thereby providing for (1) a more efficient review of this permit application and (2) a more “user friendly” document for the management of the landfill throughout its operating life.

In accordance with §330.457(f)(1) and §330.463(b)(3), this Final Closure and Post-Closure Plan will be placed in the Site Operating Record prior to the initial receipt of waste.

2 FINAL COVER SYSTEM

2.1 INTRODUCTION

The final cover system for the proposed landfill was developed to meet or exceed the requirements of §330.457. These rules define the procedures and timeframes for implementing closure of MSW landfills, including the installation of a final cover system designed and constructed to minimize infiltration and erosion. Such a system will include installation of a multi-layer final cover system and surface water drainage system. The surface water drainage system is addressed in Part III, Attachment 6A – Surface Water Drainage Plan. The final cover system design is described in Part III, Attachment 6C and depicted on Drawings 6C.2.

2.2 COVER SYSTEM DESIGN

The multi-layer final cover system will provide a low maintenance cover and reduce rainfall percolation through the cover system, thereby minimizing leachate generation within the landfill. As depicted in Attachment 3, five percent topslopes and 4H:1V sideslopes are provided to minimize erosion and facilitate drainage of the landfill.

The final cover system is designed consistent with §330.457. Details on the design of the multi-layer final cover systems are included in Attachment 6C, Drawing 6C.2. Appropriate field survey controls will be implemented to control the final lift of solid waste as well as the successive soil layers of the final cover system (see Part IV - Site Operating Plan, Section 4.18.4). The infiltration layer will be a clayey soil, placed and compacted under controlled moisture-density conditions with appropriate compaction equipment. A geomembrane liner (40-mil LLDPE or 60-mil HDPE) will be placed over the infiltration layer in accordance with §330.457(a)(1) as the landfill has synthetic bottom liner system, as described in Part III, Attachment 6C. A double-sided drainage geocomposite will be placed over the geomembrane liner on the sideslopes only.

The erosion layer will be placed directly over the geomembrane or drainage geocomposite for topslope and sideslope final cover areas, respectively. The surface of the erosion layer will be seeded or sodded immediately following placement of the final cover to establish a vegetative cover and minimize erosion. Vegetation will be established such that a minimum 90 percent coverage of native and introduced grasses is achieved.

2.3 FINAL COVER QUALITY CONTROL PLAN

Testing and evaluation of the final cover system materials and components prior to construction and during construction will be performed under the supervision of a geotechnical professional (GP), as defined in Attachment 10 – Soil Liner and Quality Control Plan, Section 1.2. Additionally, a qualified CQA Monitor will perform daily construction quality assurance and quality control (CQA/CQC) observation and testing under the direct supervision of the GP. A Final Cover System Evaluation Report (FCSER) will be provided to the TCEQ, in accordance with Section 2.4. The following subsections describe the CQA/CQC testing methods, frequencies, and material specifications that will be required for the 18-inch infiltration layer, geomembrane, geocomposite, and erosion layer. As previously stated, the components of the final cover system design is described in Part III, Attachment 6C and depicted on Drawing 6C.2.

2.3.1 Infiltration Layer Testing

2.3.1.1 Pre-Construction Testing

Prior to construction, pre-construction testing will be performed for the soil materials that are selected for the infiltration layer. The soil materials used in the final cover will be obtained from in-situ soil strata, which will be stockpiled during excavation of landfill disposal areas. Representative samples from all sources will be subject to the minimum pre-construction testing program per Table 9-2-1.

Soil types on the permitted property are predominantly clay. A soil classification will be used as a guide for identifying soils with the minimum material specifications. Typically, clays and silts (i.e., CH, CL, M) are ideal for construction of the infiltration layer, however, these soils are not required provided the recompacted soil samples comply with the following minimum material specifications: Plasticity Index (PI) ≥ 15; liquid limit (LL) ≥ 30; percent passing No. 200 sieve ≥ 30; particle size ≤ 1 inch; and hydraulic conductivity (k) ≤ 1×10^{-5} cm/sec.

Table 9-2-1. Infiltration Layer Soil Material Pre-Construction Testing Schedule

TEST	METHOD USED	FREQUENCY
Soil Classifications: USCS	ASTM D2487	1 per soil type / minimum 1 per borrow source
Particle-Size Sieve Analysis	ASTM D422 or D1140	
Atterberg Limits	ASTM D4318	
Moisture/Density Relationship (Moisture Content)	ASTM D698	
Hydraulic Conductivity (1)	ASTM D5084 (2)(3)	1 per Moisture-Density Relationship

1. Field testing of permeability (in accordance with ASTM D5093) is optional, and may be replaced by laboratory testing.
2. Testing procedures in Appendix VII of the Corps of Engineers Manual EM 1110-2-1906, November 30, 1970, Laboratory Soils Testing, may be used as an alternative method.
3. Permeability tests will be conducted with tap water or 0.05N solution of $CaSO_4$. Distilled water will not be allowed.

2.3.1.2 Construction Testing

Construction quality assurance for the infiltration layer will consist of both laboratory and field testing, as specified in Table 9-2-2. Quality assurance laboratory testing (sieve analysis, Atterberg limits, and hydraulic conductivity) will be conducted on representative samples of the constructed infiltration layer. This testing program will be conducted to verify that the infiltration layer complies with the specification provided herein.

Table 9-2-2. Infiltration Layer Construction Testing Schedule

TEST	METHOD	MINIMUM FREQUENCY
Field Moisture/Density Test	ASTM D1556, D2167, or D6938	1 per 16,000 ft^2 per 6-inch lift (1)
Sieve Analysis	ASTM D422 or D1140	1 per 200,000 ft^2 per 6-inch lift (2)
Atterberg Limits	ASTM D4318	
Hydraulic Conductivity (3) (4)	ASTM D5084 or CoE EM 1110-2-1906	1 per acre (evenly distributed through all lifts) (5)
Thickness	Survey	1 per 10,000 ft^2 (6)

1. A minimum of three tests must be conducted for each 6-inch lift, regardless of cover area.
2. A minimum of one test must be conducted for each lift, regardless of cover area.
3. Testing will be conducted on undisturbed samples.
4. Permeability tests will be run using tap water or a 0.05N solution of $CaSO_4$. Distilled water will not be allowed.
5. The requirement of 1 permeability test per surface acre of cover should be met by testing each lift for permeability at a frequency of 1 test per 3 acres.

The GP must verify passing permeability test results (i.e., < $1x10^{-5}$ cm/s) in accordance with §330.457(a)(1), conducted at a frequency of no less than one test per surface acre of final cover in accordance with §330.457(c). All laboratory permeability tests conducted must be uniformly distributed over the area. The infiltration layer will be placed and compacted in 6-inch lifts. At a minimum, the infiltration layer will be compacted to 95 percent of the maximum dry density and moisture content of 0 to +4% above optimum, as determined by ASTM D698.

Failing quality assurance tests on the constructed infiltration layer will be addressed consistent with Attachment 10 – Soil and Liner Quality Control Plan, Section 3.4, related to Procedures for Addressing Failing Tests. The results of both passing and failing tests will be recorded and documented within the FCSER.

Any penetrations required for obtaining laboratory samples will be repaired by backfilling the hole with bentonite chips or 50/50 powdered/granulated bentonite/soil/sand mixture hand-tamped into place. If the penetration is in the upper lift of soil, the upper 2 inches will be backfilled with clayey soil which will be hand-tamped sufficiently to blend the backfill into the adjacent soil lift.

The lift thicknesses of the infiltration layer will be verified by settlement plates or surveying methods. The verification points, for record purposes, will be on grid such that there exists a minimum of one verification point per 10,000 square feet. A minimum of 2 reference points are required for verification. The selected grid will be the same for both beginning and finished elevations of the cover, so that minimum thickness can be calculated and verified. All elevation calculations necessary for thickness determination will be included as part of the supporting documentation in the FCSER.

2.3.2 Geomembrane Testing

2.3.2.1 Manufacturer Quality Control Testing

Prior to the installation of the geomembrane (40-mil LLDPE or 60-mil HDPE), the manufacturer or installer will provide the GP with quality control certificates signed by a responsible party employed by the manufacturer. Each quality control certificate will include roll identification numbers, testing procedures, and results of quality control tests. The quality control tests will be performed in accordance with project-specific testing methods and subject to one test per 100,000 square feet of material or a minimum of one test per resin lot, whichever is greater.

All geomembrane properties must meet the minimum values set forth in the most recent version of Geosynthetic Research Institute (GRI) standard GM-13 for 60-mil HDPE, or GM-17 for LLDPE. The GP will review the test results prior to acceptance of the geomembrane to assure that the certified minimum properties meet specified values.

2.3.2.2 Conformance Testing

Conformance testing shall be performed by a third-party independent laboratory. Conformance testing methods and frequencies will be performed in accordance with Table 9-2-3.

Table 9-2-3. Geomembrane Conformance Testing

<table>
<tr><th>TEST</th><th>METHOD</th><th>MINIMUM FREQUENCY</th></tr>
<tr><td>Thickness (laboratory)</td><td rowspan="2">ASTM D5199 (1) or D5994</td><td>1 per 100,000 ft^2 and every resin lot</td></tr>
<tr><td>Thickness (2) (field)</td><td>1 measurement per 5 feet along leading edge of each geomembrane panel</td></tr>
<tr><td>Density</td><td>ASTM D1505 or D792</td><td rowspan="4">1 per 100,000 ft^2 and every resin lot</td></tr>
<tr><td>Carbon black content</td><td>ASTM D1603</td></tr>
<tr><td>Carbon black dispersion</td><td>ASTM D5596</td></tr>
<tr><td>Tensile properties (3)</td><td>ASTM D638, Type IV</td></tr>
</table>

1. ASTM D5994 for textured geomembrane, D5199 for smooth.
2. No single measurement will be less than ten percent below the required nominal thickness in order for the panel to be acceptable. A minimum of 5 measurements will be made per panel.
3. 2-inch initial gauge length assumed for elongation at break at 2.0 in/min.

2.3.3 Installation Monitoring and Testing

Upon delivery of geosynthetic material, the CQA Monitor will observe that the materials are handled and stored in accordance with manufacturer's recommendations.

Field seaming of the geomembrane will be performed in strict accordance with methods approved by the manufacturer. This usually includes fusion welding or extrusion welding. Tack welds (if used) will use heat only. No double-sided tape, glue, or other method will be permitted when extrusion or fusion welding is used for bonding.

Each day prior to commencing field seaming, trial seams will be made on pieces of geomembrane material to verify that conditions are adequate for production seaming. Each trial test seam will be at least 3 feet long by 1-foot wide. Four adjoining one-inch wide specimens will be die-cut from the test seam sample. Two specimens will be tested in the field for shear and 2 for peel.

The failure criteria are the same as that for destructive seam testing as described below. The test specimens must exhibit a Film Tear Bond (FTB). If one test seam fails, the trial seam will be repeated. If this trial seam fails, then 2 more trial seams must be constructed and tested. This process must continue and no welding can begin for the machine or welder until all test seams are passing. Additional trial seams will be made for all of the following:

- At the beginning of each seaming period for each seaming apparatus used that day (the beginning of each seaming period is considered to be morning, and immediately after a break);
- Each occurrence of significantly different environmental conditions (i.e., temperature, humidity, dust, etc.);
- Any time the machine is turned off for more than 30 minutes; and
- When seaming different geomembranes (i.e. tie-ins and smooth to textured).

Both the welder and the machine must be tested for each new trial seam when extrusion welding. Only the machine needs to be tested for each new trial seam when fusion welding since the machine is not as operator dependent. Each individual seaming will make at least one test seam each day he/she actually performs seaming.

2.3.4 Non-Destructive Testing

Continuous, non-destructive testing will be performed on all seams by the installer. Air pressure testing on dual-track fusion welds and vacuum-box testing for extrusion welds are the only acceptable methods. All leaks must be isolated and repaired by the following procedures:

1. Air-Pressure Testing (GRI GM6) - The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 psi, if possible. The air pump must then be shut off and the air pressure observed after 5 minutes. A loss of less than 4 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss of 4 psi or more indicates the presence of a seam leak that must then be isolated and repaired by following the procedures described under "Seam Failure Repairs and Retesting." The GP or his/her qualified representatives must observe and record all pressure gauge readings.

2. Vacuum-Box Testing (ASTM D4437) - A suction value of approximately 3 to 5 inches of gauge vacuum must be applied to all extrusion welded seams that can be tested in this manner. Examples of extrusion welded seams that do not easily lend themselves to vacuum testing would be around boots, appurtenances, etc. The seam must be observed for leaks at least ten seconds while subjected to this vacuum. The GP or his/her qualified representative must observe 100 percent of this testing.

2.3.5 Destructive Seam Testing

Destructive seam testing will be performed in accordance with ASTM D4437. Destructive samples will be taken at a minimum of one strategic location for every 1,000 linear feet of seaming or major fraction thereof. The total footage of individual repairs of leaks of more than 10 feet in seaming length and individual repairs of more than 10 feet in seaming length for failed seams must also be counted and destructively tested using the same frequency of testing described above. At a minimum, a destructive test must be done for each welding machine used for seaming or repairs. A sufficient amount of the seam must be removed in order to conduct field testing, independent laboratory testing, and archiving of enough material in order to retest the seam, if necessary. Field testing will include at least 2 peel test specimens. Destructive seam-testing locations will be cap-stripped and the cap completely seamed by extrusion welding to the geomembrane. Capped sections will be non-destructively tested. Additional destructive test samples may be taken if deemed necessary by the GP or his/her qualified representative.

All field-tested specimens from a destructive-test location must be passing in both shear and peel for the seam to be considered as passing. Field tested specimens, are determined as passing if the specimen tested in peel fails in FTB and all test specimens meet the criteria listed in the Table 9-2-4 The independent laboratory testing must confirm these field results. The minimum passing criteria for independent laboratory testing are all three of the following:

- At least four of five specimens tested in the peel mode must fail in FTB.
- At least four of five specimens from each peel and shear determination must meet the minimum specified value in Table 9-2-4.
- The average value from all five specimens from each peel and shear determination must meet the minimum specified value in Table 9-2-4.

The above criteria apply to both tracks from each dual-track fusion welded seam before it is considered as passing. It should be noted that geomembrane manufacturers may have differing values for their geomembrane sheets and therefore, the specific values are not meant to be minimum or maximum values as construction materials and specifications may vary between manufacturers and throughout the life of the site. Consequently, the manufacturer's sheet-strength values must be provided in order to determine if the test results are passing.

Table 9-2-4. Geomembrane Seam Strength

Property	Qualifier	Unit	Specified Value		Test
			60-mil HDPE	40-mil LLDPE	
Shear Strength	Min.	lb/in	120	60	ASTM D4437
Peel Strength:					
Fusion	Min	lb/in	91	50	ASTM D4437
Extrusion	Min.	lb/in	78	44	

2.3.6 Seam Failure Delineation

In the event failing tests are obtained at a destructive test location, new destructive test samples will be obtained, a minimum of 10 feet in either direction of the failing test. If one, but not both, of the additional tests fail, further additional destructive testing will be required until passing tests are obtained at both ends of the original destructive test location. A cap will be required for the areas subject to destructive testing, and testing of the cap will be placed in accordance with Section 2.3.7. If more than two failing destructive test locations are observed for a single seam, the CQA Monitor will have the alternative of requiring the entire seam be removed, and a new seam welded.

In the event more than one failing destructive test are observed for a single welding apparatus, new (passing) trial welds will be required prior to resuming geomembrane welding or seaming with the apparatus.

2.3.7 Seam Failure Repairs and Retesting

Any portion of the geomembrane with a detected flaw, or which fails a nondestructive or destructive test, or where destructive tests were cut, or where nondestructive tests left cuts or holes, must be repaired. The CQA Monitor will locate and record all repairs on the repair log. Repair techniques include the following:

- Patching - used to repair holes, tears, large panel defects, undispersed raw materials, contamination by foreign matter, and destructive sample locations.

- Extrusion - used to repair small defects in the panels and seams. In general, this procedure should be used for defects less than 3/8-inch in the largest dimension.

- Capping - used to repair failed welds or to cover seams where welds or bonded sections cannot be nondestructively tested.

- Removal - used to replace areas with large defects where the preceding methods are not appropriate. Also used to remove excess material (wrinkles, fishmouths, intersections, etc.) from the installed geomembrane. Areas of removal shall be patched or capped.

For any repair method, the following provisions will be satisfied:

- Surfaces of the geomembrane which are to be repaired using extrusion methods will be ground no more than one hour prior to the repair;

- All surface will be clean and dry at the time of repair;

- Patches or caps will extend at least 6 inches beyond the edge of the defect, and all corners of patches will be rounded with a radius of approximately 3 inches or more;

- All repairs will be nondestructively tested as previously described; and

- All seaming equipment, personnel, and operation procedures used in repair work will meet the same requirements as for new seaming operations.

The GP or his/her qualified representative will observe all destructive and non-destructive testing of repairs and will record the number of each repair, type, date and test outcome. Repairs that pass the non-destructive tests will be taken as an indication of an adequate repair. Repairs more than 150 ft long will also be required to have a destructive test performed. Repairs that fail the initial retest will be redone and retested until a passing test results. All work and testing of repairs will be fully documented in a repair log.

2.3.8 Geocomposite and Erosion Layer Testing

When placing overlying material on the geomembrane, every effort must be made to minimize wrinkle development and stress imparted to the geomembrane. If possible, cover should be placed during the coolest weather available. Small wrinkles should be isolated and covered as quickly as possible to prevent their growth. In no case will the geomembrane be allowed to fold over on itself.

2.3.8.1 Geocomposite

A double-sided geocomposite will be installed over the geomembrane on the landfill sideslopes only. The geocomposite will conform to the material and performance properties specified by the GP, consistent with project construction plans and technical specifications. The drainage geocomposite manufacturer (or supplier), will conduct quality control testing at a frequency of 1 per 100,000 square feet and certify that all materials delivered comply with project specifications. The material certifications shall be reviewed by the GP and approved for the project prior to acceptance of any of the material.

2.3.8.2 Erosion Layer

The erosion layer will consist of a 24-inch-thick soil layer, with the top 6 inches capable of sustaining vegetation in accordance with §330.457(a)(3). The required thickness of the layer will be verified by settlement plates or survey methods on an established grid system with not less than one verification point per 10,000 square feet of surface area. A minimum of two verification points is required. The selected grid will be the same for both beginning and finished elevations of the erosion layer, so that minimum thickness can be calculated and verified. All elevation calculations necessary for thickness determination will be included as part of the supporting documentation in the FCSER.

The erosion layer does not require compaction control; however, it should be stable for construction and disposal traffic. The erosion layer will be deployed in "fingers" along the geomembrane or geocomposite to control the amount of slack and minimize wrinkles and/or folds. Soil cover will generally be placed in an up-slope direction on sideslopes so that stress imparted to the geocomposite and geomembrane is minimized. Care will be exercised in placement so as not to shift, wrinkle or damage any underlying geosynthetic layers, and the placement methods will be documented.

2.4 FINAL COVER SYSTEM EVALUATION REPORT

Upon completion of each area of final cover construction and evaluation, the GP will prepare and submit in triplicate the FCSER, prepared in accordance with this plan, to the TCEQ for review and approval. This report will be submitted along with a construction documentation report.

Each FCSER will include a discussion of the construction of the final cover elements, a cover placement map which shows the covered area being submitted for approval and areas covered by all previous FCSER submittals with the dates of acceptance by the TCEQ. The map should depict the site grid system, graphic scale, and north arrow. The FCSER will be signed and/or sealed by the GP performing the evaluation and a representative of the site operator.

The construction documentation will contain a narrative describing the work performed and the testing procedures performed prior to and during construction, record drawings, and results of field and laboratory testing. The FCSER will include the following:

- All field and laboratory test documentation for infiltration layer soils, including test and sample locations plotted on plan view drawings representing each 6 inch lift;
- Geomembrane manufacturer's certifications, documentation of all manufacturer's and independent testing, geomembrane seaming and repair logs, seam testing results, and a site map showing locations of panels, repairs, and tests;
- Geocomposite manufacturer's certification and testing documentation; and
- Survey documentation for the thickness of the infiltration layer and erosion layer.

3 CLOSURE PROCEDURES

3.1 SEQUENCE OF FINAL COVER PLACEMENT

The City of Waco (Owner) will place final cover throughout the active life of the landfill. Areas being filled to final grade will follow the numerical landfill sequence of development, as portrayed on Part III, Drawing 1.2 – Fill Sequence Plan. Final cover will be installed once landfill fill areas have been constructed to the design final grades. Therefore, the sequence of final cover placement will ultimately be governed by having a sufficient area or number of sectors constructed to allow the Owner to construct the aerial fill portion of the landfill up to the design final grades. The largest area requiring final cover in the year to follow landfill closing is described in Section 3.2.1. The final cover placement procedures listed below will be followed until all areas have been closed.

- Survey controls will be implemented during waste placement to control the filling of solid waste to the bottom of the daily/intermediate cover layer elevations.
- The final cover system layers will be constructed at the appropriate time following placement of the final lift of waste. Installation and testing of the various components of the final cover system will be performed in accordance with this closure plan (see Section 2.3 of this attachment).
- A final cover certification report, complete with an as-built survey, will be prepared by an independent registered professional engineer and submitted to the TCEQ.
- The final cover certification report will be maintained in the Site Operating Record and the cover application log (see Part IV - Site Operating Plan, Section 4.18.6 - Cover Application Log) will be updated to reflect the areas where final cover has been placed. The TCEQ regional office will also be notified that final cover placement has occurred at the site.

Note, the placement of final cover does not represent closure of a portion of the site. Requirements for final closure of the site are discussed in Section 4 of this attachment. In addition, post-closure care activities will not begin until the entire site has been closed as discussed in Section 4.

3.2 CLOSURE DURING ACTIVE LIFE

As described above, the final cover will be constructed as fill areas achieve the design contours. Should closure of the landfill become necessary at any time during the active life of the landfill, the following steps will be taken:

- Consistent with TCEQ requirements, closure engineering plans will be developed to address site closure at the time of discontinued waste filling.
- The final waste received will be placed and properly compacted.
- Excavations (if any) will be graded to drain to the elevations shown in the closure engineering plans, and the site will be graded to promote runoff and prevent ponding.

- Consistent with the closure engineering plans, sections of the landfill that are above-grade will be regraded and reshaped, as needed, to provide the proper slope for positive drainage, consistent with closure engineering plans.

- The final cover system will be constructed in accordance with this attachment and closure engineering plans.

- Following application of final cover, the landfill will be seeded or sodded immediately with appropriate grasses to minimize erosion. The established grasses will provide a minimum of 90 percent coverage of the final cover system.

- Consistent with the closure engineering plans and with Attachment 6A – Surface Water Drainage Plan, a surface water drainage system will be constructed to minimize erosion.

- A closure certification will be prepared by an independent registered professional engineer and submitted to TCEQ for approval.

- All proper notices and documentation will be filed with the appropriate agencies.

3.2.1 Estimate of Largest Area Ever Requiring Final Cover

In accordance with §330.457(e)(2), the largest area ever requiring final cover in the year to follow landfill closing is estimated to be approximately 21.3 acres. The estimated largest area requiring final cover is expected to occur when waste is being placed in Sector 1 in the East Disposal Area. At the time of the Owner's annual review of the closure cost estimate, the Owner will also confirm that the estimated largest area ever requiring final cover is accurate. Based on this annual review, adjustments will be made, as appropriate.

In addition, the entire 502.5 acres of the site would also need to be administratively closed. Supporting calculations are presented in Part III, Attachment 8 - Cost Estimate for Closure and Post-Closure Care, Appendix 8A.

3.2.2 Estimate of Maximum Inventory of Waste Ever On Site

Consistent with §330.457(e)(3), the estimate of maximum inventory of waste (defined as waste and daily cover) ever on site over the active life of the facility is approximately 19,986,382 cubic yards (based upon volumes computed from top of bottom liner protective cover and top final grade elevations less final cover thicknesses). Supporting calculations are included in Part III, SDP Narrative, Appendix IIIA - Site Life Calculations.

4 CLOSURE SCHEDULE

4.1 FINAL CLOSURE REQUIREMENTS

The site will be closed in an orderly fashion, consistent with §330.457(f), §330.457(g), and §330.461 implementing the following steps:

- No later than 45 days prior to initiation of final closure activities for the MSW landfill, the Executive Director of the TCEQ will be notified that a notice of the intent to close the landfill has been placed in the operating record in accordance with §330.457(f)(2).

- No later than 90 days prior to initiation of final closure activities for the MSW landfill, a public notice of facility closure which contains the name, address, and physical location of the facility, the permit number, and the last date of intended receipt of waste, will be provided in the newspaper of the largest circulation in the vicinity of the facility, in accordance with §330.461(a). The Owner will also make available an adequate number of copies of the approved final closure and post-closure plan at the Waco-McLennan County Central Library for public access and review.

- Upon notification of the Executive Director of the TCEQ, signs will be posted at the site entrances notifying all persons utilizing the facility of the closure date or date after which further receipt of waste is prohibited. In addition, barriers or gates will be installed at access points following the closure date to prevent unauthorized dumping of solid waste at the facility.

- Final closure activities will commence at the landfill no later than 30 days after the date the landfill receives the known final receipt of wastes, in accordance with §330.457(f)(3). If the landfill has remaining capacity and there is a reasonable likelihood that the landfill will receive additional wastes, final closure activities will commence no later than one year after the most recent receipt of wastes.

- Final closure activities of the landfill will be completed in accordance with this Final Closure Plan within 180 days following the beginning of closure, in accordance with §330.457(f)(4).

- Following completion of final closure activities, a documented certification, signed by an independent professional engineer, will be submitted to the TCEQ for review and approval. This certification will verify that final closure has been completed in accordance with this Final Closure Plan and will include all applicable documentation necessary for certification of final closure. Once approved, this certification will be placed in the Site Operating Record.

- Within 10 days after completion of final closure activities of the facility, a certified copy of an Affidavit to the Public (most recent format provided by the TCEQ will be used) will be submitted to the TCEQ by registered mail in accordance with the requirements of §330.19 and §330.457(g), and a copy placed in the Site Operating Record. In addition, a certified notation will be recorded on the deed to the facility or some other instrument that will in perpetuity notify any potential purchaser of the property that the land has been used as a landfill facility and the use of the land is restricted according to the provisions specified in §330.465 and Section 6.4 of this Attachment. Within ten days after completion of final closure activities of the facility, a certified copy of the modified deed or some other instrument will be submitted to the TCEQ and placed in the Site Operating Record.

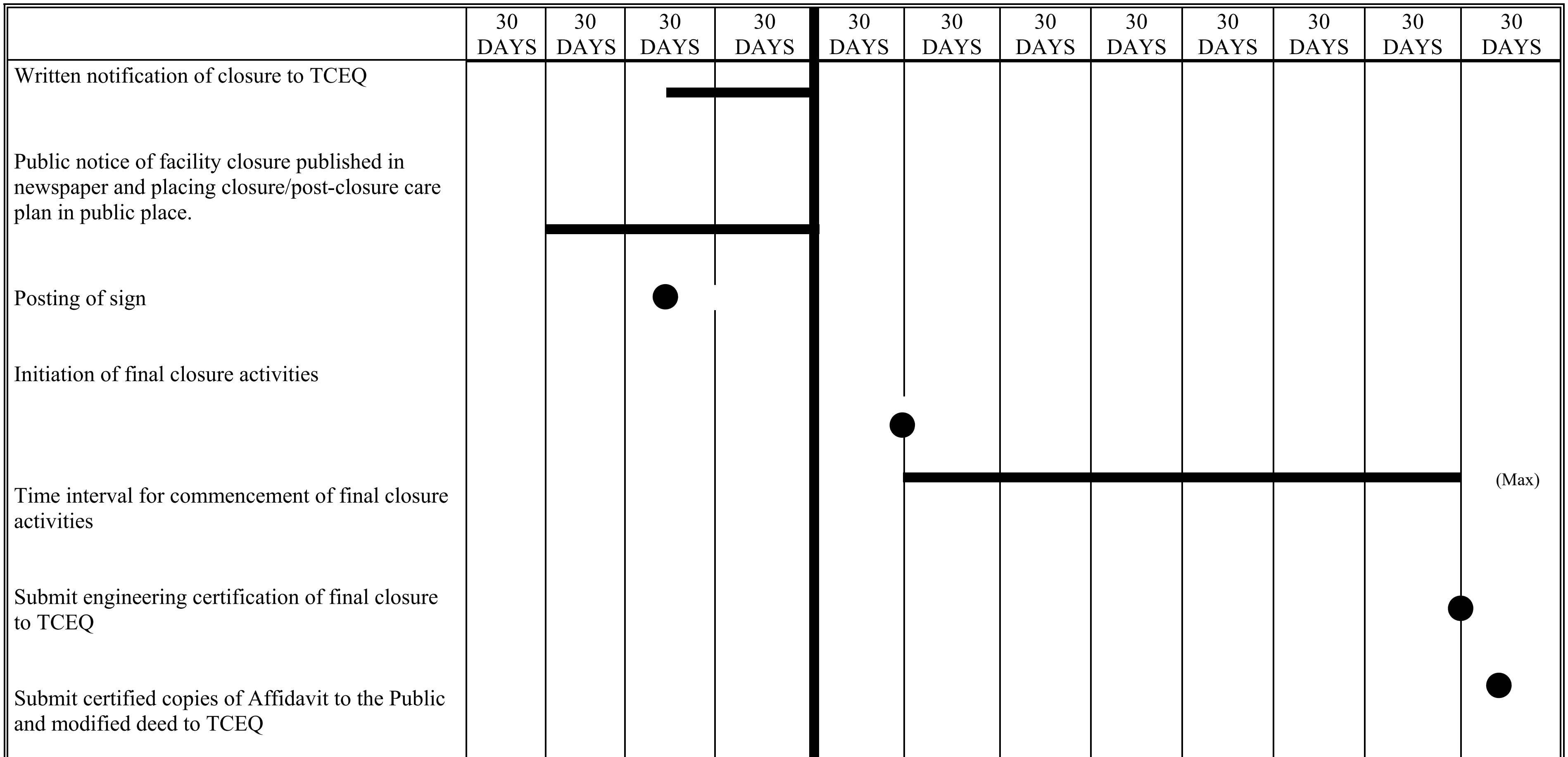
Following receipt of the required final closure documents and an inspection report from the TCEQ district office verifying proper closure of the MSW landfill facility according to this Final Closure Plan, the Executive Director may acknowledge the termination of operation and closure of the facility and deem it properly closed. The steps in the closure process are depicted on Figure 9.1 - Final Closure Schedule, in accordance with §330.457(e)(4).

4.2 PROVISIONS FOR EXTENDING CLOSURE PERIOD

Consistent with §330.457(f)(3), if the landfill has remaining capacity at the time of the last receipt of waste, final closure activities will begin no later than one year after the most recent receipt of wastes. A request for an extension beyond the one-year deadline for the initiation of final closure may be submitted to the Executive Director for review and approval and will include all applicable documentation to demonstrate that the landfill has the capacity to receive additional waste, and that the Owner has taken all steps necessary to prevent threats to human health and the environment.

Closure activities will be completed within 180 days following the initiation of final closure activities, consistent with §330.457(f)(4). If necessary, a request for an extension of the completion of final closure activities will be submitted to the Executive Director for approval. This request will include all applicable documentation necessary to demonstrate that final closure will take longer than 180 days and all steps have been taken and will continue to be taken to prevent threats to human health and the environment from the unclosed site.

City of Waco Landfill
Figure 9.1 Final Closure Schedule



Note: Schedule is based on anticipated date of beginning final closure activities.
Heavy vertical line signifies final receipt of waste.

5 CLOSURE COST ESTIMATE

A detailed written cost estimate, in current dollars, showing the cost of hiring a third party to close the largest area of the landfill ever requiring final cover in the year to follow landfill closing is provided in Part III, Attachment 8 - Cost Estimate for Closure and Post-Closure Care. Attachment 8 also describes procedures for updating the closure cost estimate consistent with TCEQ requirements.

6 POST-CLOSURE CARE ACTIVITIES

6.1 MONITORING AND MAINTENANCE

In accordance with §330.457(f)(5), post-closure care requirements, including monitoring and maintenance, as specified in §330.463(b), will commence upon completion of final closure requirements set forth in Sections 1 through 5 of this Attachment. Post-closure care maintenance will continue for a period of 30 years in accordance with §330.463(b)(1), unless the TCEQ approves a post-closure care period of a different duration. Post-closure care monitoring and maintenance will consist, at a minimum, of the following requirements to be carried out by the Owner, in accordance with §330.463(b)(3)(A):

- Retain the right of entry and maintain all rights-of-way to the closed landfill, consistent with §330.463(b)(1)(A).
- Following closure of the landfill, inspections of the landfill cover, surface water drainage system, and leachate collection system (LCS) will be conducted semiannually in accordance with §330.463(a)(1) and §330.463(a)(2). As a result of these inspections the following maintenance or remediation activities will be performed:
  - Conduct maintenance and/or remediation activities, as a result of inspections, in order to maintain the integrity and effectiveness of the final cover, site vegetation, and surface water drainage system.
  - Maintain 90 percent vegetation coverage on the final cover.
  - Maintain surface water run-on and runoff controls in order to minimize the erosion of the final cover system.
  - Correct the effects of settlement, subsidence, ponded water, erosion, or other events or failures determined to be detrimental to the integrity of the closed landfill.
- Maintain and operate the LCS in accordance with §330.331 and §330.333, as described in Attachment 12 – Leachate and Contaminated Water Management Plan. The Owner reserves the right to submit a demonstration to the TCEQ at the appropriate time that leachate will no longer pose a threat to human health and the environment. If the demonstration is approved by the TCEQ, the Owner may be allowed to discontinue the maintenance and operation of the LCS. Following the discontinuation of maintenance and operation of the LCS or completion of the post-closure care period, the leachate storage tanks will be emptied and leachate disposed of consistent with Attachment 12. The emptied leachate storage tanks will either be given to or sold to another MSW disposal facility or will be disposed at an authorized disposal facility.
- Maintain the groundwater monitoring system in accordance with Chapter 330, Subchapter J and monitor groundwater in accordance with Part III, Attachment 7 - Groundwater Sampling and Analysis Plan. In accordance with Subchapter J, the minimum monitoring frequency will be semiannually. However, the Owner reserves the right to request TCEQ

approval of (1) an alternative monitoring frequency, and (2) an alternative list of parameters to be monitored. Such requests will be based on supporting data available at the time of the request.

- Monitor the landfill perimeter LFG monitoring system in accordance with Chapter 330, Subchapter I. In accordance with Subchapter I, the minimum monitoring frequency will be quarterly. However, the Owner reserves the right to request TCEQ approval of an alternate monitoring frequency. Such a request will be based on supporting data available at the time of the request.

- If applicable, maintain and operate the LFG collection and/or control system in accordance with applicable regulations.

6.2 DECREASING POST-CLOSURE CARE PERIOD

The Owner may submit a request to decrease the length of the post-closure care maintenance period. This request will include a documented certification signed by an independent registered professional engineer. The certification will include all applicable documentation demonstrating that the reduced period is sufficient to protect human health and the environment. Applicable documentation may include data from monitoring of groundwater, surface water, leachate levels, and landfill gas. The certified documentation must be reviewed and approved by the TCEQ prior to decreasing the length of the post-closure care period.

6.3 INCREASING POST-CLOSURE CARE PERIOD

The length of the post-closure care period may be increased by the TCEQ if it is determined that the increased duration is necessary to protect human health and the environment. It is understood that the Owner will receive appropriate notification of any such proposed changes prior to the TCEQ's final determination, thereby allowing the Owner to submit appropriate documentation for TCEQ’s consideration.

6.4 COMPLETION OF POST-CLOSURE CARE PERIOD

Upon completion of the post-closure care period, the Owner will submit to the TCEQ a certification, signed by an independent professional engineer, verifying that Post-Closure care maintenance has been completed in accordance with this Post-Closure Care Plan, in accordance with §330.465(a). The submittal will include all documentation necessary for certification of completion of post-closure care maintenance. The certification will be placed in the Site Operating Record upon approval. Additionally, in accordance with §330.465(b), following completion of the post-closure care period, the Owner will submit to the TCEQ a request for voluntary revocation of the landfill permit.

7 PERSON RESPONSIBLE FOR CONDUCTING POST-CLOSURE CARE ACTIVITIES

In accordance with §330.463(b)(3)(B), at the time of development of this document, the following person is responsible for the management of this landfill:

Name and Title:	Director of Solid Waste, City of Waco
Address:	501 Schroeder Drive Waco, Texas 76710
Telephone:	(254) 750-1601

If the landfill were closed and were to start post-closure care as of the date of this permit application submittal, the Director of Solid Waste would be responsible for post-closure care. The person responsible for conducting post-closure activities is subject to change. However, as part of the closure notification to TCEQ, as required by §330 Subchapter K, the Owner will notify the TCEQ regarding the responsible person. Post-closure monitoring and maintenance activities will be conducted as described in Section 2.1 of this Attachment.

8 POST-CLOSURE LAND USE

8.1 INTENDED USE

There are no currently planned uses for the landfill after closure. If the closed landfill is considered for other use in the future, plans will be prepared and submitted to the TCEQ for review and approval in accordance with §330.465, as specified in §330.463(b)(3)(C).

8.2 CONSTRAINTS OF POST-CLOSURE CONSTRUCTION

There are no current plans to construct buildings or other structures on the landfill following final closure. Nevertheless, any construction activities proposed on the landfill following final closure will be subject to the provisions of Chapter 330, Subchapter T, which will require, among other things, prior approval of the TCEQ.

9 POST-CLOSURE CARE COST ESTIMATE

A detailed written cost estimate, in current dollars, for the cost of hiring a third party to conduct post-closure care activities for the MSW landfill, in accordance with this Post-Closure Care Plan, is provided in Attachment 8 - Cost Estimate for Closure and Post-Closure Care, in accordance with §330.463(b)(3)(D). Attachment 8 also describes procedures for updating the post-closure cost estimate consistent with TCEQ requirements.

APPENDIX 9A

CLOSURE PLAN FORM

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 9A-1 to 9A-16

Texas Commission on Environmental Quality

Closure Plan for Municipal Solid Waste Type I Landfill Units and Final Facility Closure

This form is for use by applicants or site operators of Municipal Solid Waste (MSW) Type I landfills to detail the plan for closure of a landfill unit, closure of associated storage or processing units, and final closure of the facility to meet the requirements in 30 TAC Chapter 330, §330.63(h) and 30 TAC Chapter 330 Subchapter K for a MSW Type I facility.

If you need assistance in completing this form, please contact the MSW Permits Section in the Waste Permits Division at (512) 239-2335.

I. General Information

Facility Name: City of Waco Landfill

MSW Permit No.:2400

Site Operator/Permittee Name: City of Waco

II. Landfill and Other Waste Management Units and Operations Requiring Closure at the Facility

A. Facility Units

Table 1. Description of Landfill Units.

Name or Descriptor of Unit	Operating Status of Unit	Type of Liner System Under Unit	Above Grade Class 1 Disposal Cells in this Unit	Below Grade Class 1 Disposal Cells in this Unit	Other Class 1 Disposal Cells in this Unit (describe)	Size of Unit's Waste Footprint (acres)	Maximum Inventory of Waste Ever in Unit (cubic yards)	Other Necessary Information that Pertains to the Unit
East Disposal Area	Proposed	Composite liner	☐	☐	☐	112.9	13,802,983	
West Disposal Area	Proposed	Composite liner	☐	☐	☐	62.8	6,183,399	
			☐	☐	☐			
			☐	☐	☐			
Totals						175.7	19,986,382	

Table 2. Description of Waste Storage or Processing Units or Operations Associated with this Permit.

Type of Storage or Processing Unit or Operation (individual units may be closed at any time prior to or during the final facility closure as described in this plan)	Operational Status of Unit	Size of the Area Used for the Storage or Processing Unit or Operation (Acres)	Maximum Inventory of Waste Ever in Storage or Processing Unit or Operation (indicate cubic yards or tons)	Other Information (enter other necessary information that pertains to the unit)
MSW	Proposed	N/A	180 ☒cubic yards ☐tons	6 - 30 cy roll-off containers located at citizen's collection center (CCC)
Tires	Proposed	N/A	240 ☒cubic yards ☐tons	1 - trailer (~2,000 tires) located at CCC
Metal	Proposed	N/A	90 ☒cubic yards ☐tons	3 - 30 cy roll-off containers located at CCC
Cardboard, Plastics, Aluminum, Glass	Proposed	N/A	60 ☒cubic yards ☐tons	2 - 30 cy roll-off containers located at CCC
White Goods (Appliances)	Proposed	N/A	30 ☒cubic yards ☐tons	1 - 30 cy roll-off container located at CCC
Totals			600 cy	

B. Waste Inventory Summary

Table 3. Maximum Inventory of Wastes Ever On Site.

Item	Quantity (indicate cubic yards or tons)
Maximum inventory of waste in landfill units (total from Table 1)	19,986,382 ☒cubic yards or ☐tons
Maximum inventory of waste in storage or processing units or operations (total from Table 2)	600 ☒cubic yards or ☐tons
Total Maximum Inventory of Wastes ever on site over the active life of the MSW facility (sum of totals from Tables 1 and 2)	19,986,982 ☒cubic yards or ☐tons

C. Drawings Showing Details of the Waste Management Units at Closure

Table 4. Location of the Drawings showing Details of the Waste Management Units at Closure (outlines, dimensions, maximum elevations of waste and final cover of landfill units, and waste storage or processing units or operations at closure of the facility).

Drawing Location in the SDP	Drawing Figure Number	Drawing Title	Waste Management Units Details Shown
Attachment 1	1.2-1.4	Detailed Facility Layout, Sequence Plan, and Excavation Plan	Boundaries, waste footprints, and excavation grades of East Disposal Area and West Disposal Area
Attachment 3	3.1-3.3	Landfill Completion Plan	Maximum elevations of final cover of East Disposal Area and Waste Disposal Area

III. Description of the Final Cover System Design

A. Types and Descriptions of the Final Cover Systems

Table 5. Types and Descriptions of the Final Cover Systems Permitted or Proposed for Closure of the Landfill Units.

Landfill Unit Name or Descriptor	Type of Final Cover System	Final Cover System Components Description	Other Information (Enter other information as applicable)
City of Waco Landfill	Conventional composite	See Attachment 6C, Drawing 6C.2	N/A

B. Design Details

Table 6. Design Details of the Final Cover Top and Side Slopes for the Landfill Units.

Landfill Unit Name or Descriptor	Maximum Final Elevation of Waste (feet above mean sea level [ft-msl])	Maximum Elevation of Top of Final Cover (ft-msl)	Minimum Grade of the Final Cover Top Slope (%)	Maximum Grade of the Final Cover Side Slope (%)	Other Information (enter other information as applicable, e.g. above-grade Class 1 Cell Dikes)
East Disposal Area	694.2	697.7	5	25	N/A
West Disposal Area	657.8	661.3	5	25	N/A

C. Final Cover Drainage Features

Storm water drainage and erosion and sediment control features incorporated on the final cover of the landfill units to protect the integrity and effectiveness of the final cover system include *(please list and describe the drainage features to be installed on the final cover at or prior to closure for each landfill unit, or list the drainage features and provide cross references on the location(s) of the descriptive and details (drawing) information in other parts of the SDP)*:

Attachment 6A, Section 6 - Erosion and Sedimentation Control Plan provides narrative descripition of storm water drainage, erosion control, and sedimentation control features. These features are also depicted on the following drawings:

6A.3 Landfill Completion Plan
6A.4 Channel Profile - Channel 1A1 to Channel 1A4
6A.5 Channel Profile - Channel 2A1 to Channel 2A5
6A.6 Channel Profile - Channel 3A1
6A.7 Channel Profile - Channel 4A1 to Channel 4A5
6A.8 Channel Profile - Channel 4B1 to Channel 4B7
6A.9 East Disposal Area (EDA) East Basin Plan
6A.10 East Disposal Area (EDA) West Basin Plan
6A.11 West Disposal Area (WDA) Basin Plan
6A.12 Drainage Swale Details
6A.13 Downchute Details
6A.14 Basin Outlet Details
6A.15 Specifications for Silt Fences and Hay Bales
6A.16 Specifications for Sediment Traps and Check Dams

D. Final Cover Vegetation or Other Ground Cover Material

The final cover will be seeded and/or sodded with native plants immediately following the application of the final cover in order to minimize erosion. Other materials, including **N/A**, may be incorporated over the final cover soil surface to ensure sufficient coverage of the ground surface to minimize erosion. The estimated percent ground cover to minimize soil loss and maintain long-term erosional stability of the final cover top and side slopes is: **90**%. The minimum material specifications for other ground cover materials are summarized in the table below.

For a landfill with water balance final cover design, the percentage vegetation cover (excluding other ground cover types) will not be less than that assumed in the water balance final cover model.

Table 7. Minimum Specification for Ground Cover Materials Other Than Vegetation, if Applicable.

Other Ground Cover Material	Maximum Particle Size (inches)	Minimum Particle Size (inches)	Material Placement Method	Thickness of Layer (inches)	Percentage Coverage (%)	Other (specify)
N/A						

E. Final Contour Map

Drawings **3.1 through 3.3**, facility final contour maps are provided in Attachment 3. These maps shows the final contours of the landfill units and the entire facility at closure.

Drawings **2.2, 2.3** and **2.4** showing the cross–sections of the landfill units at closure are also provided in Attachment 2.

The facility final contour and cross-section maps/drawings depict the following information:

(1) Final constructed contours of the landfill at closure.

(2) Top slopes and side slopes of the landfill units.

(3) Surface drainage features.

(4) 100-year floodplain, as applicable.

(5) Constructed features providing protection of/from the 100-year floodplain.

(6) Other (specify):
See Attachment 6A, Drawings 6A.4 through 6A.11 and 6A.14 for perimeter drainage channel profiles and detention basin plans and details

IV. Description of the Final Cover System Installation Procedure

A. Mode of Installation

Table 8. Mode of Final Cover Installation on the Landfill Units.

Landfill Unit Name or Descriptor	Largest Area of Unit Ever Requiring Final Cover (Acres)	Check this Column if Final Cover will be Placed in Installments as Permitted Elevation is Reached	Check this Column if Final Cover will be Placed when Entire Unit Area Reaches Permitted Elevation	Final Cover Installation Status
City of Waco Landfill, Sector 1	21.3	☐	☒	N/A
		☐	☐	
		☐	☐	
		☐	☐	

B. Installation Drawings for Final Cover and Drainage Features

The following attached plan and cross-section drawings show the final cover design details, the largest area requiring final cover, details of the sequence of installation of the final cover system, and all drainage features.

Table 9. List of Attached Installation Drawings for Final Cover and Drainage Features.

Drawing No.	Drawing Title	Description of Information Contained in Drawing
Attachment 3, Drawings 3.1-3.3	Landfill Completion Plan	Plan drawings of final contours
Attachment 2, Drawings 2.1-2.4	Fill Cross Sections	Fill cross section location map, including cross-sections
Attachment 6C, Drawing 6C.2	Final Cover Details	Details of final cover components
Attachment 6A, Drawings 6A.3-6A16	See Part III, C of this form	Plans and details of all drainage features
N/A	N/A	Other: N/A

C. Final Cover Quality Control Plan

A final cover quality control plan (FCQCP), is provided in **Attachment 9, Section 2.3**. The FCQCP describes the final cover system design, construction, and evaluation protocol and processes, including the personnel, materials, methods, sampling and testing standards, procedures, and practices to be used in procuring, handling, installing, and evaluating all elements of the final cover system. It establishes the material requirements; personnel qualifications and roles; installation requirements; quality control and quality assurance monitoring, testing, documentation, and reporting programs to be used during construction of each component of the final cover system to assure and to verify that the final cover system is constructed as designed and in accordance with applicable rules and technical standards.

D. Documentation and Reporting of Final Cover System Construction and Testing

The professional of record will document all aspects and stages of the final cover installation, including materials used, equipment and construction methods, and the type and rate of sampling and quality control testing performed. Following completion of construction of the final cover, the site operator/permittee will submit to the TCEQ executive director, a Final Cover System Evaluation Report (FCSER) for each landfill unit.

V. Closure Activities and Completion Schedules for Each Landfill Unit and for the Final Facility Closure

A. Closure of a Landfill Unit

The following activities will be conducted to satisfy the closure criteria for a landfill unit:

(1) Closure Notification to the TCEQ Executive Director:

The site operator will inform the executive director of the TCEQ, in writing, of the intent to close the unit no later than 45 days prior to the initiation of closure activities and place this notice of intent in the operating record.

(2) Stoppage of Waste Acceptance and Commencement of Other Closure Activities for the Unit:

The site operator will stop accepting waste upon receiving the known final receipt of waste. The site operator will ensure that the permitted top elevations of the in-place waste, as depicted in/derived from the unit's final contour map approved by the TCEQ executive director, are not exceeded at any section or part of the landfill unit. The site operator will begin closure activities for the unit no later than:

- Thirty days after the date on which the unit receives the known final receipt of wastes; or

- One year after the most recent receipt of wastes if the unit has remaining capacity and there is a reasonable likelihood that the unit will receive additional wastes.

(3) Request for Extension Beyond the 1-Year Deadline for Commencing Closure Activities for a Unit:

The site operator may submit a written request to the executive director of the TCEQ for review and approval for an extension beyond the one-year deadline for the initiation of closure. The request will include the following:

(a) All applicable documentation necessary to demonstrate that the unit has the capacity to receive additional waste; and

(b) All documentation necessary to demonstrate that the site operator has taken and will continue to take all steps necessary to prevent threats to human health and the environment from the MSW landfill unit.

(4) Construction of Final Cover:

The site operator will construct the permitted final cover over the waste mass utilizing methods, procedures, and specifications described in the FCQCP. The final constructed contours, elevations, and slopes of the installed final cover will match the permitted final cover contours, elevations, and slopes shown in closure drawings contained in this closure plan.

(5) Construction of Drainage Features:

The site operator will construct the drainage structures shown in drawings referenced or contained in this closure plan or in the facility surface water drainage report.

(6) Completion of Outstanding or Replacement of Damaged Groundwater or Landfill Gas Monitoring Components:

The site operator will complete installation of any outstanding or replacement of any damaged groundwater or landfill gas monitoring system components and landfill gas control systems as needed to maintain current and effective groundwater or landfill gas monitoring and control systems.

(7) Submittal of Final Cover System Evaluation Report (FCSER) to the TCEQ Executive Director:

Following completion of construction of the final cover for the subject landfill unit, the site operator will submit to the TCEQ executive director for review and acceptance, a FCSER for the unit.

(8) Completion of Closure Activities for the Landfill Unit:

The site operator will complete closure activities for the unit within 180 days following the start of closure activities, unless the executive director of the TCEQ grants an extension as described in Item V.A.8(a) below.

(a) Request for Extension of the Completion of Closure Activities for the Landfill Unit:

The site operator may submit a written request for an extension for the completion of closure activities to the TCEQ for review and approval. The extension request will include:

- All applicable documentation necessary to demonstrate that closure will, of necessity, take longer than 180 days; and
- All applicable documentation necessary to document that all steps have been taken and will continue to be taken to prevent threats to human health and the environment from the unclosed MSW landfill unit.

(9) Submittal of Engineer's Certification of Closure to the TCEQ Executive Director and Request of Closure Inspection to TCEQ Regional Office:

Following completion of all closure activities for the landfill unit, the site operator will submit:

(a) Closure Inspection

A written request to the local TCEQ regional office for a closure inspection of the unit.

(b) Closure Certification

A certification, signed by an independent licensed professional engineer, to the executive director of the TCEQ for review and approval verifying that closure has been completed in accordance with this closure plan. The site operator will submit the certification via registered mail, and the submittal will contain all applicable documentation necessary for certification of closure of the unit, including:

- A final cover system evaluation report (FCSER) documenting the installation of the final cover. The FCSER may be submitted as a separate document for review and approval following the completion of the final cover installation. In that case, the certification of closure will be submitted subsequently;
- A final contour map as described under Section III.E that includes the relevant unit; and
- Copy of the letter to the TCEQ regional office requesting a closure inspection of the relevant unit.

(10) TCEQ's Acknowledgement of Termination of Operation and Closure of a Unit:

Upon receipt, the TCEQ executive director will review the closure documents for completeness and accuracy; and following receipt of the closure inspection report from the agency's regional office verifying proper closure of the MSW landfill unit according to this closure plan, the executive director will, in writing, acknowledge the termination of operation and closure of the unit and deem it properly closed. Thereafter, the site operator will comply with the post-closure care requirements described in the post-closure care plan for the unit.

(11) Deed Recordation for Disposed Regulated Asbestos Containing Materials (RACM):

Upon closure of the unit that accepted RACM, the site operator will place a specific notation that the unit accepted RACM in the deed records for the facility with a diagram identifying the RACM disposal areas. Concurrently, the site operator will submit to the TCEQ executive director, a notice of the deed recordation and a copy of the diagram identifying the asbestos disposal areas.

(12) Placement of all Closure Documentation in the Site Operating Record:

Once approved, the closure certification and all other documentation of closure will be placed in the site operating record.

(13) Closure Schedule for the Landfill Unit:

A closure schedule, is provided on Attachment 9, Figure 9.1. The schedule shows all the closure activities listed within Section V.A and the timelines for commencing and completing each activity. Also, the schedule shows that closure activities for the landfill unit will be completed within 180 days following the initiation of closure activities as required, unless an extension is granted by the TCEQ executive director.

(14) Other: (enter as applicable).

N/A

B. Closure of the Waste Storage or Processing Units or Operations

Closure of the waste storage or processing units or operations authorized under this permit will include removal of all waste, waste residues, and any recovered materials. The facility units and operations will either be dismantled and removed off-site or decontaminated. The site operator will dispose at the landfill or evacuate all materials (including feedstock, in process, and processed) to an authorized facility and disinfect all leachate handling units, tipping areas, processing areas, and post-processing areas. If there is evidence of a release from a unit or operation, the site operator will conduct an investigation, as approved by the TCEQ executive director, into the nature and extent of the release and an assessment of measures necessary to correct an impact to groundwater.

C. Final Closure of the Facility

In addition to the closure activities listed in Section V.A above for closing a landfill unit, the site operator will conduct the following activities for the closure of the entire facility:

(1) Publish Final Closure Notice and Place the closure Plan in a Public Place:

No later than 90 days prior to the initiation of the final facility closure, the site operator will:

(a) Publication of Notice:

The site operator will publish notice in the newspaper(s) of largest circulation in the vicinity of the facility to inform the public of the final closure of the facility. This notice will include:

- The name of the facility;
- The address, and physical location of the facility;
- The facility’s permit number; and
- The last date of intended receipt of waste.

(b) Place Copies of the Closure Plan in a Public Place:

The site operator will also make available an adequate number of copies of the approved final closure and post-closure plans for public access and review at the Waco-McLennan County Central Library (state public place within the area, including address, where the plan will be available for public access and review).

(2) Submit Written Notice of “Intent to Close the Facility” to the TCEQ Executive Director:

The site operator will provide written notification to the TCEQ executive director of the intent to close the facility. This notice will be provided to the executive director no later than 90 days prior to the initiation of the final facility closure, and thereafter be placed in the site operating record.

(3) Post Signs and Install Barriers:

Upon notifying the executive director of the intent to close the facility and no later than 90 days prior to the initiation of final facility closure, the site operator will:

(a) Post Final Closure Signs:

The site operator will post a minimum of one sign at the main entrance and all other frequently used points of access for the facility notifying all persons who may utilize the facility of the date of closing for the entire facility and the prohibition against further receipt of waste materials after the stated date.

(b) Install Barriers:

Also, the site/operator will install suitable barriers at all gates or access points to adequately prevent the unauthorized dumping of solid waste at the closed facility.

(4) Filling of "Affidavit to the Public" and Performance of the Final Deed Recording:

Upon closure of all the landfill units or upon final closure of the facility, the site operator will:

(a) File Affidavit

File with the county deed records an "Affidavit to the Public" in a form provided by the TCEQ executive director that includes an updated metes and bounds description of the extent of the disposal areas at the facility and the restrictions to future use of the land in accordance with applicable provisions under 30 TAC Chapter 330, Subchapter T.

(b) Record a Notation on the Deed

Record a certified notation on the deed to the facility property, or on some other instrument that is normally examined during title search, that will in perpetuity notify any potential purchaser of the property that the land has been used as a landfill facility and use of the land is restricted according to the provisions under 30 TAC Chapter 330, Subchapter T.

(c) Place Documents in the Operating Record

Place a copy of the "Affidavit to the Public" and a copy of the modified deed in the site operating record.

(5) Submittal of a Copy of the "Affidavit to the Public" and the "Modified Deed" to the TCEQ Executive Director:

Within ten days after completion of final closure activities of the facility, the site operator will submit the following to the TCEQ executive director by registered mail:

(a) A certified copy of the "Affidavit to the Public";

(b) A certified copy of the modified deed to the facility property; and

(c) A certification, signed by an independent licensed professional engineer, verifying that final facility closure has been completed in accordance with the approved closure plan. The submittal will contain all applicable documentation necessary for certification of final facility closure, including:

- Final Cover System Evaluation Report (FCSER) documenting the installation of the final cover. The FCSER may be submitted earlier as a separate document for review and approval following the completion of the final cover installation. In that case, the certification of closure will be submitted subsequently;
- A final contour map as described under Item III.G above;
- Copy of a letter to the TCEQ regional office requesting a final closure inspection of the facility; and
- Copies of documents verifying newspaper publication of the notice of the final facility closure.

(6) Other

Additional items relating to the schedule for final facility closure, and additional closure activities specific to the final closure of this facility include:
N/A

(7) TCEQ's Acceptance of Termination of Operation and Closure of a Landfill Facility:

Following the TCEQ executive director's receipt and completion of the review of the professional engineer's certification of the completion of facility closure and the final closure documents, and receipt of the inspection report from the agency's regional office verifying proper closure of the facility according to this closure plan, the executive director will, in writing, accept the termination of operation and closure of the facility and deem it properly closed. Thereafter, the site operator will comply with the post closure care requirements described in the post closure plan for the facility.

(8) Final Closure Schedule for the Facility:

The attached Figure 9.1, Final Closure Schedule, provides the closure schedule for the final facility closure. It incorporates the schedule for closure of a unit as discussed in Section V.A and also shows the commencement and completion timelines for the final closure activities listed within this Section.

VI. Summary of Attachments

A. Drawings and Maps

The following Drawings and Maps are attached as part of this plan.

- Attachment 1, Drawings 1.2-1.4, Detailed Facility Layout, Sequence Plan, and Excavation Plan.
- Attachment 3, Drawings 3.1-3.3, Landfill Completion Plan.
- Attachment 2, Drawings 2.1-2.4, Cross-Section Layout Plan and Fill Cross-Sections
- Attachment 6C, Drawing 6C.2, Final Cover Details.
- Attachment 6A, Drawings 6A.4-6A16, Final Cover Surface Water Drainage Features.
- Other Drawings/Maps: N/A

B. Documents

- Attachment 7, Groundwater Sampling and Analysis Plan.
- Attachment 9, Section 2.3, Final Cover Quality Control Plan (FCQCP).
- Attachment 9, Figure 9.1, Final Closure Schedule Chart.
- Other: N/A

C. Additional Items Attached (enter as applicable)

N/A

VII. Professional Engineer's Statement, Seal, and Signature

Name: Ryan R. Kuntz, P.E. Title: Vice President, Project Director

Date:

Company Name: SCS Engineers Firm Registration Number: F-3407

Professional Engineer's Seal

Signature

APPENDIX 9B

POST-CLOSURE CARE PLAN FORM

SCS Engineers
TBPE Reg. # F-3407
Inclusive of pages 9B-1 to 9B-19

Texas Commission on Environmental Quality

Post-Closure Care Plan for Municipal Solid Waste Type I Landfill Units and Facilities

This form is for use by applicants or site operators of Municipal Solid Waste (MSW) Type I landfills to provide landfill unit or final facility post-closure care closure plans to meet the requirements in 30 TAC Chapter 330, §330.63(h) and as set out under 30 TAC Chapter 330 Subchapter K for a MSW Type I facility.

If you need assistance in completing this form, please contact the MSW Permits Section in the Waste Permits Division at (512) 239-2335.

I. General Information

Facility Name: City of Waco Landfill

MSW Permit No.: 2400

Site Operator/Permittee Name: City of Waco

II. Party Responsible for Overseeing and Conducting Post Closure Care Activities

Name (Person or Office Responsible): Director of Solid Waste, City of Waco

Position or Title: Director of Solid Waste

Mailing Address: 501 Schroeder Dr.

City: Waco

State: TX

Zip Code: 76710

Telephone Number: (254) 750-1601

III. Post-Closure Care Status of Landfill Units at the Facility

Check the applicable box for the post-closure care status of the units at the facility and complete the applicable tables as indicated:

A. ☒ No landfill unit is in post-closure care in this facility at the time this application is submitted (skip Table 1 and complete Table 2 below if you check this item)

B. ☐ This facility includes landfill units currently in post-closure care and landfill units that are not yet in post-closure care (complete Tables 1 and 2 below if you check this item).

C. ☐ This facility contains only landfill units currently in post-closure care (complete Table 1 below if you check this item; do not complete Table 2).

Table 1: Landfill Units Currently in Post-Closure Care

Landfill Unit Name	Drawing Number Showing the Landfill Unit	Date TCEQ Acknowledged Closure of Unit	Date Post-Closure Care Commenced	Projected Date of End of Post-Closure Care
N/A				

Table 2: Landfill Units Not yet in Post-Closure Care

Category of Landfill Unit (Regarding Status of Waste Receipt)	Landfill Unit Names or Descriptors	Site Development Plan Drawing Titles and Numbers Showing the Units
Stopped Receiving Waste Prior to October 9, 1993	N/A	N/A
Received Waste on or after October 9, 1993	N/A	N/A
Proposed to be Constructed	City of Waco Landfill	Attachments 1, 2, 3, 11, and 12 (See below for list of drawing titles)

Category of Landfill Unit (Regarding Status of Waste Receipt)	Landfill Unit Names or Descriptors	Site Development Plan Drawing Titles and Numbers Showing the Units
Other (enter as applicable)	N/A	N/A

List of Drawings:

Attachment 1, Figure 1.2, Detailed Facility Layout and Sequence Plan

Attachment 1, Figures 1.3-1.4, Excavation Plan

Attachment 2, Figure 2.1, Cross Section Layout Plan

Attachment 3, Figures 3.1-3.3, Landfill Completion Plan

Attachment 11, Figure 11.1, Gas Monitoring Plan

Attachment 12, Figures 12.1-12.2, Leachate Collection System Layout Plan

IV. Post-Closure Care Maintenance Requirements and Activities to be Conducted

A. Categories of Landfill Units and Applicable Post-Closure Care Maintenance Requirements and Activities

Check the appropriate boxes to indicate the categories of landfill units at the facility and complete the applicable section of the post-closure care maintenance requirements and activities below.

This facility includes landfill units that:

☐ Stopped receiving waste prior to October 9, 1993

If you check this item, complete the post-closure care maintenance requirements and activities specified in Subsection IV.B below. Skip Subsection IV.B if this item does not apply to your facility.

☐ Received waste on or after October 9, 1993

If you check this item, complete the post-closure care maintenance requirements and activities specified in Subsection IV.C below. Skip Subsection IV.C if this item does not apply to your facility.

☒ Are proposed to be constructed

If you check this item, complete the post-closure care maintenance requirements and activities specified in Subsection IV.C below. Skip Subsection IV.B, unless your facility also contains units that stopped receiving waste prior to October 9, 1993.

B. Post-Closure Care Maintenance Requirements and Activities for the Landfill Units that Stopped Receiving Waste Prior to October 9, 1993

The site operator will commence and conduct post-closure care maintenance of the units that stopped receiving waste prior to October 9, 1993 for a minimum of the first **five years** following commencement of post-closure care as specified below and in accordance with applicable rules under 30 TAC §330.463(a). Post-closure care maintenance will start on the date the professional engineer's certification of the completion of closure is accepted in writing by the TCEQ executive director and the site operator will carry out the following activities and operations during the period.

1. Maintenance of Right of Entry and Rights of Way

The site operator will retain the right of entry to and maintain all rights-of-way of the closed units in order to conduct periodic inspections of the units throughout the post-closure care period. TCEQ staff will have access to the site to conduct inspection or investigation that may be necessary during the period.

2. Inspection Activities and Correction of Problems

The site operator will conduct inspection of the closed landfill units at the frequencies indicated in Table 3 below, utilizing the inspection protocol maintained in the site operating record, and will correct all identified problems as needed.

Table 3: Inspection Activities Schedule

Post-Closure Care Inspection Item	Frequency of Inspection	Types of Deficiency Conditions to be looked for during Inspection
Final Cover Condition	N/A	N/A
Vegetation	N/A	N/A
Leachate Management Systems	N/A	N/A
Landfill Gas Monitoring and Control Systems	N/A	N/A

Post-Closure Care Inspection Item	Frequency of Inspection	Types of Deficiency Conditions to be looked for during Inspection
Groundwater Monitoring Systems	N/A	N/A
Drainage Structures	N/A	N/A
Ponding of Water	N/A	N/A
Other: N/A	N/A	N/A

3. Continuation of Monitoring Programs during Post-Closure Care Period

The site operator will continue the monitoring programs listed in Table 4 during the post-closure care period. The monitoring programs will be conducted as specified in the applicable section of the facility's Site Development Plan and applicable rules.

Table 4: Monitoring and Reporting Schedule

Monitoring Program	Frequency of Monitoring	Frequency of Reporting of Results
Groundwater monitoring	N/A	N/A
Landfill gas monitoring	N/A	N/A
Other: N/A	N/A	N/A

4. Detection of a Release, Nature and Extent Investigation, and Corrective Action to Address Release from the MSW Unit

Upon detection of any evidence of a release from the landfill or other associated waste management units at the facility, the site operator will:

- Notify the executive director of the TCEQ of the condition detected;

- Investigate, if so directed by the executive director of the TCEQ, whether a release from the landfill or other associated waste management units at the facility has occurred;
- Investigate the nature and extent of the release, if a release is confirmed;
- Assess measures necessary to correct any impact to groundwater;
- Submit a corrective action plan via a permit modification for TCEQ executive director's review and approval; and
- Conduct corrective action as approved by the TCEQ executive director.

5. Extension of Post-Closure Care Period

If any of the problems listed in Table 3 occurs, or corrective action as indicated in Subsection IV.B.4 above continues, after the end of the five-year post-closure care period or persists for longer than the first five years of post-closure care, the site operator will be responsible for their correction and will continue to conduct post-closure care maintenance until the TCEQ executive director determines that all problems have been adequately resolved.

6. Reduction of Post-Closure Care Period

The site operator may request in writing for the TCEQ executive director to reduce the post-closure care period for the units if all wastes and waste residues have been removed during closure and any new or on-going corrective action to address confirmed releases from the landfill have been completed as acknowledged in writing by the executive director.

C. Post-Closure Care Requirements and Activities for Municipal Solid Waste Landfill Units that Receive Waste on or after October 9, 1993 and for New Units

The site operator will commence and conduct post-closure care maintenance of the units that receive waste on or after October 9, 1993 and new units constructed under this permit as follows and in accordance with applicable rules under 30 TAC §330.463.

1. Commencement of Post-Closure Care

Post-closure care maintenance will start on the date the professional engineer's certification of the completion of closure is accepted in writing by the TCEQ executive director and the site operator will carry out the following activities and operations during the period.

2. Period of Post-Closure Care

The site operator will conduct post-closure care for the landfill units for a period of **30 years**, unless this time period is increased or reduced by the executive director as discussed in Subsection IV.C.11.

3. Maintenance of Right of Entry and Rights of Way

The site operator will retain the right of entry to the closed units and the facility and will maintain all rights-of-way of the closed units in order to conduct periodic inspection and maintenance of the closed units until the end of the post-closure care period.

4. Inspection Activities

The site operator will conduct periodic inspection of the closed units to identify and document deficiency conditions and conduct maintenance and corrective action to maintain compliance. Sections IV.C. 8.(a)-(c) provide information on the inspection items and deficiency conditions that the site operator will look for during inspection of the major components of the landfill and the site during the post-closure care period. Other inspection and maintenance provisions that apply during the post-closure care period as specified in the facility's site operating plan, site development plan, or applicable rules will remain in effect.

5. Documentation of Inspection

The site operator will document and maintain records of the post-closure care inspections in the site operating record. The records will include:

- The date of inspection;
- Components and items inspected;
- Problems detected or observed; and
- The name of the personnel who conducted the inspection.

6. Corrective Actions

Based on the results of the inspection activities, the site operator will conduct needed restoration and remediation actions on the closed unit no later than the next scheduled inspection event. Also, the site operator will conduct maintenance action on regular periodic schedule in order to:

- Maintain the integrity and effectiveness of all final cover, facility vegetation, and drainage control systems;
- Correct any effects of settlement, subsidence, ponded water, erosion, or other events or failures detrimental to the integrity of the closed unit; and
- Prevent any surface run-on and run-off from eroding or otherwise damaging the final cover system during the post-closure care period.

7. Documentation of Corrective Actions

The site operator will document and maintain, in the facility's site operating record, records of the restoration, remediation, and maintenance activities performed, including the date of completion of the activities.

8. Inspection Activities Schedules

(a) Final Cover Inspection

Inspection Frequency: Semiannually

Other Inspection Occasions/Events: N/A

Table 5: Final Cover Inspection Items

Inspection Item	Types of Deficiency Conditions to be looked for during Inspection
Vegetation and other Ground Cover Materials	Loss of vegetation, overgrowth of vegetation
Settlement	Cracks, subsidence, ponded water
Subsidence	Cracks, subsidence, ponded water
Ponded Water	Saturated soils, overgrowth of vegetaton, vectors
Erosion	Erosional rill, animal burrows, exposed geosynthetics

Inspection Item	Types of Deficiency Conditions to be looked for during Inspection
Other (enter other events or failures detrimental to the integrity and effectiveness of the final cover): N/A	N/A
Other (enter other events or failures detrimental to the integrity and effectiveness of the final cover): N/A	N/A

9. *Drainage Control System Inspection*

Inspection Frequency: Semiannually

Other Inspection Occasions/Events: N/A

Table 6: Drainage Control System Inspection Items

Inspection Item	Types of Deficiency Conditions to be looked for during Inspection
Vegetation within Drainage Control Structures	Obstruction within channels/basin outlets, reduced channel/swale/basin capacity
Component Failures	Structural damage to channel, swale, or basin outlet structure, and channel/swale flow issues due to settlement or sediment build-up
Wash Outs	Erosion, sediment build-up, over-growth of vegetation
Sediment Build Up	Obstruction within channel/basin outlets, reduced channel/swale/basin capacity
Other(enter other events or failures detrimental to the integrity and effectiveness of drainage structures): N/A	N/A

(b) *Access and Rights-of-Way*

Inspection Frequency: Semiannually

Other Inspection Occasions/Events: N/A

Table 7: Access and Rights of Way Inspection Items

Inspection Item	Types of Deficiency Conditions to be looked for During Inspection
Gates, Gate Locks and Barriers	Damage to gates/locks, locks missing/unlocked, unauthorized entry detected
Fence and other Access Control Barriers	Damage/breach of fence, unauthorized entry detected
Vegetation Control in Areas of the Facility other than the Final Cover	Overgrowth of vegetation on access roads wthin facility or to GMPs/GMWs.
Other (enter other access control and rights-of-way inspection items): Access Roads	Damage, rutting, or erosion of access roads

9. Continuation of Operation and Maintenance of the Leachate Collection and Removal Systems (LCRS)

The site operator will continue the operation and maintenance of the LCRS and disposal of leachate during the post-closure care period in accordance with the facility's leachate management plan found in Attachment 12 of the Site Development Plan and consistent with applicable provisions under 30 TAC Sections 330.331 and 330.333.

(a) Performance Monitoring and Inspection of the LCRS

During the post-closure care period, the site operator will monitor the performance of the LCRS on a semiannual basis to assure continuous compliance with the design criteria and inspect the LCRS components on a semiannual basis, at a minimum, to determine the need for repair or maintenance. Inspection and monitoring will follow the procedure described in the facility's leachate management plan found in Attachment 12 of the Site Development Plan or in the written inspection protocol maintained in the facility's site operating record. Results of the monitoring and inspection activities will be documented in the site operating record. The items and components of the leachate collection and removal system to be inspected will include but are not limited to the items in Table 8 below.

Table 8: Leachate Collection and Removal System Inspection

Inspection Item/Component	Types of Deficiency Conditions to be looked for during Inspection
Leachate Pump	Inoperable pump, high levels at sump pump control panel, malfunctioning level-sensors,
Leachate Tanks	Damage to tanks and connections/fittings, malfunctioning level-sensors
Leachate Collection Risers	Damage

(b) LCR Maintenance and Repairs

During the post-closure care period, the site operator will perform routine and needed maintenance or repairs of the LCRS items and components based on the monitoring and inspection results. Maintenance and repair will be completed prior to the next scheduled monitoring event and documented within the site operating record.

(c) Discontinuation of Leachate Management

The site operator may submit data and information from the closed units to the TCEQ executive director to demonstrate that leachate no longer poses a threat to human health and the environment. Upon the executive director's approval of the demonstration, the site operator will be allowed to stop managing leachate at the closed unit.

10. Continuation of Monitoring Systems Operation and Maintenance:

The site operator will continue to conduct monitoring systems operation and maintenance activities to ensure the integrity of the containment system and to promptly detect and control releases to the environment during the post-closure care period as follows.

(a) Groundwater Monitoring System

The site operator will continue groundwater monitoring activities (including sampling, analysis, reporting, etc.) in accordance with the approved site-specific Groundwater Sampling and Analysis Plan (GWSAP) found in Attachment 7 of the Site Development Plan, the Groundwater Monitoring System Design found in Attachment 7 of the Site Development Plan and consistent with the provisions under 30 TAC Chapter 330 Subchapter J. Groundwater monitoring will be conducted semiannually or as otherwise approved by the TCEQ executive director during the post-closure care period.

i. Inspection of the Groundwater Monitoring System

During each groundwater monitoring event, the site operator will perform inspection of all the groundwater monitoring wells that are part of the groundwater monitoring system and other items discussed in the GWSAP or the Groundwater Monitoring System Design. The items and components of the groundwater monitoring system to be inspected are included in Table 9:

Table 9: Groundwater Monitoring Systems Inspection

Inspection Item/Component	Types of Deficiency Conditions to be looked for during Inspection
Groundwater Monitoring Wells	Damage/inoperability metal housing, well casing, locks, concrete pad; and missing locks.

ii. Maintenance and Repair of the Groundwater Monitoring System

The site operator will perform needed maintenance and/or repairs of the groundwater monitoring system items and components based on the inspection results. Maintenance and/or repairs will be performed no later than the next scheduled monitoring event.

iii. Documentation of Inspection, Maintenance, and Repairs

The site operator will document and discuss the results of the groundwater monitoring system inspection, maintenance, and repair activities in the groundwater monitoring report submitted to the TCEQ executive director, and maintain the documents in the site operating record.

(b) Landfill Gas Management System

During the post-closure care, the site operator will continue landfill gas monitoring operations and activities, documentation, and reporting in accordance with the facility's landfill gas management plan and consistent with the requirements under 30 TAC Chapter 330, Subchapter I.

i. LFG Monitoring and Monitoring System Inspection

All structures and perimeter gas monitoring probes will be sampled quarterly or more frequently as approved by the TCEQ executive director. The site operator will conduct routine inspections of the landfill gas management system components as provided in the landfill gas management plan during the post-closure care period. The items and components to be inspected are included in Table 10.

Table 10: Landfill Gas Management System Inspection

Inspection Item/Component	Types of Deficiency Conditions to be looked for during Inspection
Gas Monitoring Probes	Damage/inoperability metal housing, well casing, locks, concrete pad, monitoring port; and missing locks, monitoring port.

ii. LFG Management System Maintenance

The site operator will perform routine and needed maintenance of the landfill gas management system including calibration of the monitoring equipment. Needed maintenance and/or repair work will be performed based on the inspection and monitoring results no later than the next scheduled monitoring event.

(c) Continuation of Earth Electrical Resistivity Survey

The site operator will, if applicable, continue earth electrical resistivity surveys as applicable at the frequency stated in the approved site development plan or as otherwise approved by the TCEQ executive director.

11. Detection of a Release, Nature and Extent Investigation, and Corrective Action to Address Release from the MSW Unit

If there is evidence of a release from the landfill or other associated waste management units at the facility, the site operator will:

- Notify the executive director of the TCEQ of the condition detected;
- Investigate, if so directed by the executive director of the TCEQ, whether a release from the landfill or other associated waste management units at the facility has occurred;
- Investigate the nature and extent of the release, if a release is confirmed;
- Assess measures necessary to correct any impact to groundwater;
- Submit a corrective action plan via a permit modification for TCEQ executive director's review and approval; and
- Conduct corrective action as approved by the TCEQ executive director.

12. Revision of the Length of Post-Closure Care Period

(a) The Post-Closure Care Period May Be Decreased

The length of the post-closure care period may be decreased by the TCEQ executive director if the site operator submits a documented certification signed by a licensed professional engineer and including all applicable supporting documentation that demonstrates that the reduced period is sufficient to protect human health and the environment, and the executive director approves the decrease in writing after review.

(b) The Post-Closure Care Period May be Increased

The length of the post-closure care period may be increased by the TCEQ executive director if it is determined that the longer period is necessary to protect human health and the environment.

V. Recordkeeping

The site operator will place a copy of this post-closure plan in the facility's site operating record by the initial receipt of waste at the units proposed at the time of this application. Also, the site operator will document and maintain records of all inspection, monitoring, maintenance, repair, or remediation activities, and detail the results of any inspection and schedules of any other actions to be taken to maintain compliance, in the site operating record.

VI. Planned Use of the Land during and after the Post-Closure Care Period

Post-closure use of the property will not disturb the final cover, liners, or other containment or monitoring systems unless such disturbance is necessary for the proposed use or to protect human health and the environment and is authorized by the TCEQ executive director consistent with provisions under 30 TAC Chapter 330 Subchapter T.

Description of the Planned Use of the Land during or after the Post-Closure Care Period *(describe the planned use of the land during or after the post-closure care period; if not known at this time, enter "NOT KNOWN")*:

NOT KNOWN

VII. Post-Closure Care and Corrective Action Cost Estimates

A detailed written cost estimate in current dollars for conducting post closure care is provided in *(enter location of the post-closure care cost estimate in the application/permit document)*:

Part III, Attachment 8 - Closure and Post-Closure Cost Estimates

The cost estimate for corrective action will be provided as needed, via a permit modification, during the life and/or post-closure care period of the unit or facility.

VIII. Certification of Completion of Post-Closure Care

Upon completion of the post-closure care maintenance period for each municipal solid waste landfill unit, the site operator will submit to the TCEQ executive director for review and approval a certification, signed by an independent licensed professional engineer, verifying that post-closure care has been completed in accordance with the approved post-closure plan. The submittal to the executive director shall include all applicable documentation necessary for the certification of completion of post-closure care. These will include information relating to the condition and status of:

- The final cover integrity and stability, including the condition of the soil, vegetation, drainage structures, etc.

- Groundwater quality at the site, as determined from on-going groundwater detection or assessment monitoring or corrective measures data during the period.
- Landfill gas (methane) migration, as determined from on-going landfill gas monitoring and remediation data during the period.
- Leachate generation rate and quantity as determined from on-going leachate management data over the period.
- The surface water management system.
- Access control structures.

The engineer's certification of post-closure will show that, based on a summary of monitoring and inspection results, the final cover system continues to maintain its integrity, stability, and function; groundwater remains uncontaminated and monitoring is no longer required; landfill gas is not migrating beyond the facility boundary or accumulating in structures at action levels and monitoring is no longer required; leachate generation rate and quantity will not result in greater than 12 inches of head above the liner, no breakouts have occurred, and all slopes remain as approved and leachate management is no longer required; the surface water management system continues to function as designed; and the access control structures remain intact.

Documentation supporting the professional engineer's certification will be furnished to the TCEQ executive director upon request and will be maintained in the site operating record until the executive director acknowledges termination of post-closure in writing.

IX. Voluntary Revocation Request

Upon completion of the post-closure care period for the final unit at the facility, the site operator will submit to the executive director a request for voluntary revocation of the facility permit.

X. Attachments

The following figures and documents are attached as part of this post-closure care plan:

A. Drawings:

Attachment 1, Drawings 1.2-1.4, Detailed Facility Layout, Sequence Plan, and Excavation Plan.

Attachment 2, Drawings 2.1-2.4, Cross Section Layout Plan and Fil Cross-Sections.

Attachment 3, Drawings 3.1-3.3, Landfill Completion Plan.

Attachment 11, Drawing 11.1, Gas Monitoring Plan.

Attachment 12, Drawings 12.1-12.2, Leachate Collection System Layout Plan.

B. Documents:

Part III, Attachment 7 - Groundwater Sampling and Analysis Plan

Part III, Attachment 9 - Final Closure and Post-Closure Plan

XI. Engineer's Seal and Signature

Name: Ryan R. Kuntz, P.E. Title: Vice President, Project Director

Date:

Company Name: SCS Engineers Firm Registration Number: F-3407

Professional Engineer's Seal

____

Signature

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
McLENNAN AND LIMESTONE COUNTIES, TEXAS

PART III - SITE DEVELOPMENT PLAN
ATTACHMENT 10
SOILS AND LINER QUALITY CONTROL PLAN

Prepared for:

CITY OF WACO

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER

5/13/2020

Solid Waste Services
501 Schroeder Drive
Waco, TX 76710

Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 – May 2020
SCS Project No. 16216088.00

SCS Engineers
TBPE Reg. # F-3407

TABLE OF CONTENTS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

SECTION **PAGE**

TABLE OF CONTENTS (CONTINUED)

SECTION **PAGE**

Appendices

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER

5/13/2020

SCS Engineers
TBPE Reg. # F-3407

1 INTRODUCTION

1.1 PURPOSE

The following Soil and Liner Quality Control Plan (SLQCP) has been prepared for the City of Waco Landfill (Landfill) in accordance with 30 TAC §330.339. This SLQCP is intended to provide the Owner, Design Engineer, Construction Quality Assurance (CQA) Professional of Record, Contractor, and Geosynthetics Contractor the needed guidance regarding CQA/control during construction of municipal solid waste disposal units at the Landfill. This SLQCP also will provide the CQA Professional of Record the needed guidance for preparing the soil liner and geomembrane liner evaluation reports for each individual cell.

This SLQCP addresses the testing methods and other requirements set forth in the 30 TAC §330.339 of the Texas Commission of Environmental Quality (TCEQ) regulations. The proposed bottom liner system is comprised of the following components (from top to bottom):

- 2-foot-thick soil protective cover;
- Single-sided geocomposite (non-woven geotextile on the top side only of geonet);
- 60-mil high density polyethylene (HDPE) geomembrane (smooth); and
- 2-foot-thick compacted clay liner ($k \leq 1x10^{-7}$ cm/sec); and
- Prepared subgrade (excavation grade).

On sideslopes the liner section will be as follows (from top to bottom):

- 2-foot-thick soil protective cover;
- Double-sided geocomposite (non-woven geotextile on both sides of geonet);
- 60-mil textured HDPE geomembrane (textured on both sides);
- 2-foot-thick compacted clay liner ($k \leq 1x10^{-7}$ cm/sec); and
- Prepared subgrade (excavation grade).

These bottom and sideslope liner systems are depicted on Drawing 6C.1 (Attachment 6C – Groundwater Protection Plan) as required by 30 TAC §330.339(a)(1) and §330.339(b)(2)(A). The design of the leachate collection system components are described in Attachment 12 – Leachate and Contaminated Water Management Plan. Additional guidance and technical requirements for the liner, leachate collection system, and related construction will also be presented in the construction plans and technical specifications prepared prior to construction of waste disposal cell.

This SLQCP includes the CQA requirements for the following:

- Subgrade and General Fill;
- Low Permeability Soil Liner;
- Geosynthetics (geomembrane, drainage geocomposite, and geotextiles);
- Leachate Collection Piping;
- Drainage Aggregate; and
- Protective Cover.

This SLQCP, which will be followed during liner construction, outlines materials selection and evaluation, laboratory test requirements, field test requirements, and treatment of problems for the components described above. This SLQCP also includes reporting requirements for soil liner and geomembrane liner evaluation reports for the CQA of soil liner and geomembrane liner components of the liner system.

1.2 DEFINITIONS

Whenever the terms listed below are used, the intent and meaning shall be interpreted as indicated.

1.2.1 ASTM

This means the American Society for Testing and Materials.

1.2.2 Construction Quality Assurance (CQA)

A planned system of activities that provides the owner and permitting agency assurance that the facility will be constructed as specified in the design (EPA, 1993). CQA includes observations and evaluations of materials and workmanship necessary to assess and document that construction has been performed consistent with the applicable contract and permit documents. CQA refers to measures taken by the CQA geotechnical professional and/or CQA monitor to assess if the bottom and sideslope liner systems construction has been in compliance with the permit drawings and this SLQCP for the site.

1.2.3 CQA Geotechnical Professional (GP)

The GP is an authorized representative of the Owner and has overall responsibility for CQA and confirming that the bottom and sideslope liner systems have been constructed in general accordance with the permit application, as approved by the TCEQ, and the construction plans and technical specifications. The GP must be a Professional Engineer licensed in Texas with experience in either solid waste engineering and/or geotechnical engineering. Alternatively, a GP may be a geologist with experience in geotechnical testing and the evaluation of engineering properties of soils for liner systems which involve in-situ or compacted soil, provided the geologist is acting in compliance with the provisions of the Texas Engineering Practice Act.

The GP must show competency and experience in certifying similar installations and be presently employed by or practicing as a solid waste engineer, geotechnical engineer or as an engineering geologist in a geotechnical/environmental engineering organization. The credentials of the GP must meet or exceed the minimum requirements required by the TCEQ. The GP will be the professional of record, who signs the Soil Liner Evaluation Report (SLER) and Geomembrane Liner Evaluation Report (GLER) for the respective liner system construction.

1.2.4 CQA Monitors

These are representatives of the GP who work under direct supervision of the GP. The CQA Monitor is responsible for quality assurance monitoring and performing on-site tests and observations. A qualified Lead CQA Monitor shall have a minimum of two years of directly related experience; or be a graduate engineer or geologist with one year of directly related experience. A junior CQA Monitor may work under the direct supervision of the Lead CQA Monitor or the GP and may have less than one year of directly related experience. The CQA Monitor is onsite full-time during subgrade preparation, liner system construction, and leachate collection system construction and reports directly to the GP. Any references to monitoring, testing, or observations to be performed by the GP should be interpreted to mean the GP or CQA Monitor working under the GP's direction.

1.2.5 Construction Quality Control (CQC)

These actions provide a means to measure the characteristics of an item, material, or service to comply with the requirements of the contract or permit documents. CQC actions will be performed by the Contractor or manufacturer of materials. All quality control testing shall be performed prior to or during construction of the liner. In no instance shall quality control field or laboratory testing be undertaken after completion of liner construction.

1.2.6 Contract Documents

These are the official set of documents provided by the Owner. The documents include bidding requirements, contract forms, contract conditions, technical specifications, construction plans, addenda, and contract modifications.

1.2.7 Technical Specifications (or Specifications)

These are the qualitative requirements for products, materials, and workmanship upon which the construction contract is based.

1.2.8 Contractor

This is the person or persons, firm, partnership, corporation, or any combination, who as an independent contractor, has entered into a contract with the Owner.

1.2.9 Design Engineer

These individuals or firms are responsible for the design and preparation of the project construction drawings and technical specifications; also referred to as "designer" or "engineer."

1.2.10 Earthwork

This is a construction activity involving the use of soil materials as defined in the technical specifications.

1.2.11 Geomembrane Liner

This is a synthetic lining material, 60-mil high-density polyethylene (HDPE), also referred to as geomembrane, membrane, liner, or sheet. Geomembrane liner will be smooth when installed on the floor and textured on both sides when installed on the sideslope.

1.2.12 Geomembrane Liner Evaluation Report (GLER)

Construction certification report for the geomembrane liner prepared and sealed by the GP that is submitted to the TCEQ for approval.

1.2.13 Geosynthetics Contractor

This individual is also referred to as the "contractor," and is the person or firm responsible for geosynthetic construction and/or installation. This definition applies to any person installing geomembrane, geotextile, geocomposite, or other geosynthetic materials, even if not their primary function.

1.2.14 Seasonal High Water Level

The highest measured or calculated water level in an aquifer during investigations for a permit application and/or any groundwater characterization studies at a facility (30 TAC §330.3(137)).

1.2.15 Nonconformance

This is a deficiency in characteristic, documentation, or procedure that renders the quality of an item or activity unacceptable or indeterminate. Examples of non-conformance include, but are not limited to, physical defects, test failures, and inadequate documentation.

1.2.16 Operator

The organization that will operate the landfill disposal unit.

1.2.17 Operator's Representative

This is the person that is an official representative of the operator responsible for planning, organizing, and controlling the construction activities.

1.2.18 Panel

This is a unit area of geomembrane, which will be seamed in the field.

1.2.19 Soil Liner Evaluation Report (SLER)

Construction certification report for the soil liner prepared and sealed by the GP that is submitted to the TCEQ for approval.

1.2.20 Quality Assurance Laboratory

The firm(s) responsible for conducting tests on borrow and clay liner samples taken from the site, as well as testing of geomembrane index properties and field seams obtained during destructive field sampling. Multiple laboratories can be used.

2 SUBGRADE AND GENERAL FILL

2.1 SUBGRADE

Subgrade refers to a surface that is exposed after stripping topsoil or excavating to establish the grade directly beneath the bottom liner system. Grading of the prepared subgrade should generally conform to Part III, Attachment 1, Drawings 1.3 (East Disposal Area) and Drawing 1.4 (West Disposal Area). It should be noted that if an underdrain system or any other groundwater control system is installed, that this system will be documented by the GP to be capable of sufficiently mitigating uplift forces, water accumulation, seepage, and subgrade softening prior to approval and release of the overall subgrade by the GP for liner construction.

Prior to beginning liner construction, the subgrade area will be stripped to a depth sufficient to remove all loose surface soils or soft zones within the exposed excavation. The subgrade will be proof-rolled with heavy, rubber-tired construction equipment to detect areas subject to pumping caused by excessively wet soils, surface water or groundwater seepage. If soils subject to pumping cannot be disked, dried, or stabilized, these areas will be undercut to firm material and refilled with general fill, as defined in Section 2.2.

Based on visual evaluations, the GP or the CQA Monitor will determine whether additional physical testing methods are necessary to evaluate the excavated or prepared subgrade or subgrade areas where fill is placed. Testing might include shallow test holes, test trenches, density, and moisture testing. Additional proof-rolling may also be required.

The GP will approve the prepared subgrade prior to the placement of the soil liner. Approval will be based on a review of test information, if applicable, and CQA monitoring of the subgrade preparation.

Prior to soil liner construction, visual examination of the subgrade preparation and documentation by the GP must be obtained to confirm that the subgrade is suitable as a foundation for the soil liner. Criteria that may be used for this visual evaluation include, but are not limited to, the following:

- No seepage observed in excavation over a period of time of at least one week;
- No softening of the excavation surface;
- No softness or sheen within secondary features; and
- No water accumulation in low areas of excavation

2.2 GENERAL FILL

General fill material (which may also be referred to as structural or engineered fill) will be used in the establishment of proper subgrade elevations and in the construction of perimeter embankments. General fill will be placed in uniform lifts which do not exceed 8 inches in loose thickness and compacted to at least 95 percent of standard Proctor (ASTM D698) density at a moisture content ranging from -2% to +4% of optimum (as determined by ASTM D698).

For quality control purposes a standard Proctor test will be required at a minimum of at least once per borrow source, and at least one per visual change in soil type or classification (as judged by the GP or CQA Monitor based on visual observation).

For quality assurance purposes in-place density testing will be required by nuclear gauge at a frequency of 1 test per 10,000 square feet, per lift of general fill placed. A minimum of 3 compaction tests will be required per compacted lift for general fill regardless of area.

2.3 SURVEYING AND LANDFILL MARKERS

Field surveying will be conducted to verify the lines and grades of the cell subgrade. A survey grid of one survey point for every 5,000 square feet will be established with additional coverage to confirm compliance with the design grades, including top and toe of slopes and other grade changes. The survey will be used to establish as-built construction information and verify soil liner and protective cover thickness, as described in Section 3.5 and Section 10.3, respectively.

A landfill grid system will be established at the landfill, as described in Part IV – Site Operating Plan, Section 4.7. Prior to construction of new cells, the markers will be extended or restored immediately adjacent to the new cell to allow easy identification during construction. Additionally, SLER/GLER markers consistent with 30 TAC 330.143(b)(6) (see also Part IV, Section 4.7), will be installed at the completion of construction for each cell and will be maintained during operations until operations extend into the next SLER/GLER area.

2.4 CONTROL OF SURFACE WATER

The excavation may be subject to ponded water from storm events. The excavation area will therefore have a down-gradient low area or temporary sump area to collect water entering the excavation, and be graded to allow drainage to this area. Portable pumps will be on-site to dewater the low areas or temporary sump(s). Temporary internal and external diversion berms also will be constructed to divert surface water away from the excavation.

2.5 EXCAVATION BELOW THE SEASONAL HIGH GROUNDWATER TABLE

Portions of the liner system for the landfill extend below the seasonal high groundwater table (SHWT). Due to this condition, certain design and construction methods are required to maintain the stability and integrity of the liner system throughout construction, filling, and post-closure activities.

This section of the SLQCP addresses the issue of cell construction below the SHWT and provides information pertaining to site-specific conditions, analysis and design methods, construction methods, and documentation/reporting procedures to be considered during development of waste disposal cells at the site.

When the base of the cell excavation extends below the SHWT, the stability of the liner system against hydrostatic uplift is considered for two cases: (1) short-term, i.e., during construction and filling operations; and (2) long-term, i.e., after filling and into post-closure. Short-term stability against uplift of the liner system may be required by installation of an active underdrain system if groundwater seepage is observed during construction over an extended period of time (see Section 2.5.1). Underdrain systems constructed beneath the landfill cells prevent development of excessive hydrostatic uplift pressures until an adequate thickness of soils and waste ballast is achieved. Long-term stability against uplift of the liner systems is provided by the weight of the clay liner, liner protective cover, soil ballast, waste materials, and final cover system components, or collectively, ballast. Once an adequate thickness of ballast is provided, underdrain systems, if employed to provide short-term stability, are decommissioned upon approval from the TCEQ.

2.5.1 Control of Seepage During Construction (Short-Term Groundwater Control)

The base of the proposed excavation will be located in the Taylor Group (Wolfe City Formation), shale-marl, portions of which may be below the seasonal high groundwater table. The Taylor Group (Wolfe City Formation) is a highly impermeable shale formation. Based on observation during subsurface investigations, the weathered and unweathered shale at the proposed subgrade elevations is considered to be so poorly permeable that groundwater seepage is not anticipated to occur and, therefore, is not anticipated to move sufficiently to exert force that would damage or cause uplift on the liner system and as such, it is not expected to require short-term groundwater control. These conclusions are based on the results of the slug tests summarized in Attachment 4 – Geology and Groundwater Report, Section 6, and further described in Section 2.5.2 below. Consistent with 30 TAC §330.337(b)(3), this will be verified by the GP's observations during construction.

Based on the groundwater investigations at the site presented in Attachment 4 (see Section 6), seepage (i.e., measurable quantities of water seeping into the excavations) is not anticipated. However, if seepage is observed in measureable quantities that could be detrimental to the overlying liner or softening of the subgrade, the GP will provide a summary of his observations of the seepage, the methods and procedures used to control the seepage and stabilize the foundation soils, and verification that the seepage has been controlled prior to liner placement. If seepage is observed from an area for a period of greater than one week during construction, an underdrain system to control seepage will be employed for that cell area, and the design of the underdrain system will be confirmed using the calculation mythology presented in Appendix 10D. Any underdrain system installed within a respective cell will be documented in the SLER and GLER for the respective constructed cell. This underdrain design presented in Appendix 10D is based on the assumed SHWT map described in Section 2.5.3 and presented in Appendix 10B.

2.5.2 Weathered/Unweathered Shale Hydraulic Conductivity Analysis

Hydraulic conductivity test results (aquifer slug tests) for the weathered and unweathered shale formations (Units II and III) are provided in Attachment 4. The travel time for groundwater in the formations at the site was also calculated, as summarized in Attachment 4, Table III-4.13. As indicated by this data, the highest recorded groundwater movement at the site is estimated to be approximately 0.035 feet/year, which is consistent with groundwater movement through sediments with very low hydraulic conductivity. Based on this groundwater velocity value, the time for groundwater to travel one foot would be greater than 28 years. Therefore, sufficient ballast will be placed prior to the liner system experiencing any potential hydrostatic uplift.

However, as indicated in Section 2.5.3, a SHWT map has been developed for an assumed potentiometric surface for designing an underdrain system and evaluating ballast, if needed, for short- and long-term groundwater control, respectively. The assumptions and calculations for the ballast evaluation and underdrain design are described in Section 11.5 (see also Appendix 10C) and Appendix 10D, respectively.

2.5.3 Seasonal High Groundwater Table

A SHWT map has been developed based on standard standpipe piezometers and vibrating wire piezometers (VWPs) installed at the site during the subsurface and groundwater investigation (see Attachment 4, Section 6). Based on the observations presented in Attachment 4, the shallow occurrences of groundwater do not appear to be uniform across the site and may occur in isolated pockets; there exists a continuously saturated groundwater zone that occurs at deeper elevations below the base of the proposed excavation grades; and the shallow and deep occurrences of groundwater do not appear to be hydraulically connected. However, as a conservative approach to sizing underdrain components for short-term groundwater control and evaluating long-term groundwater control (waste or soil ballast), if needed, the SHWT map was developed with a culmination of high water level readings from both the shallow standpipe piezometers/VWPs and deep VWPs installed at the site during the groundwater investigation. This SHWT map, provided in Appendix 10B, depicts the measurement points, including the seasonal high groundwater table (SHWT) levels, and future excavation grades. As shown on the map, portions of the excavation grades extend below this assumed SHWT.

As noted in this SLQCP, the SHWT map will be reviewed and updated, if necessary, prior to the design of each cell based on the most recent data available at the time of design. If the groundwater elevations at monitoring points has increased since the last cell construction, the SHWT map will be revised upward to reflect those increases. An updated SHWT map will be presented in the SLER and GLER. In addition, observations of the subgrade soil characteristics and indications of groundwater seepage (if any) and potential impacts to the dewatering and ballast calculations will also be documented in the SLER and GLER.

3 LOW PERMEABILITY SOIL LINER

3.1 INTRODUCTION

Construction of the soil liner will begin after excavation, embankment construction, subgrade preparation, and grading to excavation grades has been completed. For this landfill, the soil liner constructed for all waste disposal cells will be a 2-foot thick compacted soil (clay) liner, as described in Section 1.1.

Soil for the soil liner must achieve an installed permeability of $1x10^{-7}$ cm/s or less; a liquid limit (LL) of 30 or greater; a plasticity index (PI) of 15 or greater; percent passing the No. 200 sieve of 30 percent or greater; and 100 percent passing the 1-inch sieve (i.e., no particles greater than 1 inch in size) with no more than 10 percent rocks by weight. The final lift of the soil liner shall not contain rock or other deleterious materials that can cause damage to the overlying geomembrane.

3.2 QUALITY ASSURANCE TESTING

3.2.1 Pre-Construction Testing

Pre-construction testing will be performed for each liner material borrow source and for each identifiable change in material from an individual borrow source (i.e., change in color and plasticity or gradation based on visual observation by the GP or CQA Monitor). A change in color only (with same gradation and plasticity characteristics) will not be considered a change of material. Testing will be performed according to the testing schedule set forth in Table 10-3-1. Density test results will be reported as a percentage of the maximum dry density at a corresponding optimum moisture content.

For each borrow source, correlations will be developed based on moisture-density tests and permeability tests (performed on soil samples at a calculated density) of representative soil samples demonstrating that the soils will have the required permeability at the specified level of compaction. Correlation testing will be provided to GP and CQA Monitor for use in the field during soil liner construction.

Table 10-3-1. Soil Liner Pre-Construction Testing Schedule

TEST	METHOD USED	FREQUENCY
Soil Classifications: USCS	ASTM D2487	1 per soil type / minimum 1 per borrow source
Sieve Analysis	ASTM D422 or D1140	
Atterberg Limits	ASTM D4318	
Moisture/Density Relationship	ASTM D698	
Hydraulic Conductivity (1)	ASTM D5084 (2)(3)	1 per Moisture-Density Relationship

1. Field testing of permeability (in accordance with ASTM D5093) is optional, and may be replaced by laboratory testing.
2. Testing procedures in Appendix VII of the Corps of Engineers Manual EM 1110-2-1906, November 30, 1970, Laboratory Soils Testing, may be used as an alternative method.
3. Permeability tests will be conducted with tap water or 0.05N solution of $CaSO_4$. Distilled water will not be allowed.

3.2.2 Construction Testing

Construction quality assurance for the soil liner will consist of both laboratory and field testing. The minimum frequencies and test methods for testing soil liners during construction are presented on Table 10-3-2. The sampling and test methods used during liner construction will follow the latest technical guidelines of the TCEQ. In accordance with 30 TAC §330.339(a)(2), the GP or CQA Monitor will be on-site during all liner construction activities. Laboratory testing will be performed by an independent geotechnical laboratory.

All quality assurance testing of soil liners will be performed during the construction of the liner. In no instance will any quality assurance field or laboratory testing be undertaken after completion of liner construction, except for that testing which is required of the final constructed lift, confirmation of liner thickness, or cover material thickness. All soil testing and evaluation of the soil liner will be complete prior to installing the geomembrane and leachate collection system on the area under evaluation.

Table 10-3-2. Soil Liner Construction Testing Schedule

TEST	METHOD	MINIMUM FREQUENCY
Field Moisture/Density Test	ASTM D1556, D2167, or D6938	1 per 8,000 ft^2 per 6-inch lift (1)
Sieve Analysis	ASTM D422 or D1140	1 per 100,000 ft^2 per 6-inch lift (2)
Atterberg Limits	ASTM D4318	
Hydraulic Conductivity (3) (4)	ASTM D5084 or CoE EM 1110-2-1906 (5)	
Thickness	Survey	1 per 5,000 ft^2

1. A minimum of three tests must be conducted for each 6-inch lift, regardless of cover area.
2. A minimum of one test must be conducted for each lift, regardless of cover area.
3. Testing will be conducted on undisturbed samples.
4. Permeability tests will be run using tap water or a 0.05N solution of $CaSO_4$. Distilled water will not be allowed.
5. Field testing of permeability (in accordance with ASTM D5093) is optional, and may be replaced by laboratory testing.

3.3 CONSTRUCTION PROCEDURES

3.3.1 General Requirements

During placement of the soil liner following guidelines apply:

- The excavation grade surface should be scarified (roughened) prior to placing the first lift of the soil liner, thus providing adequate bonding between the liner and underlying foundation soils.

- Bottom and sideslope soil liners will be constructed in compacted lifts not exceeding 6 inches. The top of each subsequent lift should be scarified (roughened) to a shallow depth prior to the spreading and compaction of successive lifts, thereby providing bonding between the lifts.

- The soil liners will not be compacted with a bulldozer or any track-mobilized equipment unless it is used to pull a pad-footed roller. The soil liner shall be compacted with a pad-footed or prong-footed roller only. The maximum clod size of the compacted liner soils shall be approximately one inch in diameter. In all cases soil clods shall be reduced to the smallest size necessary to achieve the coefficient of permeability reported by the testing laboratory and to destroy any macrostructure evidenced after the compaction of the clods under density-controlled conditions.

- No loose lift should be thicker than the pads of the compactor so that complete bonding with the top of the previous lift is achieved. The soil liner lifts will be compacted by a minimum 3 passes (back and forth) of the compaction equipment.

- At a minimum, soil liners will be compacted to 95 percent of the maximum dry density and at a moisture content of 0 to +4% above optimum, as determined by ASTM D698. The CQA Monitor will inspect the adequacy of the scarification and compaction effort in providing good lift bonding (i.e., no smooth interface between lifts) during the initial stages of liner installation.

- Although not anticipated since design grades are not this steep, equipment and safety limitations prohibit finished grades with slopes greater than 3H:1V if the liner is constructed parallel to the surface. Compaction equipment placing sideslope liners on slopes steeper than 3H:1V results in reduced stability of compaction equipment, and reduction in compaction efficiency.

- The top surface of the completed soil liner must be sealed with a smooth-drummed roller prior to final liner thickness surveying and placement of the geomembrane liner.

- The surface of the soil liner will be sealed by smooth drumming when construction is to be shut down for more than 24 hours to mitigate the effects of desiccation and wetting from rainfall events. Additionally, smooth drum rolling to seal the surface will be required on a routine basis during the summer months at the end of each day's liner construction to reduce desiccation.

- Any liner perforations required for obtaining laboratory samples will be repaired by backfilling the hole with bentonite chips or 50/50 powdered/granulated bentonite/soil/sand mixture hand-tamped into place. If the hole is in the upper lift of soil liner, the upper 2 inches will be backfilled by clayey liner soil which will be hand-tamped sufficiently to blend the backfill into the adjacent soil liner lift.

- Soil liner construction shall be conducted in a systematic and timely manner, such that the soil liner is not left exposed for an extended period of time. The Contractor will be required to maintain any exposed soil liner in a condition acceptable to the CQA Monitor through the completion and approval of the soil liner, and during placement of the geomembrane over the soil liner.

3.3.2 Liner Tie-ins

The leading 10 to 20 feet of the liner will **not** be covered with waste, but instead will be protected to facilitate tie-in with subsequent cell liners. Liners will not be constructed by "butting" the entire thickness of a new liner segment next to the previously constructed section of liner. Soil liner tie-ins will be performed using the following procedures:

- The edge of the previously installed liner will be uncovered, exposed, and cut back on a slope so that the entire existing liner edge is tied to new construction without superimposed construction joints.
- The surface of the existing liner will be scarified (roughened) prior to subsequent soil placement, to further reduce the possibility of construction joints.
- The length of the tie-in area should be at least 5 feet per foot thickness of liner.

3.3.3 Hydrating Liner Soil

Prior to attempting to hydrate (moisture condition by wetting) clayey soils, clod sizes will be reduced by disking, pulverizing, or other method of breaking clods as acceptable to the GP or CQA Monitor. The number of passes required for adequate clod size reduction will be determined in the field between the Contractor and GP, based on soil condition, equipment used, and equipment operation. After applying water, the soil will be mixed and stockpiled, if necessary, to allow adequate time for hydration to occur. The amount of moisture conditioning and time of hydration will be determined in the field by the GP. Water used in hydrating liner soils must be clean and will not have come into contact with waste or any objectionable material.

3.4 PROCEDURES FOR ADDRESSING FAILING TESTS

3.4.1 Failing Field Density Tests

As described in Table 10-3-2, field density tests will be performed at a frequency of 1 test per 8,000 square feet, per lift. In the event a test indicates field density less than specified, the Contractor will be required to moisture condition (either dry or moisten, if needed) the soil, and then re-compact and retest the soil. The entire 8,000 square foot area represented by the failing test will be required to be reworked.

Alternately, the contractor may perform a minimum of 3 additional field density tests spaced no less than 20 feet in a circular pattern surrounding the original failed test, and, if all tests pass field density, the rework area will be limited to the area inside of the circle formed by the passing tests. If one or more of the additional field tests fail, the entire 8,000 square foot area represented by the failed test will require reworking.

In the event of a second failed field density test, the GP will be immediately notified, and a field decision made by the GP regarding conducting a second rework of the area (as described above) or alternately, requiring that an additional Proctor test be performed on the soils comprising the failed test area. If an additional Proctor test is required, the GP will direct the contractor to either obtain soil samples from the failed area, or alternately, from the borrow source from which the failing soils were obtained. Reworking and retesting of the soils will not occur until after the additional laboratory testing has been completed, and the new Proctor test information submitted to the GP or CQA Monitor.

The results of both passing and failing tests will be recorded, and reported within the SLER.

3.4.2 Failing Gradation or Atterberg Limits Tests

As described in Table 10-3-2, gradation and Atterberg limits tests will be performed at a frequency of 1 test per 100,000 square feet, per lift of soil liner (concurrent with permeability tests). In the event of a failing test, the GP will immediately be notified, and the failing laboratory results provided to the GP. If either the LL or the PI varies by 10 or more points when compared against the appropriate moisture/density curve developed for that borrow source, the soil is considered as a separate soil borrow source and a new test series including moisture/density, compaction relationship, sieve analysis and coefficient of permeability should be determined and these results used for field construction control.

Additional test samples will be obtained at a minimum of 3 locations, spaced no less than 20 feet in a circular pattern surrounding the original failed test. If passing results are obtained for the additional test samples, the area defined by the passing tests will be removed, replaced, and retested. If one or more of the additional tests fail, a new sample will be obtained 30 feet (minimum) from the original failed test (along a line radiating from the original failed test through the failing additional test(s)), and in 10-foot (minimum) increments thereafter, until passing test results are obtained. The area requiring removal and replacement ultimately will be defined by passing test results. After removal and replacement, one additional passing test in the approximate center of the reworked area will be required.

3.4.3 Failing Permeability Tests

As described in Table 10-3-2, permeability tests will be performed at a frequency of 1 test per 100,000 square feet, per lift of soil liner (concurrent with gradation and Atterberg limits tests). In the event of a failing permeability test, the GP will immediately be notified, and the failing laboratory results provided to the GP.

Prior to requiring additional permeability sampling and testing, a field density test will be performed at the location of the failed test. If a failing field density test is obtained, the failed area will be defined as described in Section 3.4.1, above, except that additional field density testing will be performed until passing tests are obtained. After reworking and achieving passing field density tests, a new permeability sample will be obtained for testing.

If passing field density tests are obtained at the location of the failed permeability test location, additional Atterberg limits and gradation test samples will be obtained at a minimum of 3 locations, spaced no less than 20 feet in a circular pattern surrounding the original failed test. If passing results are obtained for the additional test samples (Atterberg limits and gradation tests), the area defined by the passing tests will be removed and replaced. If one or more of the additional tests fail, a new sample will be obtained 30 feet (minimum) from the original failed test (along a line radiating from the original failed test through the failing additional test(s)), and in 10-foot (minimum) increments thereafter, until passing test results are obtained. Passing Atterberg limits and gradation test results will be used to define the area requiring removal and replacement. After removal and replacement, a new permeability sample will be obtained and tested, and a passing test obtained prior to approval of the reworked area.

3.5 THICKNESS VERIFICATION

The thickness (minimum 2-foot) of constructed soil liners will be verified by surveying methods. As described in Table 10-3-2, at a minimum, one thickness verification will be performed for every 5,000 square feet of constructed soil liner. Survey locations will be based on pre-established survey grid in accordance with Section 2.3. A minimum of three (3) survey points shall be used for all constructed soil liners regardless of size. All elevation calculations necessary for thickness verification will be included in the SLER submittal.

3.6 HYDROSTATIC CONSIDERATIONS – BALLASTING

Hydrostatic considerations for excavation below the seasonal high groundwater table are described in Section 2.5 of this Attachment.

4 GEOMEMBRANE

4.1 INTRODUCTION

This section describes CQA procedures for the installation of 60-mil high-density polyethylene (HDPE) geomembrane. CQA procedures for drainage geocomposite, geotextiles, and leachate collection piping are discussed in Sections 5 through 8. The overall goal of the CQA procedures is to confirm (1) that proper materials, construction techniques and procedures are used; (2) that the Geosynthetic Contractor implements a quality control plan in accordance with this SLQCP; and (3) that the project is built in accordance with this SLQCP and the project construction plans and technical specifications. The quality assurance program is intended to identify and define problems that may occur during construction and to observe that these problems are avoided and/or corrected before construction is complete.

The GLER, prepared after completion of construction, will document that the constructed facility meets the design intent and technical specifications.

4.2 QUALITY CONTROL AND QUALITY ASSURANCE TESTING

CQC during installation of the geomembrane will be performed by the Geosynthetics Contractor. CQA during installation of geomembrane will be performed by the CQA Monitor to assure that the geomembrane is installed in accordance with this SLQCP and the project construction plans and technical specifications. To monitor compliance, a quality assurance program will include the following:

- A review of the geomembrane manufacturer's quality control submittals.
- Material conformance testing.
- CQA testing, both destructive and non-destructive.
- Construction monitoring and documentation.

Conformance testing refers to activities that take place prior to material installation. Construction testing includes activities that occur during geosynthetic installation. All quality control/assurance monitoring and testing will be conducted in accordance with this SLQCP and the project construction plans and technical specifications. The GP or CQA Monitor will be on-site, and observe all geomembrane installation and testing activities.

4.2.1 Manufacturer's Quality Control

Prior to the installation of the geomembrane, the manufacturer or installer will provide the GP with quality control certificates signed by a responsible party employed by the manufacturer. Each quality control certificate will include roll identification numbers, testing procedures, and results of quality control tests. The quality control tests will be performed in accordance with project-specific testing methods and subject to one test per 100,000 square feet of material or a minimum of one test per resin lot, whichever is greater.

All geomembrane properties must meet the minimum values set forth in the most recent version of Geosynthetic Research Institute (GRI) standard GM-13. UV Resistance testing not required for HDPE that will be immediately covered. A copy of the current version of GRI-GM13 is included in Appendix 10A.

4.2.2 Conformance Testing

Conformance testing refers to testing (by a third-party independent laboratory) performed after manufacture of the geomembrane to verify it meets the required specifications. Conformance testing methods and required frequencies are presented in Table 10-4-1.

Table 10-4-1. Geomembrane Conformance Testing

TEST	METHOD	MINIMUM FREQUENCY
Thickness (laboratory)	ASTM D5199 (1) or D5994	1 per 100,000 ft^2 and every resin lot
Thickness (2) (field)		1 measurement per 5 feet along leading edge of each geomembrane panel.
Density	ASTM D1505 or D792	1 per 100,000 ft^2 and every resin lot
Carbon black content	ASTM D1603	
Carbon black dispersion	ASTM D5596	
Tensile properties (3)	ASTM D638, Type IV	

1. ASTM D5994 for textured geomembrane, D5199 for smooth.
2. No single measurement will be less than ten percent below the required nominal thickness in order for the panel to be acceptable. A minimum of 5 measurements will be made per panel.
3. 2-inch initial gauge length assumed for elongation at break at 2.0 in/min.

4.3 INSTALLATION

4.3.1 Delivery

Upon delivery of the geomembrane, the CQA Monitor will observe that:

- The geomembrane is delivered in rolls and is not folded. Any evidence of folding (other than from the manufacturing process) or other shipping damage is cause for rejection of the material.
- Equipment used to unload and store the rolls does not damage the geomembrane.
- The geomembrane is stored in an acceptable location and in accordance with the manufacturer's recommendations and specifications. The geomembrane must not be stored more than five (5) rolls high. During delivery and storage, the geomembrane must be protected from puncture, dirt, grease, water, mud, mechanical abrasions, excessive heat, or other potentially damaging elements. During storage, the geomembrane shall be raised off the floor/ground to minimize damage.
- All manufacturing documentation required by this SLQCP, as set forth in the technical specifications, has been received and reviewed for compliance with the specifications. This documentation will be included in the GLER.

- The geosynthetics receipt log form has been completed for all materials received.

Damaged geomembrane will be rejected and removed from the site or stored at a location separate from accepted geomembrane. Geomembrane that does not have proper identification or manufacturer's documentation must be stored at a separate location until all documentation has been received, reviewed, and accepted, and will not be incorporated into work until all required documentation is received and reviewed by the CQA Monitor for completeness.

4.3.2 Panel Placement

During panel placement, the CQA Monitor must perform the following:

- Record panel and roll numbers and lengths on the panel placement and/or panel seaming log. Develop field notes documenting panel deployment that depicts the locations of panels, seams, destructive test locations and repairs. These field notes will be used to produce a record drawing of the panel placement to be included in the GLER. Alternatively, the panel placement drawing may be developed from field surveying methods.

- Conduct thickness verification tests at 5 foot intervals along the leading edge, at a minimum of 5 locations per panel. No single thickness measurement will be less than 10% below the required normal thickness.

- Observe the geomembrane surface as it is deployed and record all panel defects and repair of the defects (panel rejected, patch installed) on the repair sheet. All repairs will be made in accordance with this SLQCP, supplemental technical specifications, and located on the record drawing of panel placement.

- Observe that heavy vehicular equipment is not allowed on the geomembrane during handling (low ground-pressure support equipment, such as generators, may be allowed with rub sheet protection, as applicable).

- Observe that there are no angular stones greater than 1 inch in size, construction debris, or other deleterious items immediately beneath the geomembrane within the compacted clay soil liner, which could cause damage to the geomembrane.

- Observe that the geomembrane is placed in a manner that provides good contact with the underlying materials, and that no bridging or stretching over surface features occurs. The subgrade (clay soil liner) under the geomembrane must be smooth-rolled, and maintained in a smooth, uniform, and compacted condition during geomembrane installation. Geomembrane placement methods must be conducted as not to rut or damage underlying clay soil liner.

- Observe that the geomembrane is not dragged across a surface that would damage the material. If the geomembrane is dragged across an unprotected surface, the geomembrane must be inspected for damages and repaired or rejected, as necessary. Record weather conditions including temperature. The geomembrane must not be deployed in the presence of excess moisture (fog, dew, mist, etc.), rain, or high wind. In addition, the geomembrane should not be placed when the air temperature is less than 40°F unless this requirement is waived by the design engineer in writing. Excessive wind is that which can lift and move the geomembrane panels.

- Observe that people working on the geomembrane do not smoke, wear shoes that could damage the geomembrane, or engage in activities that could damage the geomembrane.

- Observe that the method used to deploy the geomembrane minimizes wrinkles and that the geomembrane is anchored to prevent movement by the wind. Wrinkles should be walked-out or removed at the discretion of the CQA personnel. Confirm that the geomembrane is placed in a manner that provides good contact with the underlying soil liner materials, and that no bridging or stretching over surface features occurs.

- Observe that no more panels are deployed than can be seamed on that same day.

- Observe that there are no horizontal seams on sideslopes and that the textured material extends a minimum length beyond the toe of the slope as shown on the construction plans.

The CQA Monitor must inform both the contractor and the GP of any observed variances or unacceptable conditions from above. Note, however, that the CQA Monitor's failure to identify one or more of the above conditions does not relieve the Contractor of responsibility for installing and protecting the geomembrane installation in accordance with the construction plans and technical specifications.

4.3.3 Field Seaming

A seam numbering system must be agreed to by the GP and Contractor prior to the start of seaming operations. One procedure is to identify the seam by adjacent panels. For example, the seam located between Panels 306 and 401 would be Seam No. 306/401.

Trial seam testing will be performed for each of the following events:

- At the beginning of each seaming period per workday and for each seaming apparatus, including in the morning and immediately after each extended break throughout the day.

- After any major change in environmental condition, i.e., temperature, humidity, dust, etc.

- Any time the seaming apparatus is turned off for longer than 30 minutes.

- When seaming different geomembranes, i.e., smooth to textured.

Both the welder and the welding apparatus must be tested for extrusion welding. Only the apparatus must be tested according to the above schedule for fusion welding. Each welder or seamer, whether extrusion or fusion welding, must be tested at least once daily.

Each trial seam shall be at least three (3) feet in length, and 1 foot wide. A minimum of four (4) adjoining 1-inch wide coupons will be die-cut from the test seam. Two field samples will be tested for shear, and two samples tested for peel. The apparatus used for field testing must have a current certificate of calibration issued by the appropriate state or federal agency.

If one of the test seams fails, the trial seam will be repeated and testing performed on the trial seam samples. If the second trial seam fails, two additional trial seams will be performed and tested. Trial seaming and retesting will continue until two consecutive passing test series (i.e., two consecutive trial seams) are achieved for the apparatus, and welder, if applicable (extrusion welding only).

The CQA Monitor must observe all trial welding operations, quantitative testing of each trial weld for peel and shear, and recording of the results on the trial weld form. It is important that the trial welds or seams be completed under conditions similar to those under which the panels will be welded.

CQA documentation of trial seam procedures shall include, at a minimum, the following:

- Documentation that trial seams are performed by each welder and welding apparatus prior to commencement of welding and prior to commencement of the second half of the workday, or after extended break periods throughout the day.

- The welder, the welding apparatus number, time, date, ambient air temperature, welding machine temperatures and trial seam number for each trial seam.

During geomembrane welding operations, the CQA Monitor must observe the following:

- The contractor has the number of welding apparatuses and spare parts necessary to perform the work.

- Equipment used for welding will not damage the geomembrane.

- The extrusion welder is purged prior to beginning a weld until all the heat-degraded extrudate is removed.

- Seam grinding has been completed less than one hour before seam welding, and the upper geomembrane is beveled (extrusion welding only).

- The end of welds more than five (5) minutes old are ground to expose new material before restarting a weld (extrusion welding only).

- The ambient temperature, measured six (6) inches above the geomembrane surface, is between 41° and 104° Fahrenheit.

- The contact surfaces of the geomembrane are clean, free of dust, grease, dirt, debris, and moisture prior to welding.

- The seams are overlapped a minimum of three (3) inches for extrusion and hot wedge welding, or in accordance with manufacturer's recommendations, whichever is more stringent. Panels should be overlapped (shingled) in the down-grade direction.

- No solvents or adhesives are present in the seam area.

- The procedure used to temporarily hold the panels together does not damage the panels and does not preclude CQA testing.

- The panels are being welded in accordance with the plans and specifications. Seams should be oriented parallel to the line of maximum slope. In corners and odd-shaped geometric locations, the number of field seams should be minimized.

- There is no free moisture in the weld area.

- Observe that at the end of each day or installation segment, all unseamed panel edges are anchored with sandbags or other approved devices. Penetration anchors shall not be used to secure the geomembrane.

- If seaming operations are carried out at night, adequate illumination shall be provided and must be approved by the GP.

4.4 SEAM TESTING

During seam testing, the CQA Monitor will perform the following tasks:

- Review technical specifications regarding test procedures.

- Observe that equipment operators are properly trained and qualified to perform their work.

- Observe that test equipment meets project technical specifications.

- Observe that the entire length of each seam is tested in accordance with the specifications.

- Observe continuity testing and record results on the appropriate test log.

- Observe that all testing is completed in accordance with the technical specifications.

- Identify the failed areas by marking the area with a waterproof marker compatible with the geomembrane, and inform the contractor of any required repairs, then record the repair area on the repair log.

- Observe that all repairs are completed and tested in accordance with the project specifications.

- Record all completed and tested repairs on the repair log.

For destructive samples, the CQA Monitor will select locations where seam samples will be cut for laboratory testing. Sample locations should not be disclosed to the Contractor prior to completion of the seam.

Destructive samples must be shipped to the third-party laboratory for seam testing. Test methods and required frequencies are presented in Section 4.4.1. The third-party laboratory must provide test results within 24 hours, in writing or via telephone, to the GP. Certified test results are to be provided within 5 days. The CQA Monitor must immediately notify the GP in the event of a calibration discrepancy or failed test results.

4.4.1 Non-Destructive Testing

Continuous, non-destructive testing will be performed on all seams by the installer. Air pressure testing on dual-track fusion welds and vacuum-box testing for extrusion welds are the only acceptable methods. All leaks must be isolated and repaired by the following procedures:

1. Air-Pressure Testing (GRI GM6) - The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 psi, if possible. The air pump must then be shut off and the air pressure observed after five (5) minutes. A loss of less than 4 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss of 4 psi or more indicates the presence of a seam leak that must then be isolated and repaired by following the procedures described under "Seam Failure Repairs and Retesting." The GP or his/her qualified representatives must observe and record all pressure gauge readings.

2. Vacuum-Box Testing (ASTM D4437) - A suction value of approximately 3 to 5 inches of gauge vacuum must be applied to all extrusion welded seams that can be tested in this manner. Examples of extrusion welded seams that do not easily lend themselves to vacuum testing would be around boots, appurtenances, etc. The seam must be observed for leaks at least ten seconds while subjected to this vacuum. The GP or his/her qualified representative must observe 100 percent of this testing.

4.4.2 Destructive Testing

Destructive seam testing will be performed in accordance with ASTM D6392. Destructive samples shall be taken at a minimum of one location for every 500 linear feet of field seam. The total footage of individual repairs of leaks of more than 10 feet and individual repairs of more than 10 feet for failed seams must also be counted and destructively tested using the same frequency of testing described above. At a minimum, a destructive test must be done for each welding machine used for seaming or repairs. A sufficient amount of the seam must be removed in order to conduct field testing, independent laboratory testing, and archiving of enough material in order to retest the seam when necessary.

Field testing shall include at least two (2) peel test specimens (four (4) when possible for testing both tracks on dual-track fusion welded seams). Independent laboratory testing shall consist of five (5) shear test specimens and five (5) peel test specimens (10 when possible for both tracks of dual-track fusion welded seams). Destructive seam-testing locations shall be cap-stripped and the cap completely seamed by extrusion welding to the parent geomembrane. Capped sections shall be nondestructively tested. Additional destructive test samples may be taken if deemed necessary by the GP or CQA Monitor.

All field-tested specimens from a destructive test location must be passing in both shear and peel for the seam to be considered as passing. Field-tested specimens are determined as passing if the specimen tested in peel fails in film tear bond (FTB) and all test specimens meet the criteria listed in Table 10-4-2. Independent laboratory testing must confirm these field results. The minimum passing criteria for independent laboratory testing are all three of the following:

- At least 4 of 5 specimens tested in the peel mode must fail in FTB.
- At least 4 of 5 specimens from each peel and shear determination must meet the minimum specified values in Table 10-4-2.
- The average value from all 5 specimens from each peel and shear determination must meet the minimum specified value in Table 10-4-2.

The above criteria must be met by both tracks from each dual-track fusion welded seam before it is considered as passing. It should be noted that geomembrane manufacturers may have differing values for their geomembrane sheets and, therefore, the required specific values are not provided herein. Consequently, the manufacturer’s sheet strength values must be provided in order to determine if the test results are passing.

Table 10-4-2. Geomembrane Seam Strength

Property	Qualifier	Unit	Value
Shear Strength	Min.	lb/in	120
Peel Strength:			
Fusion	Min	lb/in	91
Extrusion	Min.	lb/in	78

4.4.3 Seam Failure Delineation

In the event failing tests are obtained at a destructive test location, new destructive test samples will be obtained, a minimum of 10 feet in either direction of the failing test. If one, but not both, of the additional tests fail, further additional destructive testing will be required until passing tests are obtained at both ends of the original destructive test location. A cap will be required for the areas subject to destructive testing, and testing of the cap will be required as set forth in this SLQCP. If more than two failing destructive test locations are observed for a single seam, the

CQA Monitor will have the alternative of requiring the entire seam be removed, and a new seam welded.

In the event more than one failing destructive test are observed for a single welding apparatus, new (passing) trial welds will be required prior to resuming geomembrane welding or seaming with the apparatus. All additional testing shall be at the Contractor’s expense.

4.5 REPAIRS AND RETESTING

All seam leaks and destructive test locations shall be repaired for a distance of at least six (6) inches on each side of the leak or destructive test location. At a minimum, these repairs shall be non-destructively retested in accordance with Section 4.4.1. Destructive testing shall be performed in accordance with Section 4.4.2, or at the discretion of the CQA Monitor.

4.6 REPAIRS

Any portion of the geomembrane with a detected flaw, or which fails a non-destructive or destructive test, or where destructive tests were cut, or where non-destructive tests left cuts or holes, must be repaired in accordance with the specifications. The CQA Monitor must locate and record all repairs on the repair sheet. Repair techniques include the following:

- Patching - used to repair holes, tears, large panel defects, undispersed raw materials, contamination by foreign matter, and destructive sample locations.
- Extrusion - used to repair small defects in the panels and seams. In general, this procedure should be used for defects less than 3/8-inch in the largest dimension.
- Topping – used to repair inadequate seam areas, which have an exposed edge, for lengths of seams under five (5) feet. An extruded weld shall be permitted along the outside edge.
- Capping - used to repair failed welds or to cover seams, less than five (5) feet in length, where welds or bonded sections cannot be non-destructively tested. An extrusion weld or fusion weld shall be allowed.
- Spot welding and seaming – used to repair small tears, pinholes, or other minor, localized flaws.
- Removal - used to replace areas with large defects, greater than five (5) feet in length, where the preceding methods are not appropriate. Also used to remove excess material (wrinkles, fishmouths, intersections, etc.) from the installed geomembrane. Areas of removal shall be patched or capped.

Repair procedures will include the following:

- Abrade geomembrane surfaces to be repaired (extrusion welds only) no more than one hour prior to the repair.

- Clean and dry all surfaces at the time of repair.

- Extend patches or caps at least 6 inches beyond the edge of the defect, and round all corners of patches to a radius of at least 3 inches. Bevel the top edges of patches prior to extrusion welding.

- geomembrane below large caps should be approximately cut to avoid water or gas collection between the two sheets.

4.6.1 Wrinkles

During placement of cover materials over the geomembrane, temperature changes or creep can cause wrinkles to develop in the geomembrane. Any wrinkles which can fold over must be repaired either by cutting out the excess material or, if possible, by allowing the liner to contract by temperature reduction. In no case can material be placed over the geomembrane which could result in the membrane folding. The CQA Monitor must monitor the geomembrane for wrinkles and notify the contractor if wrinkles are being covered by soil. The CQA Monitor is then responsible for documenting corrective action to remove the wrinkles.

4.6.2 Folded Material

All folded geomembrane must be removed. Remnant folds evident after deployment of the roll which are due to manufacturing process are acceptable.

4.6.3 Bridging or Induced Tension

Bridging or Induced Tension: Bridging is defined as areas where the geomembrane is not in contact with the subgrade due to a void in the subgrade or the sheet is pulled in tension so as to span over depressions in the subgrade. Areas likely to promote bridging, i.e. trenches, toe of slopes, etc., shall be loaded with sandbags after deployment and after seaming. Induced tension is stress introduced into the geomembrane during installation or covering. These areas will likely result in bridging. Areas with excessive bridging shall be identified and repaired by either of the following methods:

1. The geomembrane shall be cut, by the Contractor, so the tension is relieved and the geomembrane conforms to the subgrade contours. The cut geomembrane shall be repaired and tested according to the specifications regarding repairs and testing.

2. The geomembrane shall be cut, by the Contractor, and subgrade material shall be added and placed, in accordance with the contract specifications, so as bring the geomembrane in contact with the subgrade. The cut geomembrane shall be repaired and tested according to the specifications regarding repairs and testing.

4.6.4 Anchor Trench

An anchor trench will be constructed around all portions of the geomembrane where the leading edge(s) of the geomembrane will not be needed for future tie-in for expansion into the next lined cell. The anchor trench backfill material will be placed as outlined in the technical specifications. Care will be taken when backfilling and compaction to prevent damage to the underlying geomembrane. Slightly rounded corners will be provided in anchor trenches where the geomembrane enters the trench as to avoid sharp bends in the geomembrane.

The geomembrane anchor trench will be left open until seaming is completed. Expansion and contraction of the geomembrane should be accounted for in the liner placement. The anchor trench will be filled in the morning when temperatures are coolest to reduce bridging of the geomembrane.

The anchor trench backfill material will be placed in uniform lifts compacted to at least 90 percent of standard Proctor (ASTM D 698) density at a moisture content ranging from -2 to +4 percent of optimum. Compaction density and moisture of the anchor trench backfill will be visually verified by the CQA Monitor. Specific density and moisture testing of in-place anchor trench backfill will be at the discretion of the CQA Monitor.

4.7 GEOMEMBRANE ACCEPTANCE

The contractor retains all ownership and responsibility for the geomembrane until acceptance by the Owner. In the event the contractor is responsible for placing cover over the geomembrane, the contractor retains all ownership and responsibility for the geomembrane until all required documentation is complete, and the cover material is placed. After panels are placed, seamed, tested successfully, and any repairs are made, the completed installation will be inspected by the Owner's and Contractor's representatives. Any damage or defect found during this inspection will be repaired by the installer. The installation will not be accepted until it meets the requirements of both representatives. In addition, the geomembrane will be accepted by the GP only when the following has been completed:

- The installation is finished.
- All seams have been inspected and verified to be acceptable.
- All required laboratory and field tests have been completed and reviewed.
- All required contractor-supplied documentation has been received and reviewed.
- Record drawings of the panel placement, testing, and repairs have been completed and verified by the GP. The record drawings show the panel dimensions, the location of all panels, seams, destructive tests, and repairs.
- Acceptance of the GLER by TCEQ.

5 DRAINAGE GEOCOMPOSITE

5.1 INTRODUCTION

This section describes CQA procedures for the installation of drainage geocomposite in the liner. All quality control testing will be conducted in accordance with this SLQCP and the project construction plans and technical specifications. The GP or CQA Monitor will be on-site, and observe all geocomposite installation.

5.2 DELIVERY

Upon delivery, the CQA Monitor must observe the following:

- Unloading equipment will not damage the drainage geocomposite rolls.
- Drainage geocomposite rolls are wrapped in impermeable and opaque protection covers.
- Care is used when unloading the rolls.
- All documentation required by the SLQCP and technical specifications has been received and reviewed for compliance.
- Each roll is marked or tagged with the manufacturer's name, lot number, roll number, and roll dimensions.
- Materials are stored in a location that will protect the rolls from precipitation, mud, dirt, dust, puncture, cutting, impact forces, or any other damaging or deleterious conditions.

Any damaged rolls shall be rejected and removed from the site or stored at a location, separate from accepted rolls, designated by the Owner. All rolls which do not have proper manufacturer's documentation shall also be stored at a separate location until all documentation has been received and approved.

5.3 QUALITY CONTROL TESTING

The drainage geocomposite manufacturer (or supplier), will conduct quality control testing in accordance with the manufacturer's quality control program and certify that all materials delivered comply with technical specifications. The material certifications shall be reviewed by the GP and approved for the project prior to acceptance of any of the material.

The geocomposite manufacturer also shall certify that geocomposite transmissivity meets or exceeds the transmissivity requirements set forth in the technical specifications (see Attachment 12 – Leachate and Contaminated Water Management Plan for transmissivity requirements). The manufacturer shall further certify that transmissivity results meet or exceed all requirements for the gradient and confining pressures listed in the technical specifications. If alternate gradient or confining pressures are used for the certification, the geocomposite manufacturer shall certify that the material meets or exceeds the technical specification requirements. However, even with the manufacturer's certification, the GP reserves the right to reject any materials not meeting the transmissivity requirements, including gradient and confining pressure requirements.

5.4 INSTALLATION

5.4.1 Surface Preparation

Prior to geocomposite installation, the CQA Monitor must observe the following:

- All lines and grades have been verified by the Contractor.
- All debris, soil, dust and other materials shall be removed from the geomembrane surface being prepared prior to deployment of the overlying geocomposite.
- When placed over a geomembrane, the geomembrane installation, including all required documentation, has been completed.
- The supporting surface does not contain stones that could damage the geocomposite or the geomembrane.

5.4.2 Placement

During placement, the CQA Monitor must perform the following:

- Observe the geocomposite as it is deployed and record all defects and disposition of the defects (panel rejected, patch installed, etc.). All repairs are to be made in accordance with the specifications.
- Verify that equipment used to deploy the geocomposite does not damage the geocomposite or underlying geomembrane by handling, trafficking, leakage of hydrocarbons, or by other means.
- Verify that people working on the geocomposite do not smoke, wear shoes that could damage the geocomposite, or engage in activities that could damage the geocomposite or underlying geomembrane.
- Verify that the geocomposite is anchored to prevent movement by the wind (the contractor is responsible for any damage resulting to or from wind blown geocomposite. Use sandbags, or equivalent, to prevent bridging).
- Verify that the geocomposite remains free of contaminants such as soil, grease, fuel, etc.
- Observe that the geocomposite is laid smooth and free of tension, stress, folds, wrinkles, or creases.
- Observe that on slopes the geocomposite is secured in the anchor trench and then rolled or lowered down the slope in a controlled fashion.

- Observe that adjacent rolls of geocomposite are overlapped, tied, and seamed in accordance with the manufacturer's recommendations and the specifications.

- Observe that the geonet components are tied at the specified interval with plastic fasteners. In the absence of other specifications, the adjoining geonet panels will be tied approximately every 5 feet along the roll length (edges) and every 1 foot along the roll width (ends).

- Observe that geotextile component is overlapped and either thermal bonded or sewn together.

- All seams should run parallel to the line of the slope. Seams shall be overlapped a minimum of four (4) inches. Typing material shall be white or yellow for easy inspection. Metallic material shall not be allowed. The geotextile shall then be overlapped and sewn.

5.5 REPAIRS

Repair procedures include the following:

- Holes or tears in the drainage geocomposite will be repaired by placing a geocomposite patch extending 2 feet beyond the edges of the hole or tear.

- Secure patch to the originally installed geocomposite by tying every 6 inches.

- Where the hole or tear width across the roll is more than 50 percent of the roll width, the damaged area will be removed and replaced across the entire roll width.

6 GEOTEXTILES

6.1 INTRODUCTION

This section describes CQA procedures for the installation of geotextiles for liner construction. All quality control testing will be conducted in accordance with this SLQCP and the project construction plans and technical specifications. The GP or CQA Monitor will be on-site, and observe all geotextile installation.

6.2 DELIVERY

During delivery the CQA Monitor must observe the following:

- Unloading equipment will not damage the geotextile rolls.
- Geotextile rolls are wrapped in impermeable and opaque protection covers.
- Care is used when unloading the rolls.
- All documentation required by the SLQCP and technical specifications has been received and reviewed for compliance.
- Each roll is marked or tagged with the manufacturer's name, lot number, roll number, and roll dimensions.
- Materials are stored in a location that will protect the rolls from precipitation, mud, dirt, dust, puncture, cutting, impact forces, or any other damaging or deleterious conditions.

Any damaged rolls must be rejected and removed from the site or stored at a location separate from accepted rolls, designated by the Owner. All rolls which do not have proper manufacturer's documentation must also be stored at a separate location until all documentation has been received and approved.

6.3 QUALITY CONTROL TESTING

The geotextile manufacturer (or supplier), will conduct quality control testing in accordance with the manufacturer’s quality control program and certify that all materials delivered comply with technical specifications. The material certifications shall be reviewed by the GP and approved for the project prior to acceptance of any of the material.

6.4 INSTALLATION

6.4.1 Surface Preparation

Prior to geotextile installation, the CQA Monitor must observe the following:

- All lines and grades have been verified by the Contractor.

- Except where a geotextile is used as wrap around gravel (such as around chimney drains), all debris, soil, dust and other materials shall be removed from the surface being prepared for geotextile deployment.
- When placed over a geomembrane or geocomposite, the underlying material installation, including all required documentation, has been completed.

6.4.2 Placement

During placement, the CQA Monitor must observe the following:

- Observe the geotextile as it is deployed, and record all defects and disposition of the defects (panel rejected, patch installed, etc.). All repairs are to be made in accordance with the specifications.
- Observe that equipment used does not damage the geotextile by handling, equipment transit, leakage of hydrocarbons, or other means.
- Observe that people working on the geotextile do not smoke, wear shoes that could damage the material, or engage in activities that could damage the material.
- Observe that the geotextile is securely anchored as applicable.
- Observe that the geotextiles are temporarily anchored as necessary to prevent movement by the wind.
- Observe that the panels are overlapped in accordance with the construction plans, technical specifications and manufacturer's recommendations.
- Examine the geotextile after installation to confirm that no potentially harmful foreign objects are present.
- Observe that seams (where required) are continuously sewn or thermal bonded in accordance with the manufacturer's recommendations and project specifications.

The CQA Monitor must inform both the Contractor and GP if the above conditions are not met.

6.5 REPAIRS

Repair procedures include the following:

- Patching - used to repair holes, tears and large defects.
- Removal - used to replace areas with large defects where the preceding method is not appropriate.

Holes, tears, and defects must be repaired in the following manner. Soil or other material which may have penetrated the defect must be removed completely prior to repair. If located on a slope, the defect must be patched using the same type of material. On a sideslope, should any tear, hole, or defect exceed 10 percent of the width of the panel, the panel must be removed and replaced. If the defect is not located on a slope, the patch must be made using the same type of material and placed with a minimum of 24 inches overlap in all directions. All geotextile patches should be thermal bonded in place.

7 EQUIPMENT ON GEOSYNTHETIC MATERIALS

Use of construction equipment on the liner system under construction will be minimized to reduce the potential for geomembrane puncture or damage to the other geosynthetic components. The CQA Monitor will verify that small equipment such as generators are placed on scrap geomembrane material (rub sheets) above geosynthetic materials being installed for the liner system. Drainage aggregate and/or protective cover will be placed using low ground pressure equipment, using procedures that do not shove or displace the geosynthetics. The CQA Monitor will verify that the geosynthetics are not displaced while overlying drainage aggregate or protective cover layers are being placed.

Unless otherwise specified by the GP, all lifts of drainage aggregate or protective soil material placed over geosynthetics shall be placed by equipment based on the following guidelines:

Equipment Ground Pressure (psi)	Minimum Lift Thickness (in.)
< 5	12
5 - 8	18
8 - 16	24
> 16	36

No equipment will be left running and unattended over the liner system area under construction.

8 LEACHATE COLLECTION PIPING

8.1 INTRODUCTION

This section describes CQA procedures for the installation of pipe for the leachate collection system. The objective of the following requirements are (1) to assure that proper construction techniques and procedures are used, and (2) that the project is built in accordance with the construction plans and technical specifications. To monitor compliance, a quality assurance program will be implemented that includes (1) a review of the contractor's quality control submittals and (2) construction monitoring.

8.2 DELIVERY

The CQA Monitor will observe the following:

- That upon delivery, the pipe and pipe fittings are in compliance with the requirements of the technical specifications.
- That a pipe laydown area is designated in which the pipe and pipe fittings are protected from excessive heat, cold, construction traffic, hazardous chemicals, and solvents. If the pipe and pipe fittings are stored at a location where other construction materials are present, the CQA Monitor will observe that stacking or insertion of the other construction materials onto or into the pipe and pipe fitting is prohibited. The CQA Monitor will periodically examine the storage area to observe that the pipe fittings are undamaged, and have been adequately protected.
- That upon transporting pipe and fittings from the storage location to the construction site, the contractor will use pliable straps, slings, or rope to lift the pipe. Steel cables or chains will not be used to transport or lift the pipe.
- That the contractor will provide that pipe greater than 20 feet in length will be lifted with at least two support points. The contractor will not drop, impact, or bump into the pipe, particularly at the pipe ends. Pipe and fitting ends must be cleaned of all dirt, debris, oil, or any other contaminant which may prohibit making a sound joint.

The CQA Monitor will document all activities associated with the handling and storage of this material in order to maintain compliance with this portion of the SLQCP plan.

8.3 QUALITY CONTROL TESTING

Prior to the acceptance of the pipe, the pipe manufacturer will provide the CQA Monitor with a quality control certificate for each lot or batch of pipe provided. The quality control certificate will be signed by a responsible party employed by the pipe manufacturer, such as the quality control manager. The quality control certificate will include:

- A description of the pipe delivered to the project, including but not limited to the strength classification, diameter, dimensional ratio, perforations, and production lot.

- Property data sheet including, at a minimum, all specified properties, measured using test methods indicated in the specifications or equivalent.

- A list of quantities and descriptions of materials which comprise the pipe.

- The sampling procedure and results of testing for actual samples manufactured in the same lot as the pipe delivered to the project.

- A certification that property values given in the property data sheet are minimum values and are guaranteed by the pipe manufacturer.

The CQA Monitor will observe that the property values certified by the pipe manufacturer meet all of the technical specifications and that measurements of properties by the pipe manufacturer are properly documented and that the test methods used are acceptable.

8.4 INSTALLATION

8.4.1 Surface Preparation

Prior to pipe installation, the CQA Monitor must observe the following:

- All lines and grades have been verified by the Contractor.

- The area where pipe is to be installed is free of deleterious material which may damage the pipe or underlying geomembrane or might clog the pipe.

- Pipe perforations for leachate collection system are drilled in the pipe prior to delivery to the site, or while in the staging or laydown area, outside of the area where the pipe is to be installed. Drilling will not be allowed over the geomembrane. The pipe shall be cleaned of drill cuttings (inside and out) prior to being placed.

- Pipe perforations are drilled at the correct size and spacing according to the construction plans and technical specifications. Perforations can be either factory-predrilled or field-drilled.

8.4.2 Placement

During pipe and fitting installation, the CQA Monitor will perform the following:

- Observe all pipe, pipe fittings, and joints as the pipe is being laid. The CQA Monitor will observe that pipes and fittings are not broken, cracked, or otherwise damaged or unsatisfactory. Prior to fusing (if required), the pipe installer will provide for a fusion surface area which is clean and free of moisture, dust, dirt, debris of any kind, and foreign material. Prior to gluing (if gluing is required), the pipe and fittings must be clean and dry.

- Observe that the pipe and fittings are being constructed in accordance with technical specifications, manufacturer's recommendations and accepted practices.

- Observe that the people and equipment utilized to install the pipe do not damage the pipe or any other component of the liner system. No butt fusion welding equipment shall be allowed directly on the geomembrane, and no primer or glue shall be used directly over the geomembrane. If butt fusion welding is performed within the cell, a protective piece of geomembrane will be placed beneath welder.

- Observe placement of aggregate chimney drains or protective cover over pipe.

9 DRAINAGE AGGREGATE

9.1 MATERIALS

Granular drainage material around the leachate collection pipes (i.e., chimney drains), and within and above the leachate collection sumps will consist of durable particles of crushed stone, natural gravel, or lightweight aggregate free of silt, clay, or other unsuitable materials. River rock or rounded particles are not suitable as leachate pipe bedding. The aggregate shall have a loss of mass due to calcium carbonate of less than 15 percent (in accordance with J&L Test Designation S-105-89 or ASTM D3042 modified to use a solution of hydrochloric acid having a pH of 5). A minimum one test per borrow source will be required.

Drainage aggregate will be placed using low ground pressure equipment, as specified in Section 7 of this Attachment. Drainage aggregate will be placed by spreading in front of the placement equipment with a minimum lift thickness of 12 inches separating the equipment and the underlying geosynthetics.

The drainage aggregate will meet the following gradation:

Sieve Size Square Opening	Percent Passing
2 inches	100
½ inch	0 – 5

Drainage aggregate of this gradation will meet a minimum permeability requirement of 1×10^{-2} cm/s, therefore no permeability testing is required.

9.2 TESTING

The drainage aggregate shall be tested for gradation and calcium carbonate, in accordance with ASTM C136 and J&L Test Designation S-105-89 or ASTM D3042 modified, respectively, at the supply source at a minimum of 1 test per 3,000 cubic yards or 1 test per lined area or cell (if less than 3,000 cubic yards required). The aggregate shall be free of organics, foreign objects, or other deleterious materials. The physical characteristics of the aggregate shall be evaluated through visual inspection and laboratory classification testing before construction and visual inspection during construction. The drainage aggregate may be tested during construction at the discretion of the CQA Monitor. The test results for the drainage aggregate used in the leachate collection system will be included in the GLER.

10 PROTECTIVE COVER

10.1 MATERIALS

Protective cover will be placed over the drainage geocomposite in accordance with the construction plans and technical specifications. The drainage geocomposite will be covered with a minimum of two (2) feet of protective cover, with exception to the chimney drains and leachate collection sumps. The protective cover shall be free of organics, angular rocks, foreign objects, or other deleterious materials which might damage the geocomposite or underlying geomembrane.

Chimney drains will be installed within the protective cover to provide leachate drainage access to the underlying leachate collection system. Typical chimney drain details are provided in the Attachment 12 drawings. Material requirements for the chimney drain aggregate are described in Section 9 of this SLQCP.

10.2 INSTALLATION

The protective cover layer will be placed using low ground pressure equipment, as specified in Section 7 of this Attachment. The protective cover shall be placed by spreading in front of the placement equipment with a minimum lift thickness of 12 inches of soil separating the equipment and the underlying geosynthetics. Placement methods will be monitored that excessive shoving or stretching of the geosynthetics does not occur. Under no circumstance shall the construction equipment come in direct contact with the installed geosynthetics.

During construction the GP or CQA Monitor will:

- Provide full-time inspection during all periods when protective cover is being installed.
- Verify that survey control staking is performed prior to work. Great care will be required of the surveyor and Contractor that survey stakes are not left in the protective cover after placement and confirmation surveying, or that survey stakes are not broken off and left in the protective cover, or that survey stakes do not perforate the underlying liner system.
- Verify that underlying installed geosynthetics are not damaged during placement operations.
- If damage to geosynthetics occurs, mark damaged geosynthetics and verify that damage is repaired.
- Monitor haul road thickness over geosynthetic installations and verify that equipment hauling and material placement meet equipment specifications.

10.3 THICKNESS VERIFICATION

Coordinate the thickness verification of the protective cover upon completion of placement operations. The thickness (minimum 2-foot) of protective cover will be verified by surveying methods. One thickness verification will be performed for every 5,000 square feet of protective cover. Survey points will correspond to the same locations (survey grid) used for thickness verification of the soil liner (see Section 3.5). A minimum of three (3) survey points shall be used for all constructed areas regardless of size. All elevation calculations necessary for thickness verification will be included in the GLER submittal.

11 DOCUMENTATION

11.1 INTRODUCTION

The quality assurance plan depends on thorough monitoring and documentation of all construction activities. Therefore, the GP and CQA Monitors will document that all quality assurance requirements have been addressed and satisfied. Documentation will consist of daily recordkeeping, testing and installation reports, nonconformance reports (if necessary), progress reports, photographic records, and design and specification revisions to be included in the reports to the TCEQ. Standard report forms will be provided by the GP prior to construction.

11.2 LINER EVALUATION REPORTS

After construction of the bottom and sideslope liner system, a Liner Evaluation Report (LER) will be prepared and submitted to the TCEQ. The LER will include a Soil and Liner Evaluation Report (SLER) for the low permeability soil liner, and a Geomembrane Liner Evaluation Report (GLER) for the geomembrane component of the bottom and sideslope liner systems. At the discretion of the Owner, the SLER may be submitted to the TCEQ for approval in advance of the GLER.

No area may be used for receipt of solid waste until the TCEQ has given confirmation of its acceptance of the SLER and GLER, or 14 days have lapsed from the dates of arrival of the SLER and GLER to the TCEQ MSW Permits Section.

Additionally, as portions of the bottom and sideslope liner will be constructed below the seasonal high groundwater table, the SLER must also discuss observations for groundwater seepage. In the event measureable quantities of groundwater seepage are encountered during excavation or during installation of the soil liner, the procedures described in Section 2.5.1 of this attachment will be implemented (i.e., control of seepage during construction (short-term groundwater control)). However, as mentioned in Section 2.5, groundwater seepage is not anticipated during cell construction. Additionally, due to the poorly permeable characteristics of the underlying formations, sufficient ballast will be placed prior to hydrostatic uplift occurring.

11.3 LINER EVALUATION REPORT (LER) FORMAT

Each LER submittal must include a clearly legible site map, which depicts the grid system on site, graphic scale, north arrow, sectorized fill layout plan, filled area, present active area, and area covered by the current submittal. The site map must show the areas covered by all previous LER submittals with the dates of acceptance by the TCEQ. It may be a printed drawing from a master drawing, which is annotated and updated with each new submittal. In addition, each LER submittal to the TCEQ must include all or part of the following items as appropriate and depending on the constructed elements of the liner:

- All field and laboratory test documentation for liner soils, borrow source test results, and installation test and sample locations plotted on a location plan (SLER);

- All test documentation for leachate collection and protective cover layers (GLER);
- For geomembrane, include manufacturer's certifications, documentation of all manufacturer's and independent testing, seam tests (non-destructive and destructive seam testing), and seaming and repair records (GLER);
- Manufacturer's certification and testing documentation for all geosynthetics (SLER/GLER); and
- Survey documentation of the thickness of the soil liner (SLER), a geomembrane drawing showing locations of panels, repairs, and destructive tests (GLER), leachate collection (GLER), and protective cover layers (GLER).

11.4 INTERIM STATUS REPORT

For any liner that will remain uncovered with waste for a period exceeding 6 months, Interim Status Reports will be prepared and submitted to the TCEQ, in accordance with 30 TAC §330.341(d). Any damaged areas will be repaired promptly. A new report shall be submitted on the new construction for all liners that need repair due to damage.

11.5 BALLAST EVALUATION REPORT (BER)

If ballasting is required, a BER will be prepared and submitted to the TCEQ, in accordance with the requirements set forth in 30 TAC §330.337(j).

The BER will incorporate the following components:

- Summary of soil stratigraphy and soil properties exposed on the bottom and sideslopes of the constructed cell.
- Adjusted seasonal high water table based on groundwater monitoring well data and other site observations.
- Calculation of ballast required, and type of ballast to be used (soil and/or waste), as described in Section 11.5.1.
- Discussion of whether an underdrain system or other dewatering system will be installed, as described in Section 2.5. In the event a dewatering system is required, the design of the dewatering system will be submitted with the SLER, GLER and BER and maintained in the Site Operating Record.
- Method of controlling uplift forces during construction (low-permeability foundation soil, dewatering, or combination).
- Monitoring of dewatering system, if required, to demonstrate that hydrostatic forces did not develop during liner construction.

- Subgrade and top-of-liner elevations, as reported in the respective SLER and confirmation of liner weight.

- Certification that ballast met the criteria established in Section 11.5.1 and in the liner quality control plan.

- The BER will be signed and sealed by an independent licensed professional engineer performing the evaluation and will include the signature of the facility operator or their authorized representative.

A BER should be submitted to the TCEQ after sufficient ballast is in place to demonstrate adequate uplift resistance against the long-term seasonal high groundwater table for a given waste phase. If the TCEQ provides no response within 14 days of the date of receipt of the BER, the Owner may discontinue the operation of the underdrain system, in the event a dewatering system is installed.

11.5.1 Ballast Calculations (Long-Term Groundwater Controls)

Calculations will be prepared that demonstrate that the weight of the liner system, including ballast, is sufficient to offset any unbalanced upward or inward hydrostatic forces on the liner by a factor of 1.2 (for soil ballast) or 1.5 (for waste ballast). Sample ballasting calculations are provided in Appendix 10C. The unit weight values used in the sample calculations are assumptions only. Field-verified values will be incorporated into the BER.

11.5.2 Soil as Ballast

If soil is to be used as ballast, it will be placed after liner system construction. Soil ballast may include the protective cover, leachate collection system, additional soil over the liner or waste, and intermediate and final cover soils. For soil ballast placed during cell construction, the SLER should include a statement that the soil ballast, or a component of the ballast (i.e. protective cover or additional soil over protective cover) will be documented in the GLER, which will include the following field confirmations and calculations:

- Determine the density of the soil used as ballast. An estimate of soil density will be developed using geotechnical properties developed during soil construction.

- Initial and final survey of the area to receive soil as ballast, which should be accomplished at the same frequency required in this SLQCP for the liner. The top of clay survey or geomembrane survey may be used as the initial survey for soil ballast.

- Calculate the thickness of soil utilized as ballast (from survey), to determine the resulting confining pressure from the soil ballast. The calculated confining pressure for soil ballast will be reduced by a factor-of-safety of 1.2 in accordance with 30 TAC §330.337(b)(1).

11.5.3 Waste as Ballast – 40,000 Pound or Greater Compactor

If waste is a component used for ballast, the approval of the GLER must first be received from TCEQ prior to ballasting. The BER must include (in addition to the items described in Section 11.4) the following documentation and calculations:

- Certification from the landfill operator that the wheeled compactor used to compact the waste weighs no less than 40,000 pounds, and that the compactor was utilized during the entire period of placing the waste ballast.
- Certification from the landfill operator that the type of waste placed in the lower 5 feet was free of brush and large bulky items, which would damage the underlying system or which cannot be compacted to the required density.
- Initial and final survey of the area to receive waste as ballast to determine the thickness of waste. The survey of the top of protective cover can be used as the initial survey.
- Calculation of the confining pressure of the waste by assuming a density of 1,200 pounds per cubic yard in accordance with 30 TAC §330.337(h)(2). The confining pressure for the waste ballast will be reduced by a factor-of-safety of 1.5.

11.5.4 Waste as Ballast – Less Than 40,000 Pound Compactor

If a less than 40,000 pound compactor is used, calculations to determine the in-place density of waste will be performed. These calculations will include the following:

- Initial survey of the area to receive waste as ballast. The survey of the top of the protective cover may be used for this initial survey.
- Weight of waste placed, based on actual measurements of truck weights at the scalehouse.
- Survey of the top of waste to document that the thickness calculated in the GLER has been placed.
- Calculate the volume of waste used as ballast from the survey. The actual density of the placed waste will be calculated by dividing the previously recorded weight by the volume of waste determined by the survey. The calculated density will be used in the ballast calculations. In the event the calculated density is greater than 1,200 pounds per cubic yard, a density of 1,200 pounds per cubic yard will be used for the ballast calculations. As previously stated, the confining pressure for the waste ballast will be reduced by a factor of safety of 1.5 in accordance with 30 TAC §330.337(h)(2).

APPENDIX 10A

GEOSYNTHETIC RESEARCH INSTITUTE TEST METHOD GM13 (GRI-GM13)

Geosynthetic Institute

475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441

Revision 15: September 9, 2019
Revision schedule on pg. 11

GRI - GM13 Standard Specification*

Standard Specification for

"Test Methods, Test Properties and Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes" SM

1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive

*This GRI standard specification is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version and it is kept current on the Institute's Website <<geosynthetic-institute.org>>.

values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792	Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004	Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238	Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505	Test Method for Density of Plastics by the Density-Gradient Technique
D 1603	Test Method for Carbon Black in Olefin Plastics
D 3895	Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
D 4218	Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199	Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397	Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
D 5596	Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5721	Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885	Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994	Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370	Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
D 6693	Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238	Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
D 7466	Test Method for Measuring the Asperity Height of Textured Geomembranes

2.2 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

Nominal - Representative value of a measurable property determined under a set of conditions, by which a product may be described. Abbreviated as nom. in Tables 1 and 2.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet (see Note 6)

Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

ENGLISH UNITS

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.) - mils • lowest individual of 10 values - %	D5199	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	per roll
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	200,000 lb
Tensile Properties *(1)* (min. ave.) • yield strength - lb/in. • break strength - lb/in. • yield elongation - % • break elongation - %	D 6693 Type IV	 63 114 12 700	 84 152 12 700	 105 190 12 700	 126 228 12 700	 168 304 12 700	 210 380 12 700	 252 456 12 700	20,000 lb
Tear Resistance (min. ave.) - lb	D 1004	21	28	35	42	56	70	84	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	54	72	90	108	144	180	216	45,000 lb
Stress Crack Resistance *(2)* - hr.	D5397 (App.)	500	500	500	500	500	500	500	per GRI-GM10
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	200,000 lb
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (METRIC) UNITS

Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - (min. ave.) - mm • lowest individual of 10 values - %	D5199	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	per roll
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	90,000 kg
Tensile Properties *(1)* (min. ave.) • yield strength - kN/m • break strength - kN/m • yield elongation - % • break elongation - %	D 6693 Type IV	 11 20 12 700	 15 27 12 700	 18 33 12 700	 22 40 12 700	 29 53 12 700	 37 67 12 700	 44 80 12 700	9,000 kg
Tear Resistance (min. ave.) - N	D 1004	93	125	156	187	249	311	374	20,000 kg
Puncture Resistance (min. ave.) - N	D 4833	240	320	400	480	640	800	960	20,000 kg
Stress Crack Resistance *(2)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM-10
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	9,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885	 N. R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness mils (min. ave.) - mils • lowest individual for 8 out of 10 values - % • lowest individual for any of the 10 values - %	D 5994	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	per roll
Asperity Height mils (min. ave.) - mils	D 7466	16	16	16	16	16	16	16	every 2nd roll *(1)*
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	200,000 lb
Tensile Properties (min. ave.) *(2)* • yield strength - lb/in. • break strength - lb/in. • yield elongation - % • break elongation - %	D 6693 Type IV	 63 45 12 100	 84 60 12 100	 105 75 12 100	 126 90 12 100	 168 120 12 100	 210 150 12 100	 252 180 12 100	20,000 lb
Tear Resistance (min. ave.) - lb	D 1004	21	28	35	42	56	70	84	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	45	60	75	90	120	150	180	45,000 lb
Stress Crack Resistance *(3)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM10
Carbon Black Content (range) - %	D 4218 *(4)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 lb
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	200,000 lb
Oven Aging at 85°C *(6), (7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 3895 D 5885	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	per each formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches

(3) SP-NCTL per ASTM D5397 Appendix, is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness (min. ave.) - mm • lowest individual for 8 out of 10 values - % • lowest individual for any of the 10 values - %	D 5994	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	per roll
Asperity Height mils (min. ave.) - mm	D 7466	0.40	0.40	0.40	0.40	0.40	0.40	0.40	every 2nd roll *(1)*
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	90,000 kg
Tensile Properties (min. ave.) *(2)* • yield strength - kN/m • break strength - kN/m • yield elongation - % • break elongation - %	D 6693 Type IV	 11 8 12 100	 15 10 12 100	 18 13 12 100	 22 16 12 100	 29 21 12 100	 37 26 12 100	 44 32 12 100	9,000 kg
Tear Resistance (min. ave.) - N	D 1004	93	125	156	187	249	311	374	20,000 kg
Puncture Resistance (min. ave.) - N	D 4833	200	267	333	400	534	667	800	20,000 kg
Stress Crack Resistance *(3)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM10
Carbon Black Content (range) - %	D 4218 *(4)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	9,000 kg
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(6), (7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 3895 D 5885	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	per each formulation

(1) Alternate the measurement side for double sided textured sheet
(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
(3) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

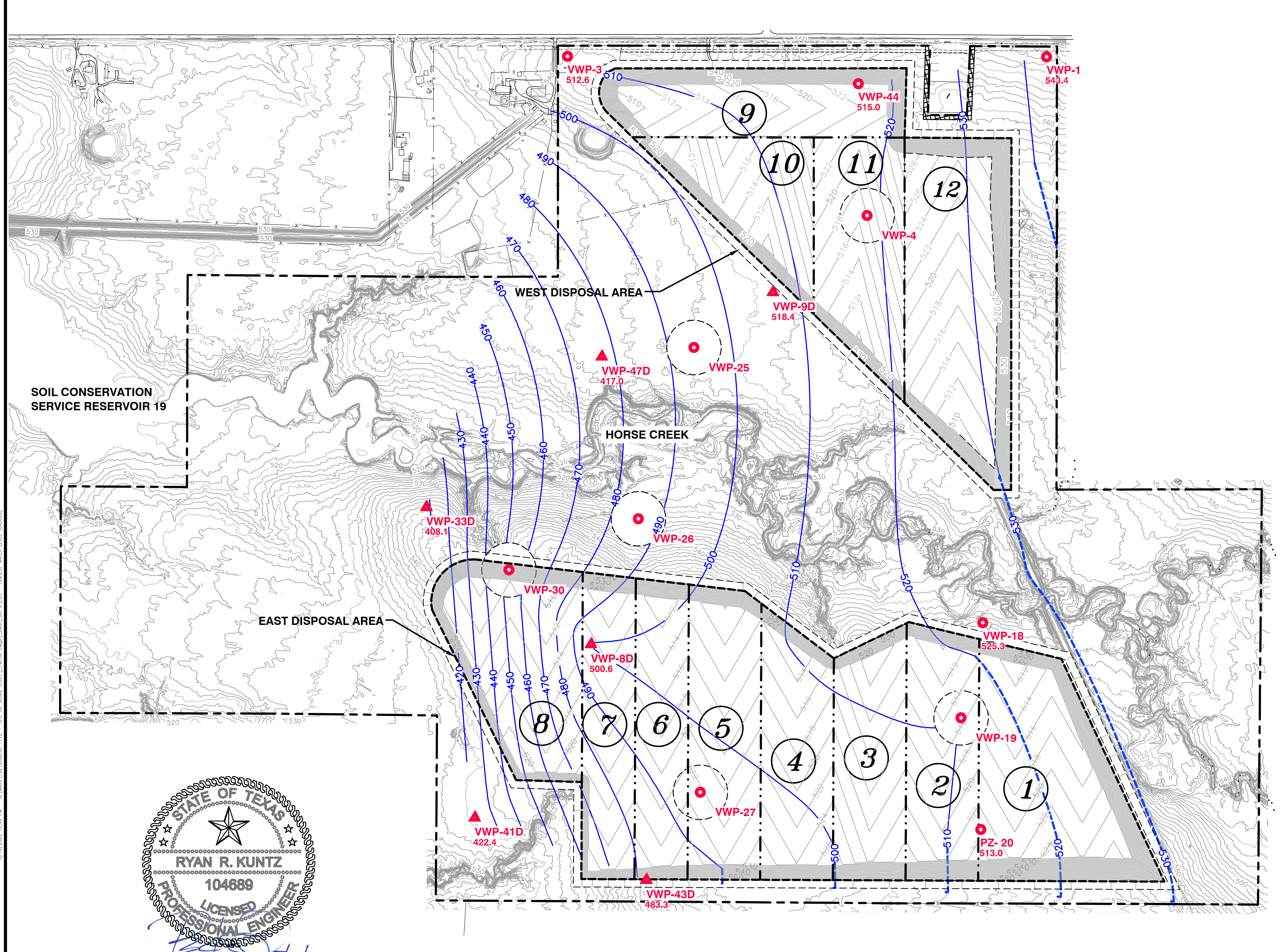
Adoption and Revision Schedule
for
HDPE Specification per GRI-GM13

"Test Methods, Test Properties, Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
Revision 7:	February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
Revision 8:	Removed recommended warranty from specification.
Revision 9:	June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
Revision 10	April 11, 2011: Added alternative carbon black content test methods
Revision 11	December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
Revision 12	November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
Revision 13	November 4, 2015: Removed Footnote (1) on asperity height from tables.
Revision 14	January 6, 2016: Removed Trouser Tear from Note 5.
Revision 15:	September 9, 2019: Editorial update to harmonize tables.

APPENDIX 10B

SEASONAL HIGH GROUNDWATER TABLE MAP



LEGEND

	PERMIT BOUNDARY
	LIMITS OF WASTE
	SECTOR BOUNDARY
535	GROUND ELEVATIONS
510	ASSUMED POSITIVE PRESSURE CONTOURS
510	ASSUMED GROUNDWATER CONTOURS (INFERRED)
PZ-1/VWP-1	PIEZOMETER/VWP LOCATION – SHALLOW (SEE NOTE 3)
VWP-8D	VWP LOCATION – DEEP (SEE NOTE 2)
517.0	CALCULATED/MEASURED GROUNDWATER MSL ELEVATION
PZ-4/VWP-25	PIEZOMETER/VWP LOCATION WITH NO WATER LEVEL DATA
1	SECTOR DESIGNATION

HIGHEST GROUNDWATER RECORDED

PIEZOMETER NAME	ELEVATION	DATE RECORDED
PZ– 20	513.00	09/17/2019
VWP–1	543.40	09/25/2019
VWP–3	512.60	02/25/2020
VWP–8D	500.60	02/25/2020
VWP–18	525.30	12/12/2019
VWP–33D	408.10	02/25/2020
VWP–41D	422.40	02/25/2020
VWP–43D	483.30	02/25/2020
VWP–44	515.00	12/19/2019

NOTE:

1. THE EXISTING TOPOGRAPHY SHOWN ON THIS PLAN WAS DEVELOPED BY DAS GEOSPATIAL FLOWN ON JULY 03, 2018.
2. AT EACH DEEP VWP LOCATION, THERE ALSO EXISTS A SHALLOW STAND–PIPE PIEZOMETER AND SHALLOW VWP (SEE ATTACHMENT 4 FOR MORE INFORMATION).
3. STANDPIPE PIEZOMETERS ARE LOCATED AT THE CORRESPONDING NUMBERED SHALLOW AND DEEP VWP. AS SUCH, STANDPIPE PIEZOMETERS ARE LOCATED AT PZ–1, PZ–3, PZ–8, PZ–9, PZ–18, PZ–20, PZ–33, PZ–41, PZ–43, PZ–47. STANDPIPE PIEZOMETERS ARE NOT LOCATED AT VWP–4, VWP–19, VWP–25, VWP–26, VWP–27, VWP–30, AND VWP–44.

REV. DATE DESCRIPTION BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: HIGHEST RECORDED GROUNDWATER LEVEL MAP

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO 501 SHROEDER WACO, TEXAS 76710

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00 DSN. BY: AB DWN. BY: BJ CHK. BY: AB Q/A RVW BY: JXL APP. BY: JXL

CADD FILE: EXH - HIGHEST WATER LEVEL (043020)

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 10B.1

APPENDIX 10C

SAMPLE BALLAST CALCULATIONS

SCS Engineers
TBPE Reg. # F-3407

Inclusive of Pages 10C-1 to 10C-2

OBJECTIVE: Sample waste-as-ballast calculations were performed for the worst-case scenario (Sector 12) that may experience hydrostatic uplift on the liner based on the currently assumed seasonal high groundwater map (see Appendix 10B). These calculations were performed for hydrostatic uplift at the bottom of the sump at the toe of the excavation sideslope to estimate the thickness of waste required for ballast. See attached Drawing 10C.1, which depicts the waste-as-ballast for the area above the Sector 12 sump (greatest potential hydrostatic uplift).

Groundwater Elevation: **527.9** **ft MSL** [1]   **Sideslope Angle:** **18.4** **Degrees** [2]

Excavation Grade El. (ft MSL)	Hydrostatic Head, H (ft)	Design Hydrostatic Uplift [3] (psf)	Protective Cover Thickness (ft)	Protective Cover Unit Weight (γ_s, pcf)	Unit Weight Waste Ballast (γ_{Waste}, pcf)	Required Waste Ballast Depth (ft)	Permitted Bottom of Final Cover (ft MSL)	Permitted Depth of Waste [4] (ft)
510	17.9	1,675.4	2	110	44	33.1	563.0	46.0
514	13.9	1,301.0	2	110	44	26.2	560.0	42.0
518	9.9	926.6	2	110	44	17.2	557.0	35.0
522	5.9	552.2	2	110	44	8.2	554.0	28.0
526	1.9	177.8	2	110	44	0.0	551.0	21.0
530	0	0.0	2	110	44	0.0	548.0	14.0
534	0	0.0	2	110	44	0.0	545.0	7.0
538	0	0.0	2	110	44	0.0	542.0	0.0

Note:

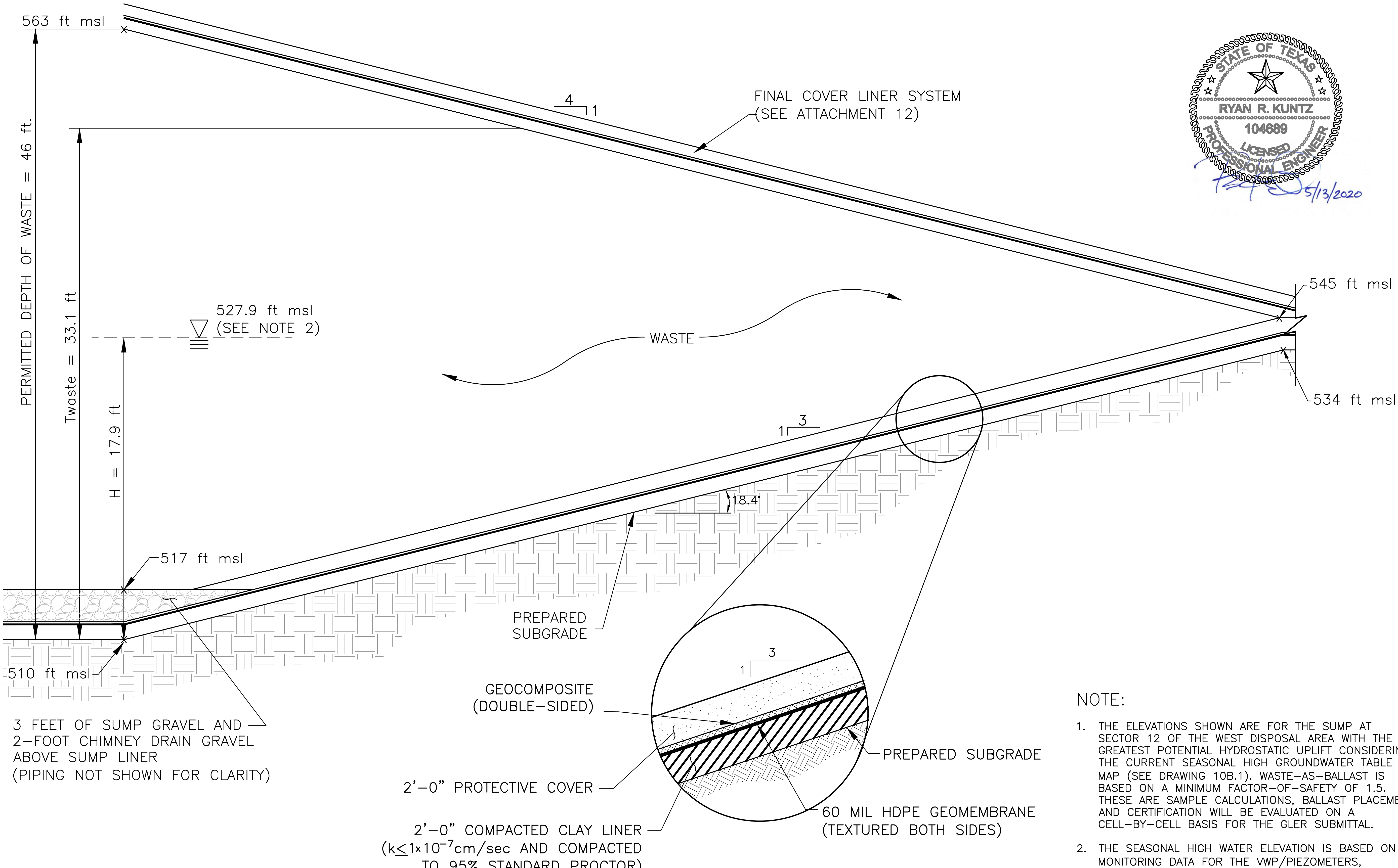
[1] Based on assumed seasonal high groundwater table map (see Attachment 10, Section 2.5.3), measured through February 2020, see Appendix 10B, Drawin

[2] Excavation sideslopes at the landfill are 3H:1V.

[3] In accordance with §330.337(h)(2), the design hydrostatic uplift is based on a minimum factor-of-safety of 1.5 for waste-as-ballast.

[4] The depth of waste on the sideslope has been provided to demonstrate that sufficient capacity is available to achieve ballast. At the lowest point the permitted waste depth is 7 feet above excavation due to sump contents; for all other areas it is 4 feet above excavation for liner components only.

Waste ballast is achievable, as the permitted waste depths are greater than the waste ballast depth requirements. Actual waste-as-ballast depth requirements will be determined on a cell-by-cell basis for the GLER submittal. Ballast placement and certification will be provided in the BER consistent with TCEQ requirements.



WASTE BALLAST EXAMPLE

NTS

NOTE:

1. THE ELEVATIONS SHOWN ARE FOR THE SUMP AT SECTOR 12 OF THE WEST DISPOSAL AREA WITH THE GREATEST POTENTIAL HYDROSTATIC UPLIFT CONSIDERING THE CURRENT SEASONAL HIGH GROUNDWATER TABLE MAP (SEE DRAWING 10B.1). WASTE–AS–BALLAST IS BASED ON A MINIMUM FACTOR–OF–SAFETY OF 1.5. THESE ARE SAMPLE CALCULATIONS, BALLAST PLACEMENT AND CERTIFICATION WILL BE EVALUATED ON A CELL–BY–CELL BASIS FOR THE GLER SUBMITTAL.

2. THE SEASONAL HIGH WATER ELEVATION IS BASED ON MONITORING DATA FOR THE VWP/PIEZOMETERS, THROUGH FEBRUARY 2020 (SEE DRAWING 10B.1).

3. PROPOSED UNDERDRAIN (WHERE EXCAVATION EXTENDS BELOW THE SEASONAL HIGH GROUNDWATER TABLE) IS NOT SHOWN FOR CLARITY.

FOR PERMITTING PURPOSES ONLY

REV | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: WASTE BALLAST EXAMPLE

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00 | DSN. BY: SS | DWN. BY: SS | CHK. BY: RRK | Q/A RVW BY: RRK | APP. BY: RRK

CADD FILE: 10C.1 – WASTE BALLAST

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 10C.1

APPENDIX 10D

TYPICAL UNDERDRAIN DESIGN

SCS Engineers
TBPE Reg. # F-3407

Inclusive of Pages 10D-1 to 10D-8

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
TYPICAL UNDERDRAIN CALCULATIONS

General Information:

1. The sideslopes and bottom of the proposed landfill excavation will generally be within Unit II (weathered silty shale with calcareous content) and/or Unit III (unweathered dark gray to black calcareous shale bedrock with thin, interbedded limestone and sand/silt lenses, and fossils).
2. Site characteristics including permeability are defined in Attachment 4 - Geology and Groundwater Report of the landfill permit
3. The base of the West Development Area (WDA) excavation is approximately 20 to 25 feet below grade. Based on site hydrogeologic data, the geometric mean of the hydraulic conductivity within the unweathered shale was calculated to be $3.07x\ 10^{-8}$cm/sec (see Attachment 4, Table III-4.13 of the landfill permit application).
4. Based upon the assumed Season High Groundwater Table (SHWT) being above portions of the proposed excavation grades, this underdrain design has been provided for guidance in designing an underdrain for use as short-term groundwater control in the event groundwater seepage occurs over an extended period of time within the cell excavation during construction, as described in Attachment 10, Section 2.5.

Method of Analysis:

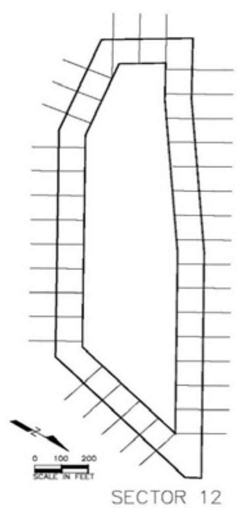
1. Summarize data for future cells and determine worst-case conditions for potential hydrostatic uplift based on the
2. Using the worst-case potential hydrostatic uplift from the available groundwater data, evaluate underdrain design based on maximum drainage lengths to ensure that the entire system will work as designed.
3. Use a flow net to determine base grade flows.
4. Use a confined flow analysis assuming a single source slot, fully penetrating the source saturation zone.

References:

1. Cedergren, Harry, *Seepage, Drainage, and Flow Nets, Third edition* , 1989.
2. Departments of the Army, Navy, and Air Force (NAVFAC P-418), *Dewatering and Groundwater Control* , November 1983.
3. Koerner, R.M., *Designing With Geosynthetics, Third Edition* , 1994.

Solution:

A) **Design the Cell Floor Underdrain:** Based on the worst-case scenario, use plan view flow net to estimate groundwater inflow. Based on the assumed SHWT map (see Appendix10B), the maximum head on the liner in Sector 12, where the liner excavation grade is approximately 510 ft msl and the top of groundwater is approximately 527.9 ft msl, is about 17.9' of hydrostatic head.



Based on the geometric configuration of Sector 12 the following can be concluded:
two draw downs will occur every 200 feet, since flow tubes were spaced every 100 feet
to provide equipotential flowlines into the cell.

N_f = 36 (number of flow tubes spaced at 100 feet)
N_e = 2 (number of head drops to point of no influence 200 feet)

To calculate the flow to the excavation, use NAVFAC, Figure 4-27, Equation (5), Page 4-31.

$Q_T = kDH'S_f$ where:
- Q_T = Total flow
- k = Permeability of saturated zone = 3.07E-08 cm/sec or 6.04E-08 ft/min
- D = saturated zone thickness = 75 feet
- H' = average head on cell floor = 14.5 feet
- $S_f = N_f/N_e$ = 36/2 = 18

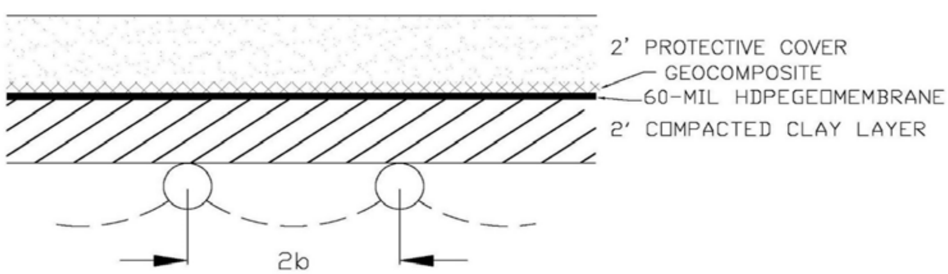
Thickness of saturated zone was assumed as 75 feet due to decreasing permeability with depth and since this is the average height (approximate) of groundwater depth across the proposed excavation.

Q_T =	**0.0088 gallons/minute**	(this included a conversion of 7.48 gallons/cubic foot)
	13 gallons/day	

The overall infiltration rate through the floor area, $q = Q_T$/Area Area = 816,129 square feet Sector 12
18.7 acres

q = 2.09E-06 feet/day = 1.45E-09 feet/min

B) **Design Floor Underdrain Spacing:** using Equation. 9.2, Page 344 from Cedergren. This analysis will determine the required underdrain spacing to relieve uplift pressure on the bottom of the liner (see drawing below).



From Cedergren:

$$\frac{q}{k} = \frac{(h)^2}{(b)^2}$$

where:
- q = infiltration rate = 1.45E-09 feet/min
- k = permeability = 6.04E-08 feet/min
- b = 1/2 of underdrain spacing
- h = excess head between drains = 5.9 feet (see below for calculation)

to calculate h as follows = h is equal to the weight of the liner and protective cover above the underdrain with a factor of safety of 1.2. Do not provide credit for the minimum 1-foot protective pad over the underdrain (to protect it during liner construction).

h = (4 ft)(110 pcf)/(1.2)(62.4 pcf) = 5.9 feet of water

Next, solving for the parameter "b" above to set the spacing:

$$(b)^2 = \frac{(h)^2 k}{q}$$

based on the parameters above then: 1,440 $\text{feet}^2 = b^2$
or b = 37.9 feet
and 2b = 75.9 feet

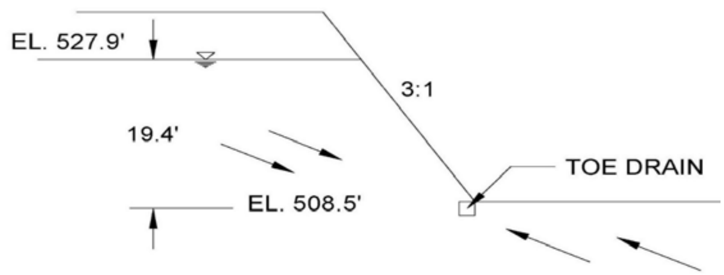
Therefore, an underdrain spacing of 75 feet or less may be required to meet the worst-case design conditions for the landfill:

Use 75 feet center to center for cell floor spacing between underdrain components.

C) **Design the Sideslope Underdrain System**

First, analyze the sideslope seepage.

Based on the proposed sump locations, the assumed SHWT, and as shown in the ballast calculations the sump (and therefore sideslope) in Sector 12 has the highest head on the sideslope. Assume a bottom elevation 18 inches below the sump excavation for the slot drain bottom (see drawing below).



To calculate the flow to the slot drain, use NAVFAC, Figure 4-1, Equation (1), Page 4-2.

$$Q = \frac{kDx}{L}(H - h_e)$$

where: k = permeability = 3.07E-08 cm/sec or 6.04E-08 ft/min
D = saturated thickness = 19.4 feet
x = slot length = (Area/Length of sideslope)
Area of sideslope = 111,549 ft^2
Length of sideslope (below SWHT) = 2,800 feet
x = 40 feet
H = maximum head = 19.4 feet
h_e = head at the drain = 5.9 feet (see intermediate calculation below)
L = point where drawdown occurs (see calculation below for the equivalent "R")

to calculate h_e as follows = h is equal to the weight of the liner and protective cover above the underdrain with a factor of safety of 1.2. Do not provide credit for the minimum 1-foot protective pad over the underdrain (to protect it during liner construction).

h = (4 ft)(110 pcf)/(1.2)(62.4 pcf) = 5.9 feet of water

To determine "L", the point where drawdown occurs, use NAVFAC, Figure 4-23, equation (1), Page 4-24.

$$R = C(H - h_w)\sqrt{k}$$

where: R = radius of influence, equivalent of "L" in above equation
C = coefficient of flow = 3 (for artesian and gravity flows to a well)
H = maximum head = 19.4 feet
$h_w = h_e$ = 5.9 feet
k = permeability = 0.000307 (expressed in units of 10^{-4} cm/sec)

Therefore, R = 0.71 feet

Solving for Q above using L **Q = 0.000889 ft^3/min per foot**

q = infiltration rate = Q/Area (note that area here is equal to the maximum head multiplied by 3 to compensate for the 3H:1V slope)

therefore; q = 8.0E-09 feet/min = 1.15E-05 feet/day

D) Determine the Underdrain Spacing along the Sideslope

Using the same equation that was used to space the underdrain for the cell floor we will use the following equation:

$$(b)^2 = \frac{(h)^2 k}{q}$$

where: q = infiltration rate = 8.0E-09 feet/min
k = permeability = 3.07E-08 cm/sec or
b = 1/2 of underdrain spacing
h = excess head between drains = 5.9 feet

to calculate h as follows = h is equal to the weight of the liner and protective cover above the underdrain with a factor of safety of 1.2. Do not provide credit for the minimum 1-foot protective pad over the underdrain (to protect it during liner construction).

h = (4 ft)(110 pcf)/(1.2)(62.4 pcf) = 5.9 feet of water

based on the parameters above then: 133 feet^2 = b^2
or b = 11.5 feet
and 2b = 23.1 feet

Therefore, an underdrain spacing of 23 feet or less may be requried meet the worst-case design conditions for the landfill:

Use 20 feet center to center for cell sideslope spacing between underdrain components.

E) Size the Underdrain Components Based on Established Spacing

Starting with the bottom underdrain:

i) Under item B), these calculations indicate a spacing of 75 feet center to center was established for the bottom underdrain.
ii) Under item A) these calculations indicate the infiltration rate into the bottom underdrain = 2.09E-06 feet/day
iii) The maximum geocomposite drainage layer length along the bottom underdrain = 293 feet

Using each of these maximums, the required drain capacity is calculated as follows:

Q_{REQD} = (q)(Area of infiltration) = (2.09 E-06 ft/day)(75 ft c-c)(293 feet)(7.48 gallons/ft^3) = **0.34 gallons/day**

Assume the use of a 3-foot wide geocomposite consisting of a geonet with a geotextile heat bonded to each side to transmit this groundwater to the floor drain. The geocomposite strips components have a slope of 1.7%.
For the double-sided geocomposite assume a transmissivity of 2 x 10^{-4} m^3/sec.

Compare the geocomposite capacity to the Q_{REQD} 0.34 gallons/day

For the geocomposite, Q_T = Tiw where: Q_T = Flow in geocomposite under laboratory conditions
T = transmissivity = 2.0E-04 m^2/sec = 1.29E-01 ft^2/min
I = gradient = 0.017 feet/feet
width = 3 feet

Q_T = 70.92 gallons/day

Q_{ALL} = Q_T/FS where: Q_T= Flow in geocomposite under laboratory conditions
Q_{ALL}= Allowable flow taking into consideration factors of safety
FS = 4, assuming FS of 2 for intrusion and 2 for creep

Therefore Q_{ALL}= 17.7 gallons/day which is > 0.34 gallons/day

Therefore, as long as the geocomposite chosen has a transmissivity meeting or exceeding that shown in this calculation, a 75-foot c-c spacing of 3-foot wide geocomposite along the floor will provide adequate pressure relief for the bottom of the excavation.

F) Size the Sideslope Underdrain Components Based on Established Spacing

i) Under item D) of these calculations indicates a spacing of 20 feet center to center was established for the sideslope underdrain.
ii) Under item C) of these calculations indicates the infiltration rate into the sideslope underdrain = 1.15E-05 feet/day
iii) The maximum geocomposite drainage layer length along the sideslope underdrain = 95 feet
(It should be noted that only the portion of the sideslope below the seasonal high groundwater table need be considered here)

Using each of these maximums, the required drain capacity is calculated as follows:

Q_{REQD} = (q)(Area of infiltration) = (1.15 E-05 ft/day)(20 ft c-c)(95 feet)(7.48 gallons/ft^3) = 0.16 gallons/day

For the geocomposite, Q_T = Tiw where: Q_T = Flow in geocomposite under laboratory conditions
T = transmissivity = 1.3E-01 ft^2/sec
I = gradient = 0.33 (3H:1V sideslope)
width = 3 feet

Q_T = 1,391 gallons/day

$Q_{ALL} = Q_T/FS$ where: Q_T= Flow in geocomposite under laboratory conditions
Q_{ALL}= Allowable flow taking into consideration factors of safety
FS = 4, assuming FS of 2 for intrusion and 2 for creep

Therefore Q_{ALL}= 348 gallons/day which is > 0.16 gallons/day

Therefore, as long as the geocomposite chosen has a transmissivity meeting or exceeding that shown in this calculation, a 20-foot c-c spacing of 3-foot wide geocomposite along the floor will provide adequate pressure relief for the bottom of the excavation.

G) Floor and Toe Drain Design:

i) The maximum drain length = 1,500 feet
ii) The minimum slope of drain = 0.01 equivalent of 1% where toe drain parallels leachate collection trench
iii) Use 1' x 1' gravel trench for floor and toe drain
iv) Infiltration for the floor = 2.09E-06 feet/day

Flow to toe drain, $Q_{TD} = (q_{floor})(A_{floor})$

where: Q_{TD} = Total flow to floor drain (gallons per minute)
q_{floor} = Infiltration into floor (feet/day) = 2.09E-06
A_{floor} = Floor Area, Sector 12 (ft^2) = 816,129

Q_{TD} = 13 gallons/day = 0.009 gallons per minute

Use Darcy's law to calculate flow capacity of trench: Q_{trench} = kiA; where;

k = hydraulic conductivity of aggregate, conservatively assumed to be:	1 cm/sec =	2,834.65	ft/day
i = slope of gravel trench, assumed to be:	1 % =	0.01	ft/ft
A = area of gravel trench (1 ft x 1 ft) :	1 ft^2		

$Q_{aggregate}$ = 28.35 ft^3/day
= 212.03 gallons/day

FS = $Q_{aggregate}/Q_{flow}$ = 16.6

Therefore, a gravel trench with an area of 1ft^2, wrapped in a 12-oz geotextile will be sufficient to drain the expected seepage to occur at the cell

H) Underdrain Sump Design

Evaluate the storage capacity of the underdrain sump, based on the specified sump geometry.

Flow to sump, $Q_{TOTAL} = Q_{floor} + Q_{sideslope}$

Q_{floor} = 13 gallons/day

$Q_{sideslope} = (q_{sideslope})(A_{sideslope})$

where: q_{floor} = Infiltration into sideslope (feet/day) = 1.15E-05

A_{floor} = Sideslope Area, Sector 12 (ft^2) = 111,549

$Q_{sideslope}$ = 9.6 gallons/day = 0.007 gallons per minute

Q_{TOTAL} = 22 gallons/day

Selection of Sump Geometry:

Assumed sideslope of sump = (X)H : 1V = 2 ft

Assumed depth of sump = 3 ft

Based on Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook*, 30 TAC 330.201, 1993.

$$V_{TOT} = \frac{X_T^{\,2} h_T}{3} - \frac{X_B^{\,2} h_B}{3} - B$$

Where:

V_{TOT} =	Total sump volume	
X_T =	Length of top side	
X_B =	Length of bottom side	
h_T =	Height of pyramid with (X)H:1V sideslope and width X_T	
h_B =	Height of pyramid with (X)H:1V sideslope and width X_B	

X_T =	15	ft	
X_B =	3	ft	
h_T =	4	ft	
h_B =	1	ft	
B =	11	cu ft	(Pump head vol. of 6" in bottom of sump)
V_{TOT} =	268	cu ft total sump volume	
=	701	gallons capacity	(assumes an aggregate porosity of 0.35)

Based on above calculations, an underdrain sump with dimension of 15 ft x 3 ft x 3 ft will have sufficient capacity to handle the volume of water that may be encountered.

SUMMARY OF RESULTS

Calculations have been performed for an underdrain system for the City of Waco Landfill, since portions of the landfill excavation will be below the assumed SHWT. As indicated in Attachment 10, Section 2.5, the base of the excavation grades will be founded in a low permeabiable weathered/unweathered shale, and therefore it is anticipated that short-term groundwater controls will not be required. However, in the event groundwater seepage is observed during construction over a duration in excess of one week, an underdrain or other sutitable short-term groundwater controls will be installed and documented in the SLER/GLER by the GP.

Calculations were performed at each step for worst-case conditions over the proposed landfill (Sector 12), resulting in an overall design that should have higher factors of safety than those shown and provide a design that is good for all portions of the landfill. The calculations here should be adjusted for site specific considitions of the respective cell cosntruction and as new data becomes available in the future.

FLOOR UNDERDRAIN SYSTEM

Finger drains spaced at 75 ft. c-c were designed for the cell floor excavations. These drains will consist of minimum 3-foot wide geocomposite strips (with non-woven geotextile heat bonded to each side). These drains will be connected to a free-flowing floor drain which drains to a dewatering sump.

SIDESLOPE UNDERDRAIN SYSTEM

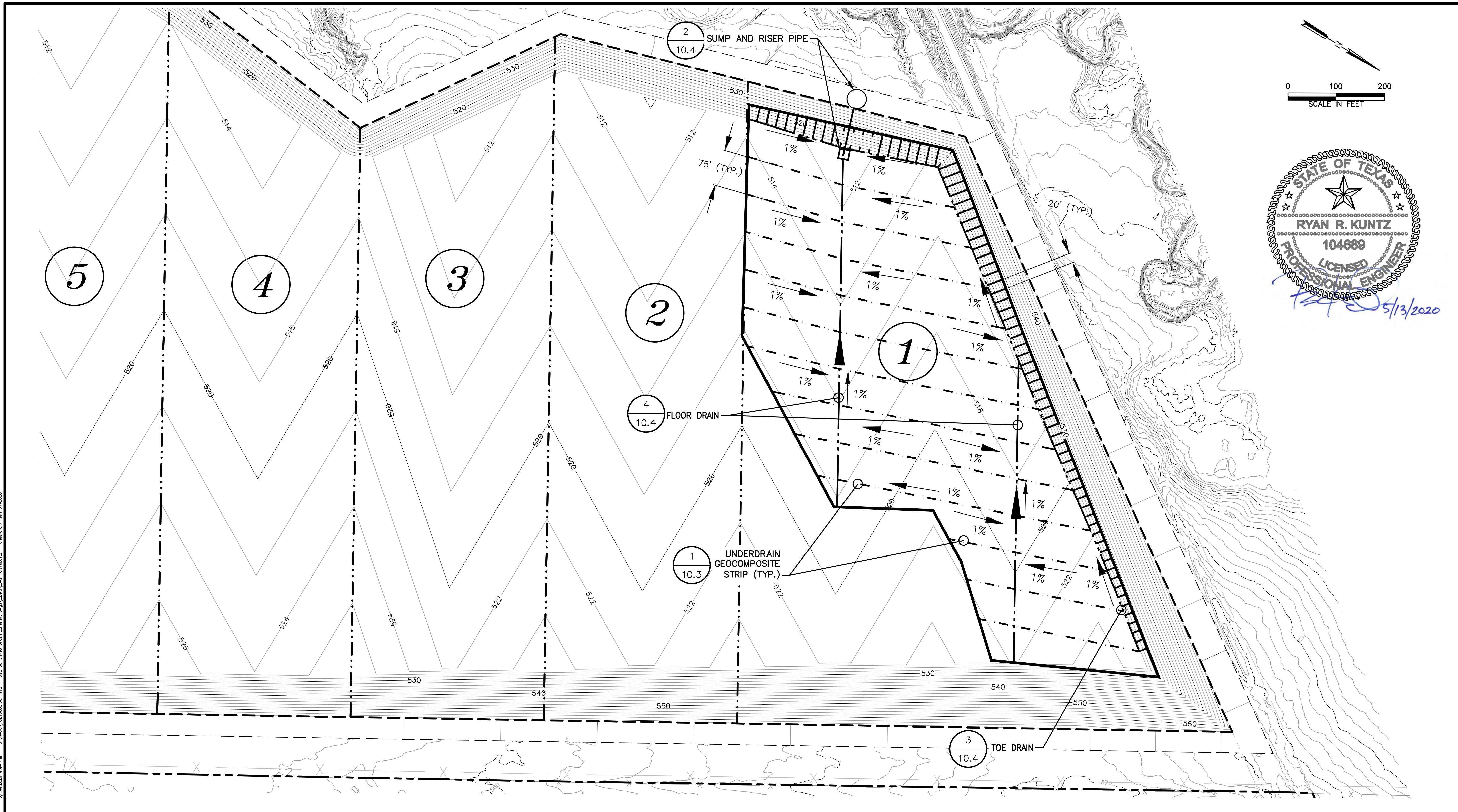
Finger drains spaced at 20 ft. c-c were designed for the cell sideslope excavations. These drains will consist of minimum 3-foot wide geocomposite strips (with non-woven geotextile heat bonded to each side). These drains will be connected to a free-flowing toe drain which drains to a dewatering sump.

FLOOR AND TOE DRAINS

A gravel trench with an area of 1ft^2, wrapped in a 12-oz geotextile, and sloped at 1%, will be sufficient to drain collected groundwater on the cell floor and sideslope.

SUMP

An underdrain sump with dimension of 15 ft x 3 ft x 3 ft will have sufficient capacity to handle the volume of water that may be encountered.



LEGEND

- PERMIT BOUNDARY
- LIMITS OF WASTE
- CELL/SECTOR BOUNDARY
- 480 EXISTING GROUND CONTOURS (SEE NOTE 1)
- 480 EXCAVATION CONTOURS (SEE NOTE 2)
- PROPOSED GEOCOMPOSITE STRIPS
- PROPOSED FLOOR OR TOE DRAIN AND FLOW DIRECTION (SEE NOTE 3)
- AREA OF CELL IMPACTED BY POTENTIAL GROUNDWATER INSTRUSION
- X SECTOR DESIGNATION

NOTES:

1. THE EXISTING TOPOGRAPHY SHOWN ON THIS PLAN WAS DEVELOPED BY DAS GEOSPATIAL FLOWN ON JULY 03, 2018.
2. ELEVATIONS SHOWN ON THIS DRAWING ARE EXCAVATION GRADES OR BOTTOM OF LINER ELEVATIONS IN FEET MEAN SEA LEVEL (FT MSL).

FOR PERMITTING PURPOSES ONLY

REV	DATE	DESCRIPTION	BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: UNDERDRAIN SYSTEM SITE PLAN - EDA

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

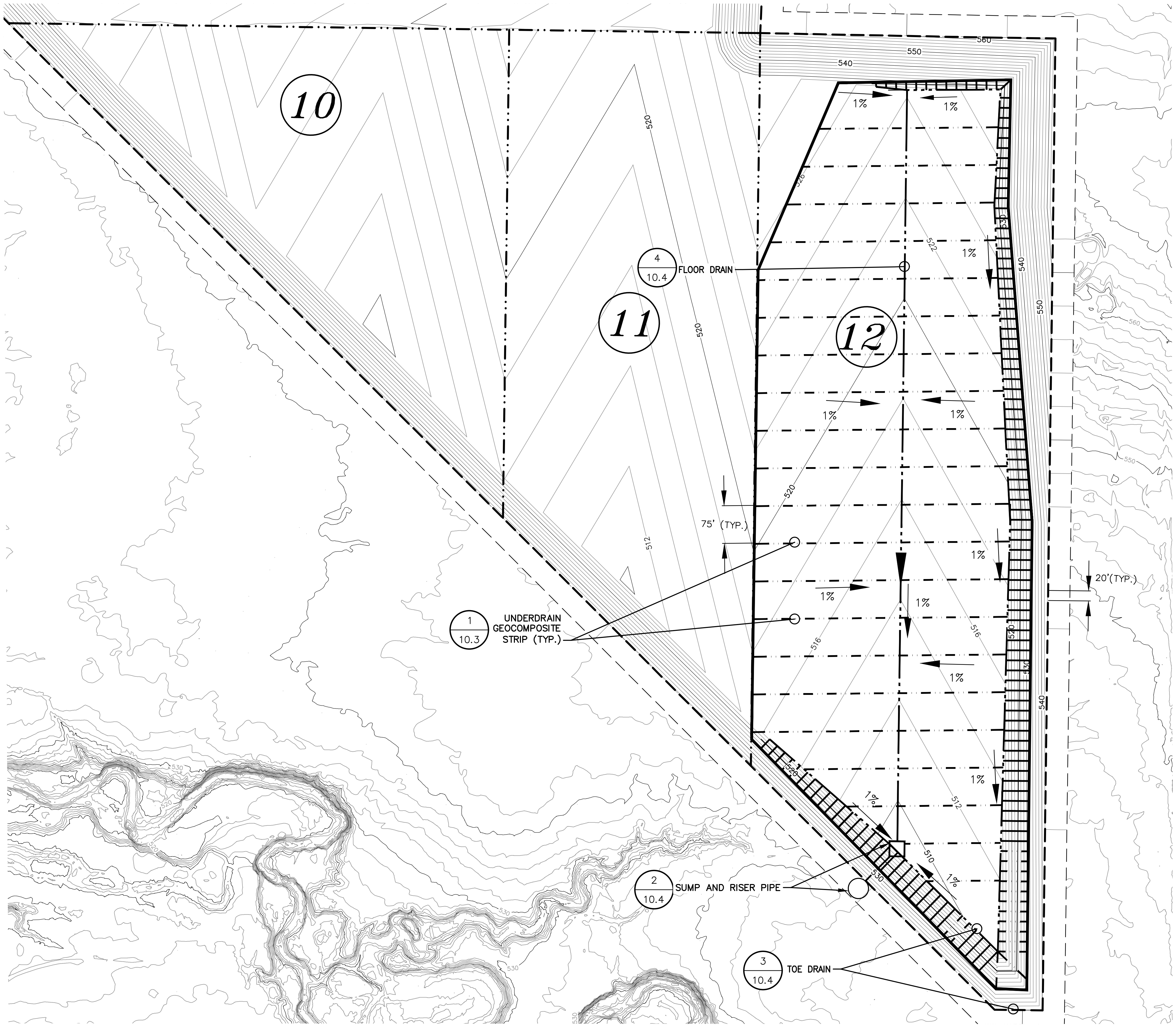
PROJ. NO.: 16216088.00 | DSN. BY: SS | DWN. BY: SS | CHK. BY: RRK | Q/A RVW BY: RRK | APP. BY: RRK

CADD FILE: 10D.1.2 – UNDERDRAIN PLAN 5142020

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 10D.1



0 100 200
SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LIMITS OF WASTE
- CELL/SECTOR BOUNDARY
- 480 EXISTING GROUND CONTOURS (SEE NOTE 1)
- 480 EXCAVATION CONTOURS (SEE NOTE 2)
- PROPOSED GEOCOMPOSITE STRIPS
- PROPOSED FLOOR OR TOE DRAIN AND FLOW DIRECTION (SEE NOTE 3)
- AREA OF CELL IMPACTED BY POTENTIAL GROUNDWATER INSTRUSION
- X SECTOR DESIGNATION

NOTES:

1. THE EXISTING TOPOGRAPHY SHOWN ON THIS PLAN WAS DEVELOPED BY DAS GEOSPATIAL FLOWN ON JULY 03, 2018.
2. ELEVATIONS SHOWN ON THIS DRAWING ARE EXCAVATION GRADES OR BOTTOM OF LINER ELEVATIONS IN FEET MEAN SEA LEVEL (FT MSL).

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

FOR PERMITTING PURPOSES ONLY

REV	DATE	DESCRIPTION	BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: UNDERDRAIN SYSTEM SITE PLAN - WDA

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO.: 16216088.00 DWN. BY: SR Q/A RVW BY: RRK
DSN. BY: BG/RRK CHK. BY: BRK APP. BY: RRK

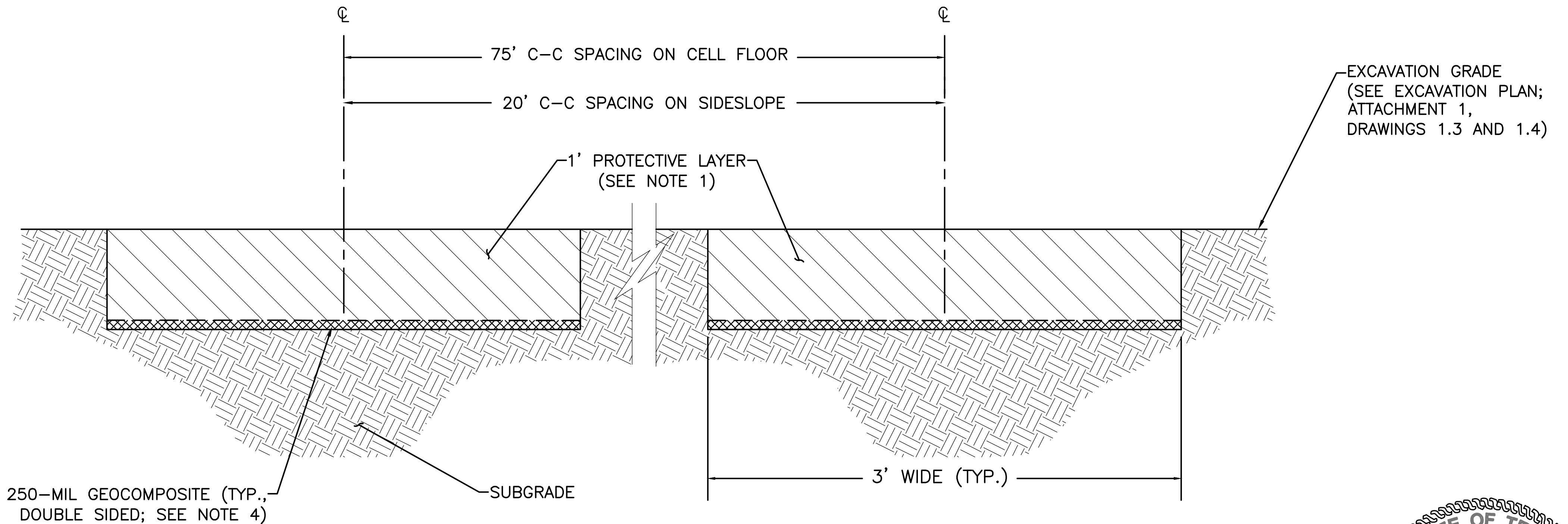
CADD FILE: 10D.2 - UNDERDRAIN PLAN 5142020

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 10D.2

5/14/2020 4:39 PM G:\WACO\16216088.00 T1T2 - SITE 50 SITING STUDY_Permit Dwgs_DWG_All 10\10D.2 - Underdrain Plan 5142020



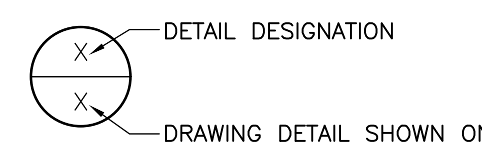
UNDERDRAIN GEOCOMPOSITE STRIP 1 / 10.3

NTS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

DETAILS 1 AND 2 NOTES:

1. THE 1 – FOOT PROTECTIVE LAYER SHALL BE PLACED OVER ALL UNDERDRAIN COMPONENTS.
2. PROTECTIVE LAYER SHALL BE PLACED USING LOW PRESSURE GROUND EQUIPMENT AS DESCRIBED IN THE SLQCP, SECTION 7.
3. ROLL ENDS OF THE GEOCOMPOSITE SHALL BE OVERLAPPED A MINIMUM OF 12 INCHES. ROLL ENDS SHALL BE SHINGLED; THE UPHILL ROLL END SHALL BE OVERLAPPED 12 INCHES OVER THE DOWNHILL ROLL END.



FOR PERMITTING PURPOSES ONLY

REV | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: UNDERDRAIN DETAILS - 1

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00 | DSN. BY: SS | DWN. BY: SS | CHK. BY: RRK | Q/A RVW BY: RRK | APP. BY: RRK

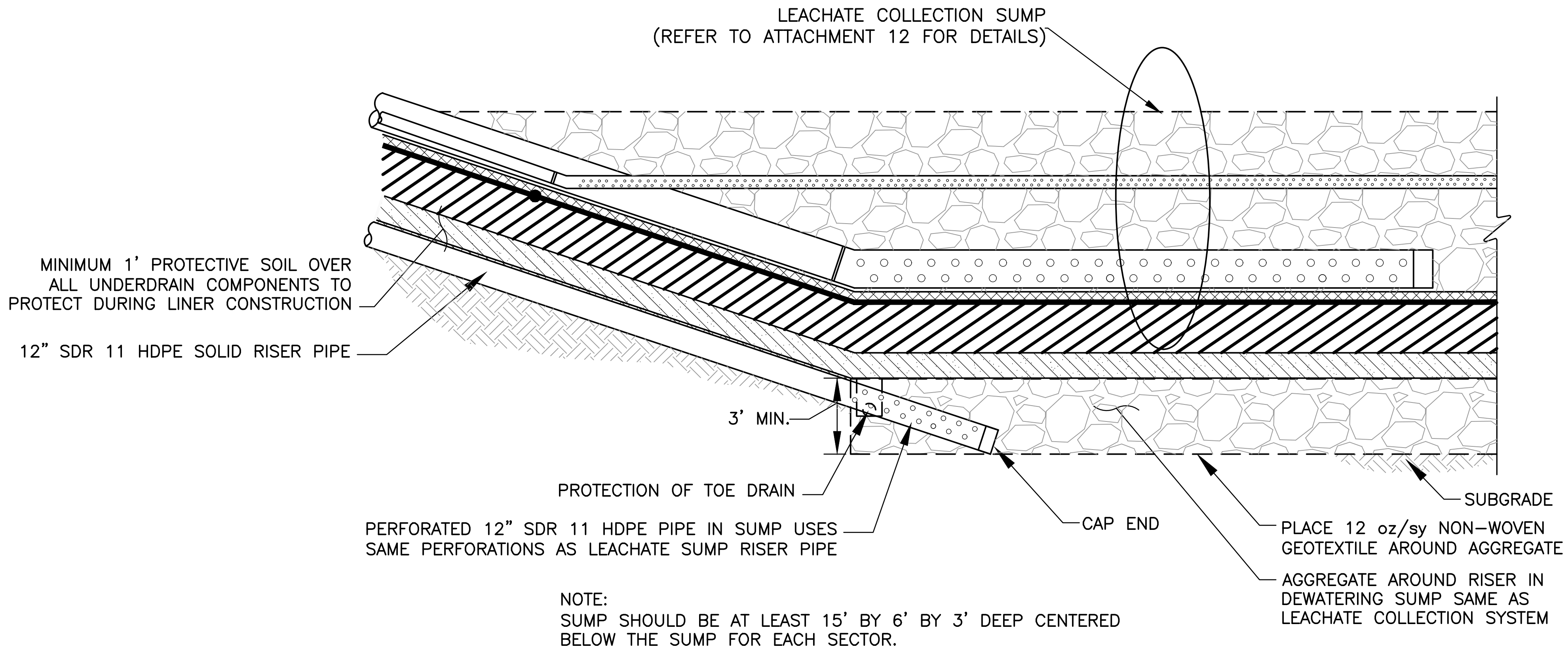
CADD FILE: 10D.3.4 – UNDERDRAIN DETAILS

DATE: 04/2020

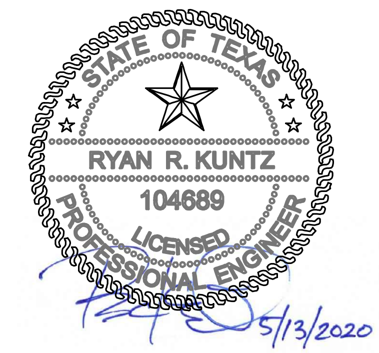
SCALE: AS SHOWN

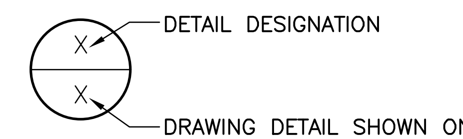
DRAWING NO. 10D.3

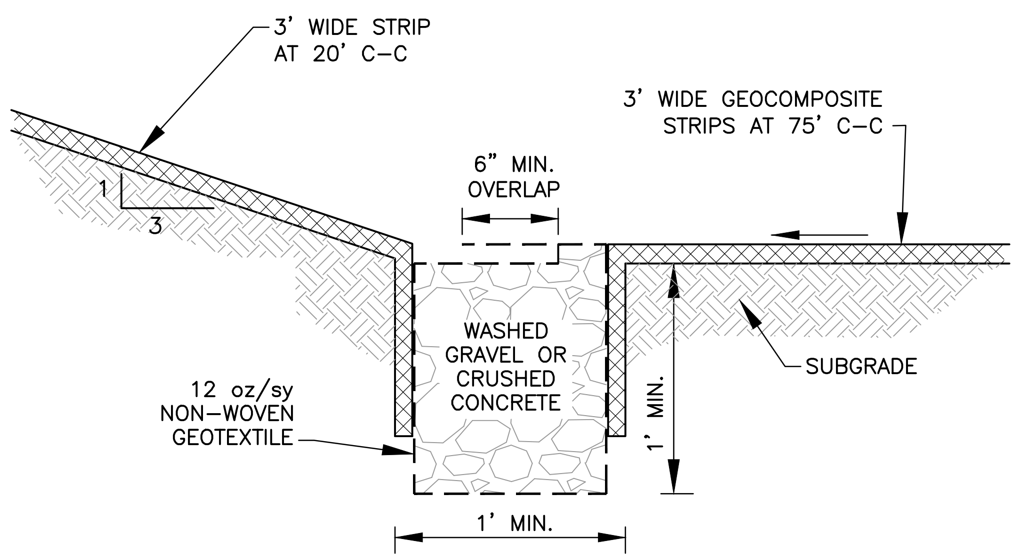
5/14/2020 1:02 PM G:\WACO\16216088.00 T172 – SITE 50 SITING STUDY_Permit Dwgs_DWG_Att 10\10D.3.4 – Underdrain Details



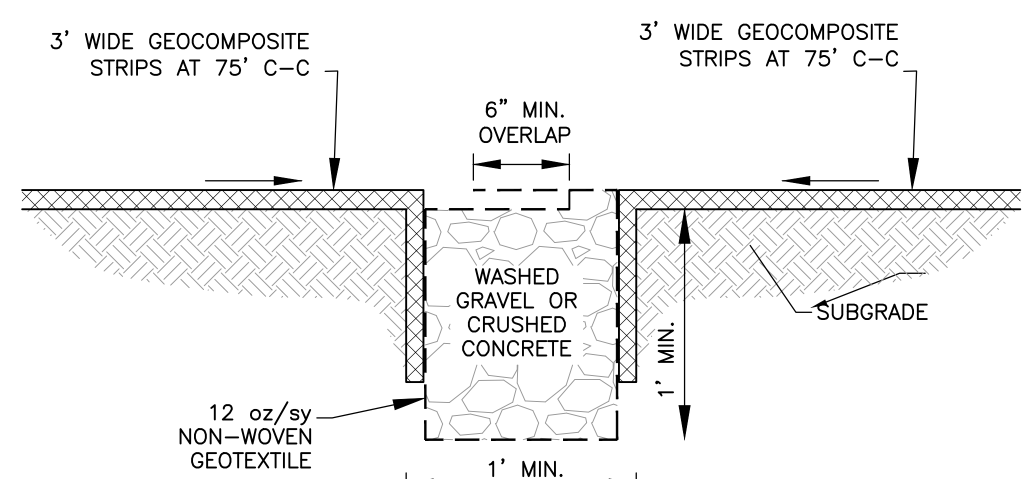
TYPICAL DEWATERING SUMP SECTION 2 / 10D.4
NTS







TYPICAL TOE DRAIN AT BOTTOM OF SIDESLOPE 3 / 10D.4
NTS



TYPICAL FLOOR DRAIN ALONG CELL FLOOR 4 / 10D.4
NTS

FOR PERMITTING PURPOSES ONLY

REV | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: UNDERDRAIN DETAILS - 2

PROJECT TITLE: CITY OF WACO LANDFILL
TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO
SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00 | DSN. BY: SS | DWN. BY: SS | CHK. BY: RRK | Q/A RVW BY: RRK | APP. BY: RRK

CADD FILE: 10D.3.4 - UNDERDRAIN DETAILS

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 10D.4

5/14/2020 1:03 PM G:\WACO\16216088.00 T172 - SITE 50 SITING STUDY_Permit Dwgs_DWG_Att 10\10D.3.4 - Underdrain Details

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
MCLENNAN AND LIMESTONE COUNTIES, TEXAS

PART III - SITE DEVELOPMENT PLAN
ATTACHMENT 11
LANDFILL GAS MANAGEMENT PLAN

Prepared for:

CITY OF WACO

Solid Waste Services
501 Schroeder Drive
Waco, Texas 76710

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 – April 2020
SCS Project No. 16216088.00

TABLE OF CONTENTS

SECTION **PAGE**

Drawings

Appendices

SCS Engineers
TBPE Reg. # F-3407

1 INTRODUCTION

1.1 SCOPE

The purpose of the Landfill Gas Management Plan (LGMP) is to provide management practices for the monitoring and control of landfill gas (LFG) generated by the City of Waco Landfill (landfill). This LGMP was developed in accordance with the requirements of 30 TAC 330.63(g) and 330.371. The monitoring program described in this LGMP will continue for thirty years after certification of final closure of the landfill or until the owner or operator receives written authorization to reduce the program in accordance with 30 TAC §330.371(e). This LGMP will be modified as needed throughout the active life and the post-closure care period of the landfill to provide effective gas monitoring and control systems, in accordance with 30 TAC §330.371(f). Future modifications to this LGMP will be performed consistent with TCEQ Regulations, specifically 30 TAC §305.70.

It is the intent of the City of Waco (City) to comply with other applicable air-related federal and state regulations, including, but not limited to, New Source Performance Standards (NSPS), New Source Review (NSR), Prevention of Significant Deterioration (PSD), Title V, and the National Emission Standards for Hazardous Air Pollutants (NESHAPS). The City also intends to comply with all emissions reporting, as required, including the State of Texas annual emissions inventory and federal greenhouse gas reporting. Of the above-mentioned state and federal requirements, the NSPS rules drive a potential future requirement to operate a landfill gas collection and control system (GCCS). The landfill will be above the capacity threshold of the current NSPS rules that will require periodic emissions reporting. Once emissions are above a certain NSPS threshold, the current NSPS rules will require that a GCCS be installed and operated to collect and manage landfill gas from all areas that have waste-in-place for 5 years or more, or 2 years or more after closure or at final grade.

1.2 PURPOSE

Compliance with §330.371(a) requires landfills to implement a routine methane monitoring program to verify: (1) the concentration of methane does not exceed 1.25 percent methane by volume in facility structures, excluding gas collection and control system components; and (2) the concentration of methane does not exceed 5 percent methane by volume at the permit boundary. In some cases, the perimeter monitoring points (gas monitoring probes [GMPs] and utility trench vents) are located closer to the limits of waste than the permit boundary as shown in Drawing 11.1 to accommodate protection of human health, adequate access, and the 100-year floodplain of Horse Creek.

This LGMP presents design features and guidelines to monitor for potential gas migration at perimeter monitoring points and in on-site structures within the permit boundary, as described in Section 3 of this attachment. Additionally, this plan includes an action plan (see Section 4) and remediation plan options (see Section 5) in the event methane is detected at the perimeter monitoring points or within on-site structures above these thresholds.

This LGMP also includes the procedures to manage and control landfill gas as per 30 TAC §330.371(g)(1), and a description of the proposed system(s), including installation procedures and time lines for installation, monitoring procedures, and procedures to be used during maintenance in accordance with §330.371(g)(2), as described in Section 6.

2 SITE CHARACTERISTICS

2.1 INTRODUCTION

This section of the LGMP describes the site characteristics such as soil; hydrological and hydraulic conditions; facility structures; on-site utilities; and offsite structures that were considered in the design of the methane monitoring program for the landfill in accordance with 30 TAC §330.371(b).

The proposed monitoring program is described in Section 3 of this attachment, and the proposed GMP and utility trench vent locations are depicted on Drawing 11.1 in accordance with 30 TAC §330.371(i). The overall perimeter monitoring program, including the proposed schedule for installation of the GMPs and utility vents is described in Section 3.1 of this attachment. Each GMP will be designed to monitor the subsurface soil above the excavation grade of adjacent disposal areas. The designed GMPs and utility vents will be monitored, at least quarterly, as specified in Section 3.3 of this attachment.

Monitoring the interior of any enclosed on-site structures will be accomplished by either continuous LFG monitors/alarms or a calibrated portable gas indicator, as described in Section 3.2 of this attachment.

2.2 SOIL CONDITIONS

The geologic conditions present on and adjacent to the landfill property are discussed in Part III, Attachment 4 - Geology Report of this permit application. As described in Attachment 4, site geologic conditions encountered on the property are consistent with a shale-marl, which are bulk rock materials composed of high plasticity clays. Based on field and laboratory tests described in Attachment 4, the geologic conditions are generally homogeneous both horizontally and vertically across the site. Site lithology has been divided into surficial alluvial (Unit I), upper “weathered” calcareous shale-marl (Unit II) and lower “unweathered” calcareous shale-marl (Unit III) horizons based on field observations. Based on field observations and laboratory testing, both Unit II and Unit III are low permeability clayey soils.

2.3 HYDROGEOLOGIC CONDITIONS

The hydrogeologic conditions present on and adjacent to the landfill property are discussed in detail in Part III, Attachment 4 - Geology Report of this permit application. The seasonal low groundwater elevations present at the site, as well as the elevation of the cell excavation within 1,000 feet of the proposed GMP, will govern the depth of the proposed GMP. As indicated in Section 3.1, prior to GMP installation, available data from on-site groundwater monitoring wells, piezometers, and designed excavation elevations will be evaluated to specify the respective GMP installation depth.

2.4 HYDRAULIC CONDITIONS

The hydraulic conditions on and surrounding the landfill property are discussed in Part III, Attachment 6A - Surface Water Protection Plan of this permit application. As described in Attachment 6A, Horse Creek flows through the approximate center of the property, across the north and south property boundaries towards Packwood creek and Reservoir 19, located near the south and southeastern permit boundaries. Additionally, a proposed perimeter drainage system will be installed within the buffer zone of the landfill. As shown in Attachment 6A, the proposed perimeter drainage system are fairly shallow. Therefore, these hydraulic features will not influence the GMP's ability to monitor potential offsite LFG migration, as the GMPs will be installed and screened to a depth below the bottom of these hydraulic features.

2.5 FACILITY STRUCTURES WITHIN THE PERMIT BOUNDARY

The only proposed on-site structures within the landfill permit boundary will be the maintenance/administration building, scale house, and existing structures within the boundary of the West Disposal Area (WDA). The existing structures within the boundary of the WDA will be abandoned and demolished prior to development of their respective sector (i.e., Sectors 10 and 11) of the WDA where the existing structure is located. During demolition of the existing structures, existing utilities will be properly disconnected and abandoned, including any appropriate utility seal-offs.

The maintenance/administration building, scale house, and any other enclosed structure constructed/existing on the property will be monitored for methane in accordance with Section 3.2 of this attachment.

2.6 UNDERGROUND UTILITIES

There is one known existing underground utility located on the landfill property, comprised of a waterline, as described in Parts I/II, Section 3. This waterline is located near the west property boundary parallel to Farm-to-Market (FM) 939. GMPs installed along the west property boundary will be located between the waterline and waste disposal limits, which will provide monitoring of potential LFG along this utility corridor.

In accordance with §330.371(f), the waterline trench will be vented and monitored regularly for the presence of LFG where it crosses the property boundary. Utility trench vents will be installed at the locations shown Drawing 11.1 consistent with the detail shown on Drawing 11.2. Utility vents on the waterline will be installed consistent with the schedule described in Section 3.1.1. Monitoring of utility vents will be performed quarterly with GMPs, as described in Section 3.1.

2.7 OFF-SITE STRUCTURES

Currently, surrounding land-use is primarily undeveloped ranchland and pasture, vegetated with native grasses and trees.

There are four properties that contain offsite structures within 1,000 feet of the permit boundary, which corresponds to Property ID No. 8, 11, 12, and 13 on Drawing I/II-3 (see Parts I/II). Additionally, the current land ownership of these properties is provided in Part I/II, Section 5.

2.8 CHANGES TO MAINTAIN EFFECTIVE GAS MONITORING

In accordance with 30 TAC §330.371(f), the gas monitoring and control systems will be revised as needed to maintain current and effective gas monitoring and control systems. Changes might include installation of temporary structures on or near waste fill areas, or other activities that will require changes to the gas monitoring or control systems. Additionally, post-closure land use will not interfere with the function of the gas monitoring or control systems. The period of post-closure operation of the gas monitoring and control systems is described in Attachment 9 of this permit application.

3 MONITORING

3.1 PERIMETER MONITORING

3.1.1 Perimeter Monitoring Network

Eighteen (18) gas monitoring probes (GMP) (GMP-1 through GMP-18) will be installed along the permit boundary to provide detection points for potential subsurface LFG migration in accordance with 30 TAC §330.371(h). The proposed GMPs will be located such that the maximum spacing between the GMPs is 1,000 feet along the periphery of the landfill. The variables that will influence the design depth of the GMPs are the geologic formations and historically seasonal low groundwater elevations present at the site. The approximate locations of the proposed GMPs are shown on Drawing 11.1. Following TCEQ approval of this permit application and prior to initial acceptance of waste, the City will install GMP-1 through GMP-5 corresponding to the construction of Sector 1 in the EDA. The remaining GMPs will be installed incrementally prior to placement of waste within 1,000 feet of the proposed GMP location. The proposed installation frequency of GMPs is considered sufficient to detect any potential gas migration, since on-site soils are comprised of high plasticity clays, which exhibit low permeability, as described in Section 2.2 of this attachment.

Four (4) utility trench vents (TV-1 through 4) will be installed in or near the underground waterline crossing the permit boundary prior to waste being placed within 1,000 feet of the underground utility. In addition, utility vents will be installed in or near any future underground utilities that crosses the permit boundary within 60 days after new utility construction.

Proposed GMP and utility vent locations shown on Drawing 11.1 are subject to the feasibility of installation at that location, as controlled by areas of steep site topography, dense vegetation, on-site structures, and/or un-trafficable conditions. If the location of the GMP needs to deviate by more than 100 feet from the proposed location, a permit modification will be submitted to the TCEQ for the new proposed GMP location(s).

Prior to installing each GMP or utility vent, the City will verify that the GMP or utility vent location can be accessed for monitoring. During GMP or utility vent installation, the City will clear vegetation to provide an on-site access road to each location, as needed.

3.1.2 Proposed GMPS

GMPs will be installed to monitor the soil strata above the higher of the lowest measured groundwater level at the monitoring point or the lowest current or future elevation of waste within 1,000 feet of the monitoring point. If the seasonal low groundwater elevation has not been determined for a particular GMP, the depth of the GMP will be conservatively established as the deepest design elevation of the cell excavation within 1,000 feet of the proposed GMP. For this landfill, the maximum GMP depth will coincide with the deepest excavation elevation (EDE) of 505 ft MSL.

The probes will be screened from approximately 1-foot above the bottom of the borehole to within approximately 7 feet of the ground surface. Washed gravel will be placed in the borehole to approximately 1-foot above the screened interval and approximately 1-foot of sand will be placed over the gravel. Bentonite pellets will be placed above the sand and hydrated to form an impermeable layer to prevent air and water intrusion into the GMP boring. A metal security casing will extend into the borehole. A concrete apron will then be placed around the security casing above the ground surface. A PVC cap with a quick connect coupling will be installed at the top of the GMP for ease of monitoring. No solvents or PVC cement, which may affect monitoring results, will be used during construction of the GMP. A typical detail of the proposed GMPs is provided on Drawing 11.2.

During construction of the GMPs, boring logs and construction details will be recorded. After completion of construction of the GMPs, the boring logs and construction details will be maintained in the landfill Site Operating Record.

3.1.3 Proposed Utility Trench Vents

As previously discussed, utility trench vents will be installed in or near existing or future underground utilities crossing the permit boundary when waste is placed within 1,000 feet of the underground utility. Prior to vent installation, the underground utility location will be identified and located by representatives of the utility owner. A permit-level typical detail of the proposed utility trench vent is provided on Drawing 11.2.

During construction of the utility vent, construction details will be recorded. After completion of construction of the unity vent, the construction details will be maintained in the landfill Site Operating Record.

3.1.4 Monitoring Procedures

Methane concentrations will be measured in GMPs and utility vents (see Section 2.6) using a combustible gas indicator calibrated and maintained in accordance with the manufacturer's recommendations. Calibration and maintenance records for the monitoring instrument will be available on-site with the LFG monitoring records described in Section 3.3 of this attachment. The indicator will give a direct reading of methane concentration by volume. Equipment maintenance requirements, monitoring procedures, and calibration information for the instruments used to monitor methane concentrations will be maintained in the Site Operating Record with the LFG monitoring records described in Section 3.3 of this attachment. Monitoring will be conducted under the oversight of the Landfill Manager by individuals trained in the use of the monitoring equipment and procedures, or by a qualified consultant. The results of monitoring will be recorded on the attached Quarterly Landfill Gas Monitoring Report (see Appendix 11A), or similar forms, and maintained in the Site Operating Record.

If the monitoring results indicate that the allowable concentration of methane has been exceeded, verification procedures, as described in Section 4 of this attachment, will be implemented. If verification procedures indicate allowable limits are being exceeded, notification procedures will be implemented, also as described in Section 4 of this attachment. Exposure to carcinogenic or toxic compounds will be avoided, if possible. When there is a possibility of acute or chronic exposure to carcinogenic or toxic compounds, sampling for specified trace gases will be conducted.

3.1.5 GMP/Utility Vent Inspection and Maintenance Procedures

During each monitoring event, the integrity at the surface of the GMPs and utility vents will be inspected by the sampler. The sampler will record pertinent information on the Quarterly Methane Monitoring and Recording Form (see Appendix 11A) or similar forms. The sampler will perform the following at each monitoring event:

- Verify that the GMP or utility vent is clearly labeled on the outer casing or lid.
- Verify that the protective GMP security casing is intact and is not bent or excessively corroded.
- Verify that the concrete apron is intact (no evidence of cracking or heaving).
- Verify that the security casing padlock on the GMP is functional.
- Verify that the inner GMP casing is intact.

If damage or excessive wear to the GMP or utility vent is observed, it will be reported to the Landfill Manager. If it is not possible to repair the GMP or utility vent and the damage can potentially affect the accuracy of future monitoring results, the GMP or utility vent will be decommissioned and replaced in accordance with Sections 3.1.2, 3.1.3, and 3.4 of this attachment.

3.2 MONITORING OF FACILITY STRUCTURES

3.2.1 Monitoring Procedures

Enclosed structures within the landfill permit boundary will be monitored for methane concentrations that exceed 1.25 percent methane by volume. Methane will be monitored by using either continuous methane monitors/alarms or a calibrated portable gas indicator. Similar to GMPs and utility trench vents, all on-site structures will be monitored for methane during the monitoring period in accordance with 30 TAC §330.371(j), which also requires sampling for specified trace gases when there is a possibility of acute or chronic exposure due to carcinogenic or toxic compounds.

If allowable methane concentration limits are exceeded within on-site structures, the structure will be immediately evacuated and ventilated by opening doors and windows. Verification procedures described in Section 4 of this attachment will be implemented. If verification procedures indicate allowable limits are being exceeded, notification procedures, also described in Section 4 will be implemented.

3.2.2 Maintenance Procedures

Methane monitoring instruments will be calibrated and maintained in accordance with the manufacturer's recommendations. The maintenance requirements and testing specifications for the selected methane monitoring instrument will be available on-site with the methane monitoring records described in Section 3.3 of this attachment.

If used, continuous methane monitors/alarms will be tested in accordance with the manufacturer's testing specifications and recommended frequency.

3.3 RECORDKEEPING AND REPORTING

Field monitoring data records for GMPs, on-site structures, and utility vents will be maintained for the methane monitoring and kept on-site as part of the Site Operating Record. Field data will be recorded on the Methane Monitoring and Recording Form (Appendix 11A) or similar form. Methane monitoring will be performed quarterly in accordance with 30 TAC §330.371(b)(2) during the following periods:

Methane Monitoring Quarters

First Quarter: January – March	**Third Quarter:** July - September
Second Quarter: April - June	**Fourth Quarter:** October – December

The methane monitoring program will continue for a period of 30 years after the certification of final closure or until the owner or operator receives written authorization from the TCEQ to revise or discontinue the program.

3.4 BACKUP PLAN FOR GMPS/UTILITY VENTS AND CONTINUOUS METHANE MONITORS

In accordance with 30 TAC §330.371(g)(3), the following is a backup plan to be used if stationary GMPs/utility trench vents or continuous methane monitors become unusable or inoperative.

3.4.1 Stationary GMPs/Utility Vents

1. Unusable or inoperative GMPs/utility vents will be repaired or replaced within 60 days of discovery of being unusable or in-operative.

2. Upon completion of a replacement GMP/utility vent, an installation report including boring logs and/or construction details will be maintained in the landfill Site Operating Record.

3. Should a monitoring event occur prior to the 60-day replacement of a damaged GMP/utility vent, barhole probing will be implemented next to the damaged probe using a portable gas monitor.

3.4.2 Stationary Continuous Methane Monitor/Alarm

1. Damaged or inoperative stationary continuous methane monitors/alarms will be repaired or replaced upon discovery of damage or malfunction.

2. Alternatively a portable combustible gas indicator calibrated to detect 1.25 percent methane by volume will be used during monitoring events.

4 ACTION PLAN

4.1 INITIAL RESPONSE MEASURES

This action plan has been prepared for the protection of human health in the event concentrations of methane exceed regulatory limits either at the permit boundary or within on-site structures. The appropriate emergency response is different for each situation; therefore, the plan will address the situations for structures and permit boundaries separately.

This action plan also recognizes that a single-event exceedance of allowable limits on a combustible gas indicator or continuous methane alarm does not necessarily mean that the concentration of methane has actually exceeded allowable levels. Therefore, a procedure, as described below, will be implemented to verify the validity of a single-event exceedance on a combustible gas indicator or continuous methane alarm.

4.1.1 Immediate Emergency Action

The initial action in the event methane is detected at levels above regulatory limits is to protect human health. Therefore, immediately following an exceedance, the TCEQ Austin Office, TCEQ regional office, local and county officials, emergency officials, and the public (defined as adjacent landowners within 1,000 feet of the exceedance) will be notified that a potential exceedance has occurred and that verification procedures are being implemented. The Landfill Manager will advise the residence to consider evacuating any structure within 1,000 feet of the exceedance while further assessment of the potential for off-site migration is underway, as described in Section 4.1.2. Additionally, the following specific responses will also be implemented depending on the circumstances described below.

4.1.1.1 On-Site Structures

If an on-site structure is found to have methane concentrations that exceed 1.25 percent methane by volume, the structure is to be evacuated of all personnel immediately and the Landfill Manager will be notified. Personnel (except for qualified monitoring personnel) will not be allowed to re-enter the affected structure until additional measures have been taken, as described in Section 4.1.2 of this attachment.

4.1.1.2 Permit Boundary

If methane concentration levels that exceed 5 percent methane by volume, are detected at the permit boundary in one of the GMPs or utility trench vents, the Landfill Manager will be notified.

4.1.2 Verification Procedures

Once immediate emergency measures have been taken to protect human health, the Landfill Manager will instruct monitoring personnel to begin verification procedures. Such procedures are intended to determine if the methane levels detected are accurate, or if erroneous levels have been detected due to equipment malfunction or other reasons.

4.1.2.1 On-Site Structures

Verification of detected methane levels in the ventilated on-site structures will be accomplished by properly trained monitoring personnel using the following procedures and in the order given:

1. Recalibrate the potable combustible gas indicator if used during the initial detection in accordance with manufacturer's recommended procedures.

2. Monitor methane and oxygen levels throughout the structure using a calibrated portable gas indicator. In particular, readings will be taken in each room and in confined spaces (i.e., closets). If natural gas appliances are used in the structure, they will be checked for leaks.

3. If installed within the structure, determine if the continuous monitoring equipment is working properly.

If concentrations of combustible gases above the regulatory limit and oxygen-deficient conditions (oxygen-deficient conditions exist any time the oxygen concentration is below 19.5 percent oxygen by volume) are not detected (i.e., a malfunction or erroneous reading is confirmed), personnel may return to the structure. Methane monitoring using a portable combustible gas detector will continue daily for a period of not less than 7 days after the incident. If levels of methane above the regulatory limit are not detected during that week, daily monitoring will cease and routine monitoring will resume.

Upon completion of the verification procedures described above, follow-up notification procedures and remediation procedures must be implemented, as described in Sections 4.2 and 5, respectively, of this attachment.

4.1.2.2 Permit Boundary

Verification of methane levels above the regulatory limit in GMPs and/or utility vents will be accomplished by monitoring personnel using the following procedures:

1. Recalibrate the potable combustible gas indicator in accordance with manufacturer's recommended procedures.

2. Immediately recheck the methane concentration in the GMP or utility vent and again at least once within 24 hours of the initial detection.

If concentrations of methane above the regulatory limit are detected in the verification procedures, daily monitoring will continue for not less than 7 days after the initial reading. If levels above the regulatory limit are not detected during the subsequent 7 days, daily monitoring will cease and routine monitoring procedures will resume.

Upon completion of the verification procedures, described above, follow-up notification procedures and remediation procedures must be implemented, as described in Sections 4.2 and 5, respectively, of this attachment.

4.2 FOLLOW-UP NOTIFICATION PROCEDURES

When methane levels above the regulatory limit have been detected and initial notifications have occurred, the Landfill Manager will perform the following procedures:

- Verify the validity of the reading, as described in Sections 4.1.2.1 and/or 4.1.2.2.
- Notify the TCEQ Austin Office, TCEQ regional office, local and county officials, emergency officials, and the public (as described in Section 4.1.1.2) of the results of the verification procedures (i.e., whether an exceedance still exists or if the initial exceedance was a false alarm).
- Documentation of verified methane concentrations above the regulatory limit and a description of the steps taken to protect human health will be placed in the Site Operating Record within 7 days of verification in accordance with §330.371(c).

5 REMEDIATION PLAN

If verification procedures have confirmed that methane concentrations above regulatory limits in the on-site structures or in one or more GMPs/utility vents, an investigation of the cause of the methane levels will be implemented. The investigation may include some or all of the following elements, depending on the circumstances:

1. Bar-hole probe or hydropunch testing in the vicinity of the impacted monitoring probe, utility vent, or structure.

2. Installation of additional GMPs and/or utility vents.

3. Sampling and laboratory analysis of GMP or utility vent samples to determine concentration of methane and trace organic constituents, if applicable.

An assessment will be made to determine an appropriate course of action to remediate the gas migration. Such actions will vary with the specific incident, but may include installing passive vents between the edge of waste and the landfill perimeter or within the landfill, or installation of an active GCCS.

An incident-specific remedial plan will be implemented within 60 days after levels of methane above the regulatory limit have been detected in accordance with §330.371(c)(3). Also, within 60 days of detection, copies of the remediation plan will be placed in the Site Operating Record and provided to the TCEQ along with notification that the remediation plan has been implemented. The remediation plan will be submitted to the TCEQ for approval consistent with 30 TAC §305.70(k)(3) [related to a permit modification requiring public notice]. In accordance with 30 TAC §330.371(d), the TCEQ may establish an alternative schedule for demonstrating compliance consistent with 30 TAC §330.371(c).

6 PASSIVE LFG VENTING SYSTEM

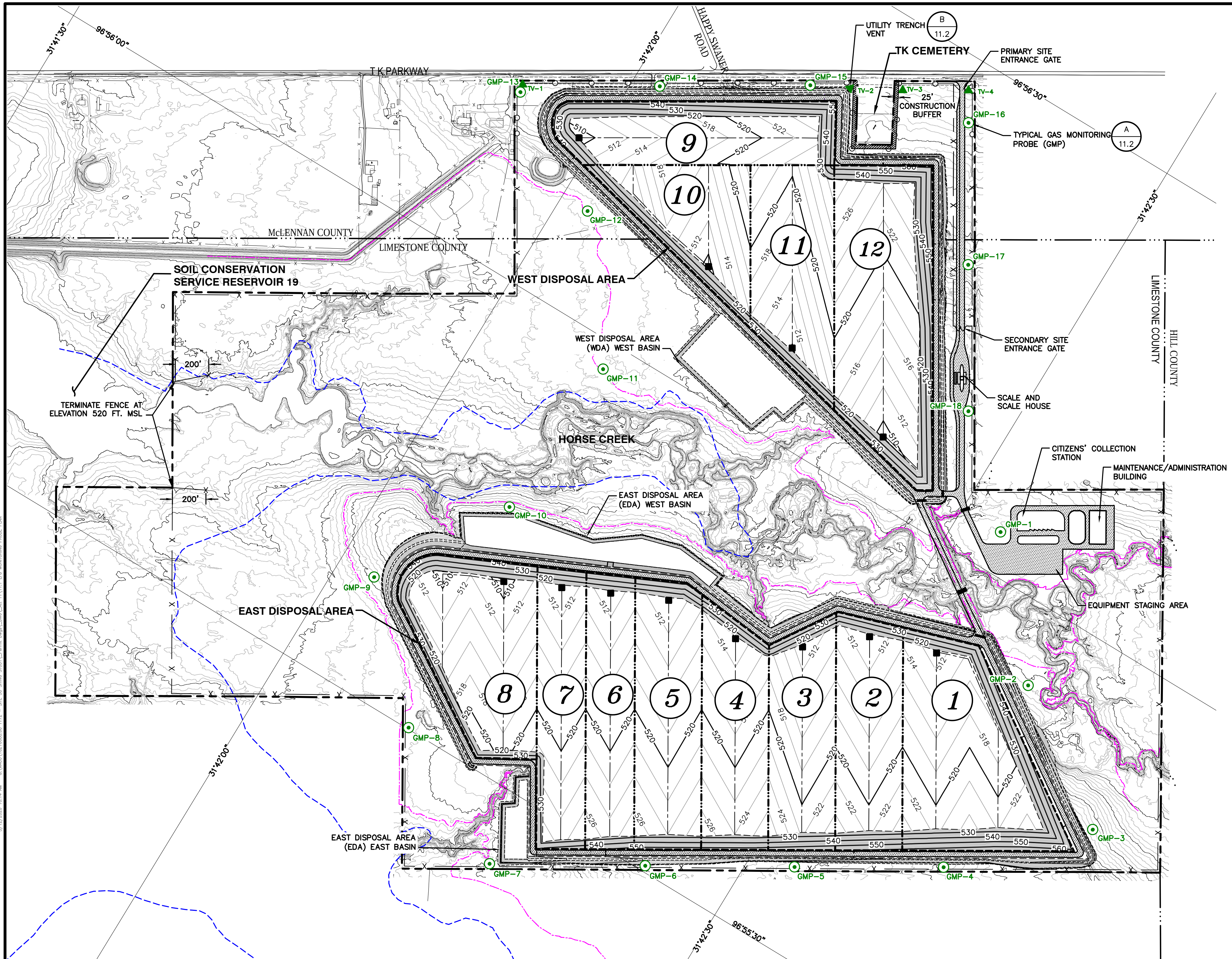
Passive LFG vents may be voluntarily installed as the landfill develops to help relieve internal LFG pressure within the refuse that may negatively impact the landfill final cover or to provide additional controls to prevent subsurface migration. In general, the vents will be installed in each area of the landfill where final cover has been installed. The vents will be installed following the landfill reaching final grade and in coordination with the placement of the final cover system.

Passive LFG vents may be converted to active LFG extraction wells in the event that an active GCCS is deemed necessary or required by NSPS. In addition to being required by NSPS, the installation of an active GCCS may be required as a result of regulatory requirements, subsurface LFG migration or odor control. In addition, an active GCCS may be voluntarily installed as part of a beneficial-use project, which would require TCEQ's approval prior to construction.

The passive LFG vent locations, spacing, and vent details will be submitted to the TCEQ for approval prior to construction at the system. A typical passive LFG vent detail is shown on Drawing 11.2.

DRAWINGS

- **Drawing 11.1 Gas Monitoring Plan**
- **Drawing 11.2 Typical Gas Monitoring and Vent Details**



0 300 600
SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LIMITS OF WASTE
- SECTOR BOUNDARY
- COUNTY LINE
- 560 EXISTING TOPOGRAPHIC CONTOURS (SEE NOTE 1)
- 100-YEAR FLOOD PLAIN (SEE NOTE 2)
- 100-YEAR STORM EVENT WATER SURFACE (SEE NOTE 5)
- EXISTING UNDERGROUND WATER LINE
- PROPOSED/EXISTING PERIMETER FENCE (CHAIN LINK OR BARBED WIRE)
- PROPOSED 8' PRIVACY FENCE
- ACCESS ROAD
- 510 EXCAVATION GRADE TOPOGRAPHIC CONTOURS (SEE NOTE 3)
- 96°55'30" LATITUDE/LONGITUDE LINES
- TOE/TOP OF SLOPE
- LEACHATE COLLECTION TRENCH
- TV-1 PROPOSED UTILITY TRENCH VENTS
- GMP-13 PROPOSED LANDFILL GAS MONITOR PROBE (SEE NOTE 4)
- X SECTOR DESIGNATION

NOTES:

1. THE EXISTING TOPOGRAPHY SHOWN ON THIS PLAN WAS DEVELOPED BY DAS GEOSPATIAL FLOWN ON JULY 03, 2018.
2. 100-YEAR FLOOD PLAN IS DESIGNATED AS ZONE A, BASED ON FIRM PANEL 48293C0125C, DATED 09/16/11.
3. ELEVATIONS SHOWN ON THIS DRAWING ARE EXCAVATION GRADES OR BOTTOM OF LINER ELEVATIONS IN FEET MEAN SEA LEVEL (FT MSL).
4. LANDFILL GAS MONITORING PROBES WILL BE INSTALLED CONSISTENT WITH ATTACHMENT 11, SECTION 3.
5. 100-YEAR STORM EVENT WATER SURFACE WAS ESTIMATED USING HEC-HMS AND HEC-RAS MODELING DISCUSSED IN ATTACHMENT 6B OF THIS PERMIT APPLICATION.

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED PROFESSIONAL ENGINEER
5/13/2020

REV. | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: GAS MONITORING PLAN

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00 | DSN. BY: BC/RRK | CHK. BY: BJD | DWN. BY: NR | APP. BY: RRK | Q/A RVW BY: RRK

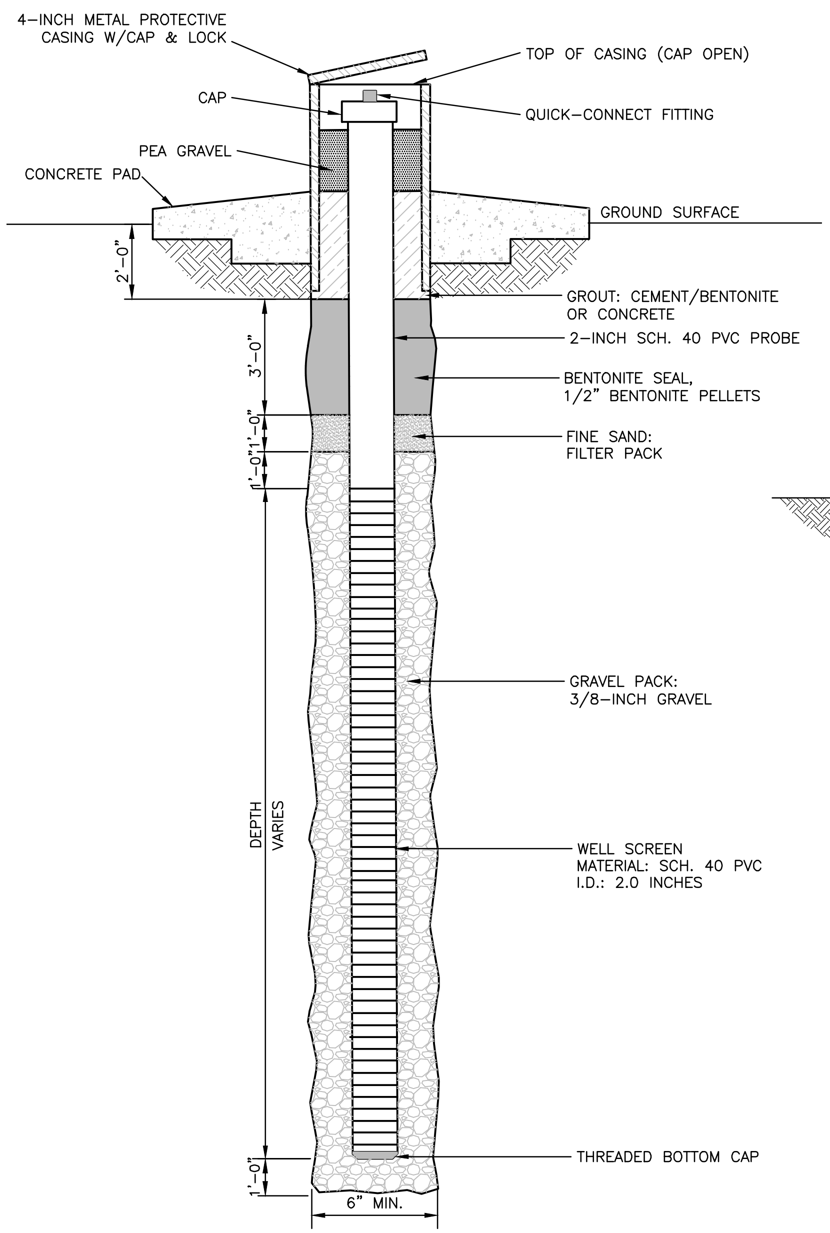
CADD FILE: 11.1 LFG MONITORING PROBE PLAN

DATE: 04/2020

SCALE: AS SHOWN

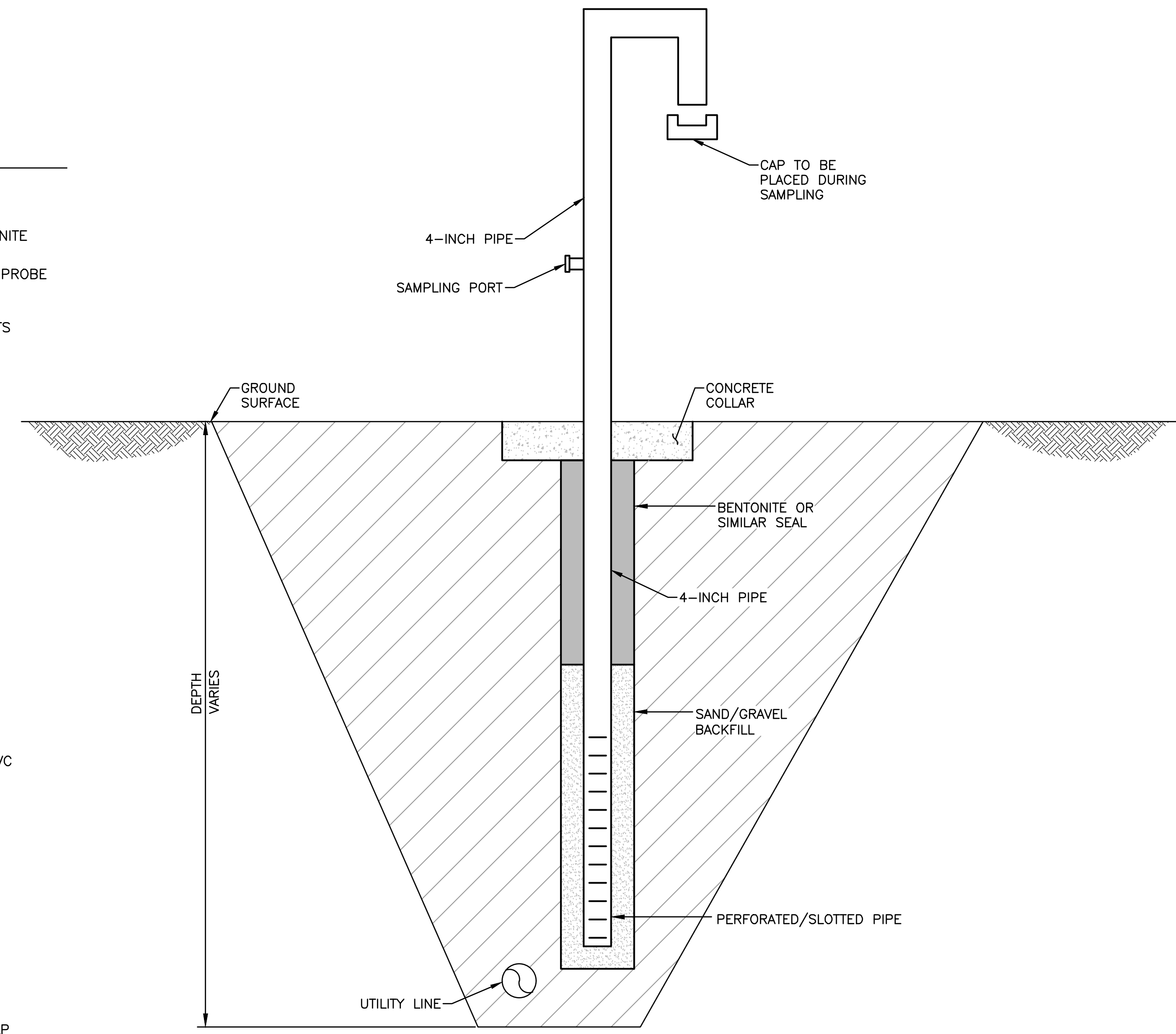
DRAWING NO. 11.1

FOR PERMITTING PURPOSES ONLY



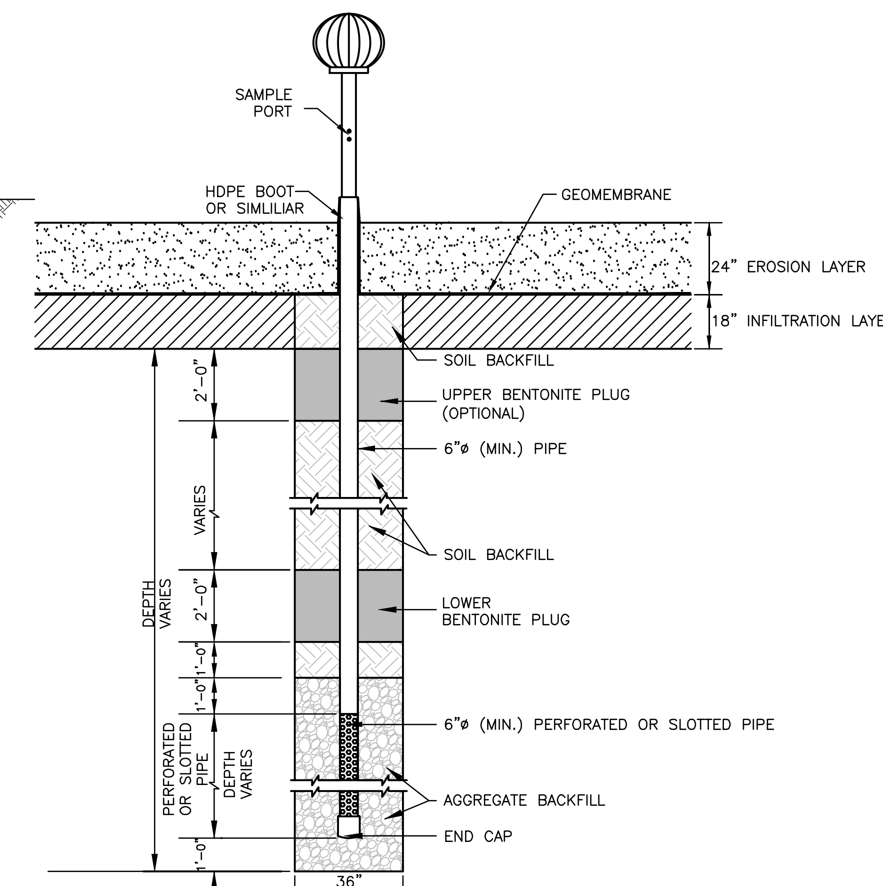
NOTE: ALL SIZES AND DIMENSIONS ARE APPROXIMATE.

TYPICAL GAS MONITORING PROBE (GMP) A 11.2
NTS



NOTE: ALL SIZES AND DIMENSIONS ARE APPROXIMATE.

UTILITY TRENCH VENT B 11.2
NTS



NOTES:

1. VENTS ARE DESIGNED TO BE CONVERTED TO LFG EXTRACTION WELLS IF AN ACTIVE LFG COLLECTION IS REQUIRED.
2. ALL SIZES AND DIMENSIONS ARE APPROXIMATE.

TYPICAL LFG PASSIVE VENT C 11.2
NTS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

REV	DATE	DESCRIPTION	BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE
TYPICAL GAS MONITORING AND VENT DETAILS

PROJECT TITLE
CITY OF WACO LANDFILL
TYPE I MSW - PERMIT APPLICATION

CLIENT
CITY OF WACO
SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00
DSN. BY: BG/RRK
DWN. BY: NR
CHK. BY: BJD
Q/A RVW BY: RRK
APP. BY: RRK

CADD FILE: 11.2 - LFG VENT DETAIL

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 11.2

FOR PERMITTING PURPOSES ONLY

5/11/2020 3:37 PM G:\WACO\16216088.00 T172 - SITE 50 SITING STUDY_Permit Dwgs_DWG_Att 11\11.2 - LFG VENT DETAIL

APPENDIX 11A

METHANE MONITORING AND RECORDING FORM

CITY OF WACO LANDFILL (MSW-2400)
Methane Monitoring and Recording Form

Sampled by:

Date: ______________ Time: ______________ Temperature: ____________

Weather: ___________ Barometric Pressure: ________in. Hg___

Monitoring Equipment: ________ Date of Calibration: __________________

Probe No.	Surface Elevation Ft. msl.	Depth of Probe (ft.)	% Methane 0-100	Static Pressure W.C.[1] (Optional)	Oxygen % (Optional)	Probe Integrity Verified Yes/No
GMP-1						
GMP-2						
GMP-3						
GMP-4						
GMP-5						

(Note: This form will be expanded as additional GMPs and/or utility trench vents are installed.)

When monitoring on-site structures using continuous alarms use the following table.

On-Site Structures	Verify Continuous LFG Alarm is Operational (circle one)		Continuous LFG Alarm Activated (Methane >1.25%) During Previous Quarter (circle one)	
Maintenance/Administration Building	Yes	No	Yes	No
Scalehouse	Yes	No	Yes	No
South Metal Building	Yes	No	Yes	No
North Metal Building	Yes	No	Yes	No
Wood Frame Building	Yes	No	Yes	No
Metal Shed	Yes	No	Yes	No
Metal Container	Yes	No	Yes	No

(Note: This form will be modified as on-site structures are constructed/removed.)

1 W.C. = Inches Water Column

CITY OF WACO LANDFILL (MSW-2400)
Methane Monitoring and Recording Form

When monitoring on-site structures using portable gas indicators use the following table.

On-Site Structure	% Methane	Comments
Maintenance/Administration Building		
Scalehouse		
South Metal Building		
North Metal Building		
Wood Frame Building		
Metal Shed		
Metal Container		

(Note: This form will be modified as on-site structures are constructed/removed.)

Name of Technician Conducting Monitoring: ____________________________

Signature: ____________________________ Date: ______________

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
McLENNAN AND LIMESTONE COUNTIES, TEXAS

PART III
SITE DEVELOPMENT PLAN -ATTACHMENT 12
LEACHATE AND CONTAMINATED WATER MANAGEMENT PLAN

Prepared for:

CITY OF WACO

Solid Waste Services
501 Schroeder Drive
Waco, TX 76710

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 – April 2020
SCS Project No. 16216088.00

TABLE OF CONTENTS

SECTION **PAGE**

Drawings

Appendices

SCS Engineers
TBPE Reg. # F-3407

1 PURPOSE AND SCOPE

This Leachate and Contaminated Water Management Plan for the City of Waco Landfill (landfill) was prepared consistent with 30 TAC §330.333. This plan provides the details of the collection, storage, and disposal systems for contaminated water, and leachate generated during the active (including final closure) and post-closure care periods of the landfill. Specifically, this plan addresses the following:

1. Leachate and contaminated water generation, including an estimation of leachate generation and removal during periods with and without leachate recirculation, performed using the Hydrologic Evaluation of Landfill Performance (HELP) model, and management of potentially contaminated water;

2. Description of the leachate collection system; including the following:

   - Geocomposite performance and material specifications.
   - Layout, capacity, and strength/stability of leachate collection piping.
   - Layout and capacity of leachate collection sumps.
   - Drainage stone specifications.

   In accordance with §330.333(1)(2), the materials specified for the leachate collection system will have sufficient strength and thickness to prevent collapse under the pressures exerted by overlying waste, soil, and equipment, as demonstrated in the calculations provided in Appendix 12B.

3. Leachate and contaminated water storage; and

4. Leachate and contaminated water disposal.

Additionally, this attachment includes drawings that depict the layout of the leachate collection system components, as well as details of the leachate collection system and liner systems (bottom and sideslope liners). Design details for the final cover system are included in Part III, Attachment 6C – Groundwater Protection Plan. Consistent with §330.331(a)(2), the leachate collection system has been designed to maintain less than 30 centimeters (approximately 12 inches) of leachate head over the bottom liner.

2 LEACHATE AND CONTAMINATED WATER GENERATION

2.1 GENERAL PROCESS

Leachate is generated as water infiltrates into the landfill cover (i.e., daily, intermediate, and final cover) and percolates through the layers of solid waste, and as moisture is released from high moisture content solid waste. The quantity of leachate produced will depend upon the climate, site topography, type of cover, construction and landfilling procedures, and waste characteristics.

Contaminated water is defined in 30 TAC §330.3(36) as "Leachate, gas condensate, or water that has come into contact with waste." Contaminated water is generated when stormwater runoff contacts solid waste at the working face of the landfill. Contaminated water will be handled and disposed in the same manner as leachate, as described in this attachment.

2.2 LEACHATE GENERATION

The HELP model, Version 3.95, was used to estimate the amount of leachate that will be generated by the landfill during periods with and without leachate recirculation (see Section 5 of this attachment) and the response of the leachate collection system components to maintain the leachate head on the liner below 30 centimeters. The HELP model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model uses climate, soil, and landfill design data in its calculations. Using the input data, the model accounts for the effects of runoff, infiltration, percolation, evapotranspiration, absorption, recirculation, soil-moisture storage, surface storage, and lateral drainage to estimate leachate generation.

Leachate generation was evaluated for active, interim, and closed landfill conditions, including the impacts on leachate generation as a result of leachate recirculation. Appendix 12A describes the HELP model demonstration, which was designed to be representative of landfill development. In addition, Appendix 12A describes the landfill profile input parameters and assumptions that were utilized in the HELP model simulations.

As presented in Appendix 12A "Help Model Summary Sheets", the HELP model results demonstrate that the leachate collection system will maintain less than the 30 centimeters of leachate head over the bottom liner for all conditions modeled.

Leachate system design calculations are presented in Appendix 12B.

2.3 STORMWATER MANAGEMENT

Surface water will be managed throughout the active life of the landfill to minimize the amount of stormwater that will come into contact with waste or leachate. Surface water run-on onto the working face will be controlled using temporary diversion berms and ditches. Diversion berms will be constructed on the up-hill side of the working face to divert stormwater away from the working face, thus reducing the volume of contaminated water generated during a storm event. Additionally, to promote runoff and prevent ponding, the landfill cover will be graded and maintained to divert surface water away from the working face of the landfill.

Surface water runoff from the working face (i.e., contaminated water) will be contained at the working face using containment berms. Water that infiltrates into the underlying waste will be managed as leachate. Contaminated water at the working face will be kept to a minimum and will be routinely removed and handled consistent with Section 5 (Leachate and Contaminated Water Disposal) of this attachment. Additionally, at no time will contaminated water be allowed to discharge offsite into waters of the United States or onto adjacent properties.

Methodologies described in the Texas Department of Transportation's Hydraulic Design Manual (revised March 2016) were used to estimate the volume of water that will be diverted around the working face or contained at the working face. These methodologies were also used to develop an approach for estimating the height of berms required to contain the contaminated water and divert uncontaminated surface water from contacting the working face of the landfill. The design calculations and sizing of the diversion and containment berms for a 25 year, 24-hour storm event are provided in Appendix 12C.

Uncontaminated stormwater runoff will be discharged from the landfill consistent with the Texas Pollutant Discharge Elimination System (TPDES) Multi-Sector General Permit (TXR05000, TPDES General Permit). Consistent with the TPDES General Permit and Part I/II, Section 10.2, a Notice-of-Intent (NOI) will be submitted to the TCEQ and a Stormwater Pollution Prevention Plan (SWP3) will be developed prior to commencement of landfill operations. Surface water will be managed throughout the active life of the landfill to minimize infiltration into the filled areas and to minimize contact with solid waste. In addition, daily, intermediate, and final cover will be graded and maintained to promote runoff and prevent ponding, thereby reducing leachate generation.

Consistent with 30 TAC §330.165(a) and (c), runoff generated from fill areas covered with a minimum 6 inches of intact earthen daily cover or 12 inches of intact intermediate cover, will be considered uncontaminated and will be allowed to discharge to the perimeter drainage system. Daily and intermediate cover will be applied consistent with the Part IV – Site Operating Plan.

3 LEACHATE COLLECTION SYSTEM

3.1 SYSTEM LAYOUT

The primary component providing leachate management in the landfill is the leachate collection system (LCS). The LCS is designed to control the accumulation of leachate within the waste disposal area during the active periods of landfilling, and after landfill closure. The LCS will consist of a primary leachate drainage layer (i.e., geocomposite) placed over the bottom and sideslope liner system, leachate collection piping, and leachate collection sumps and pumps. Layout of the LCS piping, grading, and sumps for the landfill is shown on Drawings 12.1 and 12.2 in this attachment. Liner details are shown on Drawing 12.3 and leachate collection system details are shown on Drawing 12.4.

3.2 LEACHATE DRAINAGE LAYER

The leachate drainage layer consists of a geonet-geotextile composite (referred to as geocomposite) placed directly over the bottom and sideslope liner systems. The geocomposite is utilized to collect and transfer leachate to the LCS pipes and sumps. The geocomposite consists of a high density polyethylene (HDPE) geonet with a non-woven geotextile heat bonded to one or both sides of the geonet, where single-sided geocomposite will be placed on the bottom and double-sided geocomposite will be placed on the sideslopes of the landfill. The geocomposite installed at the landfill will have hydraulic properties that will provide adequate drainage of leachate to the leachate collection piping and sump, thereby maintaining less than 30-cm leachate head above the bottom liner system. Additionally, the non-woven geotextile will provide adequate filtration of sediment and protection of the underlying geosynthetics during development of the landfill. Calculations demonstrating the minimum required material properties for the geocomposite and non-woven geotextile are presented in Appendix 12B.

A 2-foot-thick protective soil cover will be placed over the geocomposite prior to waste placement. Onsite soils, which will be used for protective cover, will have a hydraulic conductivity (k) less than 1.0×10^{-4} cm/sec. Therefore, to facilitate drainage into the leachate collection system, chimney drains, comprised of aggregate wrapped in a non-woven geotextile, will be constructed over the leachate collection piping. Additional discussion regarding the aggregate around the leachate collection piping is provided in Section 3.6 of this attachment.

3.3 LEACHATE COLLECTION PIPING

The bottom liner system of each sector will slope to drain at a minimum 2 percent toward a perforated leachate collection pipe located in the center of each sector. The leachate collection piping will be sloped at a minimum 1 percent to drain leachate into a leachate collection sump located at the perimeter of each sector. Sectors 1, 8, and 10 have two separate areas with centrally located leachate collection pipes that drain to a common sump. In this case, although centrally located leachate collection pipes within these areas will be sloped at 1 percent; leachate header pipes will be constructed at the toe of the cell sideslopes that will be sloped at a minimum 0.5 percent to drain leachate into the common sector sump.

The leachate collection pipes will be 6-inch diameter HDPE pipe with 0.5-inch perforations and a Dimensional Ratio (DR) value of 15.5 or less. Solid 6-inch diameter HDPE cleanout risers will be located on the sideslopes at the down-gradient and up-gradient ends of the leachate collection pipes to allow clean-out of the respective pipes. Solid 18-inch diameter HDPE (DR 32.5 or less) sump risers also will be located on the sideslopes at the down-gradient end of sectors that have leachate collection sumps for pump installation and removal of leachate from the leachate collection sumps. Design calculations for the leachate collection pipe and sump riser pipe are provided in Appendix 12B. These calculations demonstrate the adequacy of the pipes to convey leachate to the sumps, the structural stability of the pipes, and the satisfaction of the perforation requirements.

Due to overburden pressures in deeper portions of the landfill, it is necessary to construct chimney drains over the leachate collection piping using aggregate backfill, meeting the specifications described in Section 3.6. In addition to facilitating drainage through the protective cover, the chimney drains are necessary for pipe structural stability and provide redundant flow capacity for leachate drainage to the sumps in the event the pipes become damaged or clogged. The aggregate backfill will be separated from the adjacent protective cover and waste layers by wrapping the chimney drain in a non-woven geotextile fabric. A detail of the piping and chimney drains is provided on Drawing 12.4.

3.4 LCS DURABILITY AND LONG-TERM PERFORMANCE

In accordance with 30 TAC §330.333(1), the LCS and removal system has been designed with materials that are chemically resistant, sufficiently durable and capable of providing long-term performance. High density polyethylene (HDPE) will be used, because it is the material of choice for LCS geocomposite geonet and piping, as well as the bottom liner system, due to its durability, flexibility, and chemical resistance in aggressive chemical environments. Documentation presenting chemical resistance information for HDPE is presented in Appendix 12D. Polypropylenes incorporated into geotextiles have been demonstrated to provide similar performance in landfill applications.

Furthermore, the drainage stone incorporated into the LCS will have a low calcium carbonate content so as to avoid negative impacts by contact with leachate. Lastly, the analysis of pipe strength under the construction and fill conditions at the landfill is presented in Appendix 12B. These calculations demonstrate the pipe has been designed to perform adequately under both construction and waste loading conditions.

In conclusion, the LCS has been designed with components of sufficient chemical resistance, durability, and strength to provide adequate performance through the active life as well as the closure and post-closure periods of the landfill.

3.5 LEACHATE COLLECTION SUMPS AND PUMPS

The leachate collection sumps and pumps have been designed and sized to limit maximum head above the bottom liner system at the outside edge of the sumps to within the thickness of the geocomposite (i.e., less than 30 centimeters above the bottom liner, see Appendix 12A, Section 1.4.3.2). Each leachate collection sump will be at least 3 feet deep with minimum dimensions depending on the acreage of the area contributing to the sump, as shown on Drawing 12.4 (see Detail A). Sumps with a contributing area less than 24 areas and more than 15 acres (i.e., large sumps) will be constructed with minimum dimensions of 50 by 50 feet at the landfill floor and 32 by 32 feet at the sump base. Sumps with a contributing area less than 15 acres (i.e., small sumps) will be constructed with minimum dimensions of 40 by 40 feet at the landfill floor and 22 by 22 feet at the sump base. The leachate collection sumps have been designed to provide storage of approximately 11,900 gallons of leachate for the large sump and 7,000 gallons of leachate for the small sump (Note, these capacities exclude approximately 6 inches of lost storage required for the pump head volume). The sumps will provide approximately 1 day of leachate storage for the maximum calculated leachate generation rate, as provided in the sump design calculations provided in Appendix 12B. Sumps will be backfilled with drainage stone meeting the gradation requirements specified in Section 3.6 of this attachment.

Leachate will be removed from the sump using a submersible pump located in an 18-inch diameter sideslope sump riser pipe. Leachate will be transferred to above-ground leachate storage tank(s), as described in Section 4 of this attachment. As described in Section 5 of this attachment, leachate will be either disposed of at a local wastewater treatment plant or recirculated back into the landfill.

Each sump will be equipped with a permanent submersible pump and controls. Each pump will be equipped with sensors (i.e., pressure transducers) to turn the pump on and off based on leachate levels within the respective sump. The pump-on liquid level will be set at a maximum elevation of 30 inches above the bottom of the sump. The pump-off liquid level will be set at a maximum elevation of 6 inches above the bottom of the sump or the manufacturer's recommended minimum depth to protect the pump from damage during low-level pumping. Using the pump's level controls, leachate levels will be maintained within the sumps at a depth ranging from 6 to 30 inches, thereby preventing the sumps from overtopping. Additionally, each sump pump will be equipped with a pressure transducer that will allow monitoring of leachate levels within the sump. Landfill personnel will monitor the leachate levels within the sumps and record the levels in the Site Operating Record on a weekly basis to verify that the pumps are operating correctly and leachate levels are being maintained within the sumps. The pump control panel will also be equipped with a high-level indicator light, which will indicate when leachate levels within the sump reach a depth that may result in leachate levels above the bottom liner system greater than 30 centimeters.

In the unlikely event of a pump failure, the leachate storage capacity of the sump will provide adequate storage capacity to prevent accumulation of leachate on the liner outside the sump for a period of at least one day. Sump design calculations are presented in Appendix 12B. The leachate collection sump configuration is provided on Drawing 12.3.

3.6 DRAINAGE AGGREGATE

Granular drainage material around the leachate collection pipes and in the sumps will consist of durable particles of aggregate. The aggregate will be tested (in accordance with JLT-S-105-89 or ASTM D3042 modified to use a solution of hydrochloric acid having a pH of 5) to demonstrate that the loss of mass will be less than 15 percent.

The drainage aggregate will meet the following gradation:

Sieve Size Square Opening	Percent Passing
2 inches	100
½ inch	0 – 5

Drainage aggregate of this gradation will have a permeability greater than or equal to $1x10^{-2}$ cm/s, therefore no permeability testing is required.

The drainage aggregate will be covered by a 12 oz/sy or greater weight non-woven geotextile to maintain separation of drainage aggregate from the overlying operational layers and surrounding protective cover. The geotextile used to protect the drainage aggregate will be inert to commonly encountered chemicals, hydrocarbons, and will be mildew and rot resistant.

4 LEACHATE AND CONTAMINATED WATER STORAGE

As discussed in Section 3.5, leachate storage will be provided in the leachate collection sumps and above-ground leachate storage tank(s). Initial leachate storage will be provided in the leachate collection sumps. Each sump will provide approximately between 7,000 and 11,900 gallons of leachate storage, depending on sump size, which includes at least one day of storage time, assuming an average leachate generation rate. Sump volume calculations are provided in Appendix 12B. Leachate will be removed from the sumps by submersible pumps located within the sump riser pipes. The sump pumps will discharge leachate into above-ground leachate storage tank(s), as described below.

Additionally, contaminated water (surface water contacting waste) will be contained at the working face using containment berms, as described in Section 2.3 of this attachment. Water that infiltrates into the underlying waste will be managed as leachate. Through routine landfill operations contaminated water contained at the working face will be removed by the end of each working day, and discharged to an above-grade leachate storage tank.

Leachate and contaminated water will be stored in the storage tank(s) until it is hauled off for disposal at a local wastewater treatment plant (WWTP) or recirculated back into the landfill, as described in Section 5.

Actual leachate generation and recirculation rates will govern the ultimate number and capacity of above-ground leachate storage tank(s) required at the landfill. As the landfill is developed and leachate generation decreases/increases, the number and size of leachate storage tanks will also be decreased/increased. Storage of leachate and contaminated water will be conducted in one or a combination of the following two ways:

- Option 1 – Temporary leachate storage tanks will be located adjacent to the perimeter haul road and adjacent to one of the sector's leachate collection sump risers. At a minimum, the leachate storage tanks will be located in an area that is optimal for collection of leachate from multiple sectors and that is easily accessible to tanker or vacuum trucks for removal of leachate.

- Option 2 – Permanent leachate storage tank(s) will be located within the landfill permit boundary at the location depicted on Drawing 12.1. Leachate generated will be transported to the leachate storage tank(s) via a leachate forcemain serving both disposal areas. The permanent leachate storage tank(s) also will be installed to allow for easy access to tanker or vacuum trucks for removal of leachate.

Storage tanks will be either single or double-contained. In either event, the storage tanks used at the landfill will either be fabricated from steel, polyethylene, or fiberglass. Therefore, the storage tanks installed will be fabricated consistent with one of the following standards (i.e., depending on the material that the tank was fabricated from):

- AWWA D100 for welded carbon steel tanks;
- ASTM D1998 for upright polyethylene storage tanks; and

- ASTM D3299 for filament wound glass-fiber-reinforced thermoset resin chemical-resistant tanks (i.e., fiberglass).

If single-contained, secondary containment will be provided by construction of either geomembrane-lined or concrete-lined containment. The area encompassed and height of the containment will provide sufficient capacity to detain the capacity of the single largest tank and 7.9 inches of precipitation (i.e., 25-year, 24-hour storm event) while maintaining one-foot of freeboard over the detained volume. Additionally, each storage tank (single- and double-contained) will be equipped with level or tank float sensor(s) that communicates with each pump control panel when the tank is full and shuts down the pumps until sufficient leachate volume has been removed from the tank. Furthermore, each storage tank will be equipped with quick connects or control valves (size and type recommended by the manufacturer of the tank) that will allow tanker or vacuum trucks to connect to the tank without spilling leachate during transfer operations. Landfill personnel will inspect leachate tanks, related piping, and connections on a weekly basis. During these inspections, landfill personnel will also verify that a spill has not occurred. Records of these inspections and any maintenance as a result of the inspections will be maintained in the Site Operating Record.

In the event a leachate or contaminated water spill occurs, these liquids will be treated as contaminated water and contained by either the tank secondary containment, construction of earthen berms, or placement of sorbent pads/socks, etc. surrounding the spill, and landfill personnel will implement the following spill response procedures:

1. Immediately remove the leachate or contaminated water upon detection of the spill or leak by pumping the leachate or contaminated water to a secured tank.

2. The area subjected to the spill or leak will also be cleaned up by removing all soil or material showing any sign of contamination and disposed of at the working face of the landfill.

3. The resulting clean-up procedures will be documented in the Site Operating Record.

Additionally, potential spills and spill response efforts and cleanup, reporting, and recordkeeping related to the above-ground leachate storage tanks or any component of the leachate collection system will also be addressed in the Stormwater Pollution Prevention Plan (SWP3), which will be prepared and implemented prior to commencement of landfill operations. The SWP3 will be prepared consistent with the Texas Pollutant Discharge Elimination System (TPDES) General Permit TXR050000, including spill prevention and response measures, as required by Part III, Section A.4(e) 12D of the TPDES General Permit.

5 LEACHATE AND CONTAMINATED WATER DISPOSAL AND RECIRCULATION

Leachate and contaminated water (including gas condensate) will either be transported by tanker truck to a nearby WWTP or will be recirculated back into the landfill. The City of Waco may dispose of leachate and contaminated water from this landfill at the Central Plant (formerly known as Waco Metropolitan Area Regional Sewer System (WMARSS)) consistent with current authorization and operations at the existing City of Waco Landfill.

Leachate or contaminated water, as defined in Section 2.1, may be recirculated back into the landfill by either injecting through vertical or horizontal pipes in the waste, or spraying leachate or contaminated water back onto the waste. All areas of waste disposal will have the constructed composite liners as required for leachate recirculation in accordance with 30 TAC §330.331(b). Leachate and/or contaminated water that are recirculated by means of spraying will be performed using the following procedures:

1. Leachate and/or contaminated water will be sprayed directly onto the waste at the working face via a dedicated water truck or dedicated mobile tank unit.
2. Prior to spraying at the working face, it will be verified that containment berms and diversion berms are properly in place, as described in Section 2.3.
3. The spray application will not be performed when standing water exists or during rain events.
4. No odors are expected to be associated with this practice. Nevertheless, to provide assurance that odors and wind transmission are minimized, the following procedures will be implemented:
   a. The spray application of leachate will be performed at a minimum 100-foot setback from the limits-of-waste.
   b. The leachate and/or contaminated water will be sprayed down towards the waste, such that the water stream is not being projected up into the air.
   c. Spray applications will only be performed on days when the wind speed is less than or equal to 15 miles per hour.

   Implementing the above procedures will not only assure environmental benefits, it will help assure the efficiency of the spray application.

The Landfill Manager will maintain records of the volume of leachate or contaminated water recirculated into the landfill. The recirculation volume will be measured using either flow meters connected to pumps and/or water trucks, or by the volume discharged from leachate tanks or water trucks based on the capacity of such storage units.

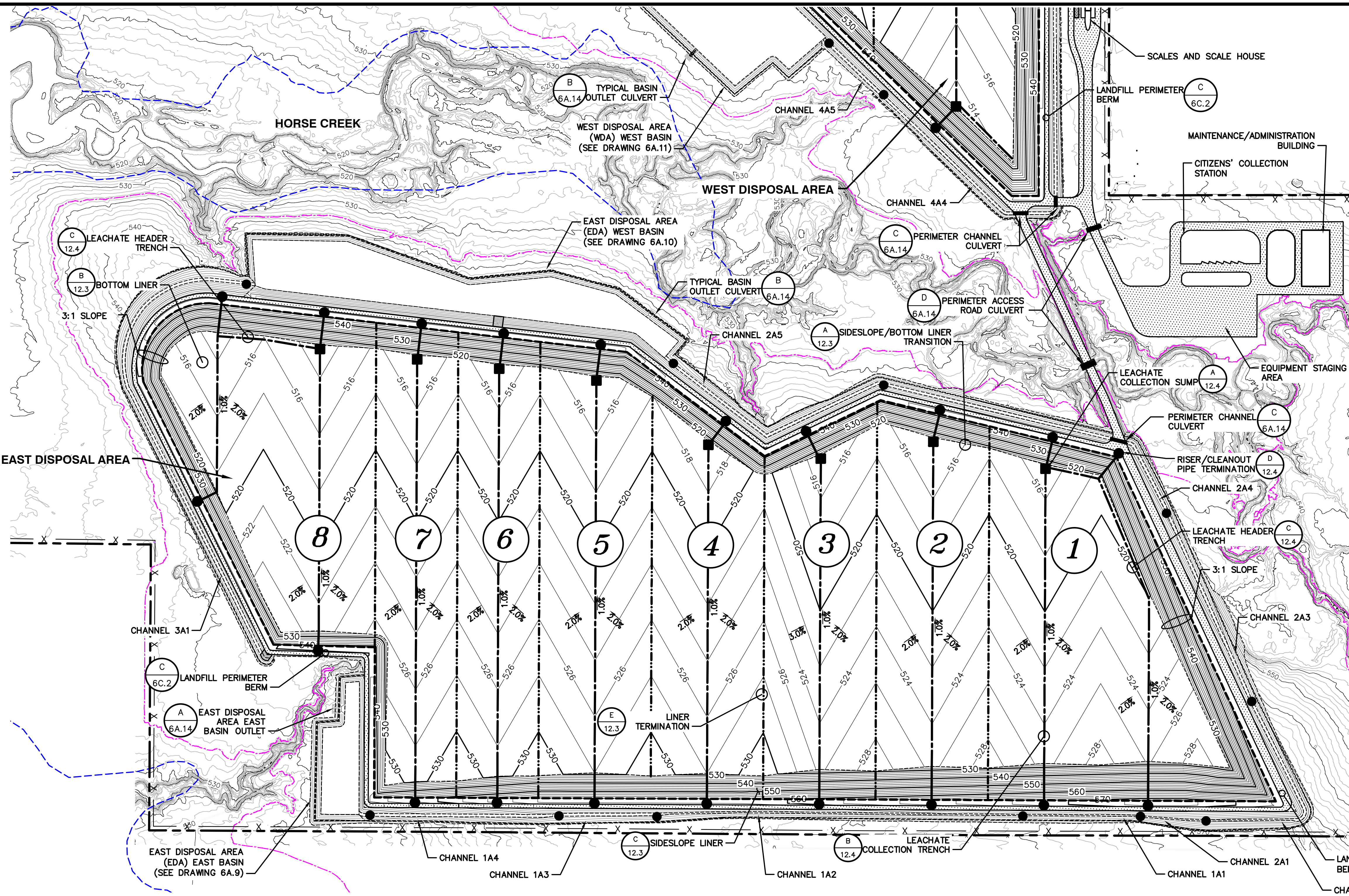
Leachate recirculation will be performed such that ponding and seeps will not occur. If either ponding or seeps are detected or if the leachate head on the liner exceeds 30 centimeters, the leachate recirculation in the respective sector will be discontinued until the condition is remediated.

Leachate recirculation will be restricted to volumes less than 80,200 gallons/acre/year during below-grade waste disposal and 26,690 gallons/acre/year during above-grade waste disposal. These allowable recirculation volumes pertain to areas draining to a common sump. The calculations and respective HELP modeling for leachate recirculation are provided in Appendix 12A of this attachment.

Consistent with 30 TAC §330.177, leachate and contaminated water that is disposed of at a WWTP will be sampled and analyzed consistent with the requirements of the receiving WWTP. Such analytical results will be placed in the Site Operating Record maintained at the landfill.

DRAWINGS

- Drawing 12.1: East Disposal Area - Leachate Collection System Layout Plan
- Drawing 12.2: West Disposal Area - Leachate Collection System Layout Plan
- Drawing 12.3: Bottom Liner Details
- Drawing 12.4: Leachate Collection System Details



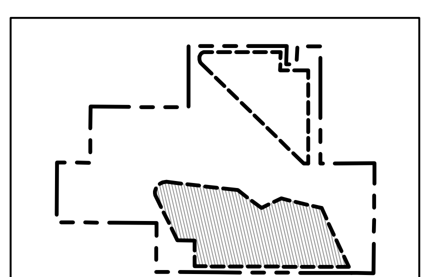
0 200 400
SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LIMITS OF WASTE
- SECTOR BOUNDARY
- EXISTING TOPOGRAPHIC CONTOURS (SEE NOTE 1)
- 100–YEAR FLOOD PLAIN (SEE NOTE 2)
- 100–YEAR STORM EVENT WATER SURFACE (SEE NOTE 5)
- PROPOSED/EXISTING PERIMETER FENCE (CHAIN LINK OR BARBED WIRE)
- ACCESS ROAD
- TOP OF PROTECTIVE COVER TOPOGRAPHIC CONTOURS (SEE NOTE 3)
- LEACHATE COLLECTION SUMP
- LEACHATE COLLECTION PIPE
- TOE/TOP OF SLOPE
- CLEANOUT/SUMP RISER
- CHANNEL SECTION
- SECTOR DESIGNATION (SEE NOTE 4)

NOTES:

1. THE EXISTING TOPOGRAPHY SHOWN ON THIS PLAN WAS DEVELOPED BY DAS GEOSPATIAL FLOWN ON JULY 03, 2018.
2. 100–YEAR FLOOD PLAIN IS DESIGNATED AS ZONE A, BASED ON FIRM PANEL 48293C0125C, DATED 09/16/11.
3. ELEVATIONS SHOWN ON THIS DRAWING WITHIN WASTE LIMITS ARE TOP OF PROTECTIVE COVER ELEVATIONS IN FEET MEAN SEA LEVEL (FT MSL).
4. SECTOR DEVELOPMENT SEQUENCE REPRESENTED BY NUMBERING. SECTORS MAY BE DEVELOPED IN SMALLER INCREMENTS (AKA SUBSECTORS OR CELLS) WITH LINER CERTIFICATIONS SUBMITTED SEPARATELY TO TCEQ FOR REVIEW. IF SECTORS ARE DEVELOPED AS SMALLER CELLS, THE DOWN–GRADIENT CELLS WITH LEACHATE COLLECTION SUMP WILL BE DEVELOPED FIRST.
5. 100–YEAR STORM EVENT WATER SURFACE WAS ESTIMATED USING HEC–HMS AND HEC–RAS MODELING AS DISCUSSED IN ATTACHMENT 6B OF THIS PERMIT APPLICATION.



KEY MAP

RYAN R. KUNTZ
104689
LICENSED PROFESSIONAL ENGINEER
STATE OF TEXAS
5/13/2020

FOR PERMITTING PURPOSES ONLY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: EAST DISPOSAL AREA LECAHTE COLLECTION SYSTEM LAYOUT PLAN

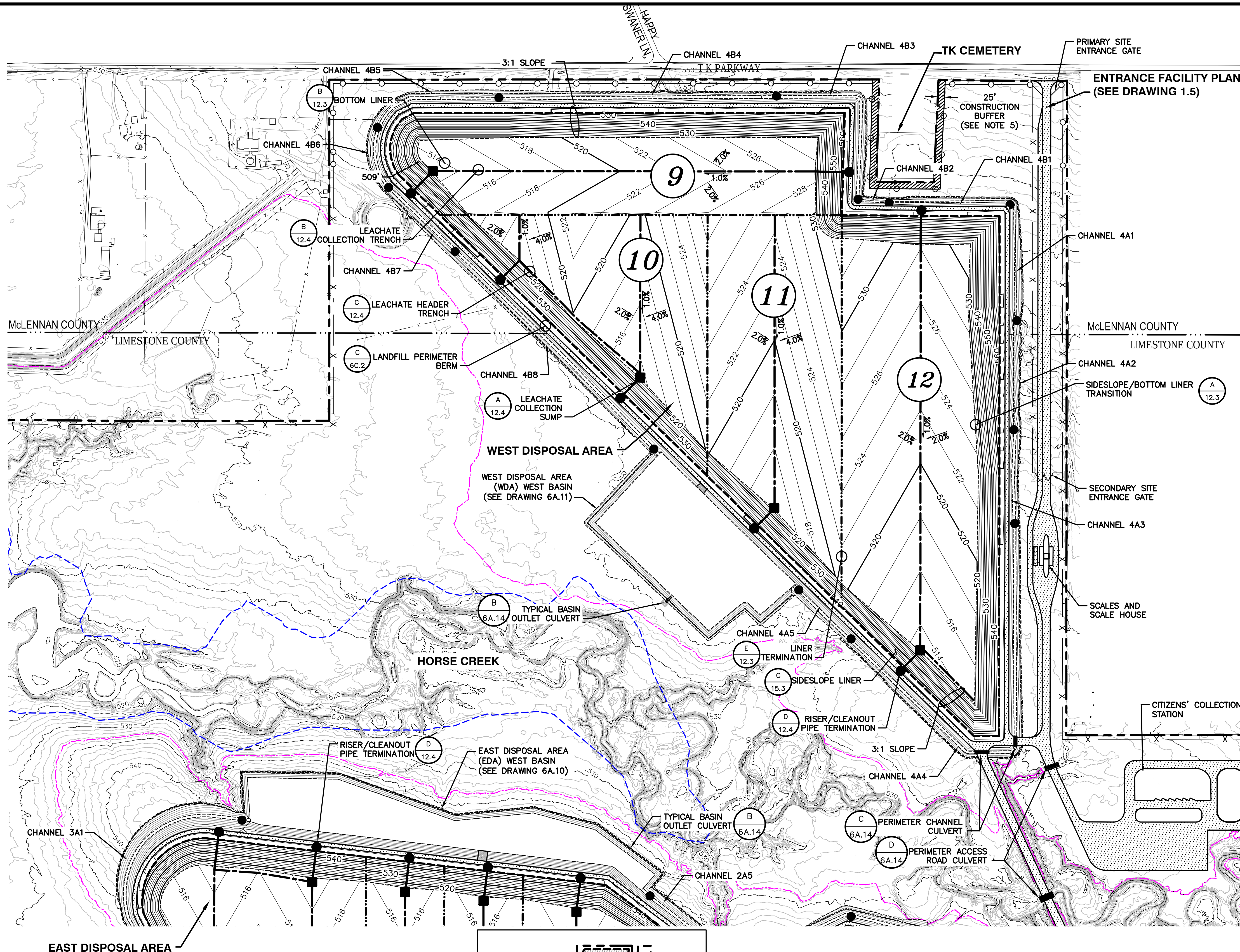
PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

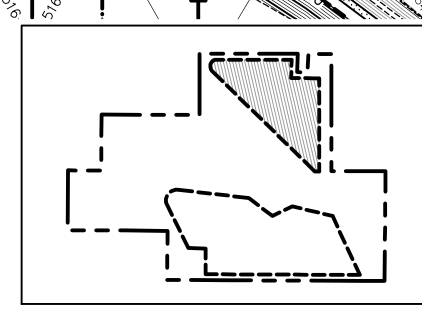
CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00 | DSN. BY: BC/RRK | DWN. BY: NR | CHK. BY: BJD | Q/A RVW BY: RRK | APP. BY: RRK

CADD FILE: 12.1 – LECHATE COLLECTION LAYOUT - EAST
DATE: 04/2020
SCALE: AS SHOWN
DRAWING NO. 12.1





KEY MAP

LEGEND

- PERMIT BOUNDARY
- LIMITS OF WASTE
- SECTOR BOUNDARY
- COUNTY LINE
- EXISTING TOPOGRAPHIC CONTOURS (SEE NOTE 1)
- 100-YEAR FLOOD PLAIN (SEE NOTE 2)
- 100-YEAR STORM EVENT WATER SURFACE (SEE NOTE 6)
- PROPOSED PERIMETER FENCE (CHAIN LINK)
- PROPOSED 8' PRIVACY FENCE
- ACCESS ROAD
- TOP OF PROTECTIVE COVER TOPOGRAPHIC CONTOURS (SEE NOTE 3)
- LEACHATE COLLECTION SUMP
- LEACHATE COLLECTION PIPE
- TOE/TOP OF SLOPE
- CLEANOUT/SUMP RISER
- CHANNEL SECTION
- X SECTOR DESIGNATION (SEE NOTE 4)

NOTES:

1. THE EXISTING TOPOGRAPHY SHOWN ON THIS PLAN WAS DEVELOPED BY DAS GEOSPATIAL FLOWN ON JULY 03, 2018.
2. 100-YEAR FLOOD PLAIN IS DESIGNATED AS ZONE A, BASED ON FIRM PANEL 48293C0125C, DATED 09/16/11.
3. ELEVATIONS SHOWN ON THIS DRAWING WITHIN WASTE LIMITS ARE TOP OF PROTECTIVE COVER ELEVATIONS IN FEET MEAN SEA LEVEL (FT MSL).
4. SECTOR DEVELOPMENT SEQUENCE REPRESENTED BY NUMBERING. SECTORS MAY BE DEVELOPED IN SMALLER INCREMENTS (AKA SUBSECTORS OR CELLS) WITH LINER CERTIFICATIONS SUBMITTED SEPARATELY TO TCEQ FOR REVIEW. IF SECTORS ARE DEVELOPED AS SMALLER CELLS, THE DOWN-GRADIENT CELLS WITH LEACHATE COLLECTION SUMP WILL BE DEVELOPED FIRST.
5. IN ACCORDANCE WITH "AN INTENSIVE CULTURAL RESOURCES SURVEY OF THE CITY OF WACO'S PROPOSED SITE 50 LANDFILL PROJECT," PREPARED BY HORIZON ENVIRONMENTAL SERVICES, INC., DATED NOVEMBER 2018 (SEE APPENDIX I/IIA), A 25-FOOT CONSTRUCTION BUFFER WILL BE MAINTAINED AROUND TK CEMETERY TO PROTECT ANY POTENTIAL UNMARKED GRAVES OUTSIDE THE PRESENT MODERN DAY CEMETERY BOUNDARIES AND FENCING.
6. 100-YEAR STORM EVENT WATER SURFACE WAS ESTIMATED USING HEC-HMS AND HEC-RAS MODELING AS DISCUSSED IN ATTACHMENT 6B OF THIS PERMIT APPLICATION.

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED PROFESSIONAL ENGINEER
5/13/2020

FOR PERMITTING PURPOSES ONLY

REV. | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: WEST DISPOSAL AREA LECAHTE COLLECTION SYSTEM LAYOUT PLAN

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

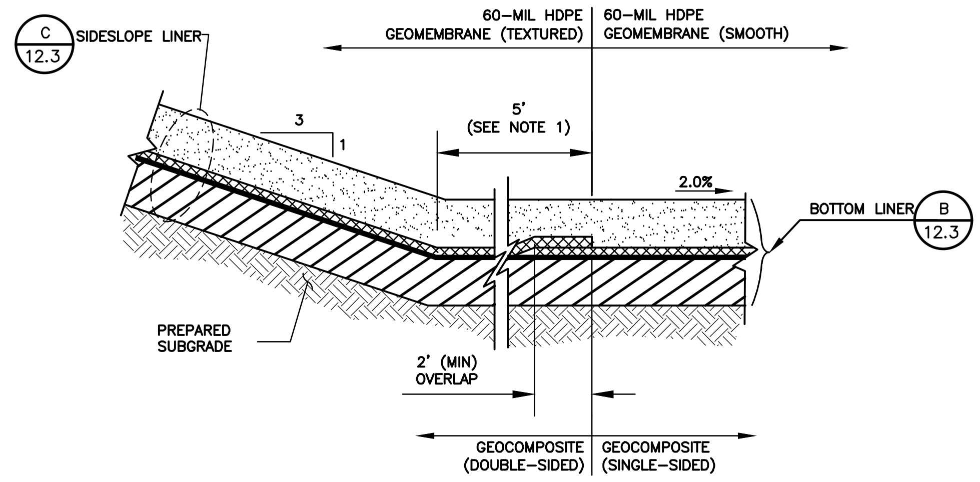
PROJ. NO. 16216088.00 | DSN. BY: BC/RRK | DWN. BY: NR | CHK. BY: BJD | Q/A RVW BY: RRK | APP. BY: RRK

CADD FILE: 12.2 - LECHATE COLLECTION LAYOUT - WEST

DATE: 04/2020

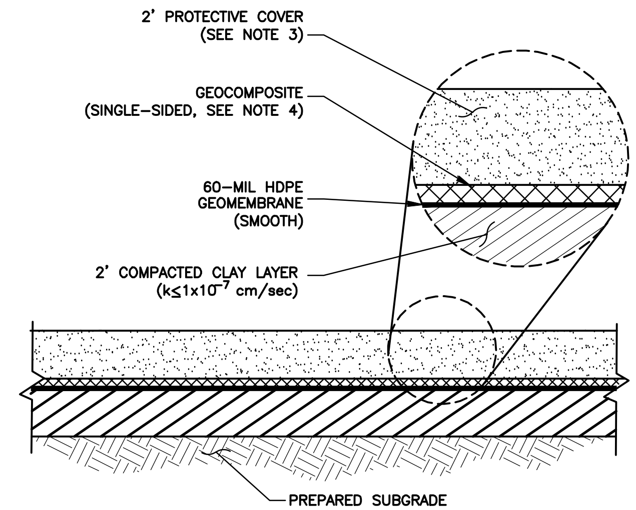
SCALE: AS SHOWN

DRAWING NO. 12.2



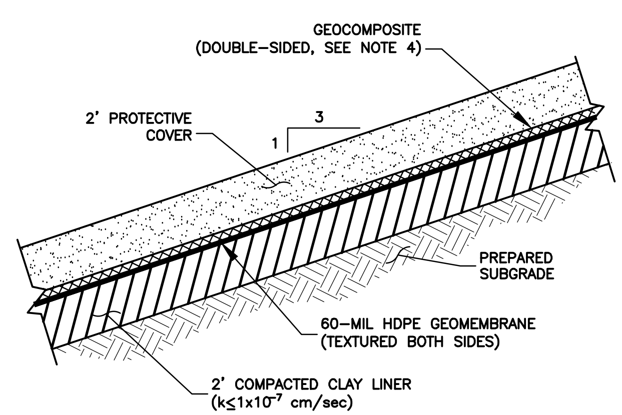
SIDESLOPE/BOTTOM LINER TRANSITION (A / 12.3)

NTS



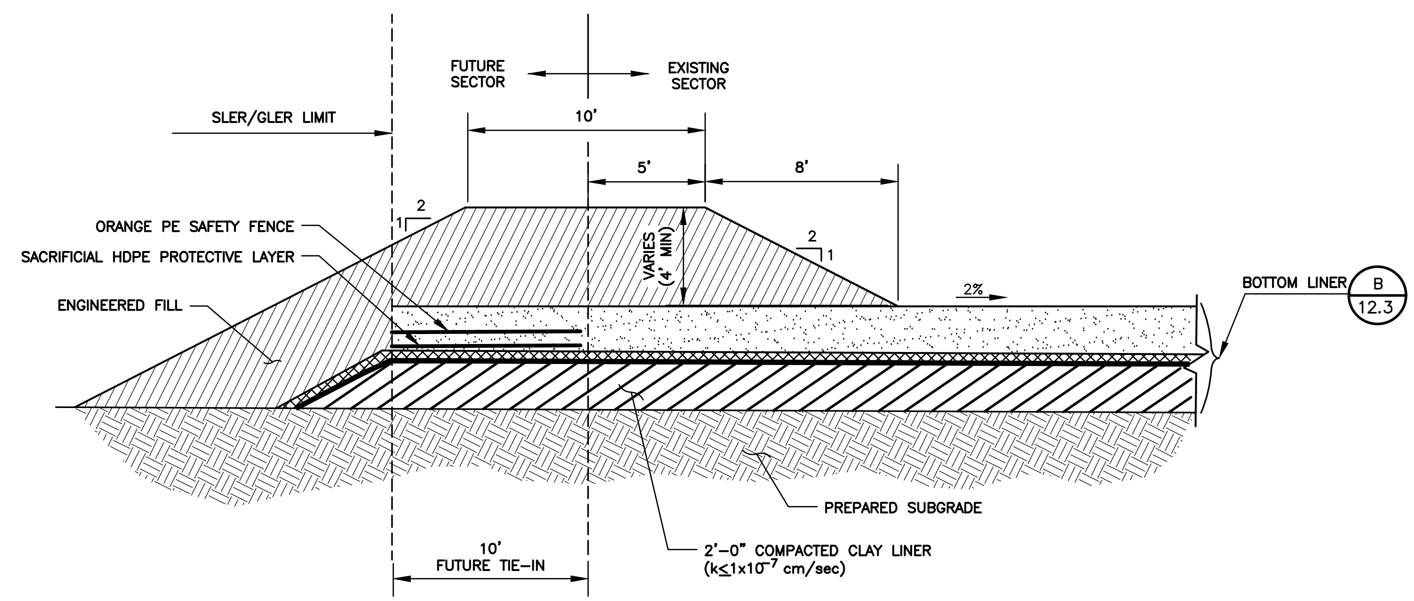
BOTTOM LINER (B / 12.3)

NTS



SIDESLOPE LINER (C / 12.3)

NTS



LINER TERMINATION (D / 12.3)

NTS

NOTES:

1. TEXTURED HDPE TO EXTEND A MINIMUM OF 5' ONTO CELL FLOOR IN ALL AREAS.
2. PROTECTIVE COVER WILL CONSIST OF ON-SITE SOILS. CHIMNEY DRAINS WILL BE UTILIZED TO FACILITATE FLOW INTO THE LEACHATE COLLECTION SYSTEM AND TO PROVIDE ADDITIONAL STABILITY TO THE COLLECTION PIPING.
3. PROTECTIVE COVER WILL BE PLACED USING LOW PRESSURE GROUND EQUIPMENT AS DESCRIBED IN ATTACHMENT 10-SLQCP, SECTION 7.
4. SEE ATTACHMENT 12-LEACHATE AND CONTAMINATED WATER MANAGEMENT PLAN FOR LEACHATE COLLECTION SYSTEM MATERIAL DESCRIPTION.

FOR PERMITTING PURPOSES ONLY

REV	DATE	DESCRIPTION	BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: BOTTOM LINER DETAILS

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

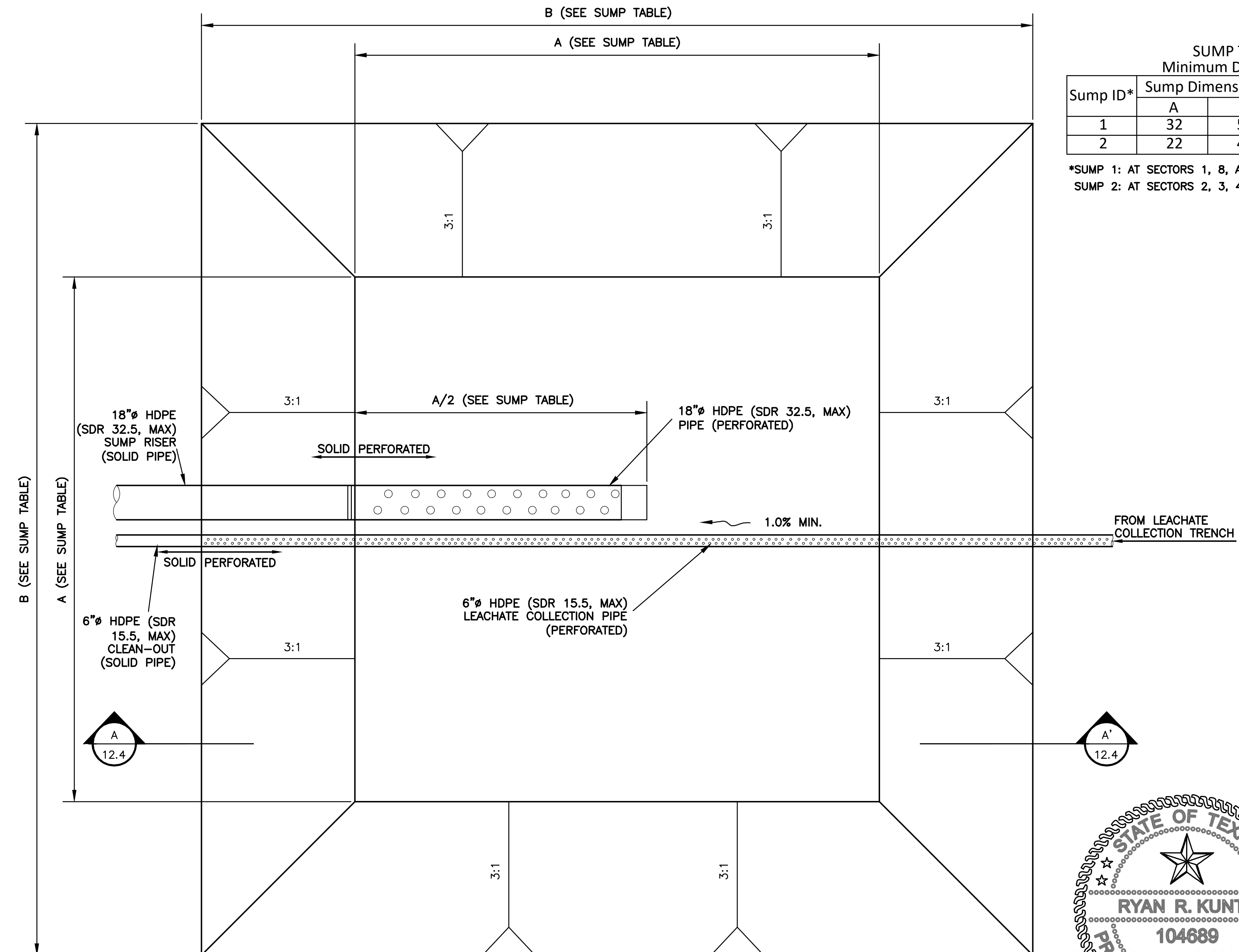
PROJ. NO. 16216088.00 | DSN. BY: BG/RRK | DWN. BY: NR | CHK. BY: BJD | Q/A RVW BY: RRK | APP. BY: RRK

CADD FILE: 12.3 – BOTTOM LINER DETAIL

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. **12.3**



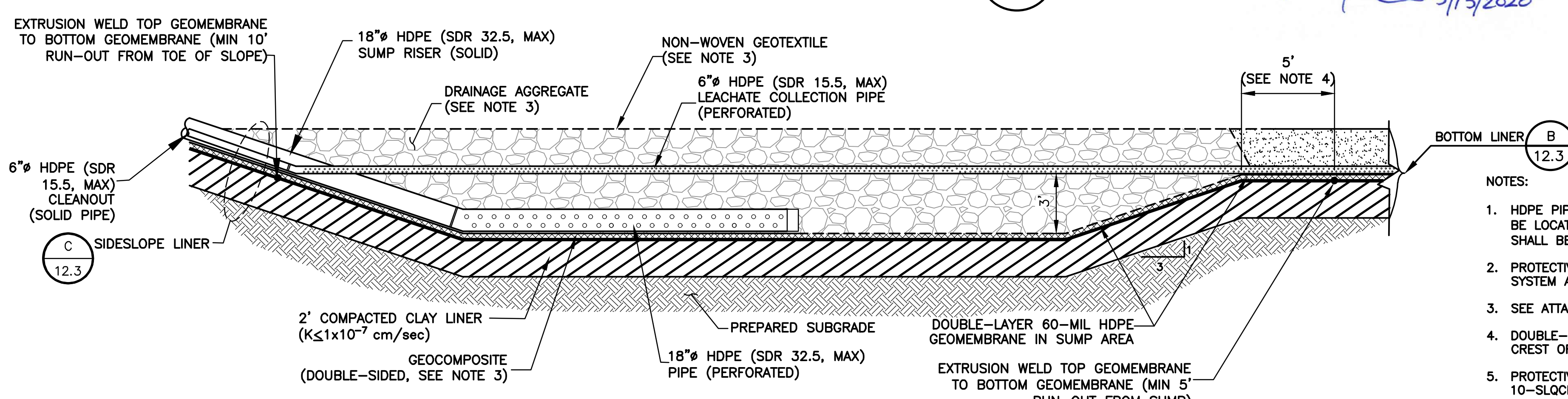
LEACHATE COLLECTION SUMP (A / 12.4)

NTS

SUMP TABLE
Minimum Dimensions

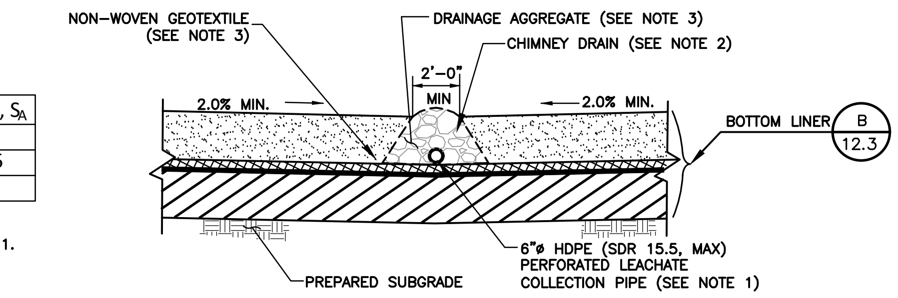
Sump ID*	Sump Dimensions (ft) A	Sump Dimensions (ft) B	Sector Area, S_A (acres)
1	32	50	$24 \geq S_A > 15$
2	22	40	$15 \geq S_A$

*SUMP 1: AT SECTORS 1, 8, AND 12; AND
SUMP 2: AT SECTORS 2, 3, 4, 5, 6, 7, 9, 10, AND 11.



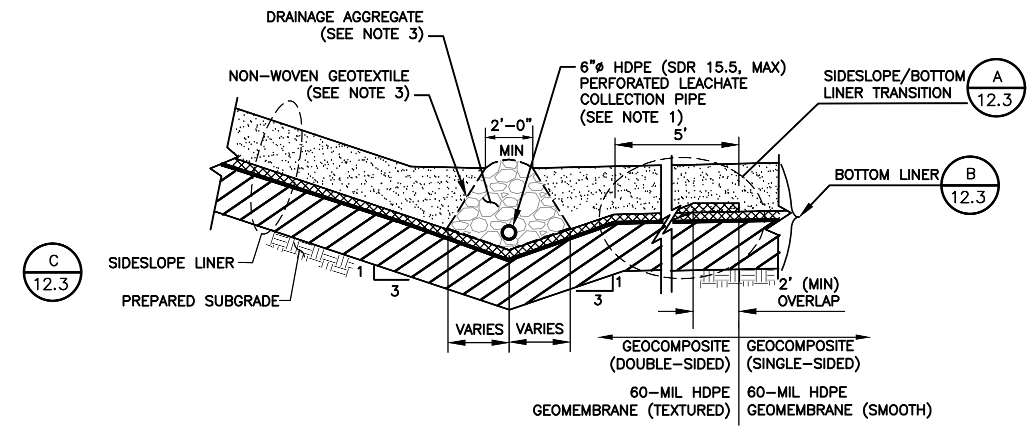
SECTION A–A' (A–A' / 12.4)

NTS



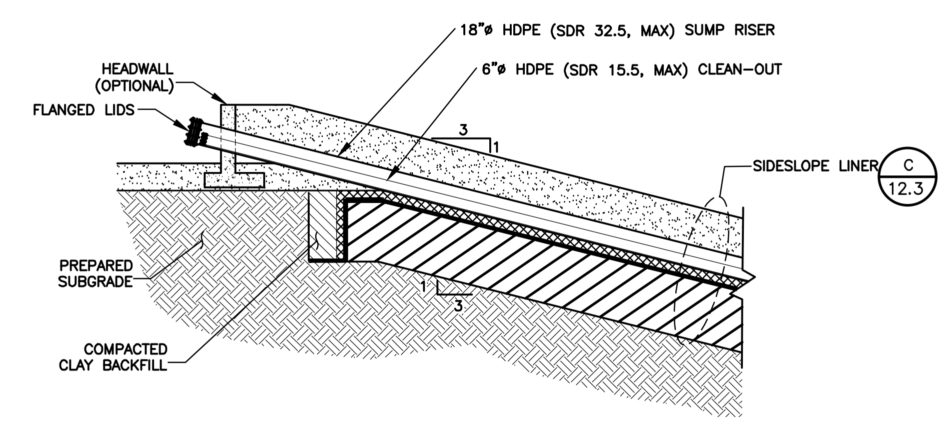
LEACHATE COLLECTION TRENCH (B / 12.4)

NTS



LEACHATE HEADER TRENCH (SEE NOTE 6) (C / 12.4)

NTS



RISER/CLEANOUT PIPE TERMINATION (D / 12.4)

NTS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED PROFESSIONAL ENGINEER
5/13/2020

NOTES:

1. HDPE PIPE PERFORATIONS SHALL BE 1/2-INCH DIAMETER. THREE ROWS OF PERFORATIONS WILL BE INSTALLED: ONE ROW OF PERFORATIONS WILL BE LOCATED AT THE TOP OF THE PIPE (0 DEGREE LOCATION); ONE AT 120 DEGREES; AND ONE AT THE 240 DEGREE LOCATION. PERFORATIONS SHALL BE PLACED EVERY 6 INCHES IN A ROW WITH THE TOP ROW STAGGERED 3" FROM THE PERFORATIONS IN THE ADJACENT ROWS.
2. PROTECTIVE COVER WILL CONSIST OF ON-SITE SOILS. CHIMNEY DRAINS WILL BE UTILIZED TO FACILITATE FLOW INTO THE LEACHATE COLLECTION SYSTEM AND TO PROVIDE ADDITIONAL STABILITY TO THE COLLECTION PIPING.
3. SEE ATTACHMENT 12–LEACHATE AND CONTAMINATED WATER MANAGEMENT PLAN FOR LEACHATE COLLECTION SYSTEM MATERIAL DESCRIPTION.
4. DOUBLE-SIDED GEOCOMPOSITE AND DOUBLE LAYER TEXTURED GEOMEMBRANE SHALL BE TRANSITION TO BOTTOM LINER SYSTEM 5-FEET FROM CREST OF SLOPE OF SUMP.
5. PROTECTIVE COVER AND DRAINAGE AGGREGATE SHALL BE PLACED USING LOW PRESSURE GROUND EQUIPMENT AS DESCRIBED IN ATTACHMENT 10–SLQCP.
6. SECTORS 1, 8, 10, AND 12 WILL BE CONSTRUCTED WITH ADDITIONAL LEACHATE HEADER TRENCHES AT THE TOE OF THE CELL SIDESLOPES THAT WILL BE SLOPED AT A MINIMUM 0.5 PERCENT TO DRAIN LEACHATE INTO THE COMMON SECTOR SUMP.

FOR PERMITTING PURPOSES ONLY

REV | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: LEACHATE COLLECTION SYSTEM DETAILS

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16216088.00 | DSN. BY: BC/RRK | DWN. BY: NR | CHK. BY: BJD | Q/A RVW BY: RRK | APP. BY: RRK

CADD FILE: 12.4 – LEACH COLL DETAIL

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 12.4

APPENDIX 12A

LEACHATE GENERATION MODEL (HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) OUTPUT FILES)

- Leachate Generation Model Narrative
- Climatological Data
- Help Model Summary Sheets
- HELP Output Files (Without Leachate Recirculation)
- HELP Output Files (With Leachate Recirculation)

LEACHATE GENERATION MODEL NARRATIVE

12ACITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
McLENNAN AND LIMESTONE COUNTIES, TEXAS

PART III
SITE DEVELOPMENT PLAN
ATTACHMENT 12, APPENDIX A
LEACHATE GENERATION MODEL NARRATIVE

Prepared for:

CITY OF WACO

Public Works Department
401 Franklin Avenue
Waco, TX 76701

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 – July 2019
SCS Project No. 16216088.00

TABLE OF CONTENTS

SECTION **PAGE**

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER

5/13/2020

SCS Engineers
TBPE Reg. # F-3407

1 LEACHATE GENERATION MODEL

1.1 OBJECTIVE

The following leachate generation modeling demonstrates that the design of the proposed leachate collection system (LCS) and the composite liner at the Waco New Landfill (landfill), complies with the requirements of 30 TAC §330.331(a)(2). Specifically, 30 TAC §330.331(a)(2) states that the LCS and composite liner shall be "…designed and constructed to maintain less than a 30 centimeters depth of leachate over the liner." Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.95D, developed by the U.S. Army Corp of Engineer and University of Hamburg, was utilized for the purpose of demonstrating that the LCS and composite liner (herein referred to as the bottom liner system) have been designed to maintain leachate levels that do not exceed the 30-centimeter (approximately 12 inches) criteria.

Furthermore, the active and interim conditions were analyzed for landfill operations during periods of no leachate recirculation and during periods of leachate recirculation. The closed condition with final cover was only analyzed during periods of no leachate recirculation.

1.2 LEACHATE COLLECTION SYSTEM

As previously described in Attachment 12, the barrier components of the bottom liner system will be comprised of a 24-inch thick compacted clay liner overlain by a 60-mil high density polyethylene (HDPE) geomembrane liner. Above these barrier layers, the LCS will include a 250-mil lateral drainage layer (geocomposite) that will convey leachate to the LCS piping and overlain by a 24-inch-thick protective soil cover. The bottom liner system of each cell will slope to drain at a minimum 2 percent toward a perforated LCS pipe located in the center of each cell. This leachate generation model is based on a maximum flow length to the LCS pipe of 340 feet at a 2 percent slope, which occurs in Sector 12, the worst case condition for leachate modeling.

Leachate generated at the landfill will enter the LCS piping by either: (1) infiltrating through the protective soil cover and into underlying geocomposite, which drains to the leachate collection piping; or (2) infiltrating through the gravel chimney drains installed over the LCS piping. The LCS piping will be sloped at a minimum 1 percent to drain leachate into a leachate collection sump.

The layout and design details of the LCS are depicted on the Attachment 12 drawings.

1.3 METHOD OF ANALYSIS

The HELP model Version 3.95D is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of the disposal facility. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, field capacity, soil moisture storage, recirculation, evapotranspiration, and lateral drainage (Berger and Schroeder, 2013). Output includes peak daily, monthly and annual leachate generation and peak leachate depth over the liner for the respective periods.

1.4 MODEL SETUP

1.4.1 Phases

The landfill was modeled as a one-acre unit area for the following conditions of landfill development:

- Case 1 - Active condition with 10 feet of waste, daily cover, and 0% runoff potential;
- Case 2 - Interim condition with 60 feet of waste, intermediate cover, and 90% runoff potential;
- Case 3 - Interim condition with 130 feet of waste, intermediate cover, and 90% runoff potential;
- Case 4 - Interim condition with 170 feet of waste (average thickness over topslope), intermediate cover, and 90% runoff potential; and
- Case 5 - Closed condition with 170 feet of waste (average thickness over topslope), final cover, and 100% runoff potential.

In the HELP model, runoff is represented by two terms, "Runoff Potential" and "Curve Number (CN)", each of which is used differently by the model. Runoff Potential (i.e., Runoff Area) represents the percentage of the area being modeled that is sloped such that it is possible for runoff to occur.

The Curve Number (CN) is similar to the Runoff Potential in that it is used by the HELP model to estimate the volume of runoff from the landfill cover for a given storm event. The HELP model uses the CN value within a subroutine based on the Curve Number Method to calculate runoff. Unlike the Runoff Potential, the CN value incorporates the effects of soil characteristics (hydraulic conductivity), vegetative cover, and antecedent moisture content in the soil (i.e., initial soil moisture content).

The Runoff Potential was user-selected as zero percent for the active condition, since precipitation contacting these areas will be contained at the working face by containment berms. For the interim condition, the Runoff Potential was user-selected as 90 percent as this represents areas of the landfill that are well graded and have temporary drainage features in place allowing most of the stormwater to runoff. The remaining 10 percent of the area is assumed to retain runoff through incidental surface storage, thus allowing some amount of infiltration into the underlying waste.

The Runoff Potential for the closed condition was user-selected to be 100 percent, since the closed condition represents the portion of the landfill that is properly graded and is equipped with a final cover system and permanent stormwater drainage structures. CN values calculated by the HELP model were used for the active, interim, and closed conditions.

The HELP model results for the above conditions were reviewed in terms of peak daily leachate depth to confirm compliance with the regulatory requirement of maintaining less than 30 centimeters of leachate over the bottom liner system.

1.4.2 Climatological Data

The climatological data required by the HELP model is dependent on the geographical location, leaf area index, evaporative zone depth, and the number of years to be modeled. From these user inputs, the HELP model generates synthetic precipitation, temperature, and solar radiation data.

For the HELP model presented in this demonstration, the leaf area index (LAI) was assumed zero for the active condition (representing bare soil cover), 1.0 and 2.0 for the interim conditions (representing poor and fair vegetative covers, respectively), and 3.5 for the closed condition (representing good vegetative cover). The LAI values correspond to the anticipated vegetative cover at each development condition. The evaporative zone depth was assumed to be 6 inches for the active condition, 12 inches for the interim conditions, and 24 inches for the closed condition, which correspond to the upper-most soil layer thickness.

The precipitation data was modeled using the HELP program's synthetic weather daily generation option for Waco, Texas for 10 year and 50 year modeling periods (i.e., active condition for 10 years; and interim and closed conditions for 50 years). HELP model default mean monthly precipitation data for Waco, Texas was modified to match the mean monthly precipitation for the vicinity of the site. Monthly precipitation data (from 1941 to 2018) was obtained for Waco Regional Airport Station (USW00013959) from National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center's (NCDC) Climate Data Online (CDO) service. Mean monthly precipitation data used in the modeling is presented in this appendix.

The temperature, relative humidity, and solar radiation data were modeled for Waco, Texas using the synthetic daily weather generation for the modeling periods.

Output from the HELP model includes the peak daily, monthly, and annual precipitation, temperature, and solar radiation.

1.4.3 Landfill Profiles

The landfill profile or layer characteristics for each condition of landfill development are presented in the HELP Model Summary Sheets included in this appendix. Information provided in the table includes the layer thickness, porosity, field capacity, wilting point, and hydraulic conductivity used by the model for each layer. Default soil and waste characteristics (i.e., hydraulic conductivity, porosity, field capacity, and wilting point) in the HELP model were used for the landfill profiles for the active condition. However, as described below, the hydraulic conductivity was adjusted based on confining pressure for the interim and final conditions. These assumptions are considered representative of onsite soils or waste to be disposed at the site.

1.4.3.1 Compacted Clay Liner and Flexible Membrane Liner

The 24-inch-thick compacted clay liner was modeled as a barrier layer using default values from the HELP model table of soil characteristics (HELP default texture 16). The flexible geomembrane liner (60 mil HDPE), which is placed directly over the compacted clay liner, was also modeled using default values from the HELP model table of soil, waste, and geosynthetics characteristics (HELP default texture 35). The geomembrane liner was modeled for good installation quality which is represented by four defects per acre and a pinhole density of one hole/acre (Berger and Schroeder, 2013).

1.4.3.2 Leachate Drainage System Layer

The LCS drainage layer is a geonet drainage layer with a geotextile adhered to one or both sides (referred to as a geocomposite). The manufactured thickness of the geocomposite is 250-mil (approximately 0.25 inches), which was reduced for compression depending on the amount of waste and soil cover for each condition modeled in HELP. The reduction in thickness of the geocomposite drainage layer, as well as reduction factors associated with creep and environmental conditions, were considered to account for changes in long-term performance.

To evaluate the performance of the geocomposite layer, the hydraulic conductivity value used in the HELP model was adjusted until the maximum depth of leachate in the geocomposite (for peak daily flow) was less than or approximately equal to the thickness of the geocomposite (i.e., less than 0.25 inches). In this manner leachate flow above the geomembrane was confined in the geocomposite layer only. The minimum allowable transmissivity was calculated based on the hydraulic conductivity and reduced geocomposite thickness and compared to published transmissivity values for 250-mil geocomposite.

This exercise was performed to confirm that typical 250-mil geocomposites have drainage characteristics sufficient for maintaining leachate flow in the geocomposite layer. The geocomposite performance demonstration is included in Appendix 12B, and is based on the worst-case conditions for leachate generation (active 10-foot of waste) and soil/waste loading (intermediate 170-foot of waste). As presented in the demonstration, a typical 250-mil geocomposite has sufficient drainage capacity to meet drainage criteria during the greatest leachate generation and worst-case soil/waste loading conditions during landfill development.

1.4.3.3 Protective Soil Cover

The protective soil cover was assumed to be a 24-inch-thick clayey soil with a hydraulic conductivity of 1.7×10^{-5} cm/s. HELP default texture 15, high plasticity clay (CH) was selected to reflect soils available on site. Recompacted soil samples of onsite soils may indicate permeability values less than the values assumed in the HELP model. Therefore, a more permeable clay was selected to simulate higher percolation through protective cover. Default soil characteristics were used for the protective soil cover (HELP default texture 15).

1.4.3.4 Waste

The waste layers described in Section 1.4.1 were utilized for the various landfill conditions in the HELP model. The waste material was modeled using default HELP model properties for municipal solid waste (MSW) (HELP default texture 18) with a modified hydraulic conductivity for interim and final conditions. For active condition and interim condition with 60 ft of waste, which correspond to fresh waste in relatively loose state, the HELP default hydraulic conductivity (1.0 x 10^{-3} cm/s) was used. For interim conditions with 130 ft and 170 ft of waste and final conditions, the hydraulic conductivity was assumed to be 1.0 x 10^{-3} cm/s (i.e., HELP default) for the top 100 ft of waste. For the remaining lower thickness of waste, where the waste has been compacted and in-place for longer periods, 5.0 x 10^{-4} cm/s was used as hydraulic conductivity

Lower hydraulic conductivity of landfilled MSW is attributed to increased overburden stress and increased finer particles resulting from degradation. Reddy et. al. (2011) reported two orders of magnitude reduction in hydraulic conductivity of synthetic MSW with degradation. In another study, hydraulic conductivities of 1 x 10^{-4} cm/s to 1 x 10^{-7} cm/s are reported for MSW for uncompacted MSW and MSW at 90 feet depth, respectively (Reddy et. al., 2009).

1.4.3.5 Daily and Intermediate Cover

The daily cover for active condition consists of a 6-inch-thick layer of soil and the intermediate cover for the interim condition has an additional 6-inch layer of soil for a total thickness of 12 inches. The daily and intermediate cover were assumed to be clayey soil, with a hydraulic conductivity of 1.7 x 10^{-5} cm/s. Default soil characteristics were used for the daily and intermediate cover soils (HELP default texture 15).

1.4.3.6 Final Cover

The topslope final cover from top to bottom will consist of a 24-inch-thick erosion layer, a 40-mil geomembrane, and an 18-inch-thick infiltration layer (compacted clay). Final cover on the landfill sideslopes from top to bottom will consist of a 24-inch thick erosion layer, a geocomposite drainage layer, a 40-mil geomembrane, and an 18-inch thick infiltration layer. The geocomposite will be installed to drain infiltrating water from the final cover sideslopes. However, only the topslope cover system was used in the HELP modeling. This approach provides a more conservative estimate of possible infiltration through the liner and subsequent leachate generation, as the topslope has a flatter slope and no geocomposite drainage layer when compared to the sideslope final cover design.

For the purposes of this model, it has been assumed that the erosion layer will consist of a clayey soil with a hydraulic conductivity of 1.7 x 10^{-5} cm/s, consistent with soil modeled from daily and intermediate cover described in Section 1.4.3.5. The geomembrane was modeled for good installation quality, 4 defect per acre, and a pinhole density of 1 hole/acre (Berger and Schroeder, 2013). The infiltration layer will consist of compacted soil with a hydraulic conductivity of 1.0 x 10^{-5} cm/s or less. Default soil characteristics from the HELP model were selected to represent the layers within the final cover system.

1.5 LEACHATE RECIRCULATION

As previously mentioned, the active and interim conditions, described in Section 1.4.1 of this appendix, were also modeled for leachate recirculation. For both scenarios, the weather data described in Section 1.4.2 was used in the model. These conditions are considered representative of the worst case below-grade and above-grade conditions for which leachate generation and resulting leachate head would be affected by leachate recirculation.

A synthetic storm duration of 10 years was modeled for the active condition. A synthetic storm duration of 50 years was modeled for the interim conditions, which is greater than the estimated site life of the landfill (note, see Part III narrative, Section 2.2 for estimated site life of the landfill). Since the maximum time leachate recirculation can take place is less than 50 years, and in accordance with standard engineering practice, this duration is appropriate for analysis of the impacts on the leachate collection system associated with leachate recirculation. Furthermore, this duration conservatively approximates the longest time period for which the below-grade and above-grade waste disposal will likely occur for a given sector of the landfill.

Incorporating the above assumptions, for both the active and interim conditions, the percentage of leachate recirculated was increased within the HELP model until the calculated leachate head on the liner was less than or equal to the compressed thickness of the geocomposite. The model results for leachate recirculation are summarized in the HELP Model Summary Sheet (with leachate recirculation) provided in this appendix.

The allowable leachate recirculation volume is provided in the table below. Based on the results of the leachate recirculation demonstration, the allowable leachate recirculation volume for below-grade and above-grade waste disposal is represented by the active, 10-foot waste condition and interim, 170-foot waste condition, respectively. As shown, during periods of leachate recirculation, leachate head on the liner is maintained within the compressed thickness of the geocomposite. However, it should be noted that in all cases, actual leachate recirculation will also be controlled by the ability of the landfill operator to meet the 30-centimeter maximum leachate head over the bottom liner criteria, as verified by monitoring of the leachate levels at the sumps, as described in Attachment 12, Section 3.5.

ALLOWABLE LEACHATE RECIRCULATION

Fill Condition	Average Annual Recirculation (cf/yr/ac) [1]	Peak Leachate Head (in)	Allowable Recirculation (gallons/yr/ac)[2]
Below-Grade	80,200	0.22	599,900
Above-Grade	26,690	0.19	199,640

[1] Referenced from the HELP Model Output (with leachate recirculation) provided in this appendix.
[2] The allowable recirculation values pertain to areas draining to a common sump.

1.6 HELP MODEL RESULTS

The HELP model results are presented in the attached HELP Model Summary Sheets for both "without leachate recirculation" and "with leachate recirculation." Additionally, the HELP model output files are also provided in this appendix. As presented in the HELP model output, the depth of leachate over the bottom liner is predicted to be confined to the geocomposite lateral drainage layer, which is well below the 30 centimeter regulatory requirement, whether during periods of with or without leachate recirculation.

1.7 REFERENCES

Berger, K. and Schroeder, P.R. “The Hydrologic Evaluation of Landfill Performance (HELP) Model, User’s Guide for HELP-D Version 3.95 D”, Version 3.95 D, Institute of Soil Science, University of Hamburg, Germany, 2013.

Reddy, K., Hettiarachchi, H., Gangathulasi, J., and Bogner, J.E. “Geotechnical Properties of Fresh Municipal Solid Waste at Orchard Hills Landfill, USA”, Waste Management, 29, pp. 952-959, 2009.

Reddy, K., Hettiarachchi, H., Gangathulasi, J., and Bogner, J.E. “Geotechnical Properties of Municipal Solid Waste at Different Phases of Biodegradation”, Waste Management, 31, pp. 2275-2286, 2011.

CLIMATOLOGICAL DATA

National Oceanic Atmospheric Administration (NOAA)
Custom Global Summary of the Month - Precipitation (inches)
Station: Waco Regional Airport, TX US

Year	January	February	March	April	May	June	July	August	September	October	November	December
1941	1.97	5.96	4.77	3.78	4.41	4.02	4.23	3.64	1	3.06	1.26	1.67
1942	0.55	1.85	1.02	10.41	3.84	4.46	0.27	3.47	9.37	3.85	3.63	2.43
1943	0.63	0.48	1.5	0.76	4.56	0.27	4.51	0.68	4.69	3.63	1.32	2.43
1944	3.29	4.56	2.57	6.93	8.01	1.19	0.43	2.17	1.05	1.15	4.5	4.26
1945	3.39	3.38	6.84	5.8	0.72	2.71	0.74	2.77	1.46	2.62	1.73	3.3
1946	3.38	3.08	4.41	2.35	7.76	1.82	0.46	0.72	2.84	1.47	3.36	2.86
1947	3.36	0.85	4.04	5.23	3.71	4.31	2.89	2.11	0.86	0.69	2.09	3.66
1948	1.56	1.22	2.08	3.34	2.92	1.33	5.02	1.02	1.85	1.37	0.98	1.74
1949	3.67	2.31	2.39	4.3	0.86	6.97	3.32	0.9	0.61	4.51	0.19	1.49
1950	1.36	4.24	0.17	3.72	4.54	2.96	2.59	0.85	4.93	2	0.31	0.04
1951	1.3	2.07	2.02	2.76	3.35	2.22	0.33	0.59	3.6	0.89	0.56	0.44
1952	0.59	1.46	2.05	5.49	4.69	1.1	0.78	0	0.73	0	6.24	4.15
1953	0.53	2.38	3.21	2.04	9.72	0.27	1.72	3.15	1.65	3.37	0.82	3.19
1954	0.79	0.44	0.86	2.5	3.87	0.79	0.37	0.17	0.56	2.48	2.02	0.07
1955	1.58	3.59	3.2	1.3	7.61	2.02	0.39	3.15	2.42	2.38	1.13	0.43
1956	2.75	1.25	0.04	0.66	4.25	0.37	0.34	0.14	0	1.08	2.34	1.94
1957	1.53	2.41	5.59	13.37	7.6	1.04	0.61	0.5	5.69	5.4	4.78	0.42
1958	2.49	3.28	0.96	3.6	5.57	2.72	0.68	7.34	4.69	1.24	1.81	0.94
1959	0.3	2.73	0.22	2.74	1.96	5.74	1.84	2.14	3.49	7.37	1.25	4.07
1960	1.8	1.91	0.69	1.67	2.38	2.74	1.2	3	1.12	5.25	0.86	7.03
1961	5.83	3.86	1.76	1.06	1.34	12.07	7.68	0.9	2.28	1.28	3.54	1.14
1962	0.66	1.41	0.81	2.96	2.19	4.7	0.07	0.72	3.93	2.37	1.48	1.34
1963	0.49	0.51	0.76	2.76	5.7	1.83	0	1.28	0.83	1.09	3.22	1.1
1964	3.15	1.3	2.85	2.86	1.48	4.32	0.23	2.3	5.48	0.79	3.67	0.9
1965	2.97	4.42	3.13	1.35	15	0.82	0.12	0.64	3.8	2.91	4.64	2.31
1966	1.15	2	0.77	9.37	2.55	2.34	0.46	4.09	4.73	0.01	0.13	0.46
1967	0.37	0.77	1.93	8.8	4.17	0.36	1.59	0.43	4.31	3.8	3.54	2.91
1968	3.46	1.79	2.15	2.94	7.13	5.11	0.98	0.87	5.61	1.46	4.77	0.45
1969	0.44	2.1	3.61	3.98	3.98	0.44	0.05	2.24	4.7	5.53	1.93	2.49
1970	0.76	3.82	4.33	1.8	2.24	0.92	0.1	2.47	7.29	3.37	0.13	0.83
1971	0.03	1.33	0.64	2.79	0.75	0.99	8.58	2.16	0.74	3.26	1.64	4.3
1972	2.54	0.17	0.09	2.04	1.95	3.05	4.14	1.79	2.57	6.63	2.87	0.78
1973	3.48	1.52	3.04	5.41	3.17	7.1	4.89	0.36	5.24	9.36	0.66	0.76
1974	1.33	1.21	0.61	3.3	2.21	1.07	0.73	8.91	6.8	6.76	2.54	1.92
1975	1.4	2.94	1.1	4.59	13.22	2.83	2.78	0.72	2.27	2.4	0.4	1.83
1976	1.74	0.33	1.61	6.54	4.99	3.23	7.41	0.24	5.66	5.19	0.66	2.5
1977	1.83	3.67	2.9	7.38	1.71	0.78	0.21	1.95	0.26	1.5	2.43	0.15
1978	1.04	2.83	2.46	2.37	2.88	1.54	0.26	1.43	0.54	1.87	4.57	2.01
1979	1.98	1.97	4.31	1.38	9.69	4.7	5.01	4.58	2.51	1.94	0.33	3.97
1980	2.26	1.83	2.14	4.04	4.47	0.34	0.01	0.16	2.03	0.76	2.29	2.7
1981	0.85	1.8	2.98	1.22	3.69	7.23	0.16	2.14	3.61	8.42	0.99	0.5
1982	1.86	1.41	3.79	2.46	5.54	3.94	2.61	0.18	0.15	1.43	3.57	2.11
1983	1.28	2.97	3.46	0.12	3.83	0.94	3.41	2.54	0.71	1.55	2.9	0.46
1984	0.82	1	3.45	0.54	3.71	1.75	1.82	1.33	1.33	10.5	3.05	5.07
1985	0.76	1.91	2.57	3.37	1.59	5.62	0.69	0.68	6.39	3.84	3.54	2.02
1986	0.07	4.51	0.43	2.74	6.89	3.95	0.37	0.68	3.94	5.09	3.57	3.48
1987	1.29	2.6	1.67	1.63	5.17	5.84	1.42	0.76	5.69	1.19	4.44	3.32
1988	0.44	1.69	3.1	1.28	0.65	5.57	1.15	0.56	5.52	0.98	1.76	2.01
1989	2.44	2.27	2.43	1.6	9.34	4.17	2	2.21	0.27	0.91	0.32	0.54
1990	2.72	2.81	5.07	3.11	6.12	0.97	0.69	1.05	6.57	4.48	3.51	1.35
1991	3.13	1.43	0.93	2.69	5.89	3.17	3.65	7.21	3.81	3.58	1.69	8.44
1992	4.49	6.3	3.57	1.27	6.35	2.67	2.39	0.49	2.22	1.51	4.05	3.31
1993	2.46	3.83	4.31	3.63	2.06	2.16	0	0.81	4.44	5.6	2.12	1.5
1994	1.52	3.31	2.23	2.78	6.66	1.97	0.31	1.17	0.36	5.26	3.98	5.02
1995	1.37	0.61	3.68	7.18	7.84	2.35	4.02	5.91	3.83	0.13	1.57	1.01
1996	0.86	0.2	0.93	2.74	1.2	2.28	2.64	6.27	1.82	0.89	4.91	2.51
1997	2.5	7.91	3.77	5.46	3.52	2.7	0.73	1.74	0.49	2.13	2.52	9.81
1998	6.1	4.05	2.38	1.31	0.55	1.24	0.18	0.62	4.92	6.61	3.5	4.09
1999	2.3	0.07	3.15	2.04	3.15	0.51	3.76	0	0.51	1.9	0.29	2.82
2000	2.05	4.55	1.6	2.82	4.95	7.6	0.82	0.05	1.11	4.57	7.77	2.66
2001	2.9	2.54	4.45	0.66	3.54	1.76	0.24	4.85	2.22	2.89	5.63	4.04
2002	0.96	1.68	2.15	1.29	3.25	2.77	2.39	0.99	3.01	9.01	1.35	7.63
2003	0.57	2.56	1.35	0.94	2.78	4.58	2.74	2.49	4.23	3.88	1.37	0.49
2004	4.06	5.22	2.3	8.47	3.86	7.91	4.97	0.53	0.8	10.34	9.72	1.3
2005	3.3	3.35	1.27	2.04	3.65	1.37	1.07	4.84	0.57	0.89	0.51	0.43
2006	2.02	1.83	3.27	2.46	2.2	2.52	0.33	0.06	1.24	4.04	1.07	2.82
2007	3.99	0.55	9.76	1.16	13.99	8.76	2.24	0.48	3.79	0.76	1.78	0.8
2008	0.67	1.22	5.01	5.2	4.66	0.19	0.66	10.33	0.61	3.9	0.43	0.68
2009	0.64	1.35	4.91	4.54	1.38	0.73	2.8	0.01	8.24	9.71	1.69	1.55
2010	5.29	3.47	4.63	4.03	0.89	5.72	3.35	0.42	9.49	0.99	1.06	0.77
2011	3.7	1.82	0.15	1.87	2.14	1.26	0.09	0.08	2.97	6.2	2.4	4.97
2012	4.24	2.8	8.33	1.66	2.8	1.81	3.52	1.69	4.63	0.06	0	0.81
2013	5.06	2.1	1.83	1.75	3.36	1.62	5.5	0.22	5.43	7.3	2.4	1.34
2014	0.3	0.46	0.87	1.76	7.75	8.31	0.15	0.98	1.28	5.01	2.68	0.55
2015	3.48	1.25	2.85	4.49	9.27	5.97	0	0.86	0.33	15.19	6.43	3.62
2016	0.29	2.16	5.34	6.56	8.31	4.59	0.14	4.61	0.72	0.22	4.37	1.27
2017	3.11	3.05	3.31	7.04	2.8	4.74	2.09	2.57	0.51	1.14	1.3	1.78
2018	0.31	2.13	2.49	0.51	2.94	0.2	0.47	0.57	4.9	12.57	3.19	
1941-2018	2.02	2.36	2.68	3.42	4.51	3.06	1.84	1.92	3.04	3.6	2.49	2.32

Annual Rainfall (in): 33.26

Historic monthly precipitation for Regional Waco Airport Station (USW00013959) was requested from NOAA National Climate Data Center's (NCDS) Climate Data Online (CDO) service. Requested data (available from 1941 to 2018) was obtained via email in CSV form on December, 19 2018.

HELP MODEL SUMMARY SHEETS

SCS Engineers
TBPE Reg. # F-3407
Inclusive of pages 12A-14 to 12A-18

CITY OF WACO LANDFILL
HELP MODEL SUMMARY SHEET
(WITHOUT LEACHATE RECIRCULATION)

HELP MODEL INPUT PARAMETERS		ACTIVE (10' WASTE)	INTERIM (60' WASTE)	INTERIM (130' WASTE)	INTERIM (170' WASTE)	CLOSED (170' WASTE)
		CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
GENERAL	No. of Years	10	50	50	50	50
INFORMATION	Ground Cover	BARE	POOR	FAIR	FAIR	GOOD
	Model Area (acre)	1	1	1	1	1
	Runoff Area (%)	0	90	90	90	100
	Maximum Leaf Area Index	0.0	1.0	2.0	2.0	3.5
	Evaporative Zone Depth (inch)	6	12	12	12	24
EROSION	Thickness (in)					24
LAYER	Porosity (vol/vol)					0.4750
(Texture = 15)	Field Capacity (vol/vol)					0.3780
	Wilting Point (vol/vol)					0.2650
	Hyd. Conductivity (cm/s)					1.7E-05
FLEXIBLE	Thickness (in)					0.04
MEMBRANE	Hyd. Conductivity (cm/s)					4.0E-13
LINER	Pinhole Density (holes/acre)					1
(Texture = 36)	Install. Defects (holes/acre)					4
	Placement Quality					GOOD
INFILTRATION LAYER	Thickness (in)					18
(Texture = 0)	Porosity (vol/vol)					0.4750
	Field Capacity (vol/vol)					0.3780
	Wilting Point (vol/vol)					0.2650
	Hyd. Conductivity (cm/s)					1.0E-05
INTERMEDIATE / DAILY	Thickness (in)	6	12	12	12	12
COVER	Porosity (vol/vol)	0.4750	0.4750	0.4750	0.4750	0.4750
(Texture = 15)	Field Capacity (vol/vol)	0.3780	0.3780	0.3780	0.3780	0.3780
	Wilting Point (vol/vol)	0.2650	0.2650	0.2650	0.2650	0.2650
	Hyd. Conductivity (cm/s)	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05
WASTE	Thickness (in)	120	720	1560	2040	2040
(Texture = 18)	Porosity (vol/vol)	0.6710	0.6710	0.6710	0.6710	0.6710
(Hyd. Conductivity of MSW	Field Capacity (vol/vol)	0.2920	0.2920	0.2920	0.2920	0.2920
deeper than 100 ft: 5.0E-04 cm/s	Wilting Point (vol/vol)	0.0770	0.0770	0.0770	0.0770	0.0770
for Cases 3, 4, and 5.)	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03

CITY OF WACO LANDFILL
HELP MODEL SUMMARY SHEET
(WITHOUT LEACHATE RECIRCULATION)

HELP MODEL INPUT PARAMETERS		ACTIVE (10' WASTE)	INTERIM (60' WASTE)	INTERIM (130' WASTE)	INTERIM (170' WASTE)	CLOSED (170' WASTE)
		CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
PROTECTIVE	Thickness (in)	24	24	24	24	24
COVER	Porosity (vol/vol)	0.4750	0.4750	0.4750	0.4750	0.4750
(Texture = 15)	Field Capacity (vol/vol)	0.3780	0.3780	0.3780	0.3780	0.3780
	Wilting Point (vol/vol)	0.2650	0.2650	0.2650	0.2650	0.2650
	Hyd. Conductivity (cm/s)	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05
LEACHATE	Thickness (in)	0.24	0.22	0.20	0.19	0.19
COLLECTION	Porosity (vol/vol)	0.8500	0.8500	0.8500	0.8500	0.8500
(Texture = 0)	Field Capacity (vol/vol)	0.0100	0.0100	0.0100	0.0100	0.0100
	Wilting Point (vol/vol)	0.0050	0.0050	0.0050	0.0050	0.0050
	Hyd. Conductivity (cm/s)	10.00	7.80	4.80	3.00	3.00
	Slope (%)	2.0	2.0	2.0	2.0	2.0
	Slope Length (ft)	340	340	340	340	340
FLEXIBLE	Thickness (in)	0.06	0.06	0.06	0.06	0.06
MEMBRANE	Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13	2.0E-13	2.0E-13
LINER	Pinhole Density (holes/acre)	1	1	1	1	1
(Texture = 35)	Install. Defects (holes/acre)	4	4	4	4	4
	Placement Quality	GOOD	GOOD	GOOD	GOOD	GOOD
COMPACTED	Thickness (in)	24	24	24	24	24
CLAY LINER	Porosity (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
(Texture =16)	Field Capacity (vol/vol)	0.4180	0.4180	0.4180	0.4180	0.4180
	Wilting Point (vol/vol)	0.3670	0.3670	0.3670	0.3670	0.3670
	Hyd. Conductivity (cm/s)	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
PRECIPITATION	Average Annual (in)	30.95	31.90	31.90	31.90	31.90
RUNOFF	Average Annual (in)	0.00	7.15	6.46	4.10	4.87
EVAPOTRANSPIRATION	Average Annual (in)	19.18	22.43	22.87	22.36	26.89
LATERAL DRAINAGE (LCS)	Average Annual (cf/year)	43,183	8,419	9,306	8,181	538
LATERAL DRAINAGE (LCS)	Average Annual (cf/day)	118.3	23.1	25.5	22.4	1.5
LATERAL DRAINAGE (LCS)	Peak daily (cf/day)	844	583	304	289	6
HEAD ON LINER	Average daily (in)	0.070	0.062	0.052	0.080	0.002
HEAD ON LINER	Peak daily (in)	0.138	0.123	0.105	0.159	0.014

CITY OF WACO LANDFILL
HELP MODEL SUMMARY SHEET
(WITH LEACHATE RECIRCULATION)

HELP MODEL INPUT PARAMETERS		ACTIVE (10' WASTE)	INTERIM (60' WASTE)	INTERIM (130' WASTE)	INTERIM (170' WASTE)
		CASE 1-RECIRCULATION	CASE 2-RECIRCULATION	CASE 3-RECIRCULATION	CASE 4-RECIRCULATION
GENERAL INFORMATION	No. of Years	10	50	50	50
	Ground Cover	BARE	POOR	FAIR	FAIR
	Model Area (acre)	1	1	1	1
	Runoff Area (%)	0	90	90	90
	Leachate Recircuation (%)	65	85	85	85
	Maximum Leaf Area Index	0.0	1.0	2.0	2.0
	Evaporative Zone Depth (inch)	6	12	12	12
INTERMEDIATE / DAILY COVER (Texture = 15)	Thickness (in)	6	12	12	12
	Porosity (vol/vol)	0.4750	0.4750	0.4750	0.4750
	Field Capacity (vol/vol)	0.3780	0.3780	0.3780	0.3780
	Init. Moisture Content (vol/vol)	0.2652	0.3203	0.3203	0.3203
	Hyd. Conductivity (cm/s)	1.7E-05	1.7E-05	1.7E-05	1.7E-05
WASTE (Texture = 18) (Hyd. Conductivity of MSW deeper than 100 ft: 5.0E-04 cm/s for Cases 3, and 4.)	Thickness (in)	120	720	1560	2040
	Porosity (vol/vol)	0.6710	0.6710	0.6710	0.6710
	Field Capacity (vol/vol)	0.2920	0.2920	0.2920	0.2920
	Init. Moisture Content (vol/vol)	0.3056	0.2943	0.2931	0.2925
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03
PROTECTIVE COVER (Texture = 15)	Thickness (in)	24	24	24	24
	Porosity (vol/vol)	0.4750	0.4750	0.4750	0.4750
	Field Capacity (vol/vol)	0.3780	0.3780	0.3780	0.3780
	Init. Moisture Content (vol/vol)	0.4228	0.3874	0.3871	0.3870
	Hyd. Conductivity (cm/s)	1.7E-05	1.7E-05	1.7E-05	1.7E-05
LEACHATE COLLECTION (Texture = 0)	Thickness (in)	0.24	0.22	0.20	0.19
	Porosity (vol/vol)	0.8500	0.8500	0.8500	0.8500
	Field Capacity (vol/vol)	0.0100	0.0100	0.0100	0.0100
	Init. Moisture Content (vol/vol)	0.0100	0.0100	0.0100	0.0100
	Hyd. Conductivity (cm/s)	10.00	7.80	4.80	3.00
	Slope (%)	2.0	2.0	2.0	2.0
	Slope Length (ft)	340	340	340	340

CITY OF WACO LANDFILL
HELP MODEL SUMMARY SHEET
(WITH LEACHATE RECIRCULATION)

HELP MODEL INPUT PARAMETERS		ACTIVE (10' WASTE)	INTERIM (60' WASTE)	INTERIM (130' WASTE)	INTERIM (170' WASTE)
		CASE 1-RECIRCULATION	CASE 2-RECIRCULATION	CASE 3-RECIRCULATION	CASE 4-RECIRCULATION
FLEXIBLE	Thickness (in)	0.06	0.06	0.06	0.06
MEMBRANE	Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13	2.0E-13
LINER	Pinhole Density (holes/acre)	1	1	1	1
(Texture = 35)	Install. Defects (holes/acre)	4	4	4	4
	Placement Quality	GOOD	GOOD	GOOD	GOOD
COMPACTED	Thickness (in)	24	24	24	24
CLAY LINER	Porosity (vol/vol)	0.4270	0.4270	0.4270	0.4270
(Texture =16)	Field Capacity (vol/vol)	0.4180	0.4180	0.4180	0.4180
	Init. Moisture Content (vol/vol)	0.4270	0.4270	0.4270	0.4270
	Hyd. Conductivity (cm/s)	1.0E-07	1.0E-07	1.0E-07	1.0E-07
PRECIPITATION	Average Annual (in)	30.95	31.90	31.90	31.90
RUNOFF	Average Annual (in)	0.00	7.15	4.10	4.10
EVAPOTRANSPIRATION	Average Annual (in)	19.18	22.43	22.87	23.67
LATERAL DRAINAGE (LCS)	Average Annual (cf/year)	43,189	7,738	8,340	14,373
LATERAL DRAINAGE (LCS)	Average Annual (cf/day)	118.3	21.2	22.8	39.4
LATERAL DRAINAGE (LCS)	Peak daily (cf/day)	461	60	64	122
LEACHATE RECIRCULATION	Average Annual (cf/day)	80,207	69,639	47,259	26,692
LEACHATE RECIRCULATION	Peak daily (cf/day)	856	540	365	226
HEAD ON LINER	Average daily (in)	0.109	0.064	0.074	0.096
HEAD ON LINER	Peak daily (in)	0.215	0.126	0.147	0.189

HELP OUTPUT FILES
(WITHOUT LEACHATE RECIRCULATION)

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 12A-19 to 12A-58

```
******************************************************************************
 ******************************************************************************
 **                                                                          **
 **                                                                          **
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
 **                                                                          **
 **              HELP Version 3.95 D          (10 August 2012)               **
 **                               developed at                               **
 **        Institute of Soil Science, University of Hamburg, Germany         **
 **                                 based on                                 **
 **              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
 **                    USAE WATERWAYS EXPERIMENT STATION                     **
 **             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
 **                                                                          **
 **                                                                          **
 ******************************************************************************
 ******************************************************************************


 TIME:  10.26     DATE:  11.01.2019


 PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-10.d4
 TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-10.d7
 SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-10.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-10.d11
 SOIL AND DESIGN DATA FILE  1: C:\Users\4575sbg\Desktop\Waco\Case 1.d10
 OUTPUT DATA FILE:             C:\Users\4575sbg\Desktop\Waco\Case 1.out


 ******************************************************************************

      TITLE:  Waco New LF - Case 1

 ******************************************************************************


                           WEATHER DATA SOURCES
 ------------------------------------------------------------------------------



          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WACO                TEXAS

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

      JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
      -------      -------      -------      -------      -------      -------
        2.02         2.36         2.68         3.42         4.51         3.06
        1.84         1.92         3.04         3.60         2.49         2.32

          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WACO                TEXAS
```

```
           NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)
   JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
   -------      -------      -------      -------      -------      -------
    46.20        50.50        58.10        67.10        74.20        81.90
    85.90        85.60        79.20        68.80        57.00        49.50


       NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    WACO                TEXAS
                  AND STATION LATITUDE  =  31.37 DEGREES


******************************************************************************

                              LAYER DATA   1
------------------------------------------------------------------------------

                           VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                LAYER  1
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  15
          THICKNESS                    =      6.00   INCHES
          POROSITY                     =      0.4750 VOL/VOL
          FIELD CAPACITY               =      0.3780 VOL/VOL
          WILTING POINT                =      0.2650 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2966 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                                LAYER  2
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =    120.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3071 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC
```

```
                     LAYER  3
                     --------

         TYPE 1 - VERTICAL PERCOLATION LAYER
             MATERIAL TEXTURE NUMBER  15
THICKNESS                  =     24.00   INCHES
POROSITY                   =      0.4750 VOL/VOL
FIELD CAPACITY             =      0.3780 VOL/VOL
WILTING POINT              =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4009 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                     LAYER  4
                     --------

           TYPE 2 - LATERAL DRAINAGE LAYER
             MATERIAL TEXTURE NUMBER  20
THICKNESS                  =      0.24   INCHES
POROSITY                   =      0.8500 VOL/VOL
FIELD CAPACITY             =      0.0100 VOL/VOL
WILTING POINT              =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0341 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       10.00     CM/SEC
SLOPE                      =      2.00   PERCENT
DRAINAGE LENGTH            =    340.0    FEET


                     LAYER  5
                     --------

           TYPE 4 - FLEXIBLE MEMBRANE LINER
             MATERIAL TEXTURE NUMBER  35
THICKNESS                  =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY      =   3 - GOOD


                     LAYER  6
                     --------

             TYPE 3 - BARRIER SOIL LINER
             MATERIAL TEXTURE NUMBER  16
THICKNESS                  =     24.00   INCHES
POROSITY                   =      0.4270 VOL/VOL
FIELD CAPACITY             =      0.4180 VOL/VOL
WILTING POINT              =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC
```

```
******************************************************************************

             GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                         VALID FOR  10 YEARS


          NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                   SOIL DATA BASE USING SOIL TEXTURE #15 WITH BARE
                   GROUND CONDITIONS, A SURFACE SLOPE OF  3.% AND
                   A SLOPE LENGTH OF  300. FEET.

         SCS RUNOFF CURVE NUMBER                =     96.62
         FRACTION OF AREA ALLOWING RUNOFF       =      0.0    PERCENT
         AREA PROJECTED ON HORIZONTAL PLANE     =      1.000  ACRES
         EVAPORATIVE ZONE DEPTH                 =      6.0    INCHES
         INITIAL WATER IN EVAPORATIVE ZONE      =      1.779  INCHES
         UPPER LIMIT OF EVAPORATIVE STORAGE     =      2.850  INCHES
         FIELD CAPACITY OF EVAPORATIVE ZONE     =      2.268  INCHES
         LOWER LIMIT OF EVAPORATIVE STORAGE     =      1.590  INCHES
         SOIL EVAPORATION ZONE DEPTH            =      6.000  INCHES
         INITIAL SNOW WATER                     =      0.000  INCHES
         INITIAL INTERCEPTION WATER             =      0.000  INCHES
         INITIAL WATER IN LAYER MATERIALS       =     58.515  INCHES
         TOTAL INITIAL WATER                    =     58.515  INCHES
         TOTAL SUBSURFACE INFLOW                =      0.00   INCHES/YEAR


******************************************************************************

                        EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                        VALID FOR  10 YEARS


          NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                   WACO                    TEXAS
              STATION LATITUDE                         =  31.37 DEGREES
              MAXIMUM LEAF AREA INDEX                  =   0.00
              START OF GROWING SEASON (JULIAN DATE)    =     55
              END OF GROWING SEASON (JULIAN DATE)      =    336
              EVAPORATIVE ZONE DEPTH                   =   6.0  INCHES
              AVERAGE ANNUAL WIND SPEED                =  11.30 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  69.0  %
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  69.0  %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  62.0  %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  69.0  %

******************************************************************************
```

```
*******************************************************************************

                FINAL WATER STORAGE AT END OF YEAR   10
-------------------------------------------------------------------------------

                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1            1.7670         0.2945

                    2           35.0399         0.2920

                    3           10.1288         0.4220

                    4            0.0212         0.0884

                    5            0.0000         0.0000

                    6           10.2480         0.4270

    TOTAL WATER IN LAYERS       57.205

    SNOW WATER                   0.000

    INTERCEPTION WATER           0.000

    TOTAL FINAL WATER           57.205

*******************************************************************************


*******************************************************************************

               PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
-------------------------------------------------------------------------------

                                                 (INCHES)      (CU. FT.)
                                                ----------    -------------
      PRECIPITATION                               3.97          14411.101

      RUNOFF                                      0.000             0.0000

      DRAINAGE COLLECTED FROM LAYER  4            0.23261         844.36792

      PERCOLATION/LEAKAGE THROUGH LAYER  6        0.000000            0.00090

      AVERAGE HEAD ON TOP OF LAYER  5             0.070

      MAXIMUM HEAD ON TOP OF LAYER  5             0.138

      LOCATION OF MAXIMUM HEAD IN LAYER  4
            (DISTANCE FROM DRAIN)                 3.8 FEET

      SNOW WATER                                  2.07           7531.4780

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.4440
```

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2650

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 10

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.43	2.31	3.59	2.50	3.41	3.71
	0.90	3.01	2.74	3.06	2.13	2.17
STD. DEVIATIONS	1.16	1.67	1.51	1.42	2.01	2.07
	1.44	1.83	1.66	1.73	1.22	1.24
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
POTENTIAL EVAPOTRANSPIRATION						
TOTALS	2.835	3.292	4.737	6.341	8.008	8.786
	10.288	9.196	7.174	5.078	3.645	2.686
STD. DEVIATIONS	0.232	0.250	0.219	0.309	0.316	0.366
	0.268	0.281	0.375	0.266	0.190	0.200
ACTUAL EVAPOTRANSPIRATION						
TOTALS	0.982	1.542	2.072	1.910	2.327	2.150
	0.819	1.374	1.647	1.881	1.370	1.106
STD. DEVIATIONS	0.657	0.818	0.870	0.843	1.038	1.270
	0.850	0.664	1.015	1.111	0.954	0.609
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	1.1194	0.5723	0.8062	1.1103	0.8834	1.0958
	1.2992	0.6384	1.0812	1.2208	1.1671	0.9018

```
     STD. DEVIATIONS          0.6742   0.3676   0.7676   1.0042   0.5734   0.9915
                              0.9385   0.5378   0.8500   0.8725   0.7089   0.6704

  PERCOLATION/LEAKAGE THROUGH LAYER  6
  ------------------------------------
     TOTALS                   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

     STD. DEVIATIONS          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  5
  -------------------------------------
     AVERAGES                 0.0108   0.0061   0.0078   0.0111   0.0085   0.0110
                              0.0126   0.0062   0.0108   0.0118   0.0117   0.0087

     STD. DEVIATIONS          0.0065   0.0038   0.0074   0.0100   0.0055   0.0099
                              0.0091   0.0052   0.0085   0.0084   0.0071   0.0065

*******************************************************************************


*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   10
-------------------------------------------------------------------------------

                                       INCHES            CU. FEET      PERCENT
                                 -------------------  -------------  ---------
 PRECIPITATION                   30.95    (   5.379)     112334.0     100.00

 RUNOFF                           0.000   (  0.0000)         0.00      0.000

 POTENTIAL EVAPOTRANSPIRATION    72.065   (  0.6312)     261595.36

 ACTUAL EVAPOTRANSPIRATION       19.181   (  2.7880)      69626.66    61.982

 LATERAL DRAINAGE COLLECTED      11.89605 (  2.60164)     43182.656   38.44131
   FROM LAYER  4

 PERCOLATION/LEAKAGE THROUGH      0.00002 (  0.00000)         0.059    0.00005
   LAYER  6

 AVERAGE HEAD ON TOP              0.010   (    0.002)
   OF LAYER  5

 CHANGE IN WATER STORAGE         -0.131   (  1.4331)       -475.40    -0.423

*******************************************************************************
*******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


TIME:  10.39     DATE:  31.05.2019


PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-50.d4
TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-50.d7
SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-50.d13
EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-Interim.d11
SOIL AND DESIGN DATA FILE  1: C:\Users\4575sbg\Desktop\Waco\Case 2.d10
OUTPUT DATA FILE:             C:\Users\4575sbg\Desktop\Waco\Case 2.out


******************************************************************************

     TITLE:  Waco New LF - Case 2

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------



         NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS

                  NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
     -------      -------      -------      -------      -------      -------
       2.02         2.36         2.68         3.42         4.51         3.06
       1.84         1.92         3.04         3.60         2.49         2.32


         NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS
```

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.20	50.50	58.10	67.10	74.20	81.90
85.90	85.60	79.20	68.80	57.00	49.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WACO TEXAS
AND STATION LATITUDE = 31.37 DEGREES

****

LAYER DATA 1

VALID FOR 50 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 15

```
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.4750 VOL/VOL
FIELD CAPACITY             =      0.3780 VOL/VOL
WILTING POINT              =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.3493 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=     0.1700E-04 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

```
THICKNESS                  =    720.00   INCHES
POROSITY                   =      0.6710 VOL/VOL
FIELD CAPACITY             =      0.2920 VOL/VOL
WILTING POINT              =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2930 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=     0.1000E-02 CM/SEC
```

```
                              LAYER  3
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  15
       THICKNESS                          =     24.00   INCHES
       POROSITY                           =      0.4750 VOL/VOL
       FIELD CAPACITY                     =      0.3780 VOL/VOL
       WILTING POINT                      =      0.2650 VOL/VOL
       INITIAL SOIL WATER CONTENT         =      0.3893 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=             0.1700E-04 CM/SEC


                              LAYER  4
                              --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER   0
       THICKNESS                          =      0.22   INCHES
       POROSITY                           =      0.8500 VOL/VOL
       FIELD CAPACITY                     =      0.0100 VOL/VOL
       WILTING POINT                      =      0.0050 VOL/VOL
       INITIAL SOIL WATER CONTENT         =      0.0228 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=              7.800     CM/SEC
       SLOPE                              =      2.00   PERCENT
       DRAINAGE LENGTH                    =    340.0    FEET


                              LAYER  5
                              --------

                   TYPE 4 - FLEXIBLE MEMBRANE LINER
                     MATERIAL TEXTURE NUMBER  35
       THICKNESS                          =      0.06   INCHES
       EFFECTIVE SAT. HYD. CONDUCT.=             0.2000E-12 CM/SEC
       FML PINHOLE DENSITY                =      1.00   HOLES/ACRE
       FML INSTALLATION DEFECTS           =      4.00   HOLES/ACRE
       FML PLACEMENT QUALITY              =  3 - GOOD


                              LAYER  6
                              --------

                     TYPE 3 - BARRIER SOIL LINER
                     MATERIAL TEXTURE NUMBER  16
       THICKNESS                          =     24.00   INCHES
       POROSITY                           =      0.4270 VOL/VOL
       FIELD CAPACITY                     =      0.4180 VOL/VOL
       WILTING POINT                      =      0.3670 VOL/VOL
       INITIAL SOIL WATER CONTENT         =      0.4270 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=             0.1000E-06 CM/SEC
```

```
******************************************************************************

              GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                         VALID FOR  50 YEARS


         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                  SOIL DATA BASE USING SOIL TEXTURE #15 WITH A
                  POOR STAND OF GRASS, A SURFACE SLOPE OF  3.%
                  AND A SLOPE LENGTH OF  300. FEET.

        SCS RUNOFF CURVE NUMBER                =    93.37
        FRACTION OF AREA ALLOWING RUNOFF       =    90.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE     =     1.000  ACRES
        EVAPORATIVE ZONE DEPTH                 =    12.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE      =     4.192  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE     =     5.700  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE     =     4.536  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE     =     3.180  INCHES
        SOIL EVAPORATION ZONE DEPTH            =    12.000  INCHES
        INITIAL SNOW WATER                     =     0.000  INCHES
        INITIAL INTERCEPTION WATER             =     0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS       =   234.740  INCHES
        TOTAL INITIAL WATER                    =   234.740  INCHES
        TOTAL SUBSURFACE INFLOW                =     0.00   INCHES/YEAR


******************************************************************************

                     EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                        VALID FOR  50 YEARS


         NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                  WACO                TEXAS
             STATION LATITUDE                         =  31.37 DEGREES
             MAXIMUM LEAF AREA INDEX                  =   1.00
             START OF GROWING SEASON (JULIAN DATE)    =     55
             END OF GROWING SEASON (JULIAN DATE)      =    336
             EVAPORATIVE ZONE DEPTH                   =  12.0  INCHES
             AVERAGE ANNUAL WIND SPEED                =  11.30 MPH
             AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  69.0  %
             AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  69.0  %
             AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  62.0  %
             AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  69.0  %

******************************************************************************

******************************************************************************

                FINAL WATER STORAGE AT END OF YEAR   50
------------------------------------------------------------------------------
```

LAYER	(INCHES)	(VOL/VOL)
1	4.3667	0.3639
2	210.2521	0.2920
3	9.7415	0.4059
4	0.0023	0.0106
5	0.0000	0.0000
6	10.2480	0.4270

TOTAL WATER IN LAYERS	234.611
SNOW WATER	0.000
INTERCEPTION WATER	0.000
TOTAL FINAL WATER	234.611

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 50

	(INCHES)	(CU. FT.)
PRECIPITATION	5.66	20545.799
RUNOFF	4.426	16066.1328
DRAINAGE COLLECTED FROM LAYER 4	0.16052	582.67401
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00081
AVERAGE HEAD ON TOP OF LAYER 5	0.062	
MAXIMUM HEAD ON TOP OF LAYER 5	0.123	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.6 FEET	
SNOW WATER	2.59	9392.4756
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4541	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2650	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 50

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.09	2.55	2.88	2.82	4.24	3.28
	1.61	2.02	2.85	3.09	2.28	2.20
STD. DEVIATIONS	1.16	1.39	1.58	1.71	2.31	2.14
	1.80	1.54	1.81	2.07	1.35	1.33
RUNOFF						
TOTALS	0.263	0.423	0.589	0.612	1.141	0.832
	0.454	0.349	0.671	1.017	0.422	0.378
STD. DEVIATIONS	0.294	0.473	0.563	0.698	1.128	0.976
	0.728	0.587	0.770	1.241	0.502	0.466
POTENTIAL EVAPOTRANSPIRATION						
TOTALS	2.825	3.214	4.948	6.416	7.903	8.848
	10.150	9.273	7.323	5.080	3.489	2.836
STD. DEVIATIONS	0.232	0.248	0.382	0.363	0.319	0.379
	0.308	0.315	0.386	0.253	0.233	0.236
ACTUAL EVAPOTRANSPIRATION						
TOTALS	1.421	1.692	2.093	2.322	3.202	2.518
	1.323	1.485	1.914	1.624	1.400	1.436
STD. DEVIATIONS	0.514	0.594	0.819	0.804	1.253	1.185
	1.261	0.905	1.032	0.807	0.673	0.511
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.3821	0.2773	0.4213	0.3795	0.2302	0.1001
	0.0616	0.0351	0.0174	0.0452	0.1578	0.2118
STD. DEVIATIONS	0.4030	0.2645	0.3729	0.3352	0.2370	0.1491
	0.1206	0.0940	0.0454	0.0997	0.2513	0.2402

```
 PERCOLATION/LEAKAGE THROUGH LAYER  6
 ------------------------------------
   TOTALS                  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


 DAILY AVERAGE HEAD ON TOP OF LAYER  5
 -------------------------------------
   AVERAGES                0.0047   0.0038   0.0052   0.0049   0.0029   0.0013
                           0.0008   0.0004   0.0002   0.0006   0.0020   0.0026

   STD. DEVIATIONS         0.0050   0.0036   0.0046   0.0043   0.0029   0.0019
                           0.0015   0.0012   0.0006   0.0012   0.0032   0.0030

*******************************************************************************


*******************************************************************************

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   50
-------------------------------------------------------------------------------

                                     INCHES            CU. FEET        PERCENT
                               -------------------   -------------   ---------
 PRECIPITATION                  31.90    (   5.608)    115783.9      100.00

 RUNOFF                          7.151   (  2.2558)     25957.83     22.419

 POTENTIAL EVAPOTRANSPIRATION   72.306   (  1.0943)    262470.91

 ACTUAL EVAPOTRANSPIRATION      22.429   (  3.2297)     81416.20     70.317

 LATERAL DRAINAGE COLLECTED      2.31936 (  1.12071)     8419.272    7.27154
   FROM LAYER  4

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)        0.018     0.00002
   LAYER  6

 AVERAGE HEAD ON TOP             0.002   (   0.001)
   OF LAYER  5

 CHANGE IN WATER STORAGE        -0.003   (  1.1579)        -9.38     -0.008

*******************************************************************************
*******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                                developed at                              **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                  based on                                **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


TIME:  10.11     DATE:  31.05.2019


PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-50.d4
TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-50.d7
SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-50.d13
EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-Interim-2.d11
SOIL AND DESIGN DATA FILE  1: C:\Users\4575sbg\Desktop\Waco\Case 3.d10
OUTPUT DATA FILE:             C:\Users\4575sbg\Desktop\Waco\Case 3.out


******************************************************************************

     TITLE:  Waco New LF - Case 3

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------


         NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS

                  NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
       2.02        2.36        2.68        3.42        4.51        3.06
       1.84        1.92        3.04        3.60        2.49        2.32


         NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS
```

```
            NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
    -------      -------      -------      -------      -------      -------
     46.20        50.50        58.10        67.10        74.20        81.90
     85.90        85.60        79.20        68.80        57.00        49.50


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WACO                TEXAS
                   AND STATION LATITUDE  =  31.37 DEGREES


*******************************************************************************

                                LAYER DATA   1
-------------------------------------------------------------------------------

                             VALID FOR  50 YEARS


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  15
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4750 VOL/VOL
          FIELD CAPACITY               =      0.3780 VOL/VOL
          WILTING POINT                =      0.2650 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3466 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                   LAYER  2
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =   1200.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2927 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC
```

```
                         LAYER  3
                         --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                  =    360.00   INCHES
POROSITY                   =      0.6710 VOL/VOL
FIELD CAPACITY             =      0.2920 VOL/VOL
WILTING POINT              =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.5000E-03 CM/SEC


                         LAYER  4
                         --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  15
THICKNESS                  =     24.00   INCHES
POROSITY                   =      0.4750 VOL/VOL
FIELD CAPACITY             =      0.3780 VOL/VOL
WILTING POINT              =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3926 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                         LAYER  5
                         --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                  =      0.20   INCHES
POROSITY                   =      0.8500 VOL/VOL
FIELD CAPACITY             =      0.0100 VOL/VOL
WILTING POINT              =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0435 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       4.800     CM/SEC
SLOPE                      =      2.00   PERCENT
DRAINAGE LENGTH            =    340.0    FEET


                         LAYER  6
                         --------

               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
THICKNESS                  =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  3 - GOOD
```

```
                         LAYER  7
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.4270 VOL/VOL
   FIELD CAPACITY               =      0.4180 VOL/VOL
   WILTING POINT                =      0.3670 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
   EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC


******************************************************************************

          GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                      VALID FOR  50 YEARS


  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE #15 WITH A
           POOR STAND OF GRASS, A SURFACE SLOPE OF  3.%
           AND A SLOPE LENGTH OF  300. FEET.

  SCS RUNOFF CURVE NUMBER           =     93.37
  FRACTION OF AREA ALLOWING RUNOFF   =     90.0    PERCENT
  AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
  EVAPORATIVE ZONE DEPTH             =     12.0    INCHES
  INITIAL WATER IN EVAPORATIVE ZONE  =      4.159  INCHES
  UPPER LIMIT OF EVAPORATIVE STORAGE =      5.700  INCHES
  FIELD CAPACITY OF EVAPORATIVE ZONE =      4.536  INCHES
  LOWER LIMIT OF EVAPORATIVE STORAGE =      3.180  INCHES
  SOIL EVAPORATION ZONE DEPTH        =     12.000  INCHES
  INITIAL SNOW WATER                 =      0.000  INCHES
  INITIAL INTERCEPTION WATER         =      0.000  INCHES
  INITIAL WATER IN LAYER MATERIALS   =    480.193  INCHES
  TOTAL INITIAL WATER                =    480.193  INCHES
  TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


******************************************************************************

                   EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                     VALID FOR  50 YEARS


  NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
           WACO                TEXAS
      STATION LATITUDE                       =  31.37 DEGREES
      MAXIMUM LEAF AREA INDEX                =   2.00
      START OF GROWING SEASON (JULIAN DATE)  =     55
      END OF GROWING SEASON (JULIAN DATE)    =    336
```

```
          EVAPORATIVE ZONE DEPTH                       =  12.0  INCHES
          AVERAGE ANNUAL WIND SPEED                    =  11.30 MPH
          AVERAGE 1ST QUARTER RELATIVE HUMIDITY        =  69.0  %
          AVERAGE 2ND QUARTER RELATIVE HUMIDITY        =  69.0  %
          AVERAGE 3RD QUARTER RELATIVE HUMIDITY        =  62.0  %
          AVERAGE 4TH QUARTER RELATIVE HUMIDITY        =  69.0  %

******************************************************************************


******************************************************************************

                FINAL WATER STORAGE AT END OF YEAR   50
------------------------------------------------------------------------------

                 LAYER        (INCHES)       (VOL/VOL)
                 -----        --------       ---------
                   1            4.3472         0.3623

                   2          350.6811         0.2922

                   3          105.3794         0.2927

                   4            9.6019         0.4001

                   5            0.0020         0.0100

                   6            0.0000         0.0000

                   7           10.2480         0.4270

    TOTAL WATER IN LAYERS     480.260

    SNOW WATER                  0.000

    INTERCEPTION WATER          0.000

    TOTAL FINAL WATER         480.260

******************************************************************************
```

```
******************************************************************************

               PEAK DAILY VALUES FOR YEARS     1 THROUGH   50
------------------------------------------------------------------------------

                                                 (INCHES)      (CU. FT.)
                                                ----------    -------------
      PRECIPITATION                               5.66          20545.799

      RUNOFF                                      3.738         13570.0391

      DRAINAGE COLLECTED FROM LAYER  5            0.08383         304.30020

      PERCOLATION/LEAKAGE THROUGH LAYER  7        0.000000          0.00070

      AVERAGE HEAD ON TOP OF LAYER  6             0.052

      MAXIMUM HEAD ON TOP OF LAYER  6             0.105

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)                 0.7 FEET

      SNOW WATER                                  2.59           9392.4756

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.4536

      MINIMUM VEG. SOIL WATER (VOL/VOL)                   0.2650


       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************




*******************************************************************************

        AVERAGE MONTHLY VALUES IN INCHES FOR YEARS     1 THROUGH   50
-------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                2.09     2.55     2.88     2.82     4.24     3.28
                          1.61     2.02     2.85     3.09     2.28     2.20

    STD. DEVIATIONS       1.16     1.39     1.58     1.71     2.31     2.14
                          1.80     1.54     1.81     2.07     1.35     1.33

  RUNOFF
```

```
------
  TOTALS                   0.251    0.407    0.546    0.532    0.998    0.734
                           0.410    0.315    0.588    0.918    0.394    0.368

  STD. DEVIATIONS          0.272    0.437    0.526    0.607    0.966    0.842
                           0.668    0.511    0.657    1.136    0.456    0.448

POTENTIAL EVAPOTRANSPIRATION
----------------------------
  TOTALS                   2.825    3.214    4.948    6.416    7.903    8.848
                          10.150    9.273    7.323    5.080    3.489    2.836

  STD. DEVIATIONS          0.232    0.248    0.382    0.363    0.319    0.379
                           0.308    0.315    0.386    0.253    0.233    0.236

ACTUAL EVAPOTRANSPIRATION
-------------------------
  TOTALS                   1.400    1.685    2.148    2.626    3.129    2.587
                           1.339    1.546    2.003    1.622    1.386    1.402

  STD. DEVIATIONS          0.499    0.545    0.803    0.951    1.342    1.244
                           1.278    0.948    1.086    0.832    0.656    0.486

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                   0.2769   0.3264   0.3696   0.4360   0.3983   0.2436
                           0.1139   0.0588   0.0390   0.0419   0.0871   0.1720

  STD. DEVIATIONS          0.3102   0.2871   0.3363   0.3734   0.3416   0.3553
                           0.1820   0.1268   0.0918   0.0668   0.1007   0.1817

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
  TOTALS                   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


DAILY AVERAGE HEAD ON TOP OF LAYER  6
-------------------------------------
  AVERAGES                 0.0056   0.0072   0.0075   0.0091   0.0080   0.0051
                           0.0023   0.0012   0.0008   0.0008   0.0018   0.0035

  STD. DEVIATIONS          0.0063   0.0063   0.0068   0.0078   0.0069   0.0074
                           0.0037   0.0026   0.0019   0.0013   0.0021   0.0037

*******************************************************************************
```

```
*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   50
-------------------------------------------------------------------------------

                                   INCHES            CU. FEET       PERCENT
                              -------------------  -------------  ---------
 PRECIPITATION                31.90     (   5.608)    115783.9     100.00

 RUNOFF                        6.460    (  2.0273)     23448.33     20.252

 POTENTIAL EVAPOTRANSPIRATION 72.306    (  1.0943)    262470.91

 ACTUAL EVAPOTRANSPIRATION    22.872    (  3.3018)     83025.15     71.707

 LATERAL DRAINAGE COLLECTED    2.56353 (  1.30093)      9305.599    8.03704
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH   0.00001 (  0.00000)         0.029     0.00003
   LAYER  7

 AVERAGE HEAD ON TOP           0.004    (    0.002)
   OF LAYER  6

 CHANGE IN WATER STORAGE       0.001    (  1.3616)         4.83      0.004

*******************************************************************************
*******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


TIME:  10.14     DATE:  31.05.2019


PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-50.d4
TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-50.d7
SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-50.d13
EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-Interim-2.d11
SOIL AND DESIGN DATA FILE  1: C:\Users\4575sbg\Desktop\Waco\Case 4.d10
OUTPUT DATA FILE:             C:\Users\4575sbg\Desktop\Waco\Case 4.out


******************************************************************************

     TITLE:  Waco New LF - Case 4

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------



         NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS

                  NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
     -------      -------      -------      -------      -------      -------
       2.02         2.36         2.68         3.42         4.51         3.06
       1.84         1.92         3.04         3.60         2.49         2.32


         NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS
```

```
              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

       JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
       -------      -------      -------      -------      -------      -------
        46.20        50.50        58.10        67.10        74.20        81.90
        85.90        85.60        79.20        68.80        57.00        49.50


         NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                 TEXAS
                    AND STATION LATITUDE  =  31.37 DEGREES


 ******************************************************************************

                              LAYER DATA   1
 ------------------------------------------------------------------------------

                           VALID FOR  50 YEARS


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  15
           THICKNESS                   =     12.00   INCHES
           POROSITY                    =      0.4750 VOL/VOL
           FIELD CAPACITY              =      0.3780 VOL/VOL
           WILTING POINT               =      0.2650 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.3464 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                  LAYER  2
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  18
           THICKNESS                   =   1200.00   INCHES
           POROSITY                    =      0.6710 VOL/VOL
           FIELD CAPACITY              =      0.2920 VOL/VOL
           WILTING POINT               =      0.0770 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2930 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC
```

```
                        LAYER  3
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    840.00   INCHES
POROSITY                     =      0.6710 VOL/VOL
FIELD CAPACITY               =      0.2920 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.5000E-03 CM/SEC


                        LAYER  4
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  15
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.4750 VOL/VOL
FIELD CAPACITY               =      0.3780 VOL/VOL
WILTING POINT                =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3975 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                        LAYER  5
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.19   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0938 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       3.000      CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    340.0    FEET


                        LAYER  6
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

```
                              LAYER  7
                              --------

                    TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER  16
     THICKNESS                    =     24.00    INCHES
     POROSITY                     =      0.4270 VOL/VOL
     FIELD CAPACITY               =      0.4180 VOL/VOL
     WILTING POINT                =      0.3670 VOL/VOL
     INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
     EFFECTIVE SAT. HYD. CONDUCT.=       0.1000E-06 CM/SEC


******************************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                        VALID FOR  50 YEARS


    NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
             SOIL DATA BASE USING SOIL TEXTURE #15 WITH A
             FAIR STAND OF GRASS, A SURFACE SLOPE OF  5.%
             AND A SLOPE LENGTH OF  240. FEET.

        SCS RUNOFF CURVE NUMBER              =    90.26
        FRACTION OF AREA ALLOWING RUNOFF     =    90.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE   =     1.000  ACRES
        EVAPORATIVE ZONE DEPTH               =    12.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE    =     4.157  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE   =     5.700  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE   =     4.536  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE   =     3.180  INCHES
        SOIL EVAPORATION ZONE DEPTH          =    12.000  INCHES
        INITIAL SNOW WATER                   =     0.000  INCHES
        INITIAL INTERCEPTION WATER           =     0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS     =   620.814  INCHES
        TOTAL INITIAL WATER                  =   620.814  INCHES
        TOTAL SUBSURFACE INFLOW              =     0.00   INCHES/YEAR


******************************************************************************

                      EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                       VALID FOR  50 YEARS


    NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
             WACO                TEXAS
         STATION LATITUDE                        =  31.37 DEGREES
         MAXIMUM LEAF AREA INDEX                 =   2.00
         START OF GROWING SEASON (JULIAN DATE)   =     55
```

```
          END OF GROWING SEASON (JULIAN DATE)    =    336
          EVAPORATIVE ZONE DEPTH                 =  12.0  INCHES
          AVERAGE ANNUAL WIND SPEED              =  11.30 MPH
          AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  69.0  %
          AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  69.0  %
          AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  62.0  %
          AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  69.0  %

******************************************************************************


******************************************************************************

                FINAL WATER STORAGE AT END OF YEAR   50
------------------------------------------------------------------------------

                LAYER        (INCHES)       (VOL/VOL)
                -----        --------       ---------
                  1            4.3333         0.3611

                  2          350.9964         0.2925

                  3          245.9570         0.2928

                  4            9.3591         0.3900

                  5            0.0067         0.0351

                  6            0.0000         0.0000

                  7           10.2480         0.4270

    TOTAL WATER IN LAYERS    620.900

    SNOW WATER                 0.000

    INTERCEPTION WATER         0.000

    TOTAL FINAL WATER        620.900

******************************************************************************
```

```
******************************************************************************

              PEAK DAILY VALUES FOR YEARS     1 THROUGH   50
------------------------------------------------------------------------------

                                                  (INCHES)      (CU. FT.)
                                                 ----------    -------------
      PRECIPITATION                                5.66         20545.799

      RUNOFF                                       3.677        13347.2627

      DRAINAGE COLLECTED FROM LAYER  5             0.08033        291.59042

      PERCOLATION/LEAKAGE THROUGH LAYER  7         0.000000         0.00102

      AVERAGE HEAD ON TOP OF LAYER  6              0.080

      MAXIMUM HEAD ON TOP OF LAYER  6              0.159

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)                  2.1 FEET

      SNOW WATER                                   2.59          9392.4756

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.4750

      MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.2650

       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************


******************************************************************************

       AVERAGE MONTHLY VALUES IN INCHES FOR YEARS     1 THROUGH   50
------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 2.09     2.55     2.88     2.82     4.24     3.28
                           1.61     2.02     2.85     3.09     2.28     2.20

    STD. DEVIATIONS        1.16     1.39     1.58     1.71     2.31     2.14
                           1.80     1.54     1.81     2.07     1.35     1.33

  RUNOFF
```

```
 ------
   TOTALS                    0.126     0.232     0.327     0.318     0.652     0.466
                             0.277     0.183     0.374     0.679     0.224     0.212

   STD. DEVIATIONS           0.167     0.327     0.374     0.434     0.794     0.652
                             0.522     0.355     0.513     1.032     0.318     0.310

 POTENTIAL EVAPOTRANSPIRATION
 ----------------------------
   TOTALS                    2.825     3.214     4.948     6.416     7.903     8.848
                            10.150     9.273     7.323     5.080     3.489     2.836

   STD. DEVIATIONS           0.232     0.248     0.382     0.363     0.319     0.379
                             0.308     0.315     0.386     0.253     0.233     0.236

 ACTUAL EVAPOTRANSPIRATION
 -------------------------
   TOTALS                    1.426     1.691     2.175     2.669     3.302     2.757
                             1.453     1.617     2.085     1.673     1.402     1.421

   STD. DEVIATIONS           0.479     0.552     0.800     0.978     1.437     1.295
                             1.382     0.999     1.126     0.835     0.651     0.482

 LATERAL DRAINAGE COLLECTED FROM LAYER  5
 ----------------------------------------
   TOTALS                    0.3748    0.4143    0.4883    0.5057    0.5785    0.4786
                             0.3391    0.2354    0.1756    0.1121    0.1771    0.2760

   STD. DEVIATIONS           0.2924    0.3111    0.3937    0.3202    0.4381    0.4065
                             0.3964    0.3440    0.3494    0.1358    0.2223    0.2293

 PERCOLATION/LEAKAGE THROUGH LAYER  7
 ------------------------------------
   TOTALS                    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                             0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

   STD. DEVIATIONS           0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                             0.0000    0.0000    0.0000    0.0000    0.0000    0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


 DAILY AVERAGE HEAD ON TOP OF LAYER  6
 -------------------------------------
   AVERAGES                  0.0121    0.0147    0.0158    0.0169    0.0187    0.0160
                             0.0109    0.0076    0.0059    0.0036    0.0059    0.0089

   STD. DEVIATIONS           0.0094    0.0111    0.0127    0.0107    0.0141    0.0135
                             0.0128    0.0111    0.0116    0.0044    0.0074    0.0074

*******************************************************************************
```

```
******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   50
------------------------------------------------------------------------------

                                      INCHES            CU. FEET       PERCENT
                                ------------------   -------------   ---------
 PRECIPITATION                   31.90    (   5.608)    115783.9     100.00

 RUNOFF                           4.068   (  1.5779)     14767.38     12.754

 POTENTIAL EVAPOTRANSPIRATION    72.306   (  1.0943)    262470.91

 ACTUAL EVAPOTRANSPIRATION       23.671   (  3.4223)     85925.71     74.212

 LATERAL DRAINAGE COLLECTED       4.15551 (  1.81879)    15084.489   13.02814
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH      0.00002 (  0.00001)        0.065    0.00006
   LAYER  7

 AVERAGE HEAD ON TOP              0.011   (   0.005)
   OF LAYER  6

 CHANGE IN WATER STORAGE          0.002   (  1.7571)         6.28     0.005

******************************************************************************
******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


TIME:  10.18     DATE:  31.05.2019


PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-50.d4
TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-50.d7
SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-50.d13
EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-Final Cover.d11
SOIL AND DESIGN DATA FILE  1: C:\Users\4575sbg\Desktop\Waco\Case 5.d10
OUTPUT DATA FILE:             C:\Users\4575sbg\Desktop\Waco\Case 5.out


******************************************************************************

     TITLE:  Waco New LF - Case 5 - Final Cover

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------



         NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS

                  NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
       2.02        2.36        2.68        3.42        4.51        3.06
       1.84        1.92        3.04        3.60        2.49        2.32


         NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS
```

```
              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

        JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
        -------      -------      -------      -------      -------      -------
         46.20        50.50        58.10        67.10        74.20        81.90
         85.90        85.60        79.20        68.80        57.00        49.50


            NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                     COEFFICIENTS FOR    WACO                TEXAS
                       AND STATION LATITUDE  =  31.37 DEGREES


*******************************************************************************

                              LAYER DATA   1
-------------------------------------------------------------------------------

                           VALID FOR  50 YEARS


        NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
                 COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                 LAYER  1
                                 --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  15
              THICKNESS                    =     24.00   INCHES
              POROSITY                     =      0.4750 VOL/VOL
              FIELD CAPACITY               =      0.3780 VOL/VOL
              WILTING POINT                =      0.2650 VOL/VOL
              INITIAL SOIL WATER CONTENT   =      0.4316 VOL/VOL
              EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC
            NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                     FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                 LAYER  2
                                 --------

                       TYPE 4 - FLEXIBLE MEMBRANE LINER
                         MATERIAL TEXTURE NUMBER  36
              THICKNESS                    =      0.04   INCHES
              EFFECTIVE SAT. HYD. CONDUCT.=      0.4000E-12 CM/SEC
              FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
              FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
              FML PLACEMENT QUALITY        =  3 - GOOD
```

```
                        LAYER  3
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     18.00   INCHES
POROSITY                   =      0.4750 VOL/VOL
FIELD CAPACITY             =      0.3780 VOL/VOL
WILTING POINT              =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4750 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-04 CM/SEC


                        LAYER  4
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  15
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.4750 VOL/VOL
FIELD CAPACITY             =      0.3780 VOL/VOL
WILTING POINT              =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3780 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                  =   1200.00   INCHES
POROSITY                   =      0.6710 VOL/VOL
FIELD CAPACITY             =      0.2920 VOL/VOL
WILTING POINT              =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC


                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =    840.00   INCHES
POROSITY                   =      0.6710 VOL/VOL
FIELD CAPACITY             =      0.2920 VOL/VOL
WILTING POINT              =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.5000E-03 CM/SEC
```

```
                    LAYER  7
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
             MATERIAL TEXTURE NUMBER  15
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4750 VOL/VOL
FIELD CAPACITY              =      0.3780 VOL/VOL
WILTING POINT               =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3780 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                    LAYER  8
                    --------

           TYPE 2 - LATERAL DRAINAGE LAYER
             MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.19   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0145 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       3.000     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    340.0    FEET


                    LAYER  9
                    --------

           TYPE 4 - FLEXIBLE MEMBRANE LINER
             MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                    LAYER 10
                    --------

             TYPE 3 - BARRIER SOIL LINER
             MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC
```

```
******************************************************************************

              GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                        VALID FOR  50 YEARS


         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                  SOIL DATA BASE USING SOIL TEXTURE #15 WITH A
                  GOOD STAND OF GRASS, A SURFACE SLOPE OF  5.%
                  AND A SLOPE LENGTH OF  240. FEET.

        SCS RUNOFF CURVE NUMBER                =    86.86
        FRACTION OF AREA ALLOWING RUNOFF       =   100.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE     =     1.000  ACRES
        EVAPORATIVE ZONE DEPTH                 =    24.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE      =    10.359  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE     =    11.400  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE     =     9.072  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE     =     6.360  INCHES
        SOIL EVAPORATION ZONE DEPTH            =    24.000  INCHES
        INITIAL SNOW WATER                     =     0.000  INCHES
        INITIAL INTERCEPTION WATER             =     0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS       =   638.448  INCHES
        TOTAL INITIAL WATER                    =   638.448  INCHES
        TOTAL SUBSURFACE INFLOW                =     0.00   INCHES/YEAR


******************************************************************************

                     EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                       VALID FOR  50 YEARS


         NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                  WACO                    TEXAS
             STATION LATITUDE                        =  31.37 DEGREES
             MAXIMUM LEAF AREA INDEX                 =   3.50
             START OF GROWING SEASON (JULIAN DATE)  =     55
             END OF GROWING SEASON (JULIAN DATE)    =    336
             EVAPORATIVE ZONE DEPTH                  =  24.0  INCHES
             AVERAGE ANNUAL WIND SPEED               =  11.30 MPH
             AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  69.0  %
             AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  69.0  %
             AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  62.0  %
             AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  69.0  %

******************************************************************************
```

```
******************************************************************************

               FINAL WATER STORAGE AT END OF YEAR   50
------------------------------------------------------------------------------

                LAYER        (INCHES)       (VOL/VOL)
                -----        --------       ---------
                  1           9.3930         0.3914

                  2           0.0000         0.0000

                  3           8.5500         0.4750

                  4           4.5360         0.3780

                  5         350.4000         0.2920

                  6         245.2800         0.2920

                  7           9.0720         0.3780

                  8           0.0022         0.0114

                  9           0.0000         0.0000

                 10          10.2480         0.4270

    TOTAL WATER IN LAYERS        637.481

    SNOW WATER                     0.000

    INTERCEPTION WATER             0.000

    TOTAL FINAL WATER            637.481

******************************************************************************


******************************************************************************

            PEAK DAILY VALUES FOR YEARS    1 THROUGH   50
------------------------------------------------------------------------------

                                                  (INCHES)      (CU. FT.)
                                                 ----------    -------------
      PRECIPITATION                                5.66         20545.799

      RUNOFF                                       3.103        11265.6875

      PERCOLATION/LEAKAGE THROUGH LAYER  3         0.001567         5.68979

      AVERAGE HEAD ON TOP OF LAYER  2            24.000

      DRAINAGE COLLECTED FROM LAYER  8             0.00156          5.65188

      PERCOLATION/LEAKAGE THROUGH LAYER 10         0.000000         0.00005
```

```
     AVERAGE HEAD ON TOP OF LAYER  9           0.002

     MAXIMUM HEAD ON TOP OF LAYER  9           0.014

     LOCATION OF MAXIMUM HEAD IN LAYER  8
           (DISTANCE FROM DRAIN)               0.0 FEET

     SNOW WATER                                2.59          9392.4756

     MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.4750

     MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.2650


      ***  Maximum heads are computed using McEnroe's equations.  ***

           Reference:  Maximum Saturated Depth over Landfill Liner
                       by Bruce M. McEnroe, University of Kansas
                       ASCE Journal of Environmental Engineering
                       Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************




*******************************************************************************

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   50
-------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
 PRECIPITATION
 -------------
   TOTALS                  2.09     2.55     2.88     2.82     4.24     3.28
                           1.61     2.02     2.85     3.09     2.28     2.20

   STD. DEVIATIONS         1.16     1.39     1.58     1.71     2.31     2.14
                           1.80     1.54     1.81     2.07     1.35     1.33

 RUNOFF
 ------
   TOTALS                  0.187    0.380    0.683    0.569    0.878    0.575
                           0.286    0.119    0.262    0.490    0.207    0.237

   STD. DEVIATIONS         0.379    0.597    0.898    0.967    1.231    0.968
                           0.667    0.277    0.451    0.838    0.481    0.428

 POTENTIAL EVAPOTRANSPIRATION
 ----------------------------
   TOTALS                  2.825    3.214    4.948    6.416    7.903    8.848
                          10.150    9.273    7.323    5.080    3.489    2.836

   STD. DEVIATIONS         0.232    0.248    0.382    0.363    0.319    0.379
                           0.308    0.315    0.386    0.253    0.233    0.236
```

```
  ACTUAL EVAPOTRANSPIRATION
  -------------------------
    TOTALS                  1.423    1.688    2.199    3.067    3.554    3.353
                            2.548    2.181    2.384    1.726    1.335    1.434

    STD. DEVIATIONS         0.471    0.561    0.741    1.423    1.645    1.424
                            1.713    1.501    1.315    0.859    0.597    0.479

  PERCOLATION/LEAKAGE THROUGH LAYER  3
  ------------------------------------
    TOTALS                  0.0151   0.0195   0.0261   0.0235   0.0195   0.0157
                            0.0091   0.0028   0.0008   0.0015   0.0044   0.0101

    STD. DEVIATIONS         0.0154   0.0143   0.0136   0.0134   0.0166   0.0156
                            0.0124   0.0070   0.0049   0.0061   0.0106   0.0136

  LATERAL DRAINAGE COLLECTED FROM LAYER  8
  ----------------------------------------
    TOTALS                  0.0151   0.0193   0.0261   0.0236   0.0196   0.0158
                            0.0093   0.0029   0.0009   0.0014   0.0043   0.0099

    STD. DEVIATIONS         0.0154   0.0143   0.0137   0.0133   0.0166   0.0156
                            0.0126   0.0071   0.0048   0.0060   0.0105   0.0136

  PERCOLATION/LEAKAGE THROUGH LAYER 10
  ------------------------------------
    TOTALS                  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                            0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                            0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  2
  -------------------------------------
    AVERAGES                7.3500  10.4134  12.7832  11.8484   9.5792   7.9564
                            4.4263   1.3533   0.4268   0.7076   2.2080   4.9221

    STD. DEVIATIONS         7.5801   7.7400   6.7492   6.8450   8.1846   7.8993
                            6.0851   3.3857   2.4802   2.9878   5.3847   6.7006

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES                0.0005   0.0007   0.0008   0.0008   0.0006   0.0005
                            0.0003   0.0001   0.0000   0.0000   0.0001   0.0003

    STD. DEVIATIONS         0.0005   0.0005   0.0004   0.0004   0.0005   0.0005
                            0.0004   0.0002   0.0002   0.0002   0.0003   0.0004

*******************************************************************************
```

```
******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   50
------------------------------------------------------------------------------

                                      INCHES            CU. FEET       PERCENT
                                -------------------   --------------  ---------
 PRECIPITATION                  31.90    (   5.608)     115783.9      100.00

 RUNOFF                          4.874   (  3.1628)      17691.43      15.280

 POTENTIAL EVAPOTRANSPIRATION   72.306   (  1.0943)     262470.91

 ACTUAL EVAPOTRANSPIRATION      26.894   (  3.3620)      97624.69      84.316

 PERCOLATION/LEAKAGE THROUGH     0.14820 (  0.09365)       537.966      0.46463
   LAYER  3

 AVERAGE HEAD ON TOP             6.165   (   3.937)
   OF LAYER  2

 LATERAL DRAINAGE COLLECTED      0.14821 (  0.09398)       538.003     0.46466
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.007      0.00001
   LAYER 10

 AVERAGE HEAD ON TOP             0.000   (   0.000)
   OF LAYER  9

 CHANGE IN WATER STORAGE        -0.019   (  1.9240)        -70.19      -0.061

******************************************************************************
******************************************************************************
```

HELP OUTPUT FILES
(WITH LEACHATE RECIRCULATION)

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 12A-59 to 12A-91

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  13.42     DATE:  11.01.2019


 PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-10.d4
 TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-10.d7
 SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-10.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-10.d11
 SOIL   AND   DESIGN   DATA   FILE     1:   C:\Users\4575sbg\Desktop\Waco\Case   1-
Recirculation.d10
 OUTPUT  DATA  FILE:                         C:\Users\4575sbg\Desktop\Waco\Case  1-
Recirculation.out


******************************************************************************

      TITLE:  Waco New LF - Case 1- With Recirculation

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------



         NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                   TEXAS

                  NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

      JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
      -------      -------      -------      -------      -------      -------
        2.02         2.36         2.68         3.42         4.51         3.06
        1.84         1.92         3.04         3.60         2.49         2.32

         NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                   TEXAS
```

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.20	50.50	58.10	67.10	74.20	81.90
85.90	85.60	79.20	68.80	57.00	49.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WACO TEXAS
AND STATION LATITUDE = 31.37 DEGREES

****

LAYER DATA 1

VALID FOR 10 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 15

```
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.4750 VOL/VOL
FIELD CAPACITY               =      0.3780 VOL/VOL
WILTING POINT                =      0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2966 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

```
THICKNESS                    =    120.00   INCHES
POROSITY                     =      0.6710 VOL/VOL
FIELD CAPACITY               =      0.2920 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3164 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC
```

NOTE: 65.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 4
IS RECIRCULATED INTO THIS LAYER.

```
                              LAYER  3
                              --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  15
       THICKNESS                  =     24.00   INCHES
       POROSITY                   =      0.4750 VOL/VOL
       FIELD CAPACITY             =      0.3780 VOL/VOL
       WILTING POINT              =      0.2650 VOL/VOL
       INITIAL SOIL WATER CONTENT =      0.4151 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=     0.1700E-04 CM/SEC


                              LAYER  4
                              --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  20
       THICKNESS                  =      0.24   INCHES
       POROSITY                   =      0.8500 VOL/VOL
       FIELD CAPACITY             =      0.0100 VOL/VOL
       WILTING POINT              =      0.0050 VOL/VOL
       INITIAL SOIL WATER CONTENT =      0.0547 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=      10.00     CM/SEC
       SLOPE                      =      2.00   PERCENT
       DRAINAGE LENGTH            =    340.0    FEET
     NOTE:   65.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
                 LAYER IS RECIRCULATED INTO LAYER #  2.


                              LAYER  5
                              --------

                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
       THICKNESS                  =      0.06   INCHES
       EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
       FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
       FML INSTALLATION DEFECTS   =      4.00   HOLES/ACRE
       FML PLACEMENT QUALITY      =  3 - GOOD


                              LAYER  6
                              --------

                      TYPE 3 - BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER  16
       THICKNESS                  =     24.00   INCHES
       POROSITY                   =      0.4270 VOL/VOL
       FIELD CAPACITY             =      0.4180 VOL/VOL
       WILTING POINT              =      0.3670 VOL/VOL
       INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=     0.1000E-06 CM/SEC
```

```
******************************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                            VALID FOR  10 YEARS


         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                  SOIL DATA BASE USING SOIL TEXTURE #15 WITH BARE
                  GROUND CONDITIONS, A SURFACE SLOPE OF  3.% AND
                  A SLOPE LENGTH OF  300. FEET.

        SCS RUNOFF CURVE NUMBER              =     96.62
        FRACTION OF AREA ALLOWING RUNOFF     =      0.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
        EVAPORATIVE ZONE DEPTH               =      6.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE    =      1.779  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE  =      2.850  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE  =      2.268  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.590  INCHES
        SOIL EVAPORATION ZONE DEPTH          =      6.000  INCHES
        INITIAL SNOW WATER                   =      0.000  INCHES
        INITIAL INTERCEPTION WATER           =      0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS     =     59.968  INCHES
        TOTAL INITIAL WATER                  =     59.968  INCHES
        TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR


******************************************************************************

                       EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                           VALID FOR  10 YEARS


         NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                  WACO                   TEXAS
              STATION LATITUDE                         =  31.37 DEGREES
              MAXIMUM LEAF AREA INDEX                  =   0.00
              START OF GROWING SEASON (JULIAN DATE)   =     55
              END OF GROWING SEASON (JULIAN DATE)     =    336
              EVAPORATIVE ZONE DEPTH                   =   6.0  INCHES
              AVERAGE ANNUAL WIND SPEED                =  11.30 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  69.0  %
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  69.0  %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  62.0  %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  69.0  %

******************************************************************************

******************************************************************************

                 FINAL WATER STORAGE AT END OF YEAR   10
```

```
--------------------------------------------------------------------------------
                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1            1.7670          0.2945

                    2           35.9164          0.2993

                    3           10.6064          0.4419

                    4            0.0356          0.1484

                    5            0.0000          0.0000

                    6           10.2480          0.4270

    TOTAL WATER IN LAYERS       58.573

    SNOW WATER                   0.000

    INTERCEPTION WATER           0.000

    TOTAL FINAL WATER           58.573

********************************************************************************


********************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
--------------------------------------------------------------------------------

                                                     (INCHES)      (CU. FT.)
                                                    ----------    -------------
      PRECIPITATION                                    3.97         14411.101

      RUNOFF                                           0.000            0.0000

      DRAINAGE RECIRCULATED INTO LAYER  2              0.23593        856.41986

      DRAINAGE COLLECTED FROM LAYER  4                 0.12704        461.14914

      DRAINAGE RECIRCULATED FROM LAYER  4              0.23593        856.41986

      PERCOLATION/LEAKAGE THROUGH LAYER  6             0.000000         0.00135

      AVERAGE HEAD ON TOP OF LAYER  5                  0.109

      MAXIMUM HEAD ON TOP OF LAYER  5                  0.215

      LOCATION OF MAXIMUM HEAD IN LAYER  4
            (DISTANCE FROM DRAIN)                      3.8 FEET

      SNOW WATER                                       2.07          7531.4780

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                       0.4440

      MINIMUM VEG. SOIL WATER (VOL/VOL)                       0.2650
```

```
      ***  Maximum heads are computed using McEnroe's equations.  ***

           Reference:  Maximum Saturated Depth over Landfill Liner
                       by Bruce M. McEnroe, University of Kansas
                       ASCE Journal of Environmental Engineering
                       Vol. 119, No. 2, March 1993, pp. 262-270.

*******************************************************************************

*******************************************************************************

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   10
-------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 1.43     2.31     3.59     2.50     3.41     3.71
                           0.90     3.01     2.74     3.06     2.13     2.17

    STD. DEVIATIONS        1.16     1.67     1.51     1.42     2.01     2.07
                           1.44     1.83     1.66     1.73     1.22     1.24

  RUNOFF
  ------
    TOTALS                 0.000    0.000    0.000    0.000    0.000    0.000
                           0.000    0.000    0.000    0.000    0.000    0.000

    STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                           0.000    0.000    0.000    0.000    0.000    0.000

  POTENTIAL EVAPOTRANSPIRATION
  ----------------------------
    TOTALS                 2.835    3.292    4.737    6.341    8.008    8.786
                          10.288    9.196    7.174    5.078    3.645    2.686

    STD. DEVIATIONS        0.232    0.250    0.219    0.309    0.316    0.366
                           0.268    0.281    0.375    0.266    0.190    0.200

  ACTUAL EVAPOTRANSPIRATION
  -------------------------
    TOTALS                 0.982    1.542    2.072    1.910    2.327    2.150
                           0.819    1.374    1.647    1.881    1.370    1.106

    STD. DEVIATIONS        0.657    0.818    0.870    0.843    1.038    1.270
                           0.850    0.664    1.015    1.111    0.954    0.609

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  ------------------------------------------
    TOTALS                 1.9577   1.6055   1.7201   1.7678   1.7513   1.8077
                           1.9415   1.7763   1.8494   1.9708   2.0046   1.9431

    STD. DEVIATIONS        0.5428   0.3419   0.4364   0.5512   0.6208   0.5918
```

```
                     0.7826    0.5729    0.4343    0.5750    0.5013    0.4607

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  ----------------------------------------
    TOTALS           1.0541    0.8645    0.9262    0.9519    0.9430    0.9734
                     1.0454    0.9565    0.9958    1.0612    1.0794    1.0463

    STD. DEVIATIONS  0.2923    0.1841    0.2350    0.2968    0.3343    0.3187
                     0.4214    0.3085    0.2339    0.3096    0.2699    0.2480

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  4 INTO L.  2
  ------------------------------------------------------
    TOTALS           1.9577    1.6055    1.7201    1.7678    1.7513    1.8077
                     1.9415    1.7763    1.8494    1.9708    2.0046    1.9431

    STD. DEVIATIONS  0.5428    0.3419    0.4364    0.5512    0.6208    0.5918
                     0.7826    0.5729    0.4343    0.5750    0.5013    0.4607

  PERCOLATION/LEAKAGE THROUGH LAYER  6
  ------------------------------------
    TOTALS           0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                     0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

    STD. DEVIATIONS  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                     0.0000    0.0000    0.0000    0.0000    0.0000    0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  5
  -------------------------------------
    AVERAGES         0.0291    0.0263    0.0256    0.0272    0.0261    0.0278
                     0.0289    0.0264    0.0285    0.0293    0.0308    0.0289

    STD. DEVIATIONS  0.0081    0.0056    0.0065    0.0085    0.0092    0.0091
                     0.0117    0.0085    0.0067    0.0086    0.0077    0.0069

*******************************************************************************


*******************************************************************************

   AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   10
-------------------------------------------------------------------------------

                                  INCHES            CU. FEET        PERCENT
                            -------------------   -------------    ---------
 PRECIPITATION                30.95    (   5.379)    112334.0      100.00

 RUNOFF                        0.000   (  0.0000)         0.00       0.000

 POTENTIAL EVAPOTRANSPIRATION 72.065   (  0.6312)    261595.36

 ACTUAL EVAPOTRANSPIRATION    19.181   (  2.7880)     69626.66      61.982
```

```
 DRAINAGE RECIRCULATED          22.09568 (   3.82882)     80207.305   71.40074
   INTO LAYER  2

 LATERAL DRAINAGE COLLECTED     11.89767 (   2.06167)     43188.555   38.44656
   FROM LAYER  4

 DRAINAGE RECIRCULATED          22.09568 (   3.82882)     80207.305   71.40074
   FROM LAYER  4 INTO L.  2

 PERCOLATION/LEAKAGE THROUGH     0.00004 (   0.00001)         0.146    0.00013
   LAYER  6

 AVERAGE HEAD ON TOP             0.028   (     0.005)
   OF LAYER  5

 CHANGE IN WATER STORAGE        -0.139   (   2.4000)       -506.28     -0.451

*******************************************************************************
*******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  10.42     DATE:  31.05.2019


 PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-50.d4
 TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-50.d7
 SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-50.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-Interim.d11
 SOIL   AND   DESIGN   DATA   FILE     1:   C:\Users\4575sbg\Desktop\Waco\Case   2-
Recirculation.d10
 OUTPUT  DATA  FILE:                          C:\Users\4575sbg\Desktop\Waco\Case  2-
Recirculation.out


******************************************************************************

      TITLE:  Waco New LF - Case 2 - With Recirculation

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------



         NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS

                  NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

      JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
      -------      -------      -------      -------      -------      -------
        2.02         2.36         2.68         3.42         4.51         3.06
        1.84         1.92         3.04         3.60         2.49         2.32
```

```
          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WACO                TEXAS

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
      -------     -------     -------     -------     -------     -------
       46.20       50.50       58.10       67.10       74.20       81.90
       85.90       85.60       79.20       68.80       57.00       49.50


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WACO                TEXAS
                     AND STATION LATITUDE  =  31.37 DEGREES


*******************************************************************************

                                LAYER DATA   1
-------------------------------------------------------------------------------

                             VALID FOR  50 YEARS


      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
               COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER  15
            THICKNESS                    =     12.00   INCHES
            POROSITY                     =      0.4750 VOL/VOL
            FIELD CAPACITY               =      0.3780 VOL/VOL
            WILTING POINT                =      0.2650 VOL/VOL
            INITIAL SOIL WATER CONTENT   =      0.3493 VOL/VOL
            EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                   LAYER  2
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER  18
            THICKNESS                    =    720.00   INCHES
            POROSITY                     =      0.6710 VOL/VOL
            FIELD CAPACITY               =      0.2920 VOL/VOL
            WILTING POINT                =      0.0770 VOL/VOL
```

```
  INITIAL SOIL WATER CONTENT  =      0.2931 VOL/VOL
  EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC
NOTE:   90.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 4
         IS RECIRCULATED INTO THIS LAYER.
                        LAYER  3
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  15
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4750 VOL/VOL
  FIELD CAPACITY              =      0.3780 VOL/VOL
  WILTING POINT               =      0.2650 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3967 VOL/VOL
  EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                        LAYER  4
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                   =      0.22   INCHES
  POROSITY                    =      0.8500 VOL/VOL
  FIELD CAPACITY              =      0.0100 VOL/VOL
  WILTING POINT               =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0261 VOL/VOL
  EFFECTIVE SAT. HYD. CONDUCT.=       7.800     CM/SEC
  SLOPE                       =      2.00   PERCENT
  DRAINAGE LENGTH             =    340.0    FEET
NOTE:   90.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


                        LAYER  5
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
  THICKNESS                   =      0.06   INCHES
  EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
  FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
  FML INSTALLATION DEFECTS    =      4.00   HOLES/ACRE
  FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  6
                        --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER  16
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4270 VOL/VOL
  FIELD CAPACITY              =      0.4180 VOL/VOL
```

```
          WILTING POINT                =      0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC

******************************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                            VALID FOR  50 YEARS


        NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                 SOIL DATA BASE USING SOIL TEXTURE #15 WITH A
                 POOR STAND OF GRASS, A SURFACE SLOPE OF  3.%
                 AND A SLOPE LENGTH OF  300. FEET.

       SCS RUNOFF CURVE NUMBER              =     93.37
       FRACTION OF AREA ALLOWING RUNOFF     =     90.0    PERCENT
       AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
       EVAPORATIVE ZONE DEPTH               =     12.0    INCHES
       INITIAL WATER IN EVAPORATIVE ZONE    =      4.192  INCHES
       UPPER LIMIT OF EVAPORATIVE STORAGE   =      5.700  INCHES
       FIELD CAPACITY OF EVAPORATIVE ZONE   =      4.536  INCHES
       LOWER LIMIT OF EVAPORATIVE STORAGE   =      3.180  INCHES
       SOIL EVAPORATION ZONE DEPTH          =     12.000  INCHES
       INITIAL SNOW WATER                   =      0.000  INCHES
       INITIAL INTERCEPTION WATER           =      0.000  INCHES
       INITIAL WATER IN LAYER MATERIALS     =    234.978  INCHES
       TOTAL INITIAL WATER                  =    234.978  INCHES
       TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR


******************************************************************************

                       EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                           VALID FOR  50 YEARS


        NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                 WACO                TEXAS
            STATION LATITUDE                     =  31.37 DEGREES
            MAXIMUM LEAF AREA INDEX              =   1.00
            START OF GROWING SEASON (JULIAN DATE) =     55
            END OF GROWING SEASON (JULIAN DATE)  =    336
            EVAPORATIVE ZONE DEPTH               =  12.0  INCHES
            AVERAGE ANNUAL WIND SPEED            =  11.30 MPH
            AVERAGE 1ST QUARTER RELATIVE HUMIDITY =  69.0  %
            AVERAGE 2ND QUARTER RELATIVE HUMIDITY =  69.0  %
            AVERAGE 3RD QUARTER RELATIVE HUMIDITY =  62.0  %
            AVERAGE 4TH QUARTER RELATIVE HUMIDITY =  69.0  %

******************************************************************************
```

```
******************************************************************************

                   FINAL WATER STORAGE AT END OF YEAR   50
------------------------------------------------------------------------------

                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1            4.3667         0.3639

                      2          219.4687         0.3048

                      3           10.1189         0.4216

                      4            0.0149         0.0677

                      5            0.0000         0.0000

                      6           10.2480         0.4270

    TOTAL WATER IN LAYERS        244.217

    SNOW WATER                     0.000

    INTERCEPTION WATER             0.000

    TOTAL FINAL WATER            244.217

******************************************************************************


******************************************************************************

                PEAK DAILY VALUES FOR YEARS    1 THROUGH   50
------------------------------------------------------------------------------

                                                (INCHES)      (CU. FT.)
                                               ----------    -------------
      PRECIPITATION                              5.66         20545.799

      RUNOFF                                     4.426        16066.1328

      DRAINAGE RECIRCULATED INTO LAYER  2        0.14867        539.66791

      DRAINAGE COLLECTED FROM LAYER  4           0.01652         59.96310

      DRAINAGE RECIRCULATED FROM LAYER  4        0.14867        539.66791

      PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000000         0.00083

      AVERAGE HEAD ON TOP OF LAYER  5            0.064

      MAXIMUM HEAD ON TOP OF LAYER  5            0.126
```

```
     LOCATION OF MAXIMUM HEAD IN LAYER  4
           (DISTANCE FROM DRAIN)                  2.0 FEET

     SNOW WATER                                   2.59          9392.4756

     MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.4541

     MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.2650

      ***  Maximum heads are computed using McEnroe's equations.  ***

           Reference:  Maximum Saturated Depth over Landfill Liner
                       by Bruce M. McEnroe, University of Kansas
                       ASCE Journal of Environmental Engineering
                       Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************



*******************************************************************************

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   50
-------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 2.09     2.55     2.88     2.82     4.24     3.28
                           1.61     2.02     2.85     3.09     2.28     2.20

    STD. DEVIATIONS        1.16     1.39     1.58     1.71     2.31     2.14
                           1.80     1.54     1.81     2.07     1.35     1.33

  RUNOFF
  ------
    TOTALS                 0.263    0.423    0.589    0.612    1.141    0.832
                           0.454    0.349    0.671    1.017    0.422    0.378

    STD. DEVIATIONS        0.294    0.473    0.563    0.698    1.128    0.976
                           0.728    0.587    0.770    1.241    0.502    0.466

  POTENTIAL EVAPOTRANSPIRATION
  ----------------------------
    TOTALS                 2.825    3.214    4.948    6.416    7.903    8.848
                          10.150    9.273    7.323    5.080    3.489    2.836

    STD. DEVIATIONS        0.232    0.248    0.382    0.363    0.319    0.379
                           0.308    0.315    0.386    0.253    0.233    0.236

  ACTUAL EVAPOTRANSPIRATION
  -------------------------
    TOTALS                 1.421    1.692    2.093    2.322    3.202    2.518
```

```
                          1.323    1.485    1.914    1.624    1.400    1.436

  STD. DEVIATIONS         0.514    0.594    0.819    0.804    1.253    1.185
                          1.261    0.905    1.032    0.807    0.673    0.511

LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
-------------------------------------------
  TOTALS                  1.5746   1.4278   1.5955   1.5983   1.6867   1.6188
                          1.6627   1.6691   1.5957   1.6248   1.5625   1.5680

  STD. DEVIATIONS         0.2454   0.2444   0.2620   0.2451   0.2516   0.2333
                          0.2472   0.2533   0.2437   0.2761   0.2434   0.1950

LATERAL DRAINAGE COLLECTED FROM LAYER  4
----------------------------------------
  TOTALS                  0.1750   0.1586   0.1773   0.1776   0.1874   0.1799
                          0.1847   0.1855   0.1773   0.1805   0.1736   0.1742

  STD. DEVIATIONS         0.0273   0.0272   0.0291   0.0272   0.0280   0.0259
                          0.0275   0.0281   0.0271   0.0307   0.0270   0.0217

LATERAL DRAINAGE RECIRCULATED FROM LAYER  4 INTO L.  2
------------------------------------------------------
  TOTALS                  1.5746   1.4278   1.5955   1.5983   1.6867   1.6188
                          1.6627   1.6691   1.5957   1.6248   1.5625   1.5680

  STD. DEVIATIONS         0.2454   0.2444   0.2620   0.2451   0.2516   0.2333
                          0.2472   0.2533   0.2437   0.2761   0.2434   0.1950

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
             AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


DAILY AVERAGE HEAD ON TOP OF LAYER  5
-------------------------------------
  AVERAGES                0.0217   0.0216   0.0220   0.0228   0.0233   0.0231
                          0.0229   0.0230   0.0227   0.0224   0.0223   0.0216

  STD. DEVIATIONS         0.0034   0.0037   0.0036   0.0035   0.0035   0.0033
                          0.0034   0.0035   0.0035   0.0038   0.0035   0.0027

*******************************************************************************
```

```
******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   50
------------------------------------------------------------------------------

                                     INCHES            CU. FEET        PERCENT
                               -------------------   -------------    ---------
 PRECIPITATION                  31.90    (   5.608)    115783.9       100.00

 RUNOFF                          7.151   (  2.2558)     25957.83       22.419

 POTENTIAL EVAPOTRANSPIRATION   72.306   (  1.0943)    262470.91

 ACTUAL EVAPOTRANSPIRATION      22.429   (  3.2297)     81416.20       70.317

 DRAINAGE RECIRCULATED          19.18435 (  2.55083)    69639.203     60.14583
   INTO LAYER  2

 LATERAL DRAINAGE COLLECTED      2.13160 (  0.28343)     7737.690      6.68287
   FROM LAYER  4

 DRAINAGE RECIRCULATED          19.18435 (  2.55083)    69639.211     60.14583
   FROM LAYER  4 INTO L.  2

 PERCOLATION/LEAKAGE THROUGH     0.00003 (  0.00000)        0.123      0.00011
   LAYER  6

 AVERAGE HEAD ON TOP             0.022   (    0.003)
   OF LAYER  5

 CHANGE IN WATER STORAGE         0.185   (  1.2963)       670.79        0.579

******************************************************************************
******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                                developed at                              **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                  based on                                **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  10.45     DATE:  31.05.2019


 PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-50.d4
 TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-50.d7
 SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-50.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-Interim-2.d11
 SOIL   AND   DESIGN   DATA   FILE     1:   C:\Users\4575sbg\Desktop\Waco\Case   3-
Recirculation.d10
 OUTPUT  DATA  FILE:                         C:\Users\4575sbg\Desktop\Waco\Case  3-
Recirculation.out


******************************************************************************

      TITLE:  Waco New LF - Case 3 - With Recirculation

******************************************************************************


                          WEATHER DATA SOURCES
------------------------------------------------------------------------------



          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WACO                TEXAS

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

       JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
       -------     -------     -------     -------     -------     -------
        2.02        2.36        2.68        3.42        4.51        3.06
```

```
         1.84         1.92         3.04         3.60         2.49         2.32


            NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                     COEFFICIENTS FOR    WACO                TEXAS

                NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

        JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
        -------      -------      -------      -------      -------      -------
         46.20        50.50        58.10        67.10        74.20        81.90
         85.90        85.60        79.20        68.80        57.00        49.50


            NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                     COEFFICIENTS FOR    WACO                TEXAS
                       AND STATION LATITUDE  =  31.37 DEGREES


*******************************************************************************

                               LAYER DATA   1
-------------------------------------------------------------------------------

                            VALID FOR  50 YEARS


        NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
                 COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  15
              THICKNESS                    =     12.00    INCHES
              POROSITY                     =      0.4750 VOL/VOL
              FIELD CAPACITY               =      0.3780 VOL/VOL
              WILTING POINT                =      0.2650 VOL/VOL
              INITIAL SOIL WATER CONTENT   =      0.3466 VOL/VOL
              EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC
            NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                     FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                  LAYER  2
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  18
              THICKNESS                    =   1200.00    INCHES
              POROSITY                     =      0.6710 VOL/VOL
```

```
    FIELD CAPACITY              =      0.2920 VOL/VOL
    WILTING POINT               =      0.0770 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.2928 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC
  NOTE:   85.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 5
          IS RECIRCULATED INTO THIS LAYER.
                            LAYER  3
                            --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
    THICKNESS                   =    360.00   INCHES
    POROSITY                    =      0.6710 VOL/VOL
    FIELD CAPACITY              =      0.2920 VOL/VOL
    WILTING POINT               =      0.0770 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.2921 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=      0.5000E-03 CM/SEC


                            LAYER  4
                            --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  15
    THICKNESS                   =     24.00   INCHES
    POROSITY                    =      0.4750 VOL/VOL
    FIELD CAPACITY              =      0.3780 VOL/VOL
    WILTING POINT               =      0.2650 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.3965 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                            LAYER  5
                            --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
    THICKNESS                   =      0.20   INCHES
    POROSITY                    =      0.8500 VOL/VOL
    FIELD CAPACITY              =      0.0100 VOL/VOL
    WILTING POINT               =      0.0050 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.0463 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=       4.800     CM/SEC
    SLOPE                       =      2.00   PERCENT
    DRAINAGE LENGTH             =    340.0    FEET
  NOTE:   85.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
          LAYER IS RECIRCULATED INTO LAYER #  2.


                            LAYER  6
                            --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
```

```
          THICKNESS                      =       0.06    INCHES
          EFFECTIVE SAT. HYD. CONDUCT.=       0.2000E-12 CM/SEC
          FML PINHOLE DENSITY            =       1.00    HOLES/ACRE
          FML INSTALLATION DEFECTS       =       4.00    HOLES/ACRE
          FML PLACEMENT QUALITY          =  3 - GOOD

                                  LAYER  7
                                  --------

                        TYPE 3 - BARRIER SOIL LINER
                        MATERIAL TEXTURE NUMBER  16
          THICKNESS                      =      24.00    INCHES
          POROSITY                       =       0.4270 VOL/VOL
          FIELD CAPACITY                 =       0.4180 VOL/VOL
          WILTING POINT                  =       0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT     =       0.4270 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=       0.1000E-06 CM/SEC


 ******************************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
 ------------------------------------------------------------------------------

                              VALID FOR  50 YEARS


        NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                 SOIL DATA BASE USING SOIL TEXTURE #15 WITH A
                 POOR STAND OF GRASS, A SURFACE SLOPE OF  3.%
                 AND A SLOPE LENGTH OF  300. FEET.

       SCS RUNOFF CURVE NUMBER               =     93.37
       FRACTION OF AREA ALLOWING RUNOFF      =     90.0    PERCENT
       AREA PROJECTED ON HORIZONTAL PLANE    =      1.000  ACRES
       EVAPORATIVE ZONE DEPTH                =     12.0    INCHES
       INITIAL WATER IN EVAPORATIVE ZONE     =      4.159  INCHES
       UPPER LIMIT OF EVAPORATIVE STORAGE    =      5.700  INCHES
       FIELD CAPACITY OF EVAPORATIVE ZONE    =      4.536  INCHES
       LOWER LIMIT OF EVAPORATIVE STORAGE    =      3.180  INCHES
       SOIL EVAPORATION ZONE DEPTH           =     12.000  INCHES
       INITIAL SNOW WATER                    =      0.000  INCHES
       INITIAL INTERCEPTION WATER            =      0.000  INCHES
       INITIAL WATER IN LAYER MATERIALS      =    480.407  INCHES
       TOTAL INITIAL WATER                   =    480.407  INCHES
       TOTAL SUBSURFACE INFLOW               =      0.00   INCHES/YEAR


 ******************************************************************************

                       EVAPOTRANSPIRATION DATA   1
 ------------------------------------------------------------------------------

                             VALID FOR  50 YEARS
```

```
        NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                  WACO                    TEXAS
            STATION LATITUDE                        =  31.37 DEGREES
            MAXIMUM LEAF AREA INDEX                 =   2.00
            START OF GROWING SEASON (JULIAN DATE)   =     55
            END OF GROWING SEASON (JULIAN DATE)     =    336
            EVAPORATIVE ZONE DEPTH                  =  12.0  INCHES
            AVERAGE ANNUAL WIND SPEED               =  11.30 MPH
            AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  69.0  %
            AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  69.0  %
            AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  62.0  %
            AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  69.0  %

******************************************************************************


******************************************************************************

                   FINAL WATER STORAGE AT END OF YEAR   50
------------------------------------------------------------------------------

                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1            4.3472         0.3623

                      2          353.7141         0.2948

                      3          115.3079         0.3203

                      4           10.0934         0.4206

                      5            0.0270         0.1352

                      6            0.0000         0.0000

                      7           10.2480         0.4270

        TOTAL WATER IN LAYERS        493.738

        SNOW WATER                     0.000

        INTERCEPTION WATER             0.000

        TOTAL FINAL WATER            493.738

******************************************************************************


******************************************************************************

                PEAK DAILY VALUES FOR YEARS     1 THROUGH   50
------------------------------------------------------------------------------

                                                   (INCHES)      (CU. FT.)
                                                  ----------    -------------
          PRECIPITATION                              5.66         20545.799
```

```
RUNOFF                                        3.738        13570.0391

DRAINAGE RECIRCULATED INTO LAYER  2           0.10046        364.65482

DRAINAGE COLLECTED FROM LAYER  5              0.01773         64.35085

DRAINAGE RECIRCULATED FROM LAYER  5           0.10046        364.65482

PERCOLATION/LEAKAGE THROUGH LAYER  7          0.000000         0.00095

AVERAGE HEAD ON TOP OF LAYER  6               0.074

MAXIMUM HEAD ON TOP OF LAYER  6               0.147

LOCATION OF MAXIMUM HEAD IN LAYER  5
      (DISTANCE FROM DRAIN)                   2.2 FEET

SNOW WATER                                    2.59          9392.4756

MAXIMUM VEG. SOIL WATER (VOL/VOL)                     0.4536

MINIMUM VEG. SOIL WATER (VOL/VOL)                     0.2650


 ***  Maximum heads are computed using McEnroe's equations.  ***

      Reference:  Maximum Saturated Depth over Landfill Liner
                  by Bruce M. McEnroe, University of Kansas
                  ASCE Journal of Environmental Engineering
                  Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************




******************************************************************************

      AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   50
------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
 PRECIPITATION
 -------------
   TOTALS                  2.09     2.55     2.88     2.82     4.24     3.28
                           1.61     2.02     2.85     3.09     2.28     2.20

   STD. DEVIATIONS         1.16     1.39     1.58     1.71     2.31     2.14
                           1.80     1.54     1.81     2.07     1.35     1.33

 RUNOFF
 ------
   TOTALS                  0.251    0.407    0.546    0.532    0.998    0.734
                           0.410    0.315    0.588    0.918    0.394    0.368

   STD. DEVIATIONS         0.272    0.437    0.526    0.607    0.966    0.842
```

```
                          0.668    0.511    0.657    1.136    0.456    0.448

 POTENTIAL EVAPOTRANSPIRATION
 ----------------------------
   TOTALS                 2.825    3.214    4.948    6.416    7.903    8.848
                         10.150    9.273    7.323    5.080    3.489    2.836
   STD. DEVIATIONS        0.232    0.248    0.382    0.363    0.319    0.379
                          0.308    0.315    0.386    0.253    0.233    0.236

 ACTUAL EVAPOTRANSPIRATION
 -------------------------
   TOTALS                 1.400    1.685    2.148    2.626    3.129    2.587
                          1.339    1.546    2.003    1.622    1.386    1.402

   STD. DEVIATIONS        0.499    0.545    0.803    0.951    1.342    1.244
                          1.278    0.948    1.086    0.832    0.656    0.486

 LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
 -------------------------------------------
   TOTALS                 1.0611   0.8876   1.0715   1.0112   0.9961   1.0934
                          1.0926   1.2107   1.1328   1.2146   1.1508   1.0967

   STD. DEVIATIONS        0.3180   0.3075   0.3273   0.3064   0.3596   0.3363
                          0.3135   0.3009   0.3528   0.3401   0.2759   0.3274

 LATERAL DRAINAGE COLLECTED FROM LAYER  5
 ----------------------------------------
   TOTALS                 0.1873   0.1566   0.1891   0.1784   0.1758   0.1929
                          0.1928   0.2136   0.1999   0.2143   0.2031   0.1935

   STD. DEVIATIONS        0.0561   0.0543   0.0578   0.0541   0.0635   0.0593
                          0.0553   0.0531   0.0623   0.0600   0.0487   0.0578

 LATERAL DRAINAGE RECIRCULATED FROM LAYER  5 INTO L.  2
 ------------------------------------------------------
   TOTALS                 1.0611   0.8876   1.0715   1.0112   0.9961   1.0934
                          1.0926   1.2107   1.1328   1.2146   1.1508   1.0967

   STD. DEVIATIONS        0.3180   0.3075   0.3273   0.3064   0.3596   0.3363
                          0.3135   0.3009   0.3528   0.3401   0.2759   0.3274

 PERCOLATION/LEAKAGE THROUGH LAYER  7
 ------------------------------------
   TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------

 DAILY AVERAGE HEAD ON TOP OF LAYER  6
 -------------------------------------
   AVERAGES               0.0252   0.0231   0.0254   0.0248   0.0236   0.0268
```

```
                          0.0259   0.0287   0.0278   0.0288   0.0282   0.0260

     STD. DEVIATIONS      0.0075   0.0080   0.0078   0.0075   0.0085   0.0082
                          0.0074   0.0071   0.0086   0.0081   0.0068   0.0078

*******************************************************************************
*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   50
-------------------------------------------------------------------------------

                                INCHES            CU. FEET        PERCENT
                          -------------------   -------------    ---------
  PRECIPITATION            31.90     (   5.608)     115783.9     100.00

  RUNOFF                    6.460    (  2.0273)      23448.33     20.252

  POTENTIAL EVAPOTRANSPIRATION  72.306    (  1.0943)     262470.91

  ACTUAL EVAPOTRANSPIRATION  22.872    (  3.3018)      83025.15     71.707

  DRAINAGE RECIRCULATED     13.01904 (  2.19633)     47259.105   40.81664
    INTO LAYER  2

  LATERAL DRAINAGE COLLECTED  2.29748 (  0.38759)      8339.842    7.20293
    FROM LAYER  5

  DRAINAGE RECIRCULATED     13.01904 (  2.19633)     47259.109   40.81664
    FROM LAYER  5 INTO L.  2

  PERCOLATION/LEAKAGE THROUGH  0.00004 (  0.00001)        0.139     0.00012
    LAYER  7

  AVERAGE HEAD ON TOP        0.026    (   0.004)
    OF LAYER  6

  CHANGE IN WATER STORAGE    0.267    (  1.4412)       967.84      0.836

*******************************************************************************
*******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  10.52     DATE:  31.05.2019


 PRECIPITATION DATA FILE:      C:\Users\4575sbg\Desktop\Waco\Waco-50.d4
 TEMPERATURE DATA FILE:        C:\Users\4575sbg\Desktop\Waco\Waco-50.d7
 SOLAR RADIATION DATA FILE:    C:\Users\4575sbg\Desktop\Waco\Waco-50.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\Users\4575sbg\Desktop\Waco\Waco-Interim-2.d11
 SOIL   AND   DESIGN   DATA   FILE      1:   C:\Users\4575sbg\Desktop\Waco\Case   4-
Recirculation.d10
 OUTPUT  DATA  FILE:                          C:\Users\4575sbg\Desktop\Waco\Case  4-
Recirculation.out


******************************************************************************

      TITLE:  Waco New LF - Case 4 - With Recirculation

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------



         NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    WACO                TEXAS

                  NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

      JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
```

-------	-------	-------	-------	-------	-------
2.02	2.36	2.68	3.42	4.51	3.06
1.84	1.92	3.04	3.60	2.49	2.32

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WACO TEXAS
NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.20	50.50	58.10	67.10	74.20	81.90
85.90	85.60	79.20	68.80	57.00	49.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WACO TEXAS
AND STATION LATITUDE = 31.37 DEGREES

****

LAYER DATA 1

VALID FOR 50 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 15

THICKNESS = 12.00 INCHES
POROSITY = 0.4750 VOL/VOL
FIELD CAPACITY = 0.3780 VOL/VOL
WILTING POINT = 0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3464 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.= 0.1700E-04 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

```
  THICKNESS                    =   1200.00   INCHES
  POROSITY                     =      0.6710 VOL/VOL
  FIELD CAPACITY               =      0.2920 VOL/VOL
  WILTING POINT                =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.2931 VOL/VOL
  EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC
NOTE:   65.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 5
         IS RECIRCULATED INTO THIS LAYER.
                          LAYER  3
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =    840.00   INCHES
  POROSITY                     =      0.6710 VOL/VOL
  FIELD CAPACITY               =      0.2920 VOL/VOL
  WILTING POINT                =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.2921 VOL/VOL
  EFFECTIVE SAT. HYD. CONDUCT.=      0.5000E-03 CM/SEC


                          LAYER  4
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  15
  THICKNESS                    =     24.00   INCHES
  POROSITY                     =      0.4750 VOL/VOL
  FIELD CAPACITY               =      0.3780 VOL/VOL
  WILTING POINT                =      0.2650 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.4028 VOL/VOL
  EFFECTIVE SAT. HYD. CONDUCT.=      0.1700E-04 CM/SEC


                          LAYER  5
                          --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =      0.19   INCHES
  POROSITY                     =      0.8500 VOL/VOL
  FIELD CAPACITY               =      0.0100 VOL/VOL
  WILTING POINT                =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.1196 VOL/VOL
  EFFECTIVE SAT. HYD. CONDUCT.=       3.000     CM/SEC
  SLOPE                        =      2.00   PERCENT
  DRAINAGE LENGTH              =    340.0    FEET
NOTE:   65.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


                          LAYER  6
                          --------
```

```
                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
       THICKNESS                    =      0.06   INCHES
       EFFECTIVE SAT. HYD. CONDUCT.=       0.2000E-12 CM/SEC
       FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
       FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
       FML PLACEMENT QUALITY        =  3 - GOOD

                              LAYER  7
                              --------

                    TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER  16
       THICKNESS                    =     24.00   INCHES
       POROSITY                     =      0.4270 VOL/VOL
       FIELD CAPACITY               =      0.4180 VOL/VOL
       WILTING POINT                =      0.3670 VOL/VOL
       INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=       0.1000E-06 CM/SEC


******************************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                         VALID FOR  50 YEARS


          NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                   SOIL DATA BASE USING SOIL TEXTURE #15 WITH A
                   FAIR STAND OF GRASS, A SURFACE SLOPE OF  5.%
                   AND A SLOPE LENGTH OF  240. FEET.

        SCS RUNOFF CURVE NUMBER              =     90.26
        FRACTION OF AREA ALLOWING RUNOFF     =     90.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
        EVAPORATIVE ZONE DEPTH               =     12.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE    =      4.157  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE   =      5.700  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE   =      4.536  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE   =      3.180  INCHES
        SOIL EVAPORATION ZONE DEPTH          =     12.000  INCHES
        INITIAL SNOW WATER                   =      0.000  INCHES
        INITIAL INTERCEPTION WATER           =      0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS     =    621.114  INCHES
        TOTAL INITIAL WATER                  =    621.114  INCHES
        TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR


******************************************************************************

                       EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                         VALID FOR  50 YEARS
```

```
        NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                 WACO                TEXAS
            STATION LATITUDE                        =  31.37 DEGREES
            MAXIMUM LEAF AREA INDEX                 =   2.00
            START OF GROWING SEASON (JULIAN DATE)   =     55
            END OF GROWING SEASON (JULIAN DATE)     =    336
            EVAPORATIVE ZONE DEPTH                  =  12.0  INCHES
            AVERAGE ANNUAL WIND SPEED               =  11.30 MPH
            AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  69.0  %
            AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  69.0  %
            AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  62.0  %
            AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  69.0  %

 ******************************************************************************


 ******************************************************************************

                   FINAL WATER STORAGE AT END OF YEAR   50
 ------------------------------------------------------------------------------

                    LAYER         (INCHES)       (VOL/VOL)
                    -----         --------       ---------
                      1             4.3333         0.3611

                      2           351.7442         0.2931

                      3           254.8373         0.3034

                      4             9.8047         0.4085

                      5             0.0342         0.1802

                      6             0.0000         0.0000

                      7            10.2480         0.4270

     TOTAL WATER IN LAYERS        631.002

     SNOW WATER                     0.000

     INTERCEPTION WATER             0.000

     TOTAL FINAL WATER            631.002

 ******************************************************************************


 ******************************************************************************

                PEAK DAILY VALUES FOR YEARS     1 THROUGH   50
 ------------------------------------------------------------------------------

                                                   (INCHES)      (CU. FT.)
                                                  ----------    -------------
```

```
      PRECIPITATION                                5.66         20545.799

      RUNOFF                                       3.677        13347.2627

      DRAINAGE RECIRCULATED INTO LAYER  2          0.06239        226.46533

      DRAINAGE COLLECTED FROM LAYER  5             0.03359        121.94287

      DRAINAGE RECIRCULATED FROM LAYER  5          0.06239        226.46533

      PERCOLATION/LEAKAGE THROUGH LAYER  7         0.000000         0.00120

      AVERAGE HEAD ON TOP OF LAYER  6              0.096

      MAXIMUM HEAD ON TOP OF LAYER  6              0.189

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)                  4.4 FEET

      SNOW WATER                                   2.59          9392.4756

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.4750

      MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.2650


       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************


*******************************************************************************

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   50
-------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 2.09     2.55     2.88     2.82     4.24     3.28
                           1.61     2.02     2.85     3.09     2.28     2.20

    STD. DEVIATIONS        1.16     1.39     1.58     1.71     2.31     2.14
                           1.80     1.54     1.81     2.07     1.35     1.33

  RUNOFF
  ------
    TOTALS                 0.126    0.232    0.327    0.318    0.652    0.466
                           0.277    0.183    0.374    0.679    0.224    0.212

    STD. DEVIATIONS        0.167    0.327    0.374    0.434    0.794    0.652
```

```
                         0.522    0.355    0.513    1.032    0.318    0.310

  POTENTIAL EVAPOTRANSPIRATION
  ----------------------------
    TOTALS                 2.825    3.214    4.948    6.416    7.903    8.848
                          10.150    9.273    7.323    5.080    3.489    2.836

    STD. DEVIATIONS        0.232    0.248    0.382    0.363    0.319    0.379
                           0.308    0.315    0.386    0.253    0.233    0.236

  ACTUAL EVAPOTRANSPIRATION
  -------------------------
    TOTALS                 1.426    1.691    2.175    2.669    3.302    2.757
                           1.453    1.617    2.085    1.673    1.402    1.421

    STD. DEVIATIONS        0.479    0.552    0.800    0.978    1.437    1.295
                           1.382    0.999    1.126    0.835    0.651    0.482

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  -------------------------------------------
    TOTALS                 0.5531   0.5215   0.6072   0.5042   0.6063   0.6147
                           0.6613   0.7010   0.6693   0.6870   0.6238   0.6036

    STD. DEVIATIONS        0.2195   0.2026   0.2187   0.2226   0.2625   0.2241
                           0.1827   0.1839   0.1495   0.1684   0.1818   0.2348

  LATERAL DRAINAGE COLLECTED FROM LAYER  5
  ----------------------------------------
    TOTALS                 0.2978   0.2808   0.3269   0.2715   0.3265   0.3310
                           0.3561   0.3774   0.3604   0.3699   0.3359   0.3250

    STD. DEVIATIONS        0.1182   0.1091   0.1177   0.1199   0.1413   0.1207
                           0.0984   0.0990   0.0805   0.0907   0.0979   0.1265

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  5 INTO L.  2
  ------------------------------------------------------
    TOTALS                 0.5531   0.5215   0.6072   0.5042   0.6063   0.6147
                           0.6613   0.7010   0.6693   0.6870   0.6238   0.6036

    STD. DEVIATIONS        0.2195   0.2026   0.2187   0.2226   0.2625   0.2241
                           0.1827   0.1839   0.1495   0.1684   0.1818   0.2348

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
```

AVERAGES	0.0275	0.0284	0.0301	0.0259	0.0301	0.0315
	0.0328	0.0348	0.0343	0.0341	0.0320	0.0300
STD. DEVIATIONS	0.0109	0.0110	0.0109	0.0114	0.0130	0.0115
	0.0091	0.0091	0.0077	0.0084	0.0093	0.0117

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 50

	INCHES	CU. FEET	PERCENT
PRECIPITATION	31.90 (5.608)	115783.9	100.00
RUNOFF	4.068 (1.5779)	14767.38	12.754
POTENTIAL EVAPOTRANSPIRATION	72.306 (1.0943)	262470.91	
ACTUAL EVAPOTRANSPIRATION	23.671 (3.4223)	85925.71	74.212
DRAINAGE RECIRCULATED INTO LAYER 2	7.35311 (0.96879)	26691.807	23.05312
LATERAL DRAINAGE COLLECTED FROM LAYER 5	3.95937 (0.52165)	14372.516	12.41322
DRAINAGE RECIRCULATED FROM LAYER 5 INTO L. 2	7.35311 (0.96879)	26691.807	23.05312
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00004 (0.00001)	0.160	0.00014
AVERAGE HEAD ON TOP OF LAYER 6	0.031 (0.004)		
CHANGE IN WATER STORAGE	0.198 (1.9865)	717.82	0.620

****
****

APPENDIX 12B

LEACHATE COLLECTION SYSTEM DESIGN CALCULATIONS

- Geocomposite Calculations
- Non-Woven Geotextile Calculations
- Pipe Structural Stability Calculations
- Pipe Flow Capacity Calculations
- Leachate Sump Design Calculations

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 12B-1 to 12B-43

GEOCOMPOSITE CALCULATIONS

Required:

Determine the hydraulic conductivity of the geocomposite drainage layer in the leachate collection system for use in the HELP model. This demonstration is based on the worst case conditions for leachate generation (active 10-foot of waste) and loading (intermediate 170-foot of waste).

Method:

1. Determine the geocomposite thickness under the expected loading conditions.
2. Determine reduction factors for strength and environmental conditions based on expected duration in each stage of landfill development.
3. Compute the required minimum hydraulic conductivity of the geocomposite using the calculated reduction factors. The minimum hydraulic conductivity for the HELP modeling is designated as the minimum value that keeps the depth of leachate over the liner confined to the geocomposite drainage layer.
4. Using the hydraulic conductivity values from Method No. 3. (above), calculate minimum transmissivity values for the geocomposite.
5. Obtain values for geocomposite transmissivity from manufacturer's data, and compare with the transmissivity values developed in Method Nos. 3. and 4. (above) to confirm that geocomposite properties used in the HELP model are respresentative of available geocomposites. The minimum transmissivity for the geocomposite shall exhibit a minimum factor-of-safety of 1.5 when compared to the manufacturer's data.

References:

1. Koerner, R.M., *Designing With Geosynthetics, Second Edition* , 1990.
2. Giroud, J.P., Zornberg, J.G., and Zhao, A., 2000, "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", Geosynthetics International, Vol. 7, Nos. 4-6, pp. 285-380
3. GSE, FabriNet HF (bi-planar) Single-sided Geocomposite Transmissivity Data.

Solution:

1. Estimate geocomposite thickness for the worst case leachate generation and loading conditions, based on an initial thickness of 250 mils:

   Assume the geocomposite will undergo linear compression due to weight of soil (i.e., daily cover or intermediate cover and protective cover) and waste.

Unloaded Geocomposite Thickness =	0.25	in
Compressibility at 15,000 psf =	65	%, as provided by manufacturers
Unit Weight of Soil Only =	120	pcf
Composite Unit Weight of Waste and Daily Cover =	60	pcf

Table 1 - Geocomposite Thickness

Fill Condition	d_W[1] (ft)	d_S[2] (ft)	P[3] (psf)	t[4] (in)
Active, 0%	10	2.5	900	0.24
Interim, 90%	170	3.0	10,560	0.19

[1] d_W is the depth of waste above the geocomposite.

[2] d_S is the depth of soil (i.e., protective, daily, and intermediate) above the geocomposite.

[3] P is the pressure on the geocomposite due to the weight of the waste and soil

[4] t is the thickness of the geocomposite after being subjected to linear compression.
t is calculated by equation (Initial Thickness) - (Max. Compression) x P/15,000.

2. Reduction Factors for Strength and Environmental Conditions

Table 2 - Reduction Factors

Environmental Condition	Range	Fill Condition Active (10' Waste)	Fill Condition Interim (170' Waste)
Geotextile Intrusion [1]	1.0 - 1.2	1.05	1.10
Creep Deformation [1,2]	1.1 - 2.0	1.20	1.50
Chemical Clogging [1,3]	1.5 - 2.0	1.50	1.75
Biological Clogging [3]	1.1 - 1.5	1.10	1.50
Composite Reduction Factor[4]	1.81 - 7.2	2.08	4.33

Notes:

[1] Range values for geotextile intrusion, creep deformation, and chemical clogging were obtained from Giroud, J.P., Zornberg, J.G., and Zhao, A., 2000, "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers",*Geosynthetics International* , Vol. 7, Nos. 4-6, pp. 285-380.

[2] Based on product literature, geocomposites/geonets will exhibit creep deformation reduction of 1.3 to 1.6 at 10,000 to 15,000 psf.

[3] Range values for biological clogging were obtained from GRI Standard GC8, Geosynthetic Institute, 2001, "Determination of the Allowable Flow Rate of a Drainage Geocomposite".

[4] The Composite Reduction Factor is the product of all of the factors for the respective fill condition

3. Develop and confirm assumptions for hydraulic conductivity (k) of the geocomposite for HELP model.

Table 3 - Assumed Hydraulic Conductivity

Fill Condition	d_W[1] (ft)	P^2 (psf)	t^3 (in)	Reduction Factor	k_{min}[5] (cm/s)	Peak Leachate Head (in)[6]
Active, 0%	10	900	0.24	2.08	10.00	0.14
Interim, 90%	170	10,560	0.19	4.33	3.00	0.16

[1] d_W is the depth of waste above the geocomposite from Table 1.
[2] P is the pressure on the geocomposite due to the weight of the waste and soil from Table 1.
[3] t is the calculated geocomposite thickness from Table 1.
[4] Reduction Factors from Table 2.
[5] k is the assumed hydraulic conductivity value for HELP model. Reduction Factors will be applied to determine required minimum manufacturer transmissivity values, below.
[6] As calculated by HELP model, assuming no leachate recirulation

4. Using the hydraulic conductivity values from Table 3 (above), calculate minimum transmissivity values for use during design and specifying geocomposites.

$$T_{min} = ((t * 2.54 \text{ cm/in}) * k_{min}) * \text{Reduction Factor}$$

Table 4 - Minimum Required Transmissivity for Geocomposite Design

Fill Condition	P (psf)	t (in)	k_{min} (cm/s)	Reduction Factor	T_{min} (cm^2/sec)	**$T_{min\ Required}$ (m^3/sec/m)**
Active, 0%	900	0.24	10.00	2.08	1.27E+01	**1.27E-03**
Interim, 90%	10,560	0.19	3.00	4.33	6.27E+00	**6.27E-04**

5. Compare T_{min} values from Method No. 4 (above) with published manufacturer transmissivity values.

Table 5 - Comparison of Manufacturer's Reported Transmissivity to the Minimum Required Transmissivity

			GSE FabriNet HF(bi-planar) Single-Sided		
Fill Condition	P (psf)	Minimum Required T Value[3] (m^2/sec)	P (psf)	T_{min}[1] (m^3/sec/m)	**Factor of Safety**
Active, 0%	900	1.27E-03	1,000	3.00E-03	**2.4**
Interim, 90%	10,560	6.27E-04	10,560	9.30E-04	**1.5**

[1] Geocomposite Transmissivity values determined from tests with hydraulic gradient of 0.02. If higher gradient used by manufacturer to determine transmissivity, manufacturer will be required to certify that geocomposite will provide comparable drainage as described in Table 4, above.
[2] The product shown in the table is provided to demonstrate the availability of products that will meet or exceed the required drainage characteristics. Other manufactured products, either bi-planar or tri-planar geocomposites are acceptable if confirmed to meet the minimum required transmissivity values indicated in Table 5 (above), while providing a minimum factor-of-safety of 1.5.

As shown on the HELP Model Summary Sheets, a geocomposite with characteristics similar to the attached chart will provide a drainage layer that will maintain less than 30 cm of leachate over the liner system. If a drainage geocomposite that has transmissivity characteristics less than those indicated in Table 5 is recommended, then a demonstration of the material's ability to maintain less than 30 cm of leachate over the liner will be submitted with an approval request to the TCEQ, and approval will be obtained prior to the selection of the alternate geocomposite.

NON-WOVEN GEOTEXTILE CALCULATIONS

Required:

Evaluate that the following non-woven geotextiles meet or exceed the required properties for retention, hydraulic conductivity, porosity, puncture resistance, and survivability for the specified design conditions:

A. Non-Woven Geotextile (12 oz/sy) to be installed around granular drainage aggregate located in the chimney drains and leachate collection sump.

B. Non-Woven Geotextile (8 oz/sy) located on the top/bottom of the drainage geocomposite.

Although it is anticipated that the protective cover soil installed at the landfill will have a hydraulic conductivity less than 1 x 10^{-4} cm/s, the geotextile design calculations were performed conservatively assuming a protective cover soil with a hydraulic conductivity of greater than and less than 1 x 10^{-4} cm/s. Therefore, these calculations were performed for the following cases:

Case 1: Hydraulic conductivity greater than or equal to 1 x 10^{-4} cm/s.

Case 2: Hydraulic conductivity less than 1 x 10^{-4} cm/s.

Method:

Evaluate the geotextile properties for retention, hydraulic conductivity, porosity, puncture resistance, and survivability in accordance to Reference 2, as described herein.

Reference:

1. GSE Lining Technology Inc., Product Data Sheet "GSE Nonwoven Geotextiles", 2007.
2. Koerner, R.M., Designing With Geosynthetics, third edition, 1994.

Solution:

A. Non-Woven Geotextile (12 oz/sy) to be installed around granular drainage aggregate located in the chimney drains and leachate collection sump.

Retention (Case 1 and Case 2):

The apparent opening size (O_{95}) was determined ; **(Ref. 1)**

O_{95} < 0.15 mm

AASHTO's Task Force # 25 report as referenced on pp. 101 of Reference 2 recommends that the following criteria be used to check the geotextile retention properties:

- For soil ≤ 50% passing the No. 200 sieve: O_{95} < 0.59mm (i.e., AOS of the fabric ≥ No. 30 sieve); and
- For soil > 50% passing the No. 200 sieve: O_{95} < 0.30mm (i.e., AOS of the fabric ≥ the No. 50 sieve).

Since the O_{95} or AOS of the 12 oz/sy geotextile is less than 0.30 mm, it meets the retention criteria for any soil.

Hydraulic Conductivity (k):

For Case 1:

$q_{allow} = q_{ult}\ [(1/FS_{SCB} \times FS_{CR} \times FS_{IN} \times FS_{CC} \times FS_{BC})]$ **(Ref. 2, pp. 159)**

Where:

q_{allow} =	allowable flow rate
q_{ult} =	ultimate flow rate
FS_{SCB} =	factor-of-safety for soil clogging and binding
FS_{CR} =	factor-of-safety for creep reduction of void space
FS_{IN} =	factor-of-safety for adjacent materials intruding into the geotextile's void space
FS_{CC} =	factor-of-safety for chemical clogging
FS_{BC} =	factor-of-safety for biological clogging

q_{ult} =	0.232	cm/sec	**(Ref. 1)**
FS_{SCB} =	7.5	(Long-term, fine soil)	**(Ref. 2, pp. 160)**
FS_{CR} =	1.75	(Long-term installation)	
FS_{IN} =	1.1	(Moderate normal stresses)	
FS_{CC} =	1.35	(Leachate unknown)	
FS_{BC} =	26.0	(Leachate unknown)	

Calculated factor-of-safety = 506.76

$q_{allow=}$	4.58E-04	cm/s

4.58E-04 > 1.00E-04 cm/s

Global F.S.$_{8oz/sy}$ = [q_{allow}/q_{soil}] = 4.58

After applying average partial factors-of-safety for the geotextile, a global factor of safety for clogging of 4.6 is determined and is acceptable.

For Case 2:

For protective cover material that has a hydraulic conductivity less than 1 x 10^{-4} cm/s, it is assumed that the hydraulic conductivity of the geotextile will be much greater than the hydraulic conductivity of the protective cover material. Therefore, the minimum hydraulic conductivity is not calculated for this case (i.e., the hydraulic conductivity of the non-woven geotextile will be sufficient to prevent head from developing in the protective cover).

Porosity (Case 1 and Case 2):

The selected non-woven geotextile should have enough openings, that the performance of the non-woven geotextile will not be significantly impaired in the event of blockage of some openings. Giroud recommends a non-woven geotextile porosity of greater than 30%. As per Giroud, the porosity of a non-woven geotextile can be calculated using the following equation.

$n = 1-[m/\rho t] \times 100$ **(Ref. 2, pp. 128)**

Where:
- n = geotextile porosity, %
- m = geotextile mass per unit area, lb/sf
- t = geotextile thickness, ft
- ρ = density of filaments, lb/cf

m =	0.083	
t =	0.01	
ρ =	182	
n =	**95.4**	***> 30%, therefore, ok***

Puncture Resistance (Case 1 and Case 2):

The selected geotextile must protect the underlying geonet and geomembrane components from damage due to the drainage aggregate. This component can be evaluated based on the puncture resistance of the geotextile. The manufacturer's values for puncture resistance are based on a point load puncture failure (ASTM D4833). The steel rod used to puncture the geotextile is 0.31 in. in diameter. The puncture value of 190 lbs can be converted to 2,520 psi for the 12 oz/sy geotextile.

Assuming a compacted waste density of approximately 60 lb/cf (waste and soil), the height of fill would need to be over 6,000 ft high to exert a pressure approaching 2,520 psi. Since the maximum above ground and below ground fill height is significantly below 6,000 ft, the geotextile is adequate to protect the underlying liner components from damage due to static weights of the final waste body.

Survivability (Case 1 and Case 2):

Depending on the severity of an application a geotextile will be used for, the required strength parameters may vary. This assessment is also referred to as a " Survivability" analysis.

Based on Reference 2 pp. 303, geotextile properties are selected based on the subgrade conditions and the operating equipment used during the cell construction. A "Low" rating (see table below) is assumed for the 12 oz/sy geotextile.

Subgrade Conditions	Construction Equipment Ground Pressure, 6 to 12 in. of Cover: Initial Lift Thickness		
	Low Pressure (4 psi)	Med. Pressure (> 4 psi)	High Pressure (>8 psi)
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level such that any shallow depressions and humps do not exceed 6 in. in depth or height. All larger depressions are filled. Alternatively a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 1 in. in depth or height. Larger depressions should be filled.	Moderate	High	Very High
Minimal site preparation is required. Trees may be felled, de-limbed, and left in place. Stumps should be cut to project not more than 6 in. ± above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders, Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very High	Not Recommended

Notes regarding the above table:

Recommendations given above are for 6 to 12 in. initial lift thickness. The recommended pressure for other initial lift thicknesses is listed below:

1. 12 to 18 in. - Reduce survivability requirement by one level
2. 18 to 24 in. - Reduce survivability requirement by two levels
3. >24 in. - Reduce survivability requirement by three levels

Survivability levels are in increasing order: low, moderate, high and very high. For special construction techniques such as pre-rutting, increase survivability requirement one level. Placement of excessive initial cover material thickness may cause bearing failure of soft subgrade. *Source* After Christopher and Holtz [146]

Using the table above, a rating of "High" was initially chosen based on optimum subgrade condition (which will be provided by the liner) and a high ground pressure of > 8 psi. However, since the soil protective cover will be 24 inches (all placed in one lift), the survivability requirement may be reduced by two levels (see Note #2) from "High to Low". Additionally, "Low" ground pressure equipment will be used on all sideslope areas to protect the liner components and a minimum of 24 inches of initial soil thickness will be maintained beneath equipment over the liner.

Based on Reference 2 pp.304, the physical property requirements for the evaluated geotextile are provided below.

PHYSICAL PROPERTY REQUIREMENTS[a] GEOTEXTILES<50% ELONGATION/GEOTEXTILES>50% ELONGATION[b,c]			
Survivability Level	**Grab Strength ASTM D4632 (lb.)**	**Puncture Resistance ASTM D4833 (lb.)**	**Trapezoidal Tear Strength ASTM D4533 (lb.)**
Medium	180/115	70/40	70/40
High	270/180	100/75	100/75

[a] Values shown are minimum average roll values. Strength values are in the weaker principal direction.

[b] Elongation (strain) at failure as determined by ASTM D4632, Grab Tensile.

[c] The values of geotextile elongation do not imply the allowable consolidation properties of the subgrade soil. These must be determined by a separate investigation.

Survivability (Case 1 and Case 2):

Since the table "Physical Property Requirements" provided on Pg. 15B-10 does not provide physical property requirements for a "low" survivability level, the "medium" survivability level values were used for comparison. Given below are the manufacturer's specifications in comparison for the evaluated 12 oz/sy non-woven geotextile ***(Reference 1, w/ >50% elongation)*** .

Grab Strength (ASTM D4632) = 320 lbs >115 lbs, therefore ok
Puncture Resistance (ASTM D4833) = 190 lbs > 40 lbs, therefore ok
Trapezoid Tear Strength (ASTM D4533) = 125 lbs > 40 lbs, therefore ok

Therefore, the evaluated 12 oz/sy geotextile meets the "LOW" survivability criteria

Summary of required properties for non-woven geotextile installed around the drainage aggregate located in chimney drains and leachate collection sump for both Case 1 & Case 2: (Reference 1)

Apparent opening size	<	0.30	mm
Hydraulic conductivity	>	1×10^{-4}	cm/sec
Porosity	>	30.0	%
Grab tensile strength	≥	115	lbs
Puncture resistance	≥	40	lbs
Trapezoid tear strength	≥	40	lbs

Overall Conclusion:

The evaluated 12 oz/sy non-woven geotextile filter fabric is sufficient to allow proper flow of the leachate without clogging based on the 3 criteria analyzed: retention, hydraulic conductivity, and porosity and is adequate to provide protection to the underlying liner components based on the 2 criteria analyzed: puncture resistance and survivability.

B. Non-Woven Geotextile (8 oz/sy) located on the top/bottom of the drainage geocomposite.

Retention (Case 1 and Case 2):

The apparent opening size (O_{95}) was determined; **(Ref. 1)**

O_{95} < 0.18 mm

AASHTO's Task Force # 25 report as referenced on pp. 101 of Reference 2 recommends that the following criteria be used to check the geotextile retention properties:

- For soil ≤ 50% passing the No. 200 sieve: O_{95} < 0.59mm (i.e., AOS of the fabric ≥ No. 30 sieve); and
- For soil > 50% passing the No. 200 sieve: O_{95} < 0.30mm (i.e., AOS of the fabric ≥ the No. 50 sieve).

Since the O_{95} or AOS of the 8 oz/sy geotextile is less than 0.30 mm, it meets the retention criteria for any soil.

Hydraulic Conductivity (k):

For Case 1:

$q_{allow} = q_{ult}\ [(1/FS_{SCB} \times FS_{CR} \times FS_{IN} \times FS_{CC} \times FS_{BC})]$ **(Ref. 2, pp. 159)**

Where:
q_{allow} = the allowable flow rate
q_{ult} = the ultimate flowrate
FS_{SCB} = the factor of safety for soil clogging and binding
FS_{CR} = the factor of safety for creep reduction of void space

FS_{IN} = the factor of safety for adjacent materials intruding into the geotextile's void space
FS_{CC} = the factor of safety for chemical clogging
FS_{BC} = the factor of safety for biological clogging

q_{ult} =	0.3	cm/sec	**(Ref. 1)**
FS_{SCB} =	7.5	(Long-term, fine soil)	**(Ref. 2, pp. 160)**
FS_{CR} =	1.75	(Long-term installation)	
FS_{IN} =	1.1	(Moderate normal stresses)	
FS_{CC} =	1.35	(Leachate unknown)	
FS_{BC} =	26.0	(Leachate unknown)	

Calculated factor-of-safety = 506.76

$q_{allow=}$	5.92E-04	cm/s

5.92E-04 > 1.00E-04 therefore, ok

Global F.S.$_{8oz/sy}$ = [q_{allow}/q_{soil}] = 5.92

After applying average partial factors-of-safety for the geotextile, a global factor of safety for clogging of 5.9 is determined and is acceptable.

For Case 2:

For protective cover material that has a hydraulic conductivity less than 1 x 10^{-4} cm/s, it is assumed that the hydraulic conductivity of the geotextile will be much greater than the hydraulic conductivity of the protective cover material. Therefore, the minimum hydraulic conductivity is not calculated for this case (i.e., the hydraulic conductivity of the non-woven geotextile will be sufficient to prevent head from developing in the protective cover).

Porosity (Case 1 and Case 2):

The selected geotextile should have enough openings to ensure that blocking of a few of them will not significantly impair the performance of the geotextile filter. Giroud recommends a non-woven porosity of greater than 30%. As per Giroud, the porosity of a non-woven geotextile can be calculated using the following equation.

$n = 1-[m/\rho t] \times 100$ **(Ref. 2, pp. 128)**

Where:
- n = geotextile porosity, %
- m = geotextile mass per unit area, lb/sf
- t = geotextile thickness, ft
- ρ = density of filaments, lb/cf

m =	0.056	
t =	0.0075	
ρ =	91	
n =	**91.8**	***> 30%, therefore, ok***

Puncture Resistance (Case 1 and Case 2):

The selected geotextile must protect the underlying geonet and geomembrane components from damage due to the protective cover. This component can be evaluated based on the puncture resistance of the geotextile. The manufacturer's values for puncture resistance are based on a point load puncture failure (ASTM D4833). The steel rod used to puncture the geotextile is 0.31 in. in diameter. The puncture value of 120 lbs can be converted to 1,589 psi for the 8 oz/sy geotextile.

Now, assuming a compacted waste density of approximately 60 lb/cf, the height of fill would need to be over 3,800 ft high to exert a pressure approaching 1,589 psi. Since our maximum above ground and below ground fill height is significantly below 3,800 ft, the geotextile is adequate to protect the underlying liner components from damage due to static weights of the final waste body.

Survivability (Case 1 and Case 2):

Depending on the severity of an application a geotextile will be used for, the required strength parameters may vary. This assessment is also referred to as a " Survivability" analysis.

Based on Reference 2 pp. 303, geotextile properties are selected based on the subgrade conditions and the operating equipment used during the cell construction. A "Low" rating (see table below) is assumed for the 8 oz/sy geotextile.

Subgrade Conditions	**Construction Equipment Ground Pressure, 6 to 12 in. of Cover: Initial Lift Thickness**		
	Low Pressure (4 psi)	**Med. Pressure (> 4 psi)**	**High Pressure (>8 psi)**
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level such that any shallow depressions and humps do not exceed 6 in. in depth or height. All larger depressions are filled. Alternatively a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 1 in. in depth or height. Larger depressions should be filled.	Moderate	High	Very High
Minimal site preparation is required. Trees may be felled, de-limbed, and left in place. Stumps should be cut to project not more than 6 in. ± above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders, Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very High	Not Recommended

Notes regarding the above table:

Recommendations given above are for 6 to 12 in. initial lift thickness. The recommended pressure for other initial lift thicknesses is listed below:

1. 12 to 18 in. - Reduce survivability requirement by one level
2. 18 to 24 in. - Reduce survivability requirement by two levels
3. >24 in. - Reduce survivability requirement by three levels

Survivability levels are in increasing order: low, moderate, high and very high. For special construction techniques such as pre-rutting, increase survivability requirement one level. Placement of excessive initial cover material thickness may cause bearing failure of soft subgrade. *Source* After Christopher and Holtz [146]

Using the table above, a rating of "High" was initially chosen based on optimum subgrade condition (which will be provided by the liner) and a high ground pressure of > 8 psi. However, since the soil protective cover will be 24 inches (all placed in one lift), the survivability requirement may be reduced by two levels (see Note #2) from "High to Low". Additionally, "Low" ground pressure equipment will be used on all sideslope areas to protect the liner components and a minimum of 24 inches of initial soil thickness will be maintained beneath equipment over the liner.

Based on Reference 2 pp.304, the physical property requirements for the evaluated geotextile are provided below.

PHYSICAL PROPERTY REQUIREMENTS[a] GEOTEXTILES<50% ELONGATION/GEOTEXTILES>50% ELONGATION[b,c]			
Survivability Level	**Grab Strength ASTM D4632 (lb.)**	**Puncture Resistance ASTM D4833 (lb.)**	**Trapezoidal Tear Strength ASTM D4533 (lb.)**
Medium	180/115	70/40	70/40
High	270/180	100/75	100/75

[a] Values shown are minimum average roll values. Strength values are in the weaker principal direction.

[b] Elongation (strain) at failure as determined by ASTM D4632, Grab Tensile.

[c] The values of geotextile elongation do not imply the allowable consolidation properties of the subgrade soil. These must be determined by a separate investigation.

Survivability (Case 1 and Case 2):

Since the table "Physical Property Requirements" provided on Pg. 15B-14 does not provide physical property requirements for a "low" survivability level, the "medium" survivability level values were used for comparison. Given below are the manufacturer's specifications in comparison for the evaluated 8 oz/sy non-woven geotextile ***(Reference 1, w/ >50% elongation)*** .

Grab Strength (ASTM D4632) = 220 lbs >115 lbs, therefore ok
Puncture Resistance (ASTM D4833) = 120 lbs > 40 lbs, therefore ok
Trapezoid Tear Strength (ASTM D4533) = 95 lbs > 40 lbs, therefore ok

Therefore, the evaluated 8 oz/sy geotextile meets the "LOW" survivability criteria

Summary of required properties for non-woven geotextile adhered to the geocomposite for both Case 1 & Case 2: (Reference 1)

Apparent opening size	=	0.30	mm
Hydraulic conductivity	=	1×10^{-4}	cm/sec
Porosity	=	30.0	%
Grab tensile strength	=	115	lbs
Puncture resistance	=	40	lbs
Trapezoid tear strength	=	40	lbs

Overall Conclusion:

The evaluated 8oz/sy geotextile filter fabric is sufficient to allow proper flow of the leachate without clogging based on the 3 criteria analyzed: retention, hydraulic conductivity, and porosity and is adequate to provide protection to the underlying liner components based on the 2 criteria analyzed: puncture resistance and survivability.

PIPE STRUCTURAL STABILITY CALCULATIONS

CITY OF WACO LANDFILL
PIPE STRUCTURAL STABILITY
6-INCH DIAMETER HDPE PIPE

Required:

Analyze the structural stability of the 6-inch diameter high density polyethylene leachate collection pipes related to wall crushing, deflection, and wall buckling failures associated with the worst case loading conditions.

Method:

A. Determine the critical load under the following two conditions:

1. Construction loading
2. Overburden loading

B. Use the critical loading pressure to analyze pipe stability under the following three possible

1. Wall crushing
2. Deflection
3. Wall buckling

References:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyes Data Corporation, 1986.
2. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.
3. CPChem Performance Pipe, a Division of Chevron Phillips Chemical Company LP, Draft Design Document titled *Technical Note XXX - Considerations for HDPE Pipe Section for Deep Fill Applications, 2002.*
4. CPChem Performance Pipe, a Division of Chevron Phillips Chemical Company LP, *The Performance Pipe Engineering Manual* , Vol. 2, 2002.
5. Caterpillar Tractor Company, C*aterpillar Product Brochure: 836H Landfill Compactor (www.cat.com),* 2007.
6. Reinhart, D.R. and Manoj, C.B., MSW Landfill Leachate Collection Systems for the New Millennium, Report #00-13, Florida Center for Solid and Hazardous Waste Management, 2000.

Solution:

A. Determine critical loading for construction versus overburden conditions.

1. Construction Loading:

Assume: CAT 637G Scraper with an even load distribution (Ref. 5)

Loaded weight =	197,000	lb
Tire pressure =	80	psi
Number of tires =	4	

For a circular tire imprint:

$$F = \frac{\text{Loaded Weight}}{\text{Number of Tires}}$$

Where: F= Force exerted by one tire (lb)

F =	49,250	lb

Determine radius of contact for circular tire imprint:

$$r = (F / \pi p)^{1/2}$$

Where: r = Radius of contact (in)
F = Force exerted by one tire (lb)
p = Tire pressure (psi)

r =	14.0	in

Use Boussinesq's solution to find the stress at a point below a uniformly loaded circular area:

$$y = p(1-((r/z)^2+1)^{-3/2})$$

Where: y = Change in vertical stress (psi)
p = Tire pressure (psi)
r = Radius of contact (in)
z = Protective cover thickness (in)

z = 24 in

y =	28.4	psi

Assume only one wheel load on pipe and add 50% for impact loading:

$P_L = 1.5y$

Where: $P_L =$ Maximum live load (psi)

$P_L =$	42.7	psi

$P_D = zw$

Where:
$P_D =$ Maximum dead load (psi)
$z =$ Protective cover thickness
$w =$ Unit weight of protective cover

$z =$	24	in
$w =$	120	pcf

$P_D =$	1.7	psi

$P_{Tconst} = P_L + P_D$

Where: $P_{T,\,const} =$ Maximum construction load (psi)

$P_{T,\,const} =$	44.4	psi

2. Overburden loading (postclosure load):

For maximum overburden load on pipe:

2.0	ft gravel & cover @	120	pcf =	240	psf	
3.5	ft final & interim cover @	120	pcf =	420	psf	
160.0	ft solid waste @	60	pcf =	9,600	psf	
10.0	ft daily cover @	120	pcf =	1,200	psf	42.857
			Σ =	11,460	psf	

$P_{Toverburd} =$	11,460	psf

$P_{Toverburd} =$	80	psi

Determine critical loading condition:

Construction loading:	$P_{Tconst} =$	44.4	psi
Overburden loading:	$P_{Toverburd} =$	80	psi

Conclusion: Overburden loading is most critical to the structural stability of the pipe and will be used to determine the design overburden pipe stress.

3. Determine design overburden stress:

Adjust critical stress to account for loss of strength in the pipe due to perforations:

$P_{DES} = 12P_T / (12-1_p)$ (Ref. 1)

Where:

1_p =	Cumulative length of perforations per foot of pipe
P_T =	Critical pipe stress (psi)
P_{DES} =	Pipe stress adjusted for loss of strength (psi), used as design pressure
6	holes/foot
0.5	in/hole

1_p =	3.0	in/ft

From determination of critical loading:

P_T =	80.0	psi
P_{DES} =	107	psi

Note: Soil arching is incorporated into the following calculations, using methods proposed by CPChem for HDPE solid wall pipe. The calculations are applicable to any solid wall HDPE pipe meeting industry standards for composition and manufacture.

B. Pipe Stability Analyses

1. Wall crushing (ring compressive stress) (Ref. 3)

Vertical Arching Factor (VAF) = $0.88 - 0.71\ (S_A-1) / (S_A+2.5)$
Hoop thrust stiffness ratio (S_A) = $1.43\ (M_s r_m/Et)$

Where:

M_s =	One dimensional modulus of soil (psi) (Ref. 3)
r_m =	Mean pipe radius, = $(D_o+D_i)/4$
D_o =	Pipe outside diameter (in)
D_i =	Pipe inside diameter (in)
E =	Pipe modulus of elasticity (psi)
t =	Pipe wall thickness (in)
DR =	Dimension Ratio, D_o/t
σ_{yield}=	HDPE compressive strength at yield (psi) = 1,600 psi (Ref. 4)

Assumed overburden stress (psi) : 107
Backfill type : Gravel, 95% Std. Proctor
Ms (from Table 1, below) (psi) : 6675

Table 1. Typical Design Values for Constrained Modulus, M_s (Ref. 3)

Vertical Soil Stress (psi)	Gravelly Sand/Gravels at 95% SPD (psi)	Gravelly Sand/Gravels @ 90% SPD (psi)	Gravelly Sand/Gravels @ 85% SPD (psi)	
10	3000	1500	500	
20	3500	1700	650	
40	4500	2100	900	
60	5500	2500	1150	
80	6000	2900	1300	
100	6500	3200	1450	6,675
150	7750	-	-	(107 psi)

SPD = Standard Proctor Density

* Based on the linear relationship generated between Vertical Soil Stress (60, 80, and 100 psi) and respective M_s (psi), linear interpolation was used to calculate a MS value of 6,675 psi at a Vertical Soil Stress of 107 psi.

CITY OF WACO LANDFILL
PIPE STRUCTURAL STABILITY
6-INCH DIAMETER HDPE PIPE

$P_{RD} = (VAF)\ P_{DES}$ (Ref. 3)

$\sigma_{actual} = P_{RD}(DR) / 2$ (Ref. 3)

Where:

P_{RD} = Radial-directed earth pressure

σ_{actual} = Actual sidewall crushing (compressive) stress

D_o (in) =	6	
E (psi) =	28,200	(Ref. 4)
M_s (psi) =	6,675	(Ref. 3, Table 1 above)
σ_{yield}=	1,600	(Ref. 4)
Factor of Safety (FS) =	$\sigma_{yield}/\sigma_{actual}$	

DR	**P_{DES}**	**t**	**r_m**	**S_A**	**VAF**	**P_{RD} (psf)**	**σ_{actual} (psi)**	**FS**
9	107	0.67	2.67	1.35	0.81	12,515	391	4.1
11	107	0.55	2.73	1.69	0.76	11,716	447	3.6
13.5	107	0.44	2.78	2.12	0.71	10,881	510	3.1
15.5	107	0.39	2.81	2.45	0.67	10,316	555	2.9
17	107	0.35	2.82	2.71	0.65	9,940	587	2.7
19	107	0.32	2.84	3.05	0.62	9,493	626	2.6
21	**107**	**0.29**	**2.86**	**3.38**	**0.59**	**9,097**	**663**	**2.4**
26	107	0.23	2.88	4.23	0.54	9,097	821	1.9

For pipe wall crushing, a minimum FS of 2.0 is desired. From above, a DR of 21 or less is required for the deepest portions of the landfill. However, higher DR pipe may be used for shallower portions of landfill provided calculations are performed during final design to confirm pipe crushing resistance for selected pipe.

2. Pipe Deflection

Rigidity Factor (R_F) = $12E_s(DR-1)^3 / E$
Secant Modulus of Soil (E_S) = $M_s (1+\mu)(1-2\mu)/(1-\mu)$
Soil Strain (ε_s) = $wH_c(100) / (0.75E_s)$
Deflection (%) = $D_F\varepsilon_S$
Dimension Ratio (DR) = D_o/t

Where:

Hc = height of fill (ft) =	see below
w = average weight of fill (pcf) =	see below
μ = soil Poisson ratio =	0.4
P_{DES} substituted for HcW (psi) =	107
M_s (psi) =	6,675
E_s (psi) =	3,115

DR	E_s	E	R_F	D_F	ε_S (%)	Deflection (%)
9	3,115	28,200	679	1.15	4.57	5.25
11	3,115	28,200	1,326	1.32	4.57	6.03
13.5	3,115	28,200	2,589	1.49	4.57	6.80
15.5	**3,115**	**28,200**	**4,041**	**1.64**	**4.57**	**7.49**
17	3,115	28,200	5,429	1.72	4.57	7.85
19	3,115	28,200	7,731	1.81	4.57	8.26

D_F = Deformation Factor obtained from table, attached.

For pipe deflection under the design loading, a target maximum deflection of 7.5 percent is desired. A pipe with DR value of **15.5** exhibits calculated deflection of less than 7.5 percent. However, higher DR pipe may be substituted at time of design for shallower loading conditions provided calculations are performed during final design to confirm pipe deflection resistance for selected pipe.

3. Pipe wall buckling (Ref. 3)

$P_{cr} = 1.63\ ((RB'M_sE) / (DR-1)^3)^{0.5}$ (Ref. 3)

$H(ft) = P_{DES}/w$

$B' = 1 / (1+4e^{(-0.065H)})$ (Ref. 3)

$FS = P_{cr} / P_{DES}$

Where:

P_{cr} = Critical buckling pressure (psi)
B' = Elastic support coefficient
R = Groundwater buoyancy factor (=1)
H = Height of fill (ft)
E = Modulus of Elasticity of pipe (psi)
P_{DES} = Design pipe external loading (psi)
FS = Factor of safety against wall buckling

Assumptions:
H (ft) = 176
B' = 1.00 (calculated using above equation)
E (psi) = 28,200

DR	R	B'	M_s	P_{cr}	P_{DES}	FS
9	1	1.00	6,675	988	107	9.27
11	1	1.00	6,675	707	107	6.63
13.5	1	1.00	6,675	506	107	4.74
15.5	1	1.00	6,675	405	107	3.80
17	1	1.00	6,675	349	107	3.28
19	1	1.00	6,675	293	107	2.75
21	**1**	**1.00**	**6,675**	**250**	**107**	**2.34**
26	1	1.00	6,675	179	107	1.68

For pipe buckling, a minimum FS value of 2.0 is desired. Pipe with DR value of 21 or less is acceptable. However, higher DR pipe may be substituted at time of design for shallower loading conditions provided calculations are performed during final design to confirm pipe deflection resistance for selected pipe.

Conclusion:

Based on the analysis presented above, in consideration of wall crushing, buckling, and allowable pipe deflection, 6-inch diameter HDPE pipe with a maximum DR value of **15.5** (wall thickness of 0.39 inches) is conservatively selected for deeper portions of landfill. Pipe with higher DR values may be suitable for areas of shallower fill, and will be analyzed at the time of final design.

CITH OF WACO LANDFILL
PIPE STRUCTURAL STABILITY
18-INCH DIAMETER HDPE PIPE

Required:

Analyze the structural stability of the 18-inch diameter high density polyethylene sump riser pipes related to wall crushing, deflection, and wall buckling failures associated with the worst case loading conditions.

Method:

A. Determine the critical load under the following two conditions:

1. Construction loading
2. Overburden loading

B. Use the critical loading pressure to analyze pipe stability under the following three possible failure conditions:

1. Wall crushing
2. Wall buckling
3. Deflection

References:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems*, Pollution Technology Review No. 138, Noyes Data Corporation, 1986.
2. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook*, 30 TAC 330.201, 1993.
3. CPChem Performance Pipe, a Division of Chevron Phillips Chemical Company LP, Draft Design Document titled *Technical Note XXX - Considerations for HDPE Pipe Section for Deep Fill Applications, 2002.*
4. CPChem Performance Pipe, a Division of Chevron Phillips Chemical Company LP, *The Performance Pipe Engineering Manual*, Vol. 2, 2002.
5. Caterpillar Tractor Company, C*aterpillar Product Brochure: 836H Landfill Compactor (www.cat.com),* 2007.
6. Reinhart, D.R. and Manoj, C.B., MSW Landfill Leachate Collection Systems for the New Millennium, Report #00-13, Florida Center for Solid and Hazardous Waste Management, 2000.

Solution:

A. Determine critical loading for construction versus overburden conditions.

1. Construction Loading:

Assume: CAT 637G Scraper with an even load distribution (Ref. 5)

Loaded weight =	197,000	lb
Tire pressure =	80	psi
Number of tires =	4	

For a circular tire imprint:

$$F = \frac{\text{Loaded Weight}}{\text{Number of Tires}}$$

Where: F = Force exerted by one tire (lb)

F =	49,250	lb

Determine radius (r) of contact for circular tire imprint:

$$r = \left(F / \pi p\right)^{1/2}$$

Where:
r = Radius of contact (in)
F = Force exerted by one tire (lb)
p = Tire pressure (psi)

r =	14.0	in

Use Boussinesq's solution to find the stress at a point below a uniformly loaded circular area:

$$y = p(1-((r/z)^2+1)^{-3/2})$$

Where:
y = Change in vertical stress (psi)
p = Tire pressure (psi)
r = Radius of contact (in)
z = Protective cover thickness (in)

z = 24 in

y =	28.4	psi

Assume only one wheel load on pipe and add 50% for impact loading:

$P_L = 1.5y$

Where: $P_L =$ Maximum live load (psi)

$P_L =$	42.7	psi

$P_D = zw$

Where: $P_D =$ Maximum dead load (psi)
$z =$ Protective cover thickness
$w =$ Unit weight of protective cover

$z =$	24	in
$w =$	120	pcf

$P_D =$	1.7	psi

$P_{Tconst} = P_L + P_D$

Where: $P_{T,\,const} =$ Maximum construction load (psi)

$P_{T,\,const} =$	44.4	psi

2. Overburden loading (postclosure load): (max. waste height at sump location is at Sector 8 sump)

For maximum overburden load on pipe:

2.0	ft gravel & cover @	120	pcf =	240	psf
3.5	ft final & interim cover @	120	pcf =	420	psf
64.0	ft solid waste @	60	pcf =	3,840	psf
3.0	ft daily cover @	120	pcf =	360	psf
			$\Sigma =$	4,860	psf

$P_{Toverburd} =$	4,860	psf

$P_{Toverburd} =$	34	psi

Determine critical loading condition:

Construction loading:	$P_{Tconst} =$	44.4	psi
Overburden loading:	$P_{Toverburd} =$	34	psi
Design loading = Construction loading:	$P_{DES} =$	44.4	psi

Conclusion: Construction loading is most critical to the structural stability of the pipe and will be used to determine the design overburden pipe stress.

B. Pipe Stability Analyses

1. Wall crushing (ring compressive stress) (Ref. 3)

Vertical Arching Factor (VAF) $= 0.88 - 0.71 (S_A-1) / (S_A+2.5)$
Hoop Thrust Stiffness Ratio (S_A) $= 1.43 (M_s r_m/Et)$

Where:

$M_s =$	One dimensional modulus of soil (psi) (Ref. 3)
$r_m =$	Mean pipe radius, $= (D_o+D_i)/4$
$D_o =$	Pipe outside diameter (in)
$D_i =$	Pipe inside diameter (in)
$E =$	Pipe modulus of elasticity (psi)
$t =$	Pipe wall thickness (in)
$DR =$	Dimension Ratio, D_o/t
$\sigma_{yield}=$	HDPE compressive strength at yield (psi) = 1,600 psi (Ref. 4)

Assumed overburden stress (psi) : 44.4
Backfill type : Gravel, 95% Std. Proctor
Ms (from Table 1, below) (psi) : 4720 (Ref. 3)

Table 1. Typical Design Values for Constrained Modulus, M_s (Ref. 3)

Vertical Soil Stress (psi)	Gravelly Sand/Gravels at 95% SPD (psi)	Gravelly Sand/Gravels @ 90% SPD (psi)	Gravelly Sand/Gravels @ 85% SPD (psi)	
10	3000	1500	500	
20	3500	1700	650	
40	4500	2100	900	
60	5500	2500	1150	4,720
80	6000	2900	1300	(44.4 psi)
100	6500	3200	1450	

SPD = Standard Proctor Density

* Based on the linear relationship generated between Vertical Soil Stress (40 and 60 psi) and respective Ms (psi), linear interpolation was used to calculate a MS value of 4,720 psi at a Vertical Soil Stress of 44.4 psi.

CITH OF WACO LANDFILL
PIPE STRUCTURAL STABILITY
18-INCH DIAMETER HDPE PIPE

$P_{RD} = (VAF)\ P_{DES}$ (Ref. 3)

$\sigma_{actual} = P_{RD}(DR) / 2$ (Ref. 3)

Where:

P_{RD} = Radial-directed earth pressure

σ_{actual} = Actual sidewall crushing (compressive) stress

D_o (in) = 18

E (psi) = 28,200 (Ref. 4)

M_s (psi) = 4,720 (Ref. 3)

σ_{yield}= 1,600 (Ref. 4)

Factor of Safety (FS) = $\sigma_{yield}/\sigma_{actual}$

DR	**P_{DES}**	**t**	**r_m**	**S_A**	**VAF**	**P_{RD} (psf)**	**σ_{actual} (psi)**	**FS**
15.5	44	1.16	8.42	1.74	0.76	4,838	260	6.1
17	44	1.06	8.47	1.91	0.73	4,686	277	5.8
19	44	0.95	8.53	2.15	0.70	4,501	297	5.4
21	44	0.86	8.57	2.39	0.68	4,334	316	5.1
26	44	0.69	8.65	2.99	0.62	3,980	359	4.5
32.5	**44**	**0.55**	**8.72**	**3.77**	**0.57**	**3,621**	**409**	**3.9**

For pipe wall crushing, a minimum FS of 2.0 desired. From above, a DR of **32.5** or less is acceptable for use in the leachate sumps and as sideslope riser piping.

2. Pipe Deflection

Rigidity Factor (R_F) = $12E_s(DR-1)^3 / E$

Secant Modulus of Soil (E_S) = $M_s\ (1+\mu)(1-2\mu)/(1-\mu)$

Soil Strain (ε_s) = $wH_c(100) / (0.75E_s)$

Deflection (%) = $D_F\varepsilon_S$

Dimension Ratio (DR) = D_o/t

Where:

Hc = height of fill (ft) =	see below
w = average weight of fill (pcf) =	see below
μ = soil Poisson ratio =	0.4
P_{DES} substituted for HcW (psi) =	44.4
M_s (psi) =	4,720
E_s (psi) =	2,203

DR	E_s	E	R_F	D_F	ε_S (%)	Deflection (%)
15.5	2,203	28,200	2,857	1.42	2.69	3.82
17	2,203	28,200	3,839	1.52	2.69	4.09
19	2,203	28,200	5,466	1.68	2.69	4.52
21	2,203	28,200	7,498	1.75	2.69	4.70
26	2,203	28,200	14,645	2	2.69	5.38
32.5	**2,203**	**28,200**	**29,296**	**2**	**2.69**	**5.38**

D_F = Deformation Factor obtained from table, attached.

For pipe deflection under the design loading, a maximum deflection of 7.5 percent is desired. From above, a DR of **32.5** or less is acceptable for use in the leachate sumps and as sideslope riser piping.

3. Pipe wall buckling (Ref. 3)

$P_{cr} = 1.63\ ((RB'M_sE) / (DR-1)^3)^{0.5}$ (Ref. 3)

$H\ (ft) = P_{DES}/w$

$B' = 1 / (1+4e^{(-0.065H)})$ (Ref. 3)

$FS = P_{cr} / P_{DES}$

Where:

P_{cr} =	Critical buckling pressure (psi)
B' =	Elastic support coefficient
R =	Groundwater buoyancy factor (=1)
H =	Height of fill (ft)
E =	Modulus of Elasticity of pipe (psi)
P_{DES} =	Design pipe external loading (psi)
FS =	Factor of safety against wall buckling

Assumptions:	H (ft) =	73	
	B' =	0.97	(calculated using above equation)
	E (psi) =	28,200	

DR	R	B'	Ms	P_{cr}	P_{DES}	FS
9	1	0.97	4,720	817	43.4	18.81
11	1	0.97	4,720	584	43.4	13.46
13.5	1	0.97	4,720	418	43.4	9.63
15.5	1	0.97	4,720	335	43.4	7.71
17	1	0.97	4,720	289	43.4	6.65
19	1	0.97	4,720	242	43.4	5.57
21	1	0.97	4,720	207	43.4	4.76
26	1	0.97	4,720	148	43.4	3.41
32.5	**1**	**0.97**	**4,720**	**105**	**43.4**	**2.41**

For pipe buckling, a minimum FS value of 2.0 is desired. From above, a DR of **32.5** or less is acceptable for use in the leachate sumps and as sideslope riser piping.

Conclusion:

Based on the analysis presented above, in consideration of wall crushing, buckling, and allowable pipe deflection, 18-inch diameter HDPE pipe with a maximum DR value of **32.5** (wall thickness of 0.55 inches) is required in landfill sumps and for sidewall risers. Pipe with lower DR values may be used to provide additional stability.

PIPE FLOW CAPACITY CALCULATIONS

CITY OF WACO LANDFILL
LEACHATE COLLECTION
PIPING FLOW CAPACITY

Required:

Demonstrate that the 6-inch diameter (SDR 11) leachate collection piping has sufficient capacity to convey leachate during the worst case leachate generation conditions. Due to pipe availability, SDR 11 is expected to be the thickest wall pipe installed at landfill. Two cases are analyzed:
Case 1: Pipe in the central leachate trench (1% slope); and
Case 2: Header pipe within the leachate collection trench at the toe of the sideslopes (Sectors 1, 8, 10, and 12 only; and at 0.5% minimum slope)

Method:

A. Use leachate production rates determined from the HELP model analysis (see Appendix 12A) as comparison to capacity of 6-inch diameter DR 11 leachate collection piping.
B. Determine required hole size (perforations) based on characteristics of the surrounding drainage media.

References:

1. Bass, J., *Avoiding failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.
2. Texas Natural Resource Conservation Commission, Leachate Collection System Handbook, 30 TAC 330.201, 1993

CITY OF WACO LANDFILL
LEACHATE COLLECTION
PIPING FLOW CAPACITY

Solution - Flow Capacity of Pipe (A - Case 1 - Central Pipe):

Determine the average and peak daily flow rate estimate:

The following table summarizes the fill conditions that are likely to be present and have the greatest contribution of leachate into the LCS. The average and peak flow rate (lateral drainage in the LCS layer) is shown for each condition. All flow rates are per acre.

From the HELP model (Appendix 12A):

CONDITION	AVERAGE ANNUAL		PEAK DAILY	
	cf/y/ac	g/d/ac	cf/d/ac	g/d/ac
Active, 10' Waste	43,183	885	844	6,313
Interim, 60' Waste	8,419	173	583	4,361

The assumed worst case condition is for Sector 12 (the largest sector at 23.4 acres) draining to a single leachate collection sump.

Maximum leachate production (and drainage) expected in the collection pipe is predicted to occur assuming the following scenario:

1.	Active, 10' Waste	10.0	ac
2.	Interim, 60' Waste	13.4	ac
	Total =	23.4	ac

CONDITION	AREA ac	AVERAGE g/d/ac	AVERAGE gpd	AVERAGE cfs
Active, 10' Waste	10.0	885	8,850	0.0137
Interim, 60' Waste	13.4	173	2,313	0.0036
		Total =	11,163	0.0173
With applied Factor of Safety of 1.5:		Total =	16,745	0.0259

CONDITION	AREA ac	PEAK g/d/ac	PEAK gpd	PEAK cfs
Active, 10' Waste	10.0	6,313	63,131	0.0976
Interim, 60' Waste	13.4	4,361	58,435	0.0904
		Total =	121,566	0.1880
With applied Factor of Safety of 1.5:		Total =	182,350	0.2820

CITY OF WACO LANDFILL
LEACHATE COLLECTION
PIPING FLOW CAPACITY

Determination of flow capacity (Q_{full}) for a 6-inch diameter perforated pipe:

$$Q_{full} = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

Where: A = Cross-sectional area of pipe, with d representing the inside diameter in feet

R = Hydraulic radius of pipe in feet under full flow conditions

From Pipe Structural Stability Calculations:

	Outside Diameter (in) =	6.625	
	Dimension Ratio (DR) =	11.0	
	Wall Thickness (t) =	0.602	
	ID =	5.420	in
	=	0.452	ft
$A = \frac{\Pi \times d^2}{4}$	A =	0.160	sq ft
$R = \frac{d}{4}$	R =	0.113	ft
S = Design slope of pipe	S =	0.010	ft / ft
n = Manning's number	n =	0.009	for HDPE smooth pipe

Q_{full} =	0.619	cfs

Compare Q_{max} and Q_{full} (Average Flow Rate):

Q_{full} =	0.619	cfs	>>	Q_{max} =	0.0259	cfs

Compare Q_{max} and Q_{full} (Peak Flow Rate):

Q_{full} =	0.619	cfs	>>	Q_{max} =	0.2820	cfs

Conclusion:
6-inch diameter HDPE pipe with a DR of 11 exceeds the required flow capacity for both average and peak flow rates.

Solution - Flow Capacity of Pipe (A - Case 2 - Header Pipe):

Determine the average and peak daily flow rate estimate:

The following table summarizes the fill conditions that are likely to be present and have the greatest

From the HELP model (Appendix 12A):

CONDITION	AVERAGE ANNUAL		PEAK DAILY	
	cf/y/ac	g/d/ac	cf/d/ac	g/d/ac
Active, 10' Waste	43,183	885	844	6,313
Interim, 60' Waste	8,419	173	583	4,361

The assumed worst case condition is for northern area of Sector 1 (10.2 areas, the largest area draining to a header pipe at the toe of a sideslope).

Maximum leachate production (and drainage) expected in the collection pipe is predicted to occur assuming

1.	Active, 10' Waste	10.2	ac
2.	Interim, 60' Waste	0.0	ac
	Total =	10.2	ac

CONDITION	AREA ac	AVERAGE g/d/ac	AVERAGE gpd	AVERAGE cfs
Active, 10' Waste	10.2	885	9,027	0.0140
Interim, 60' Waste	0.0	173	0	0.0000
		Total =	9,027	0.0140
With applied Factor of Safety of 1.5:		Total =	13,540	0.0209

CONDITION	AREA ac	PEAK g/d/ac	PEAK gpd	PEAK cfs
Active, 10' Waste	10.2	6,313	64,394	0.0996
Interim, 60' Waste	0.0	4,361	0	0.0000
		Total =	64,394	0.0996
With applied Factor of Safety of 1.5:		Total =	96,591	0.1494

CITY OF WACO LANDFILL
LEACHATE COLLECTION
PIPING FLOW CAPACITY

Determination of flow capacity (Q_{full}) for a 6-inch diameter perforated pipe:

$$Q_{full} = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

Where: A = Cross-sectional area of pipe, with d representing the inside

R = Hydraulic radius of pipe in feet under full flow conditions

From Pipe Structural Stability Calculations:

Outside Diameter (in) =	6.625	
Dimension Ratio (DR) =	11.0	
Wall Thickness (t) =	0.602	
ID =	5.420	in
=	0.452	ft

$$A = \frac{\Pi \times d^2}{4}$$

A = 0.160 sq ft

$$R = \frac{d}{4}$$

R = 0.113 ft

S = Design slope of pipe S = 0.005 ft / ft

n = Manning's number n = 0.009 for HDPE smooth pipe

Q_{full} = 0.438 cfs

Compare Q_{max} and Q_{full} (Average Flow Rate):

Q_{full} = 0.438 cfs >> Q_{max} = 0.0209 cfs

Compare Q_{max} and Q_{full} (Peak Flow Rate):

Q_{full} = 0.438 cfs >> Q_{max} = 0.1494 cfs

Conclusion:
6-inch diameter HDPE pipe with a DR of 11 exceeds the required flow capacity for both average and peak flow rates.

Solution - Perforations Configuration (B):

Pipe perforations must allow free passage of leachate and also prevent migration of drainage media into

$$\frac{D_{85} \text{ of Filter}}{\text{Hole Diameter (d)}} \geq 1.7$$

Where: D_{85} = Particle size for which 85% of all particles are smaller than the following:
For the gradation described in Attachment 12, the D_{85} will be greater than 1-inch, therefore 1-inch was used in this calculation for conservatism.

D_{85} = 25 mm
= 0.985 in

Standard hole diameter: d = 0.5 in

Check values to find that:

$$\frac{D_{85} \text{ of Filter}}{\text{Hole Diameter}} = 2.0 \geq 1.7 \quad \text{(acceptable)}$$

In Addition:

A minimum open area of 1 square inch per foot of drainage pipe is recommended by the U.S. Soil Conservation Service and the U.S. Bureau of Reclamation, as represented by the 6 perforations per foot required for leachate collection pipe, see Attachment 12 drawings.

Conclusion:
Perforations will consist of 0.5-inch diameter holes, as analyzed above.

LEACHATE SUMP DESIGN CALCULATIONS

CITY OF WACO LANDFILL
LEACHATE COLLECTION SUMP DESIGN
SUMP 1 - FOR SECTORS GREATER THAN 15 ACRES

Required:

Determine the required size of the leachate collection sump, based on the conditions of landfill development when it is anticipated that the leachate collected in an individual sump will be the greatest. **These calculations are for a leachate collection sump with a contributing area less than 24 acres but greater than 15 acres (referred to as Sump 1).** Leachate generation rates provided in this demonstration are provided in Attachment 12, Appendix 12A, Leachate Generation Model.

Method:

A. Evaluate the average leachate flow rate into the leachate collection sump, based on the greatest leachate generation potential.
B. Evaluate the storage capacity and minimum storage time of the leachate sump, based on the specified sump geometry.
C. Calculate the average daily pump cycle time, based on a specified pump size.

References:

1. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.

Solution:

A. Evaluate the average leachate flow rate into the leachate collection sump, based on the greatest leachate generation potential.

The following table summarizes the fill conditions that are likely to be present and have the greatest contribution of leachate into the LCS and sump system. The average generation rates (lateral drainage in the LCS layer) are shown for each condition. All flow rates are per acre.

Average annual leachate generation rates are from the HELP model output, as provided in Appendix 12A:

CONDITION	Average Leachate Generation		Assumed Area	Leachate Collection
	(cf/y/ac)	(cf/d/ac)	(ac) [1]	(cfd)
Active, 10' Waste	43,183	118.3	10	1,183
Interim, 60' Waste	8,419	23.1	14	323
Total	51,602	141.4	24	1,506

[1] The greatest contribution of leachate into Sump 1 is assumed to be associated with Sector 12, which is 23.4 acres. Futhermore, it was assumed that approximately 10 acres, would be the largest area at the 10-foot active condition with the rest of the cells at approximately 60 feet in height.

B. Evaluate the storage capacity and minimum storage time of the leachate sump, based on the specified sump geometry.

$$V_{REQ} = V_C / P$$

V_C = Volume, Leachate collection rate, (cfd)
P = Porosity

Assumed porosity of drainage stone: P = 0.35

Condition	V_C (cfd) [1]	V_{REQ} (cfd)
Active, 10' Waste	1,183	3,380
Interim, 60' Waste	323	923
Total	**1,506**	**4,303**

[1] The leachate collection rates shown are consistent with those calculated in Method A, above.

CITY OF WACO LANDFILL
LEACHATE COLLECTION SUMP DESIGN
SUMP 1 - FOR SECTORS GREATER THAN 15 ACRES

Selection of Sump Geometry:

Assumed sideslope of sump = (X)H : 1V = 3 ft

Assumed depth of sump = 3 ft

$$V_{TOT} = \frac{X_T^2 h_T}{3} - \frac{X_B^2 h_B}{3} - B$$

Where:
X_T = Length of top side
X_B = Length of bottom side
h_T = Height of pyramid with (X)H:1V sideslope and width X_T
h_B = Height of pyramid with (X)H:1V sideslope and width X_B

X_T =	50	ft	
X_B =	32	ft	
h_T =	8.33	ft	
h_B =	5.33	ft	
B =	562	cu ft	(Pump head vol. of 6" in bottom of sump)

V_{TOT} =	4,562	cu ft total sump volume
=	1,597	cu ft leachate capacity
=	11,943	gallons leachate capacity

Number of days storage for conditions:

$$STORAGE = \frac{V_{TOT}}{V_{REQ}}$$

V_{REQ} =	4,303	cu. ft.
V_{TOT} =	4,562	cfd

Storage = 1.1 days

C. Calculate the average daily pump cycle time, based on a specified pump size.

Specified Submersible Pump Capacity (gpm) : 20

Total Leachate Collection:	1,506	cfd
Total Leachate Collection:	11,265	gal/day
Maximum Pump Time:	9	hours/day

Notes:

[1] Pump cycles will be determined at time of pump selection, based on manufacturer's operational recommendations. Although there may be periods of landfill development (i.e., active, 10-foot waste) when the pump will operate continuously throughout the day, as waste elevations increase and the leachate collection rates decrease, the pump time will also decrease.

[2] A lower or higher capacity pump may be substituted for the 20 gpm pump, provided the sump drawdown criteria maintains less than the required 30-centimeter depth of the bottom liner.

Conclusion:

Based on above calculations, the leachate collection sumps will have sufficient capacity for storage of leachate during the time period of greatest leachate generation and subsequent contribution to the LCS. As such, Sump 1 will have the following minimum dimensions, and will be constructed for Sectors 1, 8, and 12 (larger than 15 acres), as shown on the drawings provided in Attachment 12. The sump design will provide for at least 1 day of leachate storage within the sump, without exceeding the 30 centimeters of leachate head over the bottom liner system.

Sump Top Dimension (X_T) =	**50**	ft
Sump Bottom Dimension (X_B) =	**32**	ft
Sump Sideslopes =	**3**	(X)H:1V
Sump Design Depth =	**3**	ft

CITH OF WACO LANDFILL
LEACHATE COLLECTION SUMP DESIGN
SUMP 2 - FOR SECTORS LESS THAN 15 ACRES

Required:

Determine the required size of the leachate collection sump, based on the conditions of landfill development when it is anticipated that the leachate collected in an individual sump will be the greatest. **These calculations are for a leachate collection sump with a maximum contributing sector area of 15 acres (referred to as Sump 2).** Leachate generation rates provided in this demonstration are provided in Attachment 12, Appendix 12A, Leachate Generation Model.

Method:

A. Evaluate the average leachate flow rate into the leachate collection sump, based on the greatest leachate generation potential.
B. Evaluate the storage capacity and minimum storage time of the leachate sump, based on the specified sump geometry.
C. Calculate the average daily pump cycle time, based on a specified pump size.

References:

1. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.

Solution:

A. Evaluate the average leachate flow rate into the leachate collection sump, based on the greatest leachate generation potential.

The following table summarizes the fill conditions that are likely to be present and have the greatest contribution of leachate into the LCS and sump system. The average generation rates (lateral drainage in the LCS layer) are shown for each condition. All flow rates are per acre.

Average annual leachate generation rates are from the HELP model output, as provided in Appendix 12A:

CONDITION	Average Leachate Generation		Assumed Area	Leachate Collection
	(cf/y/ac)	(cf/d/ac)	(ac) [1]	(cfd)
Active, 10' Waste	43,183	118.3	6	710
Interim, 60' Waste	8,419	23.1	9	208
Total	51,602	141.4	15	917

[1] The greatest contribution of leachate into Sump 2 is assumed to be associated with Sector 5, which is approximately 14.6 acres. Futhermore, it was assumed that approximately one-third of Cell, 5 acres, would be the largest area at the 10-foot active condition with the rest of the sector at approximately 60 feet in height.

B. Evaluate the storage capacity and minimum storage time of the leachate sump, based on the specified sump geometry.

$V_{REQ} = V_C / P$

V_C = Volume, Leachate collection rate, (cfd)
P = Porosity

Assumed porosity of drainage stone: P = 0.35

Condition	V_C (cfd) [1]	V_{REQ} (cfd)
Active, 10' Waste	710	2,028
Interim, 60' Waste	208	593
Total	**917**	**2,621**

[1] The leachate collection rates shown are consistent with those calculated in Method A, above.

CITH OF WACO LANDFILL
LEACHATE COLLECTION SUMP DESIGN
SUMP 2 - FOR SECTORS LESS THAN 15 ACRES

Selection of Sump Geometry:

Assumed sideslope of sump = (X)H : 1V = 3 ft

Assumed depth of sump = 3 ft

$$V_{TOT} = \frac{X_T^{2} h_T}{3} - \frac{X_B^{2} h_B}{3} - B$$

Where:
X_T = Length of top side
X_B = Length of bottom side
h_T = Height of pyramid with (X)H:1V sideslope and width X_T
h_B = Height of pyramid with (X)H:1V sideslope and width X_B

X_T =	40	ft	
X_B =	22	ft	
h_T =	6.67	ft	
h_B =	3.67	ft	
B =	277	cu ft	(Pump head vol. of 6" in bottom of sump)

V_{TOT} =	2,687	cu ft total sump volume
=	940	cu ft leachate capacity
=	7,034	gallons leachate capacity

Number of days storage for conditions:

$$STORAGE = \frac{V_{TOT}}{V_{REQ}}$$

V_{REQ} =	2,621	cu. ft.
V_{TOT} =	2,687	cfd

Storage =	**1.0**	**days**

C. Calculate the average daily pump cycle time, based on a specified pump size.

Specified Submersible Pump Capacity (gpm) : 20

Total Leachate Collection:	917	cfd
Total Leachate Collection:	6,863	gal/day
Maximum Pump Time:	6	hours/day

Notes:

[1] Pump cycles will be determined at time of pump selection, based on manufacturer's operational recommendations. Although there may be periods of landfill development (i.e., active, 10-foot waste) when the pump will operate continuously throughout the day, as waste elevations increase and the leachate collection rates decrease, the pump time will also decrease.

[2] A lower or higher capacity pump may be substituted for the 20 gpm pump, provided the sump drawdown criteria maintains less than the required 30-centimeter depth of the bottom liner.

Conclusion:

Based on above calculations, the leachate collection sumps will have sufficient capacity for storage of leachate during the time period of greatest leachate generation and subsequent contribution to the LCS. As such, Sump 2 will have the following minimum dimensions and will be constructed for the remaining 9 sumps (i.e. sumps for Sectors 1, 8, and 12 will have Sump 1 size sumps) with sector areas less than or equal to 15 acres, as shown on the drawings provided in Attachment 12. The sump design will provide for at least 1 day of leachate storage within the sump, without exceeding the 30 centimeters of leachate head over the bottom liner system.

Sump Top Dimension (X_T) =	**40**	ft
Sump Bottom Dimension (X_B) =	**22**	ft
Sump Sideslopes =	**3**	(X)H:1V
Sump Design Depth =	**3**	ft

APPENDIX 12C

CONTAINMENT BERM AND DIVERSION BERM CALCULATIONS

SCS Engineers
TBPE Reg. # F-3407

Inclusive of pages 12C-1 to 12C-18

Required:

1. Determine the height of the contaminated runoff containment berm required at the working face.
2. Determine the height of the surface water diversion berm required for run-on control at the working face.

Procedure:

Containment Berm Calculations

A. Determine the 25-year, 24-hour rainfall.
B. Calculate the volume of water captured behind the containment berm for 25-year, 24-hour rainfall event.
C. Calculate the height of the containment berm required to hold the volume of water calculated in "B".

Diversion Berm Calculations

A. Determine the 25-year, 24-hour flow rates for the diversion berm run-on drainage areas by the Rational Method.
B. Calculate the capacity of the diversion berm swales at various slopes.
C. Calculate the height of the diversion berm required for the flow rate of run-on surface water.

References:

1. National Weather Service, TP-40, 25-year, 24-hour rainfall depth map.
2. Texas Department of Transportation, "Bridge Division Hydraulic Manual", 2004.

CITY OF WACO LANDFILL
CONTAINMENT / DIVERSION BERM DESIGN

1. <u>Containment Berm</u> - (Contains leachate and contaminated water for disposal)

A. Based on Reference 1, the 25-year, 24-hour rainfall depth for Waco, TX is:

$R =$ 7.9 in

B. Determine the volume of storage required (V_R).

$$V_R = A_D R$$

Where:	$A_D =$	Drainage area =	varies	ac
	$R =$	25-year, 24-hour rainfall depth =	7.9	in

Where:	$A_D =$	$C * A_{active} + A_{stor}$		
	$A_{active} =$	Active area of landfilling	varies	ac
	$A_{stor} \cong$	Designated containment area	varies	ac
	$C =$	Infiltration / Abstraction Reduction Factor =	0.5	

The storage volumes required for varying drainage areas are shown on the attached table.

C. Determine the required berm height (H_B)

1. Determine the length of the storage area.

$$L = A_{stor} / W$$

Where:	$W =$	Width (ft)
	$A_{stor} =$	Designated containment area (ac)

The minimum width of the downstream berm is 100 feet.

2. Determine the average depth (D_{avg}) of the storage area

$$D_{avg} = V_R / (L * W)$$

Where:	$V_R =$	Volume of storage required (ft^3)
	$L =$	Length of storage area (ft)
	$W =$	Width (ft)

Once the length and depth are determined, the following equation may be used to determine the required berm height.

$$H_B = (L / 2) * S + D_{avg} + H_{FB}$$

Where:

H_B =	Berm height (ft)
L =	Length of storage area (ft)
S =	Slope of the containment area (ft/ft) - (minimum 1 percent)
D_{avg} =	Average depth of storage area (ft)
H_{FB} =	Minimum 6-inch freeboard height (ft)

Values for H_B are listed on Table 1 (attached) for several typical drainage areas. See Drawing No. 12C.1, which depicts the above variables related to the containment berm height.

Example calculations for a maximum working face size of 20,000 square feet

1. Required storage volume

A_{active}=	0.46	ac
A_{stor}=	0.25	ac

A_D = $C * A_{active} + A_{stor}$ = 0.48 ac

Volume: V_R = $A_D R$ = **13,753** ft^3

2. Storage area length

W =	100	ft
A_{stor}=	0.25	ac

Length: L = A_{stor} / W = **109** ft

3. Average depth of storage area

V_R =	13,753	ft^3
L =	109	ft
W =	100	ft

Depth: D_{avg} = V_R / (L * W) **1.26** ft

4. Required berm height

L =	109	ft
S =	0.05	ft/ft
D =	1.26	ft
H_{FB} =	0.5	ft

Berm height: $H_B = (L / 2) * S + D_{avg} + H_{FB}$ = **4.5** ft

2. Diversion Berm - (Diverts surface water away from the active fill area.)

As shown on the attached drawing (Attachment 12C.1), several scenarios were analyzed to determime the adequacy of the berm configuration.

Hydraulic calculations are summarized in Tables 1 and 2.

The berms were analyzed using the Rational Method.

From Reference 2 for Lamar County:

$$Q = CIA$$

Where: C = intermediate cover = 0.5
I = intensity (in/hr)
A = drainage area (ac)

$$I = b / (t_c + d)^e$$

b =	=	103.56
d =	=	11
e =	=	0.8059

Note: b, d, e are associated with a 25 - year, 24 - hour storm for Limestone Co., see Page 6A-E-72. Consistent with TxDOT guidance, a minimum time of 10 minutes was used to calculate the rainfall intensity.

I =	8.90	in/hr

Diversion Berm

Area (ac)	Flow Rate (cfs)
0.5	2.2
1.0	4.5
2.0	8.9
4.0	17.8
8.0	35.6

**TABLE 1 - CONTAINMENT BERM SUMMARY SHEET
FOR AREAS WITH A 2 PERCENT SLOPE**

Active Area (ft^2)	Active Area (ac)	Storage Area (ac)	Width (ft)	L (ft)	Slope (%)	Volume Required (cf)	Depth (ft)	Berm Height (ft)
5,000	0.11	0.25	100	109	2	8,815	0.8	**2.4**
10,000	0.23	0.25	100	109	2	10,461	1.0	**2.5**
20,000	0.46	0.25	100	109	2	13,753	1.3	**2.9**
20,000	0.46	0.50	200	109	2	20,922	1.0	**2.5**

TABLE 2 - CONTAINMENT BERM SUMMARY SHEET FOR AREAS WITH A 5 PERCENT SLOPE

Active Area (ft^2)	Active Area (ac)	Storage Area (ac)	Width (ft)	L (ft)	Slope (%)	Volume Required (cf)	Depth (ft)	Berm Height (ft)
5,000	0.11	0.25	100	109	5	8,815	0.8	**4.0**
10,000	0.23	0.25	100	109	5	10,461	1.0	**4.2**
20,000	0.46	0.25	100	109	5	13,753	1.3	**4.5**
20,000	0.46	0.50	200	109	5	20,922	1.0	**4.2**

TABLE 3 - DIVERSION BERM SUMMARY SHEET

For 5% Diversion Berm Area Slope

Drainage Area	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude Number	Berm Depth (ft)	Flow Top Width (ft)
0.5	2.2	0.01	0.025	2	20	0	0.3	1.8	0.8	1.3	7.6
1.0	4.5	0.01	0.025	2	20	0	0.4	2.2	0.8	1.4	9.6
2.0	8.9	0.01	0.025	2	20	0	0.6	2.5	0.8	1.6	12.5
4.0	17.8	0.01	0.025	2	20	0	0.7	3.0	0.9	1.7	16.2
8.0	35.6	0.01	0.025	2	20	0	1.0	3.6	0.9	2.0	21.0

Note: Calculations were performed using the HYDROCALC program developed by Dodson and Associates (Version 1.2B, 1996-2005).

For 25% Diversion Berm Area Slope

Drainage Area	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude Number	Berm Depth (ft)	Flow Top Width (ft)
0.5	2.2	0.01	0.025	2	4	0	0.6	2.4	0.8	1.6	3.4
1.0	4.5	0.01	0.025	2	4	0	0.7	2.9	0.9	1.7	4.3
2.0	8.9	0.01	0.025	2	4	0	0.9	3.4	0.9	1.9	5.6
4.0	17.8	0.01	0.025	2	4	0	1.2	4.1	0.9	2.2	7.3
8.0	35.6	0.01	0.025	2	4	0	1.6	4.9	1.0	2.6	9.5

Note: Calculations were performed using the HYDROCALC program developed by Dodson and Associates (Version 1.2B, 1996-2005).

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 26, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	2.2
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	20.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.33
Flow Velocity (fps)	1.8
Froude Number	0.776
Velocity Head (ft)	0.05
Energy Head (ft)	0.38
Cross-Sectional Area of Flow (sq ft)	1.22
Top Width of Flow (ft)	7.34

HYDROCALC Hydraulics for Windows, Version 2.0.1,
Dodson & Associates, Inc., 5629 FM 1960 West, Suite 314, Houston, TX 77069
Email:software@dodson-hydro.com,

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	4.5
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	20.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.44
Flow Velocity (fps)	2.15
Froude Number	0.811
Velocity Head (ft)	0.07
Energy Head (ft)	0.51
Cross-Sectional Area of Flow (sq ft)	2.09
Top Width of Flow (ft)	9.6

HYDROCALC Hydraulics for Windows, Version 2.0.1, Copyright(c) 1996-2010
Dodson & Associates, Inc., 5629 FM 1960 West, Suite 314, Houston, TX 77069
Email:software@dodson-hydro.com, All Rights Reserved.

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	8.9
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	20.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.56
Flow Velocity (fps)	2.54
Froude Number	0.845
Velocity Head (ft)	0.1
Energy Head (ft)	0.66
Cross-Sectional Area of Flow (sq ft)	3.5
Top Width of Flow (ft)	12.41

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	17.8
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	20.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.73
Flow Velocity (fps)	3.02
Froude Number	0.881
Velocity Head (ft)	0.14
Energy Head (ft)	0.87
Cross-Sectional Area of Flow (sq ft)	5.89
Top Width of Flow (ft)	16.1

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	35.6
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	20.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.95
Flow Velocity (fps)	3.6
Froude Number	0.921
Velocity Head (ft)	0.2
Energy Head (ft)	1.15
Cross-Sectional Area of Flow (sq ft)	9.9
Top Width of Flow (ft)	20.87

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	2.2
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	4.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.55
Flow Velocity (fps)	2.43
Froude Number	0.816
Velocity Head (ft)	0.09
Energy Head (ft)	0.64
Cross-Sectional Area of Flow (sq ft)	0.91
Top Width of Flow (ft)	3.3

HYDROCALC Hydraulics for Windows, Version 2.0.1,

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	4.5
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	4.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.72
Flow Velocity (fps)	2.9
Froude Number	0.852
Velocity Head (ft)	0.13
Energy Head (ft)	0.85
Cross-Sectional Area of Flow (sq ft)	1.55
Top Width of Flow (ft)	4.32

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	8.9
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	4.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	0.93
Flow Velocity (fps)	3.43
Froude Number	0.886
Velocity Head (ft)	0.18
Energy Head (ft)	1.11
Cross-Sectional Area of Flow (sq ft)	2.6
Top Width of Flow (ft)	5.58

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	17.8
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	4.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	1.21
Flow Velocity (fps)	4.08
Froude Number	0.925
Velocity Head (ft)	0.26
Energy Head (ft)	1.46
Cross-Sectional Area of Flow (sq ft)	4.37
Top Width of Flow (ft)	7.24

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

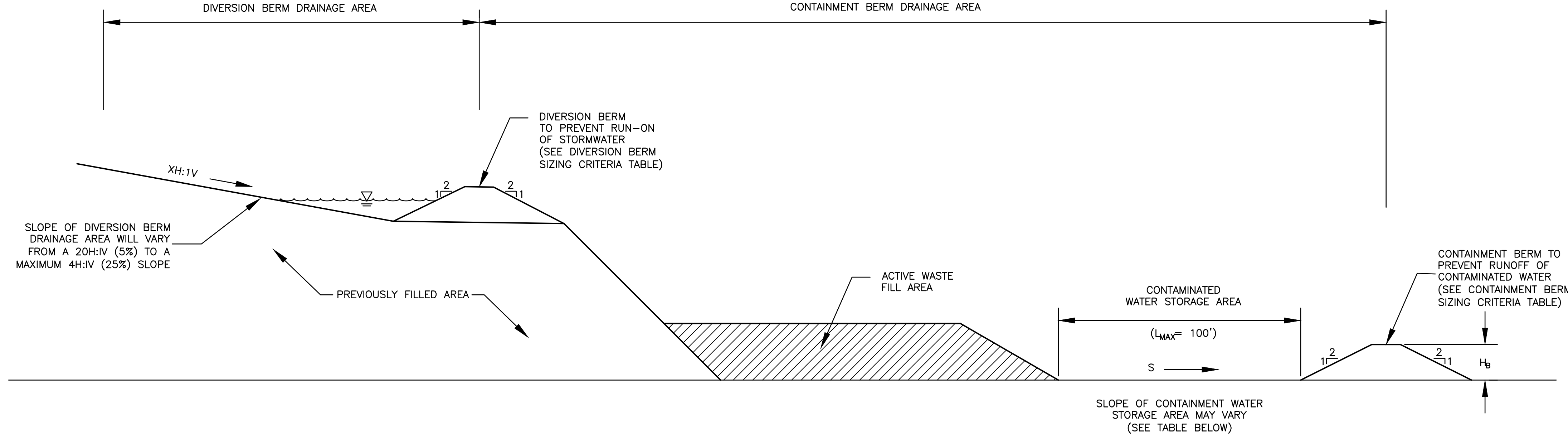
December 24, 2018

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	35.6
Channel Bottom Slope (ft/ft)	0.01
Manning's Roughness Coefficient (n-value)	0.025
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	4.0
Channel Bottom Width (ft)	0.0

COMPUTATION RESULTS

DESCRIPTION	VALUE
Normal Depth (ft)	1.56
Flow Velocity (fps)	4.86
Froude Number	0.968
Velocity Head (ft)	0.37
Energy Head (ft)	1.93
Cross-Sectional Area of Flow (sq ft)	7.33
Top Width of Flow (ft)	9.38



ACTIVE FILL AREA SECTION

NTS

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

DIVERSION BERM SIZING CRITERIA *

DIVERSION BERM DRAINAGE AREA (ACRES)	MINIMUM 5%			MAXIMUM 25%		
	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)
0.5	2.2	0.3	1.3	2.2	0.6	1.6
1.0	4.5	0.4	1.4	4.5	0.7	1.7
2.0	8.9	0.6	1.6	8.9	0.9	1.9
4.0	17.8	0.7	1.7	17.8	1.2	2.2
8.0	35.6	1.0	2.0	35.6	1.6	2.6

* DIVERSION BERM WILL BE SIZED USING THE ABOVE TABLE AS A GUIDELINE TO PREVENT RUN–ON OF STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT. SUPPORTING CALCULATIONS ARE INCLUDED ON THE DIVERSION BERM SUMMARY SHEET IN APPENDIX 12C (TABLE 3).

CONTAINMENT BERM SIZING CRITERIA *

ACTIVE AREA (ft^2)	ACTIVE AREA (ACRES)	CONTAMINATED WATER STORAGE AREA (ACRES)	REQUIRED MINIMUM HEIGHT OF CONTAINMENT BERM AT SPECIFIED STORAGE AREA SLOPE ** (FT)	
			2%	5%
5,000	0.11	0.25	2.4	4.0
10,000	0.23	0.25	2.5	4.2
20,000	0.46	0.25	2.9	4.5
20,000	0.46	0.50	2.5	4.2

* CONTAINMENT BERM WILL BE SIZED USING THE ABOVE TABLE AS A GUIDELINE TO CONTAIN STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT. SUPPORTING CALCULATIONS ARE INCLUDED ON THE CONTAMINANT BERM SUMMARY SHEET IN APPENDIX 12C (TABLES 1 AND 2). NOTE THAT THE CRITERIA SET FORTH IN THE ABOVE TABLE IS BASED ON A MAXIMUM DOWN–GRADIENT LENGTH OF 100 FEET FOR THE STORAGE AREA.

** THE CRITERIA SET FORTH IN THE ABOVE TABLE ARE BASED ON A TYPICAL ACTIVE STORAGE AREA SLOPE OF 2% OR 5%.

FOR PERMITTING PURPOSES ONLY

REV	DATE	DESCRIPTION	BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: LEACHATE AND CONTAMINATED WATER PLAN CONTAINMENT/DIVERSION BERM DETAIL

PROJECT TITLE: CITY OF WACO LANDFILL TYPE I MSW - PERMIT APPLICATION

CLIENT: CITY OF WACO SOLID WASTE SERVICES

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO.: 16216088.00 | DWN. BY: NR | Q/A RVW BY: RRK
DSN. BY: BG/RRK | CHK. BY: BJD | APP. BY: RRK

CADD FILE: 12C.1 – LEACH AND CONT WATER PLAN

DATE: 04/2020

SCALE: AS SHOWN

DRAWING NO. 12C.1

5/11/2020 3:45 PM G:\WACO\16216088.00 T1T2 – SITE 50 SITING STUDY_Permit Dwgs_DWG_Att 12\12C.1 – Leach and Cont Water Plan

APPENDIX 12D

HDPE PIPE CORROSION DURABILITY LITERATURE

Chemical & Abrasion Resistance

Revision 0

Chemical & Abrasion Resistance of Corrugated Polyethylene Pipe

Brought to you by the CPPA, a non-profit industry trade association dedicated to providing unbiased, non-branded information about the use and installation of corrugated polyethylene pipe.

Your Information Resource

CORRUGATED POLYETHYLENE PIPE ASSOCIATION™

A division of the Plastics Pipe Institute, Inc.

PLASTICS PIPE INSTITUTE

Preface

The material presented in this technical booklet has been prepared in accordance with recognized principles and practices, and is for general information only. The information should not be used without first securing competent advice with respect to its suitability for any general or specific application.

While the material is believed to be technically correct, the Corrugated Polyethylene Pipe Association makes no representation or warranty of any kind, and assumes no liability therefore. Inquiries on specific products, their attributes, and the manufacturer's warranty should be directed to member companies. An up-to-date directory of the membership of the Corrugated Polyethylene Pipe Association is available on request.

Table of Contents

Introduction

Pipe environments are determined by the chemical and physical characteristics of the effluent and soil, vary from site to site and are not always predictable. Materials that can withstand some environments may not be as tolerant of others, and so may not perform as expected.

Aggressive pipe environments that include effluent and soil can result in pipe corrosion or abrasion. These factors, alone or in combination, can lead to a shortened product life or loss of structural integrity. It is very important to select durable materials to ensure long term performance in adverse environments.

Corrugated polyethylene pipe has a documented performance record of almost 30 years. Existing installations have provided the industry with a tremendous amount of information. Research has added to that knowledge base through material analysis and by comparison with other pipe materials. Available data indicates that specifiers can confidently expect a minimum service life of 50 years in typical drainage applications, and in all likelihood even more.

Through research and testing, corrugated polyethylene pipe has demonstrated that it can last longer than many other pipe materials. Specifically, because of corrugated polyethylene pipe's material properties, it withstands corrosion and abrasion better than traditional drainage pipe materials.

Resistance to Chemically Aggressive Environments

Chemical corrosion is the deterioration of the pipe that can result from the chemical action of the effluent or soil on the pipe material. In storm sewers, evidence of chemical corrosion usually shows as deterioration of the pipe invert. Highly corrosive conditions can eventually lead to a total loss of the invert, and a corresponding loss of structural integrity.

Corrugated polyethylene pipe is the preferred choice for installations that are subjected to acidic mine runoff, aggressive landfill leachate or strong acids with a pH as low as 2.0. Plastics withstand the effects of most basic and acidic chemicals, and polyethylene is one of the most chemically stable plastics used in drainage pipe applications. pH

In fact, acidic or alkaline-based industrial solutions; hydrocarbon-based fluids such as gasoline, motor oil, diesel fuel and kerosene; and detergents, bleaches and other cleaning solutions are often stored, shipped and sold in high density polyethylene packaging. Sometimes polyethylene is even used for rehabilitating concrete pipe to extend its life in a corrosive environment. And protective coatings are often times used to prolong the life of concrete and steel pipe, but always with added cost. INDUSTRIAL SOLUTIONS

Traditional drainage pipe materials such as concrete, steel and aluminum have varying levels of resistance to chemicals. Acidic chemicals and saline conditions, from road salts or sea water can often cause deterioration in these materials.

Most corrugated polyethylene pipe systems include some type of gasket, usually made of a natural rubber or ethylene propylene (EPDM) compound. In terms of the success of the overall installation, gaskets are a critical link in the drainage system. As such, the effects of caustic solutions and chemicals on the gasket material have also been thoroughly investigated and tested. Detailed information on gasket chemical resistance can be obtained by contacting individual CPPA manufacturing members.

Potentially aggressive chemicals commonly found in storm sewers include road salts, fuels, and motor oils. In some parts of the country, acidic runoff from mines creates very severe conditions. Contaminated soils, such as those with high levels of certain hydrocarbons, can also factor into the overall picture of chemical impact. HYDROCARBON

A sampling of chemicals that have been tested for compatibility with polyethylene pipe of various materials is shown in Table 1.

Table 1
Chemical Resistance of Polyethylene Pipe to Selected Substances*

Chemical or Substance	Polyethylene Pipe (73°F/23°C)
Alcohol, ethyl	R
Antifreeze agents, vehicle	R
Bleaching solution, 12.5% active chlorine	R
Bleaching solution, 5.5% active chlorine	R
Brake fluid	R
Diesel fuel	R
Diesel fuel/oil	R
Ethane	R
Fertilizer salts, aqueous	R
Fuel oil	R
Gasoline	R to C
Hydraulic fluid/oil	R
Hydrogen peroxide, aqueous 10% - 90%	R
Jet fuels	R
Methanol, pure	R
Motor oil	R
Nitric acid, 0% - 30%	R
Nitric acid, >30% - 50%	R to C
Petroleum, sour, refined	R
Sea water	R
Sewage, residential	R
Soap solutions, aqueous	R
Sulfuric acid, 70% - 90%	R
Two-stroke engine oil	R

R = Plastic pipe is generally resistant (Specimen swells <3% or has weight loss of <0.5% and elongation at break is not significantly changed)

C = Plastic pipe has limited resistance only and may be suitable for some conditions (Specimen swells 3% - 8% at weight and loss of 0.5% - 5% and/or elongation at break decreased by <50%)

*A more complete listing of polyethylene's chemical resistance can be obtained by contacting the CPPA.

Chemicals and abrasion are the most common durability concerns for drainage pipes, especially when the effluent flows at high velocities. But in test after test, results show that it takes longer to abrade through polyethylene than concrete.

Abrasives, such as stones or debris, can result in a mechanical wearing away of the pipe. The extent of the problem depends on the type of abrasive, frequency that the material is in the pipe, velocity of the flow, and the type of pipe material. The effect of abrasives may be seen in the pipe invert where exposure is most severe. Over time, abrasives can result in a loss of pipe strength or reduction in hydraulic quality as they gradually remove wall material.

Abrasion Resistance Testing

Pipe materials vary in their resistance to abrasives. Laboratory tests have been conducted to obtain wear rates of materials under controlled conditions. One of the most widely recognized projects[1] was conducted in 1990 under the direction of Dr. Lester Gabriel at California State University. This project evaluated the wear rates of 12" and 24" (300 and 600 mm) concrete pipe and smooth interior corrugated polyethylene pipe, among other materials, under laboratory conditions.

Sections of pipe were charged with an abrasive slurry consisting of crushed quartz aggregate and water. The pipe ends were then capped. The pipe was attached to a rocker apparatus and rotated such that the average velocity of the slurry was about 3 fps (0.9 m/s). Aggregate and pH were monitored throughout the test and adjusted as necessary to keep them as close as possible to their original conditions. The test was completed after a specified number of rotations. Then the effect of the slurry was determined by measuring the loss of wall thickness.

Interpreting the test results requires an understanding of the wall sections and what constitutes a "failure" for each product. According to ASTM C76, 12" (300 mm) concrete pipe must have a minimum of 0.5" (13 mm) of concrete cover over the circumferential steel reinforcement. The failure point for concrete is typically assumed to be when the reinforcement is exposed; at this point some of the structural integrity has been lost and the reinforcement is vulnerable to corrosion.

Smooth interior corrugated polyethylene pipe in 12" (300 mm) diameter has a minimum liner thickness of 0.035" (0.9 mm), although manufacturers typically use much heavier liners. The failure point of this product is assumed to be when the liner wears away. At this point, the strength of the pipe, supplied by the corrugated outer wall, remains intact.

Table 2 presents the maximum amount of wear that occurred during the test and the "expendable" wall thickness (e.g., the thickness of the wall that can abrade before reaching failure). The remaining wall thickness is presented as a percentage of the expendable wall thickness, and is an indication of the amount of service life remaining.

Table 2
Abrasion Test Results Under Neutral Conditions (pH 7.0)

	Initial Wall Thickness in. (mm)	Max. Loss of Wall Thickness in. (mm)	Expendable Wall Thickness in. (mm)	Remaining Wall Thickness %	Visual Results
12" (300 mm) Smooth Interior Polyethylene Pipe	.110 (2.8)	0.021 (0.53)	0.035 (0.89)	40	Liner showed some evidence of wear; liner perforation did not occur.
12" (300 mm) Concrete Pipe	2.15 (54.6)	0.79 (20)	0.5 (13)	<0	Steel reinforcement would have been exposed.*

*It was the intent of the project to test Class III reinforced concrete pipe. It was not realized until the tests had been completed that the pipe was not reinforced. This booklet discusses the results of the project as if reinforcement was present, because it is commonly used in construction applications.

Abrasion Test Results on 12" (300 mm) Concrete and Smooth Interior Polyethylene Pipe Under Neutral Conditions (pH 7.0)

The test results show that polyethylene pipe had significantly more service life remaining after the test, as evidenced by the amount of wall thickness that was still present.

Wall thickness alone, without regard to wear rate, is sometimes used to estimate service life. This test proved that evaluating just the wall thickness can be deceiving. The heavier wall of the concrete pipe failed at some point prior to completion of the test, whereas 40% of the relatively thin liner on the corrugated polyethylene pipe remained intact even after the experiment was completed. The wear rate of the material can - and in this case does - take precedence over the wall thickness.

Combined Abrasion and Chemical Corrosion Testing

Another phase of the research described above was to conduct the same test but with a moderately acidic effluent. The objective was to determine what might be expected from the combined effects of a chemically aggressive environment and abrasives. The setup of the pipe and abrasives was the same as before, although the effluent pH was maintained at 4.0. Table 3 shows the results of this trial.

Table 3
Abrasion Test Results Under Moderately Acidic Conditions (pH 4.0)

	Initial Wall Thickness in. (mm)	Max. Loss of Wall Thickness in. (mm)	Expendable Wall Thickness in. (mm)	Remaining Wall Thickness %	Visual Results
12" (300 mm) Smooth Interior Polyethylene Pipe	0.110 (2.8)	0.024 (0.61)	0.035 (0.89)	31	Liner showed some evidence of wear; liner perforation did not occur.
12" (300 mm) Concrete Pipe	2.15 (54.6)	1.20 (30.5)	0.5 (13)	<0	Loss of wall thickness was much higher than in neutral conditions. Significant amounts of reinforcement would have been exposed.

10

Abrasion Test Results on 12" (300 mm) Concrete and Smooth Interior Polyethylene Pipe Under Moderately Acidic Conditions (pH 4.0)

Moderately acidic conditions, similar to what could easily be expected in a dilute mine drainage application or perhaps in concentrated acid rain areas, caused dramatically different results for the pipe. The wear rate nearly doubled for concrete pipe compared to the neutral environment, whereas it increased about 15% for the smooth interior corrugated polyethylene pipe.

The time at which the failure point was reached becomes even more obvious under this test condition. Reinforcement on the concrete pipe would have been exposed, thereby failing the pipe, long before it had in the chemically neutral environment. By contrast, the polyethylene pipe did not experience significantly more wear in a chemically aggressive environment, and over 30% of the liner thickness, or service life, remained at the completion of this test.

As in the previous trial, the larger diameter pipe wore at a noticeably lower rate than the smaller diameter material.

Laboratory tests, like the one described previously, are usually conducted under a set of rigorous conditions designed to produce results in a reasonable length of time. Test conditions may somewhat resemble field conditions in the selection of abrasives and pH conditions, but deviate in the quantity of abrasives and the constancy of their application. Thus, laboratory tests are very important for providing information on *relative* wear rates and *relative* product lives, but will likely provide misleading results if extrapolated directly into actual service life values.

Actual polyethylene pipe installations have demonstrated superior durability. In 1981, the Ohio Department of Transportation installed a corrugated polyethylene pipe in a culvert application near an abandoned strip mine in southeast Ohio. Acidic (pH 2.5-4.0) and abrasive effluent had limited the lives of previously used pipe materials to two to five years, at which time either the invert wore through or the pipe collapsed. The polyethylene pipe replaced a polymer-coated steel pipe which had reached the end of its service life.

In 1990, a report[2] was published summarizing nine years of periodic inspections. The pipe remained nearly unaffected by the abrasive and acidic conditions. A high bedload was noted during the inspection made in 1985; rocks, coal and sand had been piled on the bank in an area 35' long by 15' wide by 1' deep (10.5 m x 4.5 m x 0.3 m) on the downstream end of the pipe providing an indication of the type and velocity of the abrasives.

An update[3] was published in 1996; after 14 years of service, or nearly three times that of any other material used in that application, the pipe was in excellent condition and ready for many more years of dependable service.

Summary

Nonpressure polyethylene pipe used in drainage applications has nearly 30 years of successful applications in the United States. A tremendous amount of information has been obtained from its application and from laboratory investigations which indicate a 50 year minimum service life for typical storm drainage applications.

Polyethylene has demonstrated very high resistance to environmentally aggressive applications where other materials' performance falls short. Tests conducted at California State University to determine the effects of abrasives in neutral and acidic environments showed the service life of polyethylene to far exceed that of concrete.

Additional tests are in progress that will support these long term performance behaviors. CPPA will report on those tests as the results become available.

References

1. Gabriel, Lester. "Abrasion Resistance of Polyethylene and Other Pipes." California State University, Sacramento, California. 1990.

2. Goddard, James. "Nine Year Performance Review of a 24-inch Diameter Culvert in Ohio." Sargand, Shad; Mitchell, Gayle; and Hurd, John; eds. Structural Performance of Flexible Pipes. Proceedings of the First National Conference on Flexible Pipes; October 21-23, 1990; Columbus, Ohio. Rotterdam, Netherlands: A.A. Balkema. 1990.

3. Goddard, James. "Performance Review of a Corrugated Polyethylene Cross Drain." Public Works Magazine. January 1996, p. 47.

CITY OF WACO LANDFILL
TCEQ PERMIT NO. MSW-2400
McLENNAN AND LIMESTONE COUNTIES, TEXAS

PART IV
SITE OPERATING PLAN

Prepared for:

CITY OF WACO

Solid Waste Services
501 Schroeder Drive
Waco, TX 76710

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED
PROFESSIONAL ENGINEER
5/13/2020

Prepared by:

SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
Dallas/Fort Worth Office
1901 Central Drive, Suite 550
Bedford, Texas 76021
817/571-2288

Revision 0 - April 2020
SCS Project No. 16216088.00

TABLE OF CONTENTS

SECTION **PAGE**

SCS Engineers
TBPE Reg. # F-3407

STATE OF TEXAS
RYAN R. KUNTZ
104689
LICENSED PROFESSIONAL ENGINEER

5/13/2020

Figures

Tables

SCS Engineers
TBPE Reg. # F-3407

LIST OF ACRONYMS

ADC - Alternative Daily Cover
ADCOP - Alternative Daily Cover Operating Plan
CCS - Citizens' Collection Station
CESQG - Conditionally Exempt Small Quantity Generator
CFR - Code of Federal Regulations
CHEMTREC – Chemical Transportation Emergency Center (CHEMTREC)
DOT - Department of Transportation
EPA - U.S. Environmental Protection Agency
FWS - U.S. Fish and Wildlife Service
GLER – geomembrane liner evaluation report
LCS - leachate collection system
LFG - landfill gas
MSW - Municipal Solid Waste
MSDS - Material Safety Data Sheets
MSL - mean sea level
NRACM - nonregulated asbestos-containing material
OSHA - Occupational Health and Safety Administration
PCBs - polychlorinated biphenyls
RACM - regulated asbestos-containing material
RCRA - Resource Conservation Recovery Act
SDP - site development plan
SIP - State Implementation Plan
SLER - soils and liner evaluation report
SLQCP – soil liner quality control plan
SOP - site operating plan
TAC - Texas Administrative Code
TCEQ - Texas Commission on Environmental Quality
TNRCC – Texas Natural Resource Conservation Commission (predecessor to TCEQ)
tpd – tons per day
TPDES – Texas Pollutant Discharge Elimination System
TxDOT - Texas Department of Transportation
WWTP - wastewater treatment plant

1 INTRODUCTION

This Site Operating Plan (SOP) has been prepared for the proposed City of Waco Landfill, (landfill), to be located in McLennan and Limestone Counties consistent with Title 30 of the Texas Administrative Code (30 TAC), Chapter 330, Subchapter D. The City of Waco (Owner) proposes to develop and operate a Type I Municipal Solid Waste (MSW) management facility, as described in this permit application. Additionally, as applicable, provisions have been included in this SOP related to operation of a Citizens' Collection Station (CCS) in accordance with Chapter 330, Subchapter E (related to operational standards for municipal solid waste storage and processing units) and Chapter 328 (related to recycling); and mulching operations in accordance with Chapter 332, Subchapter A and B (related to general information and operations requiring a notification).

The purpose of this SOP is to provide general instructions to landfill management and operating personnel for the day-to-day operation of the landfill. Additionally, this document provides an operating guide for landfill management to maintain the landfill in compliance with the engineering design and applicable regulatory requirements of the Texas Commission on Environmental Quality (TCEQ). This document may also serve as a reference source and assist in personnel training. This SOP, the permit and permit application, and the current TCEQ regulations will be kept on site throughout the facility's operating life.

2 PERSONNEL AND TRAINING [30 TAC §330.127(1) AND (4)]

2.1 PERSONNEL

The Director of Solid Waste is responsible for overall facility management and is designated as the contact person for regulatory compliance matters. The Director of Solid Waste is responsible for assuring that adequate personnel and equipment are available to provide facility operation in accordance with the Site Development Plan (SDP), this Site Operating Plan (SOP), and the TCEQ regulations. The Director of Solid Waste will provide adequate personnel for operation of the landfill in accordance with §330.125(h) and Table 2.1, related to the number of personnel for each position at the various waste acceptance rates. See Figure 2.1 Organizational Chart for the personnel organization.

The following describes the landfill personnel, and their general responsibilities and minimum qualifications required to provide efficient operation of the landfill:

Director of Solid Waste: The Director of Solid Waste will administer the facility's SOP and SDP. The Director of Solid Waste is also responsible for assuring adequate personnel and equipment are available in order to operate the facility in accordance with the SOP, the TCEQ Regulations, and the landfill's waste acceptance rate. The Director of Solid Waste will be responsible for personnel management and training in accordance with this SOP. He/she is responsible for communications to personnel and outside agencies as needed for emergency, fire, other contingencies and regulatory issues.

Qualifications: Will be required to have a minimum of 3 years of solid waste experience; 2 years of college or equivalent experience; and familiarity with TCEQ regulations.

Landfill Manager: The Landfill Manager (solid waste facility's supervisor, in accordance with §330.59(f)) or designee, is responsible for daily operations, administers the facility's SOP and SDP, and will serve as the emergency coordinator during site emergencies. Under the general direction of the Director of Solid Waste, the Landfill Manager will monitor the landfill and supervise landfill personnel on a daily basis to assure the landfill personnel are operating the landfill in compliance with TCEQ regulations and this SOP. In instances where a compliance task is identified without specifying the individual responsible for the task, the Landfill Manager (or designee) will be responsible for completion of said task. In instances when the Landfill Manager or designee are not at the facility, the Landfill Supervisor will assume appropriate compliance responsibilities after checking with (1) the Landfill Manager (who will be generally available by cell phone even when offsite), or (2) the Director of Solid Waste, in that order.

Qualifications: Will be required to have a minimum of 2 years of landfill operations experience; high school diploma or equivalent; be familiar with TCEQ regulations; and the various uses and capabilities of landfill equipment. The Landfill Manager or designee will maintain a Class A license.

Landfill Supervisor: The Landfill Supervisor is responsible for daily operations of the working face and other activities as assigned by the Landfill Manager. Under the direction of the Landfill Manager, the Landfill Supervisor will supervise the equipment operators. The Landfill

Supervisor will also have the capability to perform the responsibilities of an Equipment Operator.

Qualifications: Will be required to have a minimum of 1 year of landfill operations experience; high school diploma or equivalent; and be familiar with TCEQ regulations.

Customer Service Representative: One or more Customer Service Representatives, which includes at a minimum the Gate Attendant, will be stationed at the scale house, is primarily responsible for maintaining records of vehicles entering the facility, and screening for unauthorized waste. The Gate Attendant will be trained in site safety procedures, to visually check for unauthorized wastes, to weigh vehicle loads, and to collect waste disposal fees. The Gate Attendant directs incoming vehicles to the proper location to unload refuse at the working face or CCS.

Additional Customer Service Representatives may be stationed at the scale house or administration building for administrative duties as demand warrants.

Qualifications: Will be required to have experience and education commensurate with job requirements, as described above, and computer literacy skills. If the new employee does not have previous landfill experience, he/she will be required to complete a training program or on-the-job training specific to their job responsibilities, prior to working in an unsupervised position, as described in Section 2.2. Training requirements for Customer Service Representatives are described in Table 2.2.

Equipment Operator: Will operate heavy equipment at the working face and will help Spotters monitor and visually inspect loads as they are dumped to ensure compliance with posted operating rules. Equipment Operators are responsible for the safe operation of the equipment they operate. As the personnel most closely involved with the actual landfill operation, these employees are responsible for being alert for potentially dangerous conditions or careless and improper actions on the part of non-employees and other persons while on the premises. Equipment Operators are also responsible for maintenance, construction, litter abatement, and general site cleanup. Additional duties may include, but are not limited to, light construction, constructing silt fences, constructing diversion and containment berms, site regrading for drainage and prevention of ponded water and other environmental matters, and construction and regrading onsite temporary and permanent access roads. The Equipment Operators will intervene, as necessary, to prevent accidents and report unsafe conditions immediately to the Landfill Manager or designee.

Qualifications: Will be required to have (1) 6 months (minimum) experience in equipment operation or (2) on-the-job training by supervisor; and know the limitations and uses of landfill equipment. Additional training requirements for Equipment Operators are further described in Table 2.2.

Maintenance Worker: Maintenance Workers will be employed at the landfill to perform duties of a Spotter, litter abatement, and general site maintenance/clean-up. At a minimum a total of two Maintenance Workers will be employed to perform the duties of a Spotter; at least one will be located at the working face of the landfill and one will be located at the CCS, when the CCS is in operation. A Spotter will direct waste hauling vehicles to the appropriate location to unload and will inspect and observe loads as they are disposed of at the working face or CCS. A Spotter will direct citizens to appropriate locations for unloading waste or recyclables at the CCS and observe that the respective materials are unloaded in the correct bin or container. Spotters will be trained to recognize unauthorized waste, the procedures if unauthorized waste is detected, fire procedures, and other specific training procedures as described in Section 2.2.

Qualifications: Will be required to have the ability to read and write, and will be required to have experience commensurate with job requirements, as described above. If the new employee does not have previous landfill experience, he/she will be required to complete a training program or on-the-job training specific to their job responsibilities, prior to working in an unsupervised position, as described in Section 2.2. Training requirements for Maintenance Workers are described in Table 2.2.

Temporary Laborer: Temporary Laborers may be employed from time to time in categories such as maintenance and repair, construction, litter abatement, and general site maintenance/cleanup. Landfill personnel may also call on other divisions within the City of Waco for assistance at the landfill as needed. Temporary Laborers will be required to have experience and education commensurate within their job requirements (i.e., maintenance, construction, etc.).

Qualifications: Will be required to have 6 months (minimum) experience, if employed for maintenance, construction, or other skilled labor positions. If employed for general site cleanup, litter abatement, or other non-skilled labor, the employee is not required to have previous experience. All Temporary Laborers will complete on-the-job training specific to their job responsibilities, prior to working in an unsupervised position, as described in Section 2.2. Training requirements for Temporary Laborers are described in Table 2.2.

Table 2.1 Minimum Number of Personnel

Position	Personnel at Waste Acceptance Rate (W, tpd)	
	1,000 ≤ W ≤ 1,500	1,500 < W ≤ 2,000
Landfill Manager	1	1
Landfill Supervisor	1	1
Customer Service Representative	2	3
Equipment Operator	4	6
Maintenance Worker	2	3
Temporary Laborer	2	2

The number of landfill personnel, listed in Table 2.1, third column, is sufficient to operate the landfill at the maximum anticipated annual waste acceptance rate, but additional personnel may be added at the discretion of the Owner/Operator.

2.2 TRAINING

Landfill personnel will be trained in the appropriate portions of this SOP and complete a program or on-the-job training specific to their job responsibilities and position. This SOP provides landfill personnel with general instructions and guidance for the day-to-day operation of the landfill. The SOP also serves as a general reference source to assist in the development of training programs for landfill personnel. Landfill personnel will be trained in emergency procedures, emergency equipment, and emergency systems. The training program or on-the-job training will address the following topics, when applicable:

- Procedures for using, inspecting, repairing, and replacing landfill emergency and monitoring equipment.
- Emergency communication procedures and alarm systems.
- Response procedures for fire and explosions.
- Response procedures to groundwater and surface water contamination incidents.
- Procedures for shutdown of operations.
- Applicable rules, safety procedures, contingency plans, and permit requirements.
- Customer notification and load inspection procedures.
- Identification of hazardous wastes, PCB wastes, and other unauthorized wastes.
- Waste handling procedures (acceptable and unauthorized wastes).
- Health and safety.
- Recordkeeping.

Personnel training will be directed by a person with experience in waste management procedures, and will include instruction commensurate with their position. Landfill personnel will complete training within six months after employment, promotion, or transfer at the landfill. Employees will not work in unsupervised positions until they complete a training program or on-the-job training. In addition, landfill personnel must take part in an annual review of the initial training required by the SOP and 30 TAC §335.586(c). Specific training requirements for landfill personnel are provided in Table 2.2.

Selected personnel will receive training at TCEQ-sponsored or approved training courses, as deemed appropriate by the Director of Solid Waste. Training and safety meetings will be scheduled at least once per month to discuss one or more of the topics listed above. Training schedules will be conducted so landfill operations are not interrupted.

The Landfill Manager or designee will maintain the following documents and records related to personnel training:

- Job title for each position at the landfill, and the name of the employee(s) with that position.
- A written job description for each position, including requisite skills, education, and other qualifications and responsibilities.
- A written description of the type and amount of introductory training and continuing training that will be required for each employee.
- Records that document that the landfill personnel have completed the training and job experience required above.

The above documentation for training will be placed in the Site Operating Record. Training records on current landfill personnel will be kept until closure of the landfill. Training records on former employees will be kept for at least three years from the date the employee last worked at the landfill. Personnel training records may accompany personnel transferred within the City of Waco.

Table 2.2 Personnel Training Requirements

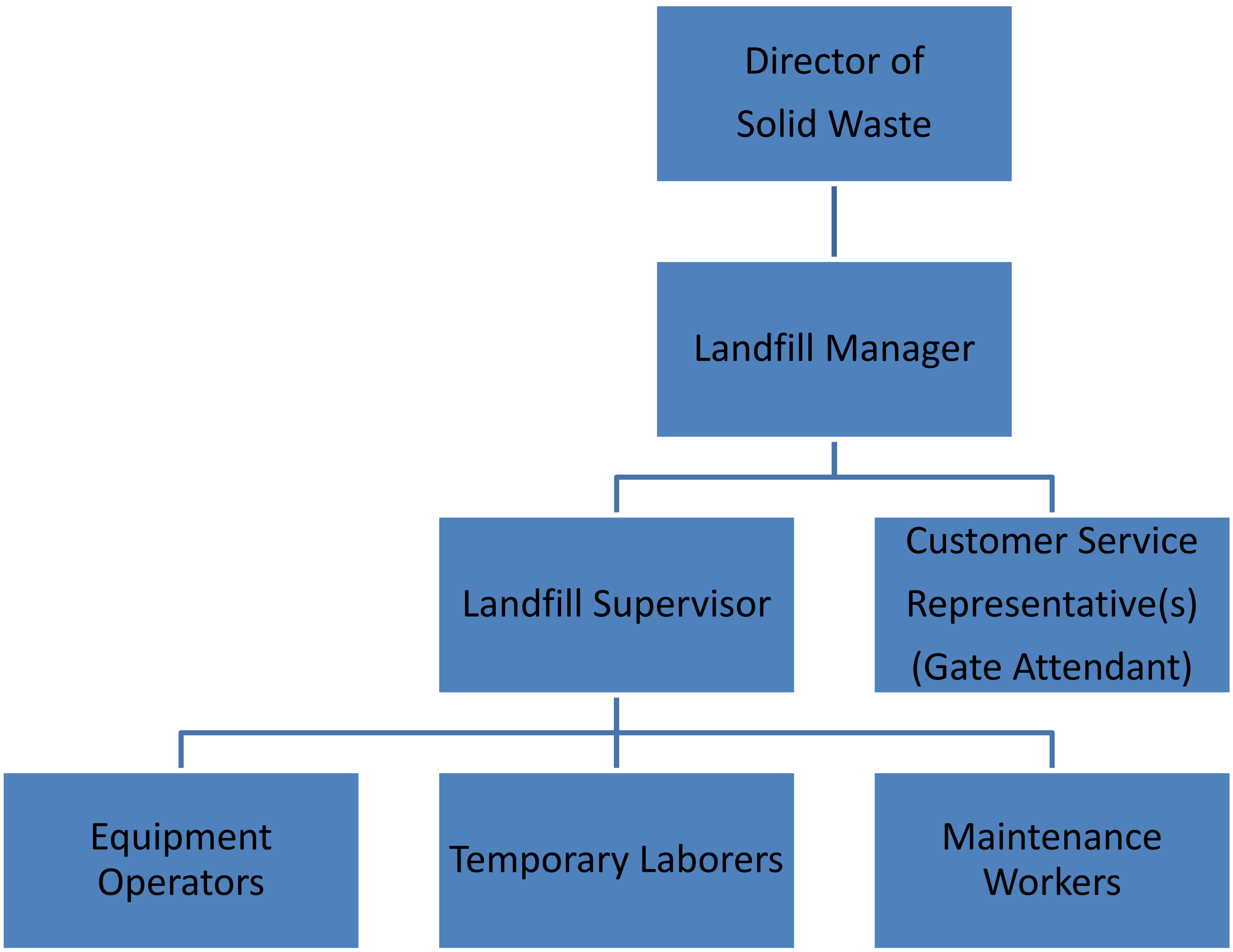
Personnel Description	On-the-Job Training [1]	Site Operations Plan [2]	Emergency/Monitoring Equipment	Emergency Communication Procedures	Fire Protection Plan	Groundwater/Surface Water Protection	Load Inspection Procedures	Unauthorized Waste Identification	Waste Handling Procedures	Odor Management Plan	Prevention of Ponded Water	Recordkeeping Procedures
Landfill Manager	X	X	X	X	X	X	X	X	X	X	X	X
Landfill Supervisor	X	X	X	X	X	X	X	X	X	X	X	X
Customer Service Representative	X	X		X	X		X	X	X	X		X
Equipment Operator	X	X		X	X	X	X	X	X	X	X	X
Maintenance Worker	X	X		X	X		X	X	X			X
Temporary Laborer	X	X		X								

Notes:

[1] On-the-job training will be required for all landfill personnel, and will be specific to their individual job responsibilities, as described in Section 2.1.

[2] All landfill personnel will be trained in the appropriate portions of the SOP, as it pertains to their individual job responsibilities.

Figure 2.1 City of Waco Landfill Organizational Chart



3 EQUIPMENT [30 TAC §330.127(2)]

The following list of equipment will be available for use at the landfill. Equipment requirements may vary in accordance with the method of landfill operations or the waste acceptance rate at any given time. Additionally, supplementary types, sizes, and quantities of equipment will be provided, as required, for increased volumes of incoming solid waste, and for operation at the waste acceptance rate provided in Table 3.1. Table 3.1 lists the number of pieces of equipment that will be required to operate the landfill at various ranges of waste acceptance rates. Other equivalent types of equipment by other manufacturers may be substituted, as needed. Equivalent equipment is defined as equipment of the same type, function, and similar weight and/or capacity as the equipment listed in Table 3.1. The equipment will be equipped with fire extinguishers.

Table 3.1 Equipment List

Equipment Description	Equipment at Waste Acceptance Rate (W, tpd)	
	1,000 < W ≤ 1,500	1,500 < W < 2,000
Compactor, Caterpillar 826 or equivalent	2	3
Bulldozer, Caterpillar D6 or equivalent	0	1
Bulldozer, Caterpillar D8 or equivalent	2	2
Excavator, Volvo EC 330B or equivalent	1	1
Loader, Caterpillar 973 or equivalent	1	1
Off-Road Dump Truck	2	2
Motor Grader	1	1
2,000-Gallon Water Truck	1	1

* The types of equipment, manufacturer, and model may vary, as needed. The Director of Solid Waste with input from the Landfill Manager or his designee, will routinely assess the equipment needed to maintain compliance with the TCEQ regulations and make adjustments, as appropriate. Equipment used by Contractors to perform construction, such as excavating and constructing waste disposal cells, are not included in the above table.

The following generally describes the typical functions of the heavy equipment listed in Table 3.1:

- Compactor - spreading and compacting the refuse and compacting the cover material.

- Bulldozers – removing, replacing, moving daily, intermediate, and final cover soils, construction and maintenance of roads and drainage control features, and moving and positioning waste for the compactor. The bulldozers also will be used to cover the working face with soil on a daily basis and in the event of a fire at the working face, as described in Section 6.1.

- Excavator – general excavation work; excavating for cover soil; and excavation of future disposal areas.

- Loader – general excavation, soil transport, and other general earthwork.

- Off-Road Dump truck – transporting cover soil from stockpile to working face on a daily basis and in the event of a fire at the working face, as described in Section 6.1.

- Motorgrader – construction and maintenance of onsite access roads, drainage control features, and daily, intermediate, and final cover.

- Water truck – dust control, fire control, and other supplemental watering.

In addition to the above list, miscellaneous pickup trucks, vans, and other light utility vehicles as well as various pumps, litter fences, instruments, and safety and training equipment will be onsite, as necessary, for operation of the landfill. In the event of equipment breakdown that would prevent proper site operation, temporary equipment will be rented as soon as practicable for use while the owned equipment is being repaired or replaced. When existing equipment is being repaired or replaced, other equivalent types and sizes of equipment will be provided to prevent disruption of landfill operations.

Diesel storage tanks of appropriate capacity, as determined by the Owner, will be located at the facility for landfill operations. Diesel tanks will be located in the general vicinity of the landfill operations, and will be moved to new locations as operations shift throughout the facility. However, at all times, the diesel tank will be kept a minimum of 50 feet from constructed cells with in-place waste, occupied structures, and other potential fire hazards (i.e. mulch stockpiles, wood waste stockpiles, bins or containers containing waste or recyclables at the CCS, etc.).

Diesel storage tanks will be registered consistent with 30 TAC Chapter 334, Subchapter F, related to Aboveground Storage Tanks, including 334.127(f)(1-3) regarding registration of movable aboveground storage tanks. Additionally, consistent with the applicable regulatory requirements, tank operations will be appropriately addressed in the stormwater pollution prevention plan (SWP3); spill prevention, containment, and countermeasures (SPCC) plan; and standard air permit.

As described in Section 4.2, the landfill will have a CCS to reduce traffic at the working face of the landfill. This CCS will be used for the acceptance and storage of waste, which will be disposed at the working face, and acceptance and storage of recyclables for transport to an authorized recycling or disposal facility. Waste and recyclable materials will be stored in separate containers or locations at the CCS, which will be properly identified for the types of waste to be received in each container or location. The type of container or storage mechanism will be based on the individual waste stream (see Section 4.2.2 for unloading waste and recyclables at the CCS). In accordance with §330.211, if any solid waste containing food waste is stored on site, it will be stored in covered or closed containers that are leak-proof, durable, and designed for safe handling and easy cleaning.

Reusable containers will be used at the CCS. In accordance with §330.211(2), all reusable containers used to store waste will be maintained to prevent spillage and leakage during storage and handling, and/or transport. The containers will be inspected daily during days when the facility is in operation for spills or leaks, and promptly repaired or replaced, if necessary, as a result of these inspections. Additionally, these reusable containers will be routinely cleaned to prevent nuisance odors and to prevent the harborage, feeding, and propagation of vectors.

4 OPERATIONAL PROCEDURES

4.1 ACCESS CONTROL (30 TAC §330.131)

Access to the landfill will be limited to the gated landfill entrance off of T K Parkway (also referred to as Farm-to-Market [FM] 939, approximately 0.4 miles south of the intersection of State Highway 31 and FM 939. The Gate Attendant will control access and monitor all vehicles entering and exiting the site.

4.1.1 Site Security

Site security measures are designed to prevent unauthorized persons from entering the site, to protect the facility and its equipment from possible damage caused by trespassers, and to prevent disruption of facility operations caused by unauthorized site entry.

Unauthorized entry into the site is minimized by controlling access to the landfill site with the perimeter fence and entrance gates. The perimeter fence will consist of either barbed wire, 6-foot chain link fencing, or 8-foot privacy fencing at the locations depicted on Part III, Attachment 1, Drawing 1.2.

Additionally, the fence on the southern portion of the property will be installed at the approximate locations shown on Part III, Attachment 1 – Site Layout Plans. The Soil Conservation Services (SCS), Reservoir 19 intersects the southern property boundary at the confluence with Horse Creek. This reservoir has a normal pool elevation of 520.2 feet above mean sea level (ft MSL), associated with the elevation of the primary outlet structure, which provides a natural barrier to access. Therefore, the perimeter fence along the southern portion of the property will be terminated at approximately elevation 520 ft MSL at the confluence with Horse Creek, and then extended an additional 200 feet north of this confluence. Additionally, signs will be posted along this section of fence indicating “No Trespassing, City of Waco Property” or similar wording to discourage trespassing onto the property.

The site entrance will be secured by two gates (primary and secondary entrance gates). The primary entrance gate will be opened at 5:30 AM on days that the facility is in operation to minimize queuing on FM 939, as described in the Transportation Impact Analysis (Part I/II, Appendix I/IID-2) The secondary entrance gate will remain locked outside operating hours to prevent unauthorized vehicle access to the landfill. Additionally, other gates may be installed on the east perimeter for access to other property owned by the Owner, which will be accessible to landfill personnel and authorized persons only.

The perimeter fence and gates will be inspected monthly. Repairs and maintenance will be performed consistent with §330.131. If the perimeter fence or gates have been damaged (i.e., breached), the TCEQ region office and any local pollution agency with jurisdiction, that has requested to be notified, will be notified within 24 hours of detection. The breach will be temporarily repaired within a 24-hour period (weather permitting), and will be permanently repaired within the timeframe approved by the TCEQ region office. Once permanent repairs are complete, the TCEQ region office will be notified. If the breach can be permanently repaired within 8 hours of detection, then a notice to the TCEQ region office is not required.

Documentation of perimeter fence and gates inspections and breaches will be maintained in the Site Operating Record. Refer to Table 4.1 of this SOP for the site inspection and maintenance schedule.

The Owner will permit entry to the landfill to designated landfill personnel, solid waste haulers authorized to use the facility, TCEQ personnel, and properly identified persons whose entry is authorized by the Landfill Manager or designee. The Owner reserves the right to deny access to the landfill to persons not demonstrating a legitimate purpose for visiting. Visitors will be allowed on the active disposal area of the landfill only when accompanied by the Landfill Manager or designee.

4.1.2 Traffic Control

Access to the landfill will be provided via the primary entrance gate located off FM 939. The site entrance is detailed on Attachment 1, Drawing 1.5 - Entrance Facility Plan. The site entrance consists of an all-weather road, site entrance gates, scale house, and scales (initially one inbound and one outbound scale). The site entrance will also include two inbound queue lanes that provide approximately 3,300 feet of queuing length from the scales back to FM 939. Furthermore, at some point in the future, an additional inbound scale may be installed to accommodate increases in the waste acceptance rate over the site operating life. The Gate Attendant controls access and monitors all vehicles entering and exiting the site.

The site entrance road will be an asphalt or concrete paved roadway, or other suitable material that transitions into onsite access roads, including perimeter and interior haul roads. The perimeter and interior haul roads will be constructed of crushed stone, concrete rubble, masonry demolition debris, gravel, caliche, concrete paving, asphalt paving, or other suitable material and will provide access from the site entrance road to the active fill area(s) and CCS. The perimeter and interior haul roads will be will be maintained in an all-weather condition and will be freely draining, and kept free of excessive ruts and potholes, as described in Section 4.12.

The approach to the working face will be maintained such that two or more vehicles may safely unload side-by-side. A vehicle turn-around area large enough to enable vehicles to arrive and turn around safely will be provided adjacent to the working face. The vehicles will back to a vacant area near the working face to unload. Upon completion of the unloading operation, the transportation vehicles will leave the working face area. Landfill personnel will direct traffic, as necessary, to expedite safe movement of vehicles.

Loitering will not be permitted at the landfill working face.

Within the site, signs will be placed along the landfill entrance and onsite access roads at a frequency adequate for users to understand where disposal areas are and which roads are to be used. No private or commercial solid waste vehicles will be allowed access to any areas other than the active portion of the landfill. Roads not being used for access to disposal areas will be blocked or otherwise marked for no entry.

4.2 UNLOADING WASTES (30 TAC §330.133)

This landfill is authorized to dispose of municipal solid waste and those special solid wastes allowable under 30 TAC §330.171. The categories of wastes that are not authorized for disposal at this site by state [specifically, 30 TAC §330.15(e)] and federal regulations are discussed in Section 5 of this SOP. Special wastes that are accepted at the landfill are described in Section 4.20.

The landfill will have a CCS to reduce traffic at the working face of the landfill. This CCS will be used for the acceptance and storage of waste, which will be disposed at the working face, and acceptance and storage of recyclables for transport to an authorized recycling or disposal facility. The CCS will only accept the waste streams authorized for disposal at the landfill and the types of recyclables described in Section 4.2.2. The unloading of waste in unauthorized areas are prohibited under 30 TAC §330.133(b).

Solid waste dumping will be controlled to prevent disposal in locations other than those specified by landfill management. Any waste deposited in an unauthorized area will be immediately removed and disposed of properly at the working face or CCS. Any unauthorized waste identified will be handled in accordance with Section 5. Landfill personnel will report questionable waste materials or other issues of concern immediately to the Landfill Manager or designee.

Signs with directional arrows and portable traffic barricades will restrict traffic to designated disposal locations. Waste hauling vehicles will be directed by signs placed along the onsite landfill access roads to the designated disposal areas. In addition, rules for waste disposal and unauthorized waste will be prominently displayed on signs near the site entrance.

4.2.1 Unloading Wastes for Disposal at the Working Face

The typical size of the working face(s) (i.e. solid waste unloading areas) at the landfill will be approximately 20,000 square feet. The maximum size of the working face(s) will be 30,000 square feet. The working face(s) will be confined to a minimum area consistent with the incoming waste stream. Typically, there will be one working face during dry weather, however there may be two working faces during wet weather, if necessary, to accommodate the efficient operation of the landfill. Also, during the initial disposal in a newly constructed cell the Owner may operate two working faces to prevent disposal of large items directly over a newly constructed liner. However, the maximum combined size of the both working faces will not exceed 30,000 square feet.

As discussed in Section 2, trained personnel will monitor the incoming waste. Additionally, the Gate Attendant will direct citizens with small or light vehicles to unload waste at the CCS, as described in Section 4.2.2, which reduces small vehicular traffic at the working face. In addition, Spotter(s) will be at the working face during operating hours to direct and observe the unloading of waste that is disposed at the landfill (see Section 5 of this SOP). These personnel will have a basic understanding of Class 1 industrial waste, hazardous wastes, and other unauthorized wastes, which are excluded from this facility. After communicating with the Landfill Manager or designee, landfill personnel will have authority and responsibility to (1) reject unauthorized loads, (2) have unauthorized material removed by the transporter or by onsite personnel, and (3) access appropriate surcharges.

4.2.2 Unloading Wastes at the Citizens' Collection Station (CCS)

The Gate Attendant will direct citizens with small or light vehicles to unload waste at the CCS into clearly identified containers (i.e., roll-offs). Trained personnel will monitor the incoming waste on the trucks. Roll-offs containing food waste will typically be removed from the CCS by the end of each day of operation, but will not be stored (i.e., maintained within containers) at the CCS longer than 48 hours following receipt of said waste. As described in Section 3, all solid waste containing food waste shall be stored in covered or closed containers that are leak-proof, durable, and designed for safe handling and easy cleaning.

The landfill may also receive recyclable materials at the CCS in accordance with Chapter 328, related to waste minimization and recycling. The CCS will be comprised of an elevated deck area with an all-weather surface, with collection containers situated behind a retaining wall for drop-off of waste and recyclables, such as aluminum, glass, plastic, cardboard/newspapers, and scrap-metal. Other recyclables will have dedicated drop-off and/or storage areas, as described below. The recyclable materials that may be accepted at the CCS are described below, in addition to the mechanism for storage of said materials:

- **Aluminum, glass, plastic, cardboard/newspaper, and scrap metal:** These materials will be unloaded into containers or bins (i.e., roll-offs, dumpsters, etc.) for either mixed or segregated recycling of aluminum, glass, plastic, cardboard/newspaper, or scrap metal.

- **Large items and/or white goods:** Large items and white goods may be accepted and stored at the CCS, as described in Section 4.9.

- **Whole used or scrap tires:** In accordance with §328.54(c), whole used, scrap tires, or tire pieces will be stored at the CCS in quantities not to exceed 500 used or scrap tires (or weight equivalent thereof) on the ground or 2,000 used or scrap tires (or weight equivalent thereof) in enclosed and lockable containers/trailers. The facility will maintain records of the number or weight of tires received, stored, and transported offsite to assist with the manifest system requirements for the transport of tires to an authorized recycling facility accepting the tires and tire pieces. Records of tires or tire pieces diverted from the landfill and transported offsite will be maintained in the Site Operating Record.

Each container or unloading area for waste or recyclables will be clearly identified. Containers used at the CCS will be inspected and maintained in accordance with Section 3. A Spotter will direct citizens to appropriate locations for unloading materials at the CCS and observe that the respective materials are unloaded in the correct bin or container. Maintenance Workers, designated as Spotters, will be trained to recognize unauthorized waste, the procedures if unauthorized waste is detected, and fire protection procedures. Fire protection procedures for the CCS are described in Section 6.1.

Except for tires, as described above, all recyclable wastes will be removed every six months, at a rate equal or greater than 50% by weight or volume of material accumulated at the beginning of the period, in accordance with §328.4(b).

The design of the CCS, including the large item/white goods storage area, as well as the brush, wood, and yard waste storage areas, will comply with the requirements of §330.303 (related to Surface Water Drainage for MSW Facilities), and the applicable requirements of §330.207 (related to Contaminated Water Management from waste storage facilities and a CCS).

4.2.3 Unloading Brush, Wood Waste, and Yard Waste at the Mulching Area

The landfill may also receive brush, wood waste, and yard waste for mulching in accordance with Chapter 332, related to mulching operations. The Gate Attendant will direct citizens with brush, untreated wood waste, and yard waste to unload these materials at a designated area. Brush, untreated wood waste, and yard waste that are diverted from landfill disposal, will be stockpiled outside the current disposal areas (i.e., active working face) in a location that will not interfere with landfill operations. Diverted brush, untreated wood waste, and yard waste will be routinely mulched.

Mulching operations will be performed in accordance with §332.4 (related to general requirements) and §332.8 (related to air quality requirements, as described in Section 4.10). Mulch may be used on intermediate cover slopes, as described in Attachment 6A, Section 6.2.3 or may be distributed or sold to other City of Waco departments or citizens for commercial and residential-use.

4.3 FACILITY OPERATION HOURS (30 TAC §330.135)

The waste acceptance hours and the hours when materials will be transported on and off site will be between the hours of 7 a.m. and 7 p.m., Monday through Saturday, unless otherwise approved by TCEQ.). The primary entrance gate will be opened at 5:30 AM on days that the facility is in operation to minimize queuing on FM 939, as described in the Transportation Impact Analysis (Part I/II, Appendix I/IID-2). The landfill will be closed on Sundays and holidays. The City of Waco is requesting that the landfill be authorized to accept waste on Saturdays for the following reasons:

- To provide disposal needs to region’s citizens and private customers that require waste disposal services on Saturdays.
- To reduce congestion at the working face during weekdays.
- To reduce traffic on area public-access roads on weekdays.
- To reduce illegal dumping within the region.
- To provide disposal services to commercial business (i.e., restaurants, bars, etc.) open on Friday evenings.

Operation of heavy equipment for compaction of waste, application of daily and intermediate cover, regrading, or construction activities will only occur between 5 a.m. and 9 p.m., Monday through Saturday. Transportation of material or heavy equipment operation will not be conducted between 9 p.m. and 5 a.m.

Consistent with TCEQ rules, the Owner may request alternate operating hours for special occasions, special purpose events, holidays or other special occurrences. The TCEQ may approve alternate operating hours up to five days in a calendar year period. Additionally, the TCEQ region office may allow temporary operating hours to address disaster or other emergency situations, or other unforeseen circumstances that could result in the disruption of waste receipt at the landfill. If the Landfill Manager determines the landfill needs to operate outside the approved operating hours, the Landfill Manager will seek approval from the TCEQ region office for the alternate operating hours prior to such occurrence. The Landfill Manager will record the dates and times of alternate or additional operating hours in the Site Operating Record.

The Director of Solid Waste or Landfill Manager may establish operating hours that are less than those noted above. These hours will be indicated on the sign at the entrance to the landfill.

4.4 SITE SIGNS (30 TAC §330.137)

A sign will be displayed at the entrance to the site. This sign will measure at least 4 feet by 4 feet, and have lettering of at least 3 inches in height that states the name of the site; type of site; hours and days of operation; an emergency 24-hour contact phone number(s) that reaches an individual with the authority to obligate the facility at all times that the facility is closed; the local emergency fire department phone number; and the TCEQ permit number. A sign will be prominently displayed at the site entrance stating that all loads will be properly covered and that a surcharge will be placed on all vehicles without adequate cover.

See Section 4.1.2 regarding signs placed along the onsite access roads directing users to active disposal area(s).

4.5 CONTROL OF WINDBLOWN WASTES AND LITTER (30 TAC §330.139)

Windblown wastes will be controlled by the following methods:

- Waste transportation vehicles using this facility will be required to use adequate covers or other means of containment. The adequacy of covers or containment of incoming wastes will be checked at the site entrance and a surcharge will be imposed for the lack of covers.

- Daily cover will be applied at the end of each day of operation to assist with the control of windblown waste.

- The facility will provide litter control fences, as necessary, at appropriate locations near the working face and elsewhere. The litter control fences will be of sufficient height and will be located as close as practical to the active area to control windblown waste and litter.

- Perimeter fencing, as described in Section 4.1.1.

- As part of the overall site maintenance program, facility personnel will collect daily the windblown waste materials that may have accumulated throughout the entire site, including but not limited to, fences and gates, onsite access roads and drainage channels throughout the site on days when the facility is in operation.

- Facility personnel will inspect public-access roads within two miles in either direction from the landfill entrance for waste spilled in route to the landfill on each day of operation, as described in Section 4.8 of this SOP.

All collected litter will be taken daily to the working face of the landfill for disposal.

4.6 EASEMENTS AND BUFFER ZONES (30 TAC §330.141)

4.6.1 Easements

In accordance with 30 TAC §330.141, solid waste unloading, storage, disposal, or facility operations will not occur within any easement or right-of-way that crosses the site. All easements will be clearly marked as specified in Section 4.7 of this SOP. At the time of landfill development or cell construction, the waste disposal footprint will be located at least 25-feet from the centerline of any utility and pipeline easement, but no closer than the easement boundary, consistent with 30 TAC §330.543(a). All pipeline and utility easements shall be clearly marked with posts that extend at least six feet above ground level, spaced at intervals no greater than 300 feet. No solid waste unloading, storage, disposal, or processing operations will occur within any easement or right-of-way that crosses the facility, unless and until the easement has been abandoned or relocated.

There are four (4) known easements on the landfill property, including a fiber optic, flowage, waterline, and electric line easement, as described in Parts I/II, Section 3 and shown on the metes and bound survey in Parts I/II, Section 14 of permit application.

4.6.2 Buffer Zones

The buffer zone for the waste disposal areas is generally located between the permit boundary and the limits of waste. No solid waste unloading, storage, disposal, or processing operations will occur within the buffer zone. However, perimeter drainage channels, detention basins, and onsite access roads may be installed within the buffer zone between the permit boundary and the limits of waste. Buffer zones may vary around the perimeter of the landfill, but in no case are they less than 125 feet in width. Access roads will be constructed within the buffer zones to allow the safe passage of fire-fighting and other emergency equipment.

Additionally, in accordance with "An Intensive Cultural Resources Survey of the City of Waco's Proposed Site 50 Landfill Property," prepared by Horizon Environmental Services, Inc., dated

November 2018 (see Appendix I/IIA), a 25-foot construction buffer will be maintained around TK Cemetery to protect any potential unmarked graves outside the present modern day cemetery boundaries and fencing. This construction buffer is depicted on Drawing I/II-5 and other site layout drawings contained in Part III – Site Development Plan.

Buffer zones will be clearly marked as specified in Section 4.7 of this SOP.

4.7 LANDFILL MARKERS AND BENCHMARK (30 TAC §330.143)

Landfill markers will be installed to clearly mark significant features and visibility will be maintained as described in 30 TAC §330.143(b). The markers will be steel or wooden posts (or other TCEQ approved material) and will extend at least six feet above the ground surface. The markers will not be obscured by vegetation and will be placed in sufficient numbers to clearly show the required boundaries. Landfill markers will be inspected monthly and will be maintained and repaired as necessary. Markers that are removed, destroyed, or otherwise fail to meet regulatory requirements will be replaced within 15 days of discovering their deficiency. Refer to Table 4.1 of this SOP for site inspection and maintenance schedule. Documentation of inspections and maintenance will be maintained in the Site Operating Record of the landfill. Markers will be repainted as needed to retain visibility. Guidelines for type, placement, and color coding of markers are outlined below.

- Site Boundary - Site boundary markers will be painted black. The markers will be placed at each corner of the site and along each boundary line at intervals no greater than 300 feet. Fencing may be placed between these markers as required. In areas where the fence is located on the permit boundary, the fence posts may be painted black and used as site boundary markers.

- Buffer Zone - Buffer zone markers will be painted yellow. The markers will be placed along each buffer zone boundary at intervals of 300 feet. The buffer zones will be a minimum of 125 feet wide from the landfill permit boundary.

- Easements and Rights-of-Way - Easement and right-of-way markers will be painted green. The markers will be placed along the centerline of an easement and along the boundary of a right-of-way, at each corner within the site, and at the intersection of the permit boundary. Where it is impractical to place a marker, the marker will be offset from the easement right-of-way and the offset distance will be clearly painted on the marker.

- Landfill Grid System - Grid markers will be painted white. Markers will be spaced no greater than 100 feet apart measured along perpendicular lines. Where feasible, intermediate markers will be installed where markers cannot be seen from opposite boundaries. At a minimum, grid markers will delineate the area expected to receive waste within the next 3 years. The grid markers will be maintained during the active life of the site, and throughout the post-closure period, as necessary.

- SLER/GLER Area – Soil liner evaluation report/geomembrane liner evaluation report (SLER/GLER) markers will be painted red. The markers will be placed so that all areas for which a SLER/GLER has been submitted are readily determinable. Such markers are to provide site workers immediate knowledge of the extent of approved disposal areas. These markers will be located and protected so that they are not destroyed during operations until operations extend into the next SLER/GLER area. The location of these markers will be tied into the landfill grid system and will be reported on each SLER/GLER submitted. SLER/GLER markers will not be placed inside the constructed areas.

- 100-Year Floodplain –100-Year floodplain protection markers will be painted blue. The markers will be installed for any area within the 100-year floodplain as delineated by FEMA. The area subject to flooding, including the 100-year storm event water surface boundary as defined in Attachment 6B, will be clearly marked by means of permanent post not more than 300 feet apart or closer if necessary to retain visual continuity.

The site will maintain at least one permanent benchmark at the site in an area readily accessible and will not be used for disposal. The benchmark(s) will be a bronze survey marker, stamped with the elevation and survey date and set in concrete. The benchmark elevation will be surveyed from a known US Coast and Geodetic survey benchmark or other reliable source.

4.8 CONTROL OF WASTE SPILLED EN ROUTE TO THE SITE (30 TAC §330.145)

The Landfill Manager or designee will take steps to assure that vehicles hauling waste to the site are enclosed or provided with a tarpaulin, net, or other means to effectively secure the load. The steps taken by the Owner will include, as necessary, the posting of signs requiring the loads to be covered, refusing acceptance of uncovered loads, reporting offenders to the police, adding disposal surcharges, or other necessary means.

On a daily basis when the landfill is in operation, landfill personnel will inspect SH 31 and FM 939 for spilled waste for a distance of two miles in either direction from the landfill entrance used for the delivery of waste to the landfill. If spilled waste is found on these public-access roads within 2 miles from the landfill, such waste will be cleaned up by landfill personnel and delivered to the landfill, assuming such waste is suitable for disposal at the landfill. The Landfill Manager or designee will consult with Texas Department of Transportation (TxDOT) officials and McLennan and Limestone Counties concerning cleanup of these public-access roads consistent with 30 TAC §330.145. Cleanup of these public-access roads will include cleanup of the respective rights-of-way as well.

4.9 DISPOSAL OF LARGE ITEMS (30 TAC §330.147)

A large item/white goods storage area will be provided at the CCS or other alternative location designated as the "large item salvage area." Alternatively, large item/white goods will be diverted from the waste stream at the active working face, and routinely relocated to the storage area. Items that can be classified as large, heavy or bulky can include, but are not limited to, white goods (household appliances), air conditioner units, metal tanks, large metal pieces and automobiles. These items will be recycled as demand warrants but will not be stored in excess of 180 days. Large items that are not recycled will be disposed of at the working face. Care will be taken during disposal of large items such that: (1) large items are excluded from the initial 5 feet of waste over the liner protective cover, (2) large items are placed such that they do not interfere with continued waste filling, and (3) other, smaller municipal solid waste is placed and compacted around them.

The Owner will properly manage chlorinated fluorocarbon (CFC) refrigerant from refrigerators, freezers, air conditioning units, or other items in accordance with 40 CFR §82.156(f). CFCs will be evacuated from refrigerators, freezers, or air conditioners by a third-party vendor, or landfill personnel certified to perform this activity, prior to landfilling or recycling the units at an offsite facility. Electrical equipment, which contain PCBs, will not be accepted, as provided in Section 5.

4.10 AIR QUALITY CONTROL AND ODOR MANAGEMENT PLAN (30 TAC §330.149)

4.10.1 Air Quality

Municipal solid waste landfills are subject to TCEQ regulations concerning burning and air pollution control. The following procedures will be implemented at the landfill for control of air pollution:

- Open burning of waste will not be permitted at the facility.
- Control of dust emissions (i.e. particulate matter control) from onsite access roads, as described in Section 4.12.
- Obtaining coverage under and complying with either the Standard Air Permit in 30 TAC Subchapter U or an individual air permit.
- For the mulching operation obtaining coverage under and complying with the air quality standard permit in 30 TAC §332.8. In accordance with §332.8(b), mulching operations will be performed as follows in order to comply with the air quality standard permit:
    - The setback distance from the property boundary for brush, untreated wood waste, yard waste, or mulch will 50 feet.
    - Except for initial start-up and shut-down, the receiving chamber on all grinders will be adequately filled prior to commencement of grinding. The receiving chambers will also remain full during grinding operations to minimize emissions from the grinder or wood chipper. In addition, the Owner will have portable watering equipment available during the grinding operations.
    - All conveyors which off-load materials from grinders will have available a water or mechanical dust suppression system.

   - These controls will be utilized, as necessary, for maximum control of dust when stockpiling ground material.

- Implementation of an Odor Management Plan.

- Investigation of visible air emissions and implementation of controls as necessary.

4.10.2 Odor Management Plan

An Odor Management Plan will be implemented at the landfill and will include, but is not limited to, the following procedures:

- Incoming waste will be promptly landfilled.

- Identification of waste that require special attention, including septage, grease trap waste, dead animals, and leachate, and immediately cover and compact with daily cover or other waste.

- Identification of loads with significant odors by the Gate Attendant, and notification to the working face personnel. In the event waste is identified at the CCS with significant odors, landfill personnel will remove the roll-off from the CCS, and dispose of said waste at the working face.

- Freshly landfilled waste will be promptly covered with daily cover at the end of each operating day.

- Keeping the size of the working face to a minimum so waste can be covered quickly.

- Ponded water at the site will be controlled as detailed in Section 4.19 of this SOP.

- Damage or erosion of daily, intermediate, or final cover will be repaired within 5 days of detection (weather permitting) consistent with Section 4.18.5.

- Regular inspection of vapor-tight gaskets on leachate riser end caps. Damaged or deficient gaskets will be repaired, as soon as practicable following the inspection.

- Leachate will be disposed and handled as described in Attachment 12 – Leachate and Contaminated Water Plan.

- Control of landfill gas emissions as detailed in the Landfill Gas Management Plan.

- Clean up spills of odorous materials as soon as possible.

- Accidental fires will be controlled as outlined in Section 6 of this SOP.

4.11 DISEASE VECTOR CONTROL (30 TAC §330.151)

The need for vector control (control of rodents, flies, mosquitoes, etc.) will be minimized through proper daily site operations, which include the application of daily and intermediate cover. The extent of the working face will also be minimized, as described in Section 4.2.1. Landfill personnel will make weekly checks for insects and rodents and will report problems to the Landfill Manager or designee. Based on the results of the inspections, a licensed professional may apply pesticides or rodenticides to enhance vector control. Care will be taken to ensure that proper chemicals are used and that they are properly applied.

In addition, if birds become a nuisance at the landfill, pyrotechnics or other similar techniques may be used to manage the bird population at the landfill.

4.12 MAINTENANCE OF SITE ACCESS ROADS (30 TAC §330.153)

The site entrance road will be an asphalt or concrete paved roadway, or other suitable material that transitions into onsite access roads, including perimeter and interior haul roads. The landfill access roads (i.e., perimeter and other constructed interior haul roads) will be constructed of crushed stone, gravel, caliche, concrete paving, asphalt paving, or other suitable material and maintained in a clean and safe condition. All-weather landfill access roads will be maintained for access from the public roadway to the waste disposal area(s) and CCS during wet-weather operation. In addition to the all-weather roads, some portions of the onsite roads will be maintained for use during dry weather only.

The all-weather entrance road will be maintained in a manner to limit tracking of mud and associated debris onto FM 939. If mud and/or associated debris is tracked onto FM 939 at the landfill entrance, it will be removed at least once per day on days when mud and associated debris are being tracked onto FM 939. Mud and associated debris that has accumulated at the landfill entrance and this section of FM 939 will removed using a motor grader or other suitable equipment capable of removing the mud and debris accumulations.

Dust will be controlled on the onsite access roads by periodic spraying from a water truck or other means as-needed during periods of significantly dry weather. Dust from onsite access roads will not become a nuisance to surrounding areas. A water source and necessary equipment or other means of dust control approved by the TCEQ will be provided.

Grading equipment will be used, as necessary, to control or remove mud accumulations on onsite access roads. All onsite access roads will be inspected for damage due to traffic or erosion following significant rainfall events. In any instance, the minimum inspection frequency of the site access roads will be monthly. Crushed stone, concrete rubble, masonry demolition debris, or other similar material will be delivered to the site on an as-needed basis for use in maintaining passable onsite access roads during wet weather. All onsite access roads will be maintained in a clean and safe condition. Site access roads will be regraded on an as-needed basis, to minimize depressions, ruts and potholes. Refer to Table 4.1 of this SOP for the site inspection and maintenance schedule.

4.13 SALVAGING AND SCAVENGING (30 TAC §330.155)

Salvaging will not be allowed to interfere with disposal of solid waste or to create public health nuisances. Salvaged materials will be considered as potential recycled materials. Salvaged items will be removed from the landfill property routinely and will not be stored in excess of 180 days to prevent the items from becoming a nuisance, to preclude the discharge of pollutants from the area, and to prevent an excessive accumulation of the material at the landfill. Special wastes received at the landfill will not be salvaged. Additionally, pesticide, fungicide, rodenticide, and herbicide containers will not be salvaged. Scavenging will be prohibited at all times.

4.14 ENDANGERED SPECIES PROTECTION (30 TAC §330.157)

Landfill operations will not result in the destruction or adverse modification of the critical habitat of endangered or threatened species, or cause or contribute to the taking of any endangered or threatened species. Further details on threatened and endangered species habitat, including coordination letters to U.S. Fish and Wildlife Service and the Texas Department of Parks and Wildlife by Horizon Environmental Services, Inc., are located in Parts I/II, Appendix I/IIA of this permit application. As noted in these coordination letters, "The Site is not in an area designated as critical habitat for any listed threatened or endangered species, nor does the site provide suitable habitat for any federally-listed species." In addition, the site will follow the requirements set forth in the Biological Assessment, including the Management Plan, as provided in Part I/II, Appendix I/IIG.

4.15 LANDFILL GAS MANAGEMENT (30 TAC §330.159)

The monitoring of LFG at the landfill will be in accordance with Attachment 11 - Landfill Gas Management Plan. Reports and other submittals will be included in the Site Operating Record and submitted to the TCEQ, consistent with TCEQ requirements.

4.16 TREATMENT OF ABANDONED OIL, GAS, AND WATER WELLS (30 TAC §330.161)

There are no known abandoned water, crude oil, or natural gas wells within the permit boundary. However, if such abandoned wells are encountered during the course of site development, the Owner will immediately provide written notification to the TCEQ's Executive Director of the location of these wells.

Within 30 days of finding any abandoned water wells, the Owner will provide written certification to the TCEQ that all such wells have been capped, plugged, and closed in accordance with all applicable rules and regulations of the TCEQ or other applicable state agency.

For abandoned onsite crude oil or natural gas wells, or other wells associated with mineral recovery, that are under the jurisdiction of the Railroad Commission of Texas, within 30 days of discovery, the Owner will provide the TCEQ with written notification of the location of such wells. Within 30 days of plugging such wells the Owner will provide the TCEQ with written certification that such wells have been properly capped, plugged, and closed in accordance with all applicable rules and regulations of the Railroad Commission of Texas.

A copy of any well-plugging report to be submitted to the appropriate state agency will also be submitted to the TCEQ within 30 days after the well has been plugged. The Owner will also submit a permit modification (if applicable) identifying any proposed changes to the liner installation plan as a result of any well abandonment.

4.17 COMPACTION OF SOLID WASTE (30 TAC §330.163)

Compaction of incoming waste provides more efficient use of available space and reduces the amount of settling after the fill is complete. The incoming waste will be spread in layers and compacted. Compaction of the waste will be accomplished by repeated passes of a landfill compactor or similar equipment. Adequate compaction will be accomplished to minimize future consolidation and settlement and provide for the proper application of intermediate and final cover.

4.18 SOIL MANAGEMENT: PLACEMENT, AND COMPACTION OF DAILY, INTERMEDIATE, AND FINAL COVER (30 TAC §330.165)

4.18.1 Soil Management

Management of soil for use in and around the landfill will be an ongoing activity at the facility. In general, soil for use as daily cover, intermediate cover, final cover, and other uses will be maintained onsite. The volume of the soil stockpile used for application of daily cover will depend on the size of the working face, but will be adequate to cover the working face with at least 6-inches, as described in Section 4.18.2. Soil used for fire control will be available within 1,880 feet of the working face (the exact distance may vary depending the size of the working face, as described in Section 6.1). The stockpile(s) will consist of soil that has not previously come in contact with waste. Section 6.1 lists the minimum size of the soil stockpile that will be maintained for firefighting purposes. This stockpile will be routinely replenished. If the volume of the soil stockpile is reduced to less than the minimum size, it will be replenished prior to the next day of waste acceptance.

4.18.2 Daily Cover

Daily cover of waste is necessary to control disease vectors, windblown waste, odors, fires, and scavenging. At the end of each working day, at least 6 inches of soil cover material that has not previously been mixed with garbage, rubbish, or other solid waste will be placed over all solid waste received subsequent to the previous cover placement.

Soil used as daily cover will have a minimum thickness of 6 inches. To ensure that the daily cover will be adequate (i.e., minimize vectors, contaminated stormwater runoff, odors, etc.), the following procedures will be followed:

- The daily cover will be sloped to drain.

- The daily cover will be spread and compacted by a bulldozer or compactor to minimize infiltration of storm water, graded to drain, and will not have waste visibly protruding through it.

- The Landfill Manager or designee will visually verify during placement that a minimum of 6 inches (compacted thickness) of daily cover soil has been placed. The Landfill Manager or designee will document on a daily basis that he/she has visually verified the thickness and condition in the Cover Application Log, as described in Section 4.18.6 of this SOP.

- After each rainfall event, the Landfill Manager or designee will inspect all daily cover areas for erosion, exposed waste or other damage, and repair, as needed as described in Section 4.18.5. Runoff from areas that have intact daily cover is considered to not have come in contact with the working face or leachate.

- The Landfill Manager or designee will inspect for seeps from daily cover. Seepage water from waste below the daily cover will be managed as contaminated water. Contaminated water will be treated as outlined in Attachment 12 - Leachate and Contaminated Water Plan.

Inactive areas with 6 inches of daily cover will be inspected weekly for erosion, ponded water, seeps, protruding waste, or other detrimental conditions that may cause contaminated runoff from the daily cover. After a period of 180 days, an additional 6 inches of earthen material not previously mixed with garbage, rubbish or other solid waste will be placed over inactive areas with daily cover for a total of not less than 12 inches of cover. This 12-inch-thick layer of cover soil will be classified as "intermediate cover" as described in Section 4.18.3 of this SOP. Once the area becomes active again, the top 6 inches may be stripped off for use as daily cover, provided it can be removed without contamination by contact with solid waste.

4.18.3 Intermediate Cover

All areas that have received waste but will be inactive for longer than 180 days will be covered with an additional 6 inches of well-compacted cover material, for a total cover thickness of at least 12 inches within 180 days after placement of daily cover. The top six inches of the intermediate cover will be capable of sustaining native plant growth and will be seeded, or sodded following application in order to control erosion. The intermediate cover will be graded and maintained to prevent ponding. Runoff from areas that have intact intermediate cover is not considered as having come into contact with the working face or leachate.

The Landfill Manager or designee will inspect intermediate cover at the site weekly for erosion, ponded water, seeps, protruding waste, or other detrimental conditions that may cause contaminated runoff. Erosion gullies or washed-out areas will be repaired within 5 days of detection, weather permitting, as described in Section 4.18.5.

4.18.4 Final Cover

Consistent with the Attachment 9 - Final Closure and Post-Closure Care Plan, final cover will be placed in a manner compatible with ongoing fill activities and landfill development. Surface water will be managed throughout the active life of the landfill to minimize infiltration into the filled areas and to minimize contact with solid waste. Erosion of final cover will be repaired within 5 days of detection, weather permitting, by restoring the cover material, grading, compacting, and seeding, as necessary. Monthly inspections and restorations will be implemented during the entire operational life. Post-closure care inspection procedures are outlined in Attachment 9, including monitoring final cover throughout the entire post-closure care period of the landfill. Refer to Table 4.1 of this SOP for a site inspection and maintenance schedule.

In general, final cover placement over completed portions of the site will consist of the following steps:

- Survey controls will be implemented to control the filling of solid waste to the appropriate elevations.
- The final cover system layers will be constructed. Testing of the various components of the final cover system will be performed in accordance with the Attachment 9.
- A final cover certification report complete with an as-built survey will be prepared by an independent registered professional engineer and submitted to the TCEQ for approval.
- The TCEQ-approved final cover certification report will be maintained in the Site Operating Record and Cover Application Log (see Section 4.18.6 of this SOP) will be updated to reflect the area where final cover has been placed. The TCEQ region office will also be notified that final cover placement has occurred at the landfill.
- The final cover system, including the erosion control structures (drainage swales and downchutes), will be maintained during and after construction.

4.18.5 Erosion of Cover

Intermediate and final cover will be inspected on a weekly and monthly basis, respectively, for erosion. Inactive areas with daily, intermediate, and final cover also will be inspected for erosion following significant rainfall events. A significant rainfall event is defined as precipitation greater than 0.5 inches. Erosion gullies or washed-out areas deep enough to impact the final or intermediate cover will be repaired within 5 days of detection (weather permitting) by restoring the cover material, grading, compacting, and/or seeding or sodding. An eroded area is considered to be deep enough to impact the final or intermediate cover if it exceeds four inches in depth as measured perpendicular to the slope. The TCEQ region office may approve more time for cover repairs if the extent of the damage indicates that more time will be needed or if repairs are delayed due to weather conditions.

The date of detection of erosion and date of completion of repairs, including justification of delays, will be documented in the Cover Application Log. Cover inspections will be conducted throughout the operational life of the landfill and post-closure care period.

4.18.6 Cover Application Log

Throughout the landfill operation, a cover application log will be maintained and be readily available for inspection in accordance with 30 TAC §330.165(h). For daily cover and intermediate cover, the log will specify the area covered (by use of the grid system), how it was placed, and when it was completed. For final cover, the log will show the final cover area and refer to the final cover certification report for each area. Each entry will be certified by the signature of the Landfill Manager or designee that the work was accomplished as stated in the log. Repairs will be documented in the appropriate cover log, including inspections for erosion, the findings, and the action taken.

4.19 PREVENTION OF PONDED WATER (30 TAC §330.167)

The prevention of ponding water is necessary to control infiltration of water into the waste. Additionally, ponded water can be a source of odor and breeding grounds for vectors. This ponding water prevention plan to be implemented at the facility includes, but is not limited to, the following procedures:

Preventative Actions:

- Inspections of the landfill cover, consist with Section 4.18 of this SOP, following periods of wet weather, to identify potential ponding locations.
- Routine site grading and maintenance to provide drainage and minimize the ponding of water over areas containing waste.

Corrective Actions:

- Should ponding occur, the water will be removed and the depressions filled within seven days of detection.
- If the ponded water has come into contact with waste, leachate, or waste-contaminated soils, it will be treated as contaminated water and handled in accordance with Attachment 12 - Leachate and Contaminated Water Management Plan.

4.20 DISPOSAL OF SPECIAL WASTES (30 TAC §330.171)

Acceptance of special wastes, as defined in 30 TAC §330.3(148), will be performed in accordance with 30 TAC §330.171. The acceptance of a special waste not specifically identified in 30 TAC §330.171(c) and 30 TAC §330.171(d) requires prior written approval from the TCEQ. The special wastes that will be accepted at the site are discussed in the following subsections.

4.20.1 Dead Animals and Slaughterhouse Waste

Dead animals and slaughterhouse wastes will be accepted at the landfill (including, but not limited to, hatchery waste, turkey eggs, chicken eggs, etc.) that are delivered to the site independent of other wastes. Dead animals and slaughterhouse wastes will be buried and covered with a minimum of 3 feet of other solid waste or a minimum of 2 feet of earthen material immediately upon receipt.

4.20.2 Regulated asbestos-containing material (RACM)

RACM as defined in 40 Code of Federal Regulations §61 may be accepted at the landfill. Prior to the receipt of RACM, the Landfill Manager or designee will dedicate a specific area or areas of the landfill that will receive RACM and will provide written notification to the TCEQ of the area or areas to be designated for receipt of RACM. After the initial authorization to receive RACM is issued, additional areas may be designated by providing written notice to the TCEQ of the location of the additional areas. The Landfill Manager will maintain the following records in the Site Operation Record related to disposal of RACM:

- The location of the area(s) designated to receive RACM must be surveyed and marked by a registered professional land surveyor and identified on a current site diagram. A copy of the current site diagram identifying the RACM area(s) will be submitted to the TCEQ immediately upon completion of the diagram.

- Each load of RACM that arrives on landfill will be documented. This documentation will include the volume of material, and the location and depth of its disposal.

- Delivery of RACM will be coordinated with the Landfill manager or his designee so that the RACM will arrive during times that it can be properly managed by landfill personnel.

- RACM will only be accepted at the landfill in tightly closed and unruptured containers or bags or will be wrapped with at least six-mil polyethylene.

- At a minimum, RACM will only be placed 20 feet or more inside (below) the final sideslope grades, and 10 feet or more below the topslope final grades.

- Bags of RACM will be carefully unloaded and placed in the disposal location. The bags will be promptly covered with 12 inches of clean soil or 3 feet of MSW containing no asbestos. Care will be taken that the bags are not ruptured.

- Upon closure of the landfill, a notation indicating that the landfill accepted RACM will be placed in the deed record. This notation will indicate where the RACM was disposed of on the property by showing its location on a site diagram. A copy of this documentation will be provided to the TCEQ.

- In the event RACM is spilled prior to proper disposal, the following procedures will be followed by the landfill personnel:

- The Landfill Manager or his designee will immediately be notified of the spill.
- The manifested owner of the RACM will be notified of the spill, and a request for trained personnel from the RACM owner will be made to assist in the cleanup, if appropriate.
- A landfill employee trained in asbestos handling and disposal processes will lead the cleanup of the spilled RACM.
- The RACM will be sprayed with water or other appropriate dust suppressant so that dust or windblown RACM is not generated. Spraying will be sufficient to control dust, without washing the spilled RACM away from the cleanup area.
- Once dust has been suppressed, the RACM will be collected by shovel or scrapped into a front-end loader and transported to the disposal area. Care will be taken that all of the RACM is removed from the spill area.
- If the quantity of spilled RACM is too large for landfill personnel to address, landfill personnel will immediately contact a licensed RACM abatement company, so that the RACM can be contained by persons trained in RACM cleanup.

4.20.3 Nonregulated asbestos-containing material (non-RACM)

Nonregulated asbestos-containing materials (non-RACM) may be accepted for disposal at this landfill provided the wastes are placed on the active working face and covered in accordance with 30 TAC 330.171(c)(4). Under no circumstances may any material containing non-RACM be placed on any surface or roadway that is subject to vehicular traffic or disposed of by any other means by which the material could be crumbled into a friable state.

4.20.4 Empty Containers

Empty containers which have been used for pesticides, herbicides, fungicides, or rodenticides will be disposed at the site in accordance with the following:

- The containers are tripled rinsed prior to receipt at the landfill.
- The containers are rendered unusable prior to or upon receipt at the landfill.
- The containers are covered by the end of the same working day they are received.

Containers for which triple-rinsing is not feasible or practical (e.g., paper bags, cardboard containers) may be disposed at the landfill consistent with the provisions of Section 4.20.5.

4.20.5 Municipal Hazardous Waste from Conditionally Exempt Generators

Municipal hazardous waste from a conditionally exempt small quantity generator (CESQG) may be accepted at the landfill without further approval from the TCEQ provided the amount of waste does not exceed 220 pounds per month per generator, and provided the landfill owner or operator authorizes acceptance of the waste.

4.20.6 Sludge, Grease Trap, Grit Trap, or Municipal Liquid Wastes

Sludge, grease trap waste, grit trap waste, or liquid wastes from municipal sources will be accepted at the landfill for disposal only if the waste has been treated or processed and the treated/processed material has been tested, in accordance with Test Method 9095 (Paint Filter Liquids Test), as described in "Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods" (EPA Publication Number SW 846), as amended, and is certified to contain no free liquids.

4.20.7 Used Oil Filters

Used oil filters (to include filters that have been crushed and/or processed to remove free-flowing used oil) from non-household generators will not be accepted at the landfill. However, used oil filters from internal combustion engines from household generators may be accepted at the landfill if the filter has been:

- Crushed to less than 20% of its original volume to remove all free-flowing used oil.
- Processed by a method other than crushing to remove all free-flowing used oil. A filter is considered to have been processed if:

  (i) the filter has been separated into component parts and the free-flowing used oil has been removed from the filter element by some means of compression in order to remove free-flowing used oil;

  (ii) the used filter element of a filter consisting of a replaceable filtration element in a reusable or permanent housing has been removed from the housing and pressed to remove free-flowing used oil; or

  (iii) the housing is punctured and the filter is drained for at least 24 hours.

4.21 VISUAL SCREENING OF DEPOSITED WASTE (30 TAC §330.175)

Methods for visually screening the working face and deposited waste include, but are not limited to, the following items consistent with 30 TAC §330.175:

- Orienting the working face away from FM 939, as feasible, and confining the working face to a minimum area, as described Section 4.2.1.

- Covering the working face daily with daily cover, and applying intermediate and final cover to the landfill, including applying vegetation to intermediate and final cover, as described in Section 4.18.

- Developing the aerial fill portion of the landfill from the exterior to the interior when warranted (i.e., by constructing landfill sideslopes prior to filling operations in the interior of the landfill).

- Providing an 8-foot privacy fence along the western permit boundary adjacent and parallel to FM 939, as depicted in Part III, Drawing 1.2.

- Maintaining existing trees and other vegetation near the landfill permit boundary that are adjacent to FM 939 to the extent practical for landfill development.

4.22 LEACHATE AND GAS CONDENSATE RECIRCULATION (30 TAC §330.177)

The Landfill Manager may recirculate leachate or gas condensate derived from the landfill into the areas of the landfill that have a leachate collection system and composite liner, as defined in 30 TAC §330.331(a)(2).

As described in Attachment 12 – Leachate and Contaminated Water Management Plan, leachate and/or gas condensate will be either recirculated back to the landfill or disposed at a local wastewater treatment plant (WWTP) permitted by the TCEQ. Recirculation may be performed by either injecting through vertical or horizontal pipes in the waste, or spraying leachate or gas condensate water onto the working face at the allowable annual rates per acre, as described in Attachment 12. Procedures for recirculating leachate or gas condensate are described in Attachment 12, Section 5. Consistent with §330.125(b)(4), the Landfill Manager will maintain records of the date, time, volume, and location (i.e., landfill unit or sector) that leachate or gas condensate is recirculated back into the landfill.

Table 4.1 Site Inspection and Maintenance Schedule

ITEM	TASK	SCHEDULE
Fence/Gates	Inspect perimeter fence and gates for damage, gaps, intrusions and the like. Make temporary repairs within 24-hours of detection (weather permitting) and permanent repairs within the timeframe approved by the TCEQ region office.	Monthly
Windblown Waste	Inspect working fence area, wind fences, access roads, entrance area, and perimeter fence for loose trash. Clean up upon detection.	Daily
Waste Spilled en Route to the Site	Inspect portions of SH 31 and FM 939 which are used for waste delivery at least two miles in either direction of the landfill entrance. Clean up upon detection.	Daily
Landfill Markers	Inspect all landfill markers for damage, color coding, and general location. Correct or replace damaged markers within 15 days of detection.	Monthly
Landfill Access Roads	Inspect landfill access roads for damage from vehicle traffic and erosion. Repair onsite access roads, as needed, based on inspections. Inspect FM 939 and landfill entrance for excessive mud and/or debris accumulation. Remove mud/debris accumulations daily using grading equipment or other road cleaning equipment.	Monthly Daily (Wet Weather) Weekly (Otherwise)
Daily Cover	Inspect for proper placement thickness, and compaction. Remedy deficiencies as needed.	Daily (Active) Weekly (Inactive)
Intermediate Cover	Inspect for proper placement, thickness, erosion, vegetation, compaction and for presence of waste or other contamination. Remedy deficiencies as needed within 5 days of detection, weather permitting.	Weekly
Final Cover	Inspect for proper placement, thickness, compaction, slope, settlement, vegetation, and erosion. Maintenance will be ongoing throughout post-closure care period. Remedy deficiencies as needed within 5 days of detection, weather permitting.	Monthly

Table 4.1 (Continued)

ITEM	TASK	SCHEDULE
Erosion Control	Inspect the intermediate and final cover for signs of erosion. Damaged areas will be repaired within 5 days (weather permitting) of detection by restoring cover material, grading, compaction, and/or seeding or sodding.	Weekly (Interim), Monthly (Final), and following wet weather.
Disease Vector Control	Inspect landfill facility for insects and rodent populations and report them to the Landfill Manager.	Weekly
Ponding Water	Inspect landfill cover for potential ponding water locations. Grade and compact potential areas within 7 days of detection, weather permitting.	Weekly (Following Wet Weather)
CCS Containers	Inspect the containers for spills and leaks, and repair or replace containers, if necessary, as a result of these inspections.	Daily

5 DETECTION AND PREVENTION OF DISPOSAL OF UNAUTHORIZED WASTES [30 TAC §330.127(5)]

5.1 GENERAL

In accordance with EPA's RCRA Subtitle D criteria, 40 CFR 258.20, and 30 TAC §330.127(5), the Owner will maintain a program to exclude unauthorized waste, including regulated hazardous and PCB waste from the landfill, as defined in 40 CFR 261 and 30 TAC §330.3. Wastes not authorized for disposal at the landfill include waste defined in 30 TAC §330.15(e) and other specific waste not accepted at the discretion of the landfill. The following wastes will specifically be prohibited from acceptance at the landfill, unless authorized for acceptance at the CCS (see Section 4.2.2):

- Regulated Hazardous Wastes,
- Wastes containing PCBs,
- Radioactive materials, as defined in Chapter 336 of TCEQ regulations,
- Class 1 Industrial Solid Waste,
- Untreated medical wastes,
- Containers holding liquid waste, except as provided in §330.15(e)(6)(B),
- Lead-acid batteries,
- Used-Oil Filters, except as provided under §330.171,
- Do-it-yourself used motor vehicle oil,
- Whole used or scrap tires,
- CFC Compounds or large items or white goods containing CFCs, unless handled in accordance with 40 CFR §82.156(f), and
- Wastes with free liquids (as determined by the paint filter test).

Whole used or scrap tires are prohibited from disposal at the landfill, but may be accepted at the CCS. Tires will not be disposed at the working face of the landfill, but will be properly stored at the CCS as described in Section 4.2.2, and then transported to an appropriate disposal or recycling facility.

The detection and exclusion program to be implemented at the landfill will include at least the following steps:

- A detection and exclusion training program for landfill personnel to include the following:
  - Recognizing and identifying unauthorized wastes at the landfill entrance;
  - Recognizing and identifying unauthorized wastes at the working face;
  - How to control site access;
  - Procedures to be implemented in the event of identification of regulated and unauthorized wastes; and
  - How to perform a random inspection.
- A sign will be posted at the site entrance that identifies the types of waste that are unauthorized for disposal at the landfill and CCS.
- Random inspections of incoming loads and compactor vehicles.
- Records of all inspections.
- Monitoring for unauthorized wastes at the landfill entrance.
- Monitoring for unauthorized wastes at the working face and CCS. Spotters will observe the unloading of waste from the vehicles and observe the waste as it is broken apart for compaction at working face or discharged into containers at the CCS.
- Controlling site access.
- Notification to TCEQ of any incident involving the disposal of regulated hazardous or PCB waste at the landfill. The TCEQ Region office and any other local pollution agency with jurisdiction, that has requested to be notified, will be notified via telephone within 24 hours and the TCEQ Austin Office, MSW Section will be notified in writing with a copy to the TCEQ Region Office within 14 days.

5.2 LOAD INSPECTION PROCEDURE

The Gate Attendant will be alert for signs of unauthorized waste, including unusual odors or visual signs of heat, fumes, large containers, unusual dust, liquids, or sludge when collection vehicles, landfill customers, etc. enter the facility. If any signs of unauthorized waste are detected by the Gate Attendant, the suspect load will be directed to the working face for an inspection. Additionally, all incoming loads will be observed and visually inspected at the working face. Landfill personnel will immediately report any indication of unauthorized waste to the Landfill Manager or designee. In turn, the Landfill Manager or designee will direct appropriate landfill personnel to conduct a thorough evaluation of the load (see below).

In the event an incoming load is suspected of containing unauthorized waste or the incoming load has been randomly selected for inspection, the following procedures will be implemented:

- The driver will be directed to a load inspection area located near the working face over an approved lined area, where the load will be discharged from the vehicle.
- The inspector will break up the waste pile and inspect the material for potential hazardous or unauthorized waste. Characteristics of unauthorized waste might be unusual odors, heat, fumes, large containers, unusual dust, liquids, or sludge.
- Suspicious wastes will be flagged and samples may be taken for laboratory analysis.
- Known unauthorized waste will be placed back into the vehicle and the driver will be instructed to depart the site. Should any regulated hazardous waste be detected or suspected, the entire load will be refused.

In addition to the above procedure, incoming loads of both compactor and other vehicles will be inspected on a random basis. The Landfill Manager or designee will be responsible for determining the random inspection schedule, but a minimum of one percent of compactor incoming loads and a minimum of one percent of other vehicle incoming loads will be inspected. The driver of the randomly selected load will be notified prior to unloading waste and the procedures for inspection of incoming loads, as described above, will be implemented. Additional waste screening will take place as described in Section 4.2 of this SOP.

During the inspection, the load inspectors will wear personal protective equipment consistent with appropriate requirements.

5.3 RECORDKEEPING

The Landfill Manager or designee will maintain and include in the Site Operating Record the following:

- Load inspection reports.
- Records of regulated hazardous or PCB waste notifications.
- Records of unauthorized waste removed from the site, including the type of waste, generator/transporter, and date of receipt.
- Personnel training records.

Load inspection reports, recorded on standardized forms, will be completed for each inspected load. The reports will include at a minimum, the date and time of inspection, the name and address of the hauling company and driver, the type of vehicle, the size and source of the load, contents of the load, indicators of unauthorized waste, and results of the inspection.

The TCEQ will be notified whenever regulated hazardous or PCB waste is detected. Records of the notification will be kept in the Site Operating Record and will include the date and time of notification, the individual contacted, and the information reported.

Personnel training records will be maintained in the Site Operating Record and will include evidence of successful completion of the training, type of training received, and the name of the instructor.

5.4 TRAINING

Maintenance Workers, Equipment Operators, and Customer Service Representatives will maintain an understanding of this SOP and will be trained in the following areas:

- Load inspection procedures.
- Identification of unauthorized wastes, including regulated hazardous and PCB waste.
- Waste handling procedures.

The Landfill Manager or designee will maintain an understanding of this SOP and will be trained in the above areas as well as customer notification and recordkeeping. Documentation of training will be placed in the Site Operating Record.

5.5 MANAGING UNAUTHORIZED WASTES

Unknown wastes undergoing analysis must be properly segregated and protected against the elements, secured against unauthorized removal or accidental burial, and isolated from other wastes and activities. An effort will be made to identify the entity that deposited the suspected unauthorized waste and to have this entity return to the site and assume full responsibility for proper disposal of the waste.

Known unauthorized wastes detected during unloading of waste or an inspection will be returned immediately to the hauler. Unauthorized waste that is not discovered by landfill employees until after it is unloaded shall be returned to the vehicle that delivered the waste. If the hauler is not available or has left the site, the waste will be safely stored until provisions for removal by the hauler and/or disposal at an authorized facility can be arranged.

If regulated hazardous or PCB wastes are detected, the TCEQ Region office will be notified via telephone within 24 hours and the TCEQ Austin Office MSW Section will be notified in writing with a copy to the TCEQ Region Office within 14 days. As soon as is practical, the hauler will be required to remove the hazardous waste from the site. Prior to removal, the hauler must demonstrate that he has an EPA identification number, package the waste in accordance with TxDOT regulations, and properly manifest the waste designating a permitted facility to treat, store, or dispose of the hazardous waste.

6 FIRE PROTECTION PLAN (30 TAC §330.129)

6.1 FIRE PREVENTION PROCEDURES

The following steps will be taken regularly by designated landfill personnel to prevent fires:

- Open burning is not authorized at any time at the landfill.
- Burning waste will be prevented from being unloaded in the active area of the landfill. The Gate Attendant, Spotters, and Equipment Operators will be alert for signs of burning waste such as smoke, steam, or heat being released from incoming waste loads. Additionally, smoking will not be allowed in active areas of the landfill. Smoking will be confined to specific areas that are away from the active working area, re-fueling areas, and other fire-sensitive areas.
- Landfill equipment will not remain in the active area of the landfill overnight.
- Fuel spills will be contained and cleaned up immediately.
- Dead trees, brush, or vegetation adjacent to the landfill will be removed and relocated, and grass and weeds mowed so that forest, grass, or brush fires cannot spread to the landfill.
- A stockpile of soil adequately sized to cover the working face will be maintained adjacent to the working face or active disposal area for fire protection (i.e. to cover the working face within one hour) of the working face or active disposal area for fire protection at all times. Two haul trucks will be available on-site for this task, and one excavator to load the haul trucks. The stockpile will be sized to cover the working face with a six-inch layer of earthen material. The following calculations are presented to demonstrate the adequacy of the maximum size soil stockpile that will be maintained within 1,880 feet of the working face:

Demonstration of Stockpile Adequacy: As noted in Section 4.2.1 of this SOP, the maximum size of the working face will be approximately 30,000 square feet. For covering this size of working face, the required stockpile will be 560 cubic yards (i.e., 30,000 sq. ft. x 0.5 ft (cover) = 15,000 cubic feet or 560 cubic yards). This soil volume would be distributed across the working face by one of the earth movers required on-site (a front-end loader or bulldozer, see Section 3 of this SOP). Additional equipment will be used, if applicable, to smother the fire within one hour of being detected.

The following calculation demonstrates the maximum distance from the working face that soil will be stockpiled to provide a 0.5-foot layer within one hour and number of haul vehicles required for this task:

Volume of Daily Cover:	560	cy
Size of Haul Vehicles :	20	cy
Number of Haul Vehicles:	2	
*Number of Loads:	14	
*Number of Trips:	28	
Average Truck Speed:	10	mph
Average Truck Speed:	880	fpm
Length of Time to Cover Working Face:	60	minutes
Distance from Working Face:	1,880	ft

*A load is defined as one load per piece of equipment or 20 cubic yards of soil. A trip is defined as the number of times the equipment travels to and from the soil stockpile. Therefore, the number of trips is twice as many as the number of loads.

In the event there are two working faces in operation due to wet weather, the maximum total size of both working faces will be less than 30,000 square feet. During this time, two soil stockpiles will be maintained less than 1,880 feet from both working faces.

6.2 GENERAL RULES FOR FIRES

The Landfill Manager will meet with the local Fire Department in a pre-planning session to discuss fire prevention as well as procedures to be implemented in the event of a fire. The following rules will be implemented in the event of a fire at the landfill:

- If readily available, the Landfill Manager or designee will first call the local Fire Department by calling 911, and then call the City of Waco Fire Department, pursuant to an inter-local mutual aid agreements that may be in place at the time. If the Landfill Manager or designee are NOT readily available, any employee will contact the Fire Department by calling 911.
- No one person will attempt to fight the fire alone.
- Do not attempt to fight the fire without adequate personal protective equipment.
- For fires in unknown materials, the Landfill Manager or Landfill Supervisor will call Chemical Transportation Emergency Center (CHEMTREC) at 1-800-424-9300.
- Alert other facility personnel.

- Assess extent of fire, possibilities for the fire to spread, and alternatives for extinguishing the fire.

- If it appears that the fire can be safely extinguished with available firefighting devices until arrival of the Fire Department, attempt to contain or extinguish the fire.

- If a fire occurs that is not extinguished within 10 minutes of detection, the Landfill Manager or designee will contact the Fire Department immediately. Additionally, the Landfill Manager or designee will contact the TCEQ region office via telephone within four hours of the fire being detected and in writing within 14 days with a description of the fire and the resulting response.

- Upon arrival of Fire Department personnel, direct them to the fire and provide assistance as requested.

- All landfill employees will be trained in and be familiar with the use and limitations of firefighting equipment available onsite.

- Firefighting methods include smothering with soil, separating burning material from other waste, and spraying with water from the water truck or water pumped from nearby ponds or streams. If detected soon enough, a small fire may be fought with hand-held fire extinguishers. Under this circumstance, the fire area should be watered or otherwise controlled to ensure that the fire is out.

The site will follow the recommendations of the local fire department regarding the type, size, location, and number of fire extinguishers. At a minimum, each piece of equipment will be equipped with a fire extinguisher. Each fire extinguisher will be fully charged and ready for use at all times, including after an incident in which the fire extinguisher was used, the extinguisher will be refilled or replaced. Each extinguisher will be inspected on an annual basis and recharged as necessary. A qualified service company will perform these inspections, and all extinguishers will display a current inspection tag. Inspection and recharging will be performed following each use. At a minimum, the maintenance/administration building, scale house, and all landfill equipment and vehicles will be equipped with fire extinguishers.

As discussed in Section 2.2 each employee (except temporary laborers) will receive training in fire and explosion response procedures. This includes firefighting training to acquaint employees with the use and limitations of on-site firefighting equipment. Documentation of all employee training will be kept in the employee's file and Site Operating Record, and be readily available to a TCEQ inspector. In the event of a significant fire at the landfill, the Fire Protection Plan will be reviewed and updated, as appropriate.

6.3 SPECIFIC FIRE-FIGHTING PROCEDURES

Prior to initial operation of the landfill, the Landfill Manager or designee will meet with the local Fire Department in a pre-planning session to discuss fire prevention as well as procedures to be implemented in the event of a fire. The following procedures will be followed in the event of a fire at the Landfill (see also Section 6.2):

- If a fire occurs on a vehicle or piece of equipment, the equipment operator will bring the vehicle or equipment to a safe stop. If safety of personnel will allow, the vehicle must be parked away from fuel supplies, uncovered solid wastes, and other vehicles. The engine will be shut off and the brake engaged to prevent movement of the vehicle or piece of equipment.

- If a fire occurs at the working face, either the burning area will be isolated and pushed away from the working face quickly, or fire breaks will be cut around the fire before it can spread. If this is not possible or is unsafe, efforts to cover the working face with soil will be initiated immediately to smother the fire, provide done safely with onsite equipment.

- The mulching operation, brush collection area (adjacent to mulching operation), and CCS are landfill operations that store, process, and/or dispose of combustible materials. The mulching operation and brush collection area contain brush, untreated wood, yard waste, and mulch. The CCS may contain brush, wood waste, yard waste, municipal solid waste, and the recyclables described in Section 4.2.2. In the event a fire occurs at one of these operations, the steps described in Section 6.2 – General Rules for Fires will be implemented. Additionally, if it appears that a fire at one of these operations can be safely fought, landfill personnel will attempt to extinguish the fire by use one of the following methods, depending on the waste stream involved:

    1. Petroleum free materials, such as brush, wood waste, yard waste, mulch, newspaper/cardboard, municipal solid waste may be extinguished by spraying with water from the water truck and taking measures using site equipment to diminish heat and segregate materials to minimize the potential for the fire to spread until arrival of the local Fire Department. Additionally, these materials may be extinguished by using dry fire extinguishing agents or devices, or smothering with soil.

    2. Materials containing petroleum products, such as tires, will be extinguished using dry fire extinguishing agents or devices, or smothering with soil.

    3. Site personnel and equipment will be utilized to assist the local Fire Department as needed and as appropriate. If the fire is small enough, it may be fought with a hand-held extinguisher.

7 RECORDKEEPING REQUIREMENTS (30 TAC §330.125)

7.1 SITE OPERATING RECORD (§330.125(B))

The Landfill Manager or designee will maintain a copy of the permit, approved SDP (Part III), SOP (Part IV), Groundwater Sampling and Analysis Plan (Part III, Attachment 7), Final Closure and Post-closure Care Plan (Part III, Attachment 9), Landfill Gas Management Plan (Part III, Attachment 11), Leachate and Contaminated Water Plan (Part III, Attachment 12), and any other required plans or documents. These plans and documents are considered a part of the Site Operating Record for the landfill. Any deviation from the permit and incorporated plans or other related documents associated with the permit is a violation of 30 TAC 330. The Owner will provide written notification to the TCEQ of any changes made to the above mentioned documents. The Site Operating Record for the landfill will be maintained at the landfill office of the Landfill Manager, digitally on the Owner's private server accessible from the landfill, or a combination of both.

The Landfill Manager is responsible for recording and retaining in the Site Operating Record the information listed below, within seven working days of completion or receipt:

- All location restriction demonstrations.
- Inspection records, training procedures, and notification procedures relating to excluding the receipt of regulated hazardous and PCB waste and other unauthorized waste.
- Personnel training requirements and records consistent with 30 TAC 335.586(d) and (e) and personnel operator licenses.
- Inspection records and training procedures relating to fire prevention and site safety.
- Results from gas monitoring events and any remediation plans relating to explosive and other gases.
- Any and all unit design documentation for the placement of leachate or gas condensate in the landfill (leachate and gas condensate recirculation).
- Leachate sump level measurements.
- Leachate disposal records.
- Demonstrations, certifications, findings, monitoring, testing, and analytical data relating to groundwater monitoring and corrective action.
- Closure plans and monitoring, testing, or analytical data relating to closure requirements.

- Post-closure care plans and monitoring, testing, or analytical data relating to post-closure requirements.

- Cost estimates and financial assurance documentation relating to financial assurance for closure and post-closure care.

- Copies of all correspondence and responses relating to the operation of the facility, modifications to the permit, approvals, and other matters pertaining to technical assistance.

- All documents, manifests, shipping documents, trip tickets, etc., involving special waste.

- Documents related to the annual waste acceptance rate, including quarterly and annual solid waste summary reports.

- Alternate operating hours, if applicable.

- A record of unauthorized waste removed from the landfill.

- Landfill Gas Management Plan reports and required submittals.

- Leachate and Contaminated Water Plan reports and required submittals, including leachate sump levels and leachate disposal records.

- Cover Application Log.

- Other documents as specified by the approved permit or by the Executive Director of the TCEQ.

- All other inspection, monitoring event, activity log (including all inspection and maintenance requirements as presented in Table 4.1), and notification records documented at the landfill.

Table 7.1 summarizes the recordkeeping requirements, described above. The Landfill Manager will retain all information contained within the Site Operating Record of the facility and all plans required for the facility for the life of the facility, including the post-closure care period. The Landfill Manager will maintain the Site Operating Record in an organized format, which allows the information to be easily located and retrieved, and upon request, make the Site Operating Record available for TCEQ inspection.

Table 7.1 Recordkeeping Requirements

Recordkeeping Requirement	TCEQ Regulation	Permit Reference	Minimum Frequency
All location restriction demonstrations.	§330.125(b)(1)	Parts I/II	NA
Inspection and notification records relating to unauthorized waste.	§330.125(b)(2)	SOP, Section 5	Per occurrence
Personnel training requirements and records, and personnel operator licenses.	§335.586(d) and (e)	SOP, Section 2.2	Annually
Inspection records relating to fire prevention.	§330.129	SOP, Section 6	Per occurrence
Results from gas monitoring events.	§330.125(b)(3)	Attachment 11	Quarterly
Remediation plans relating to explosive and other gases.	§330.125(b)(3)	Attachment 11	Per occurrence
Documentation for the placement of leachate or gas condensate in the landfill.	§330.125(b)(4)	SOP, Section 4.22	Per occurrence
Demonstrations, certifications, findings, monitoring, testing, and analytical data relating to groundwater monitoring and corrective action.	§330.125(b)(5)	Attachment 7	Semi-Annually
Closure plans and monitoring, testing, or analytical data relating to closure requirements.	§330.125(b)(6)	Attachment 9	Per occurrence
Post-closure care plans and monitoring, testing, or analytical data relating to post-closure requirements.	§330.125(b)(6)	Attachment 9	Per occurrence
Cost estimates and financial assurance documentation relating to financial assurance for closure and post-closure care.	§330.125(b)(7)	Attachment 8	Annually
Copies of all correspondence and responses relating to the operation of the facility, modifications to the permit, approvals, and other matters pertaining to technical assistance.	§330.125(b)(9)	Landfill Permit	Per occurrence
All documents, manifests, trip tickets, etc., involving special waste.	§330.125(b)(10)	SOP, Section 4.20	Per occurrence
Documents related to the annual waste acceptance rate, including quarterly and annual solid waste summary reports.	§330.125(h)	SOP, Section 7.2	Quarterly and Annually
Alternate operating hours.	§330.135	SOP, Section 4.3	Per occurrence
A record of unauthorized waste removed from the landfill.	§330.133(b)	SOP, Section 5.5	Per occurrence

Table 7.1 (Continued)

Recordkeeping Requirement	TCEQ Regulation	Permit Reference	Minimum Frequency
Leachate Sump Level Measurements	§330.125(b)(12)	Attachment 12, Section 3.5	Weekly
Inspection and maintenance of leachate storage tanks, piping, and connections	§330.125(b)(12)	Attachment 12, Section 4	Weekly
Cover Application Log.	§330.165(h)	SOP, Section 4.18.6	Following placement of cover.
Inspection of daily cover.	§330.165(a)	SOP, Section 4.18.2	Daily
Inspection of intermediate cover.	§330.165(c)	SOP, Section 4.18.3	Weekly
Inspection of final cover.	§330.165(f)	SOP, Section 4.18.4	Monthly
Perimeter fence and gates inspections.	§330.131	SOP, Section 4.1.1	Monthly
Windblown waste collection and clean-up	§330.139	SOP, Section 4.5	Daily
Waste spilled en route to site.	§330.145	SOP, Section 4.8	Daily
Inspection of Landfill Markers.	§330.143	SOP, Section 4.7	Monthly
Inspection of landfill access roads.	§330.153	SOP, Section 4.12	Monthly
Inspection for disease vectors.	§330.151	SOP, Section 4.11	Weekly
Inspection for ponded water.	§330.167	SOP, Section 4.19	Weekly

7.2 ANNUAL WASTE ACCEPTANCE RATE [30 TAC §330.125(H)]

The maximum annual acceptance rate for waste to be disposed in the landfill is expected to be approximately 454,000 tons per year. This estimate is not a limiting parameter. This annual waste acceptance rate is based on the assumption of approximately 1,590 tons per day incoming waste and 286 days of operation per year (5.5 operational days per week).

The Landfill Manager will maintain records to document the annual waste acceptance rate for the landfill. Documentation will include maintaining quarterly solid waste summary reports and annual solid waste summary reports in the Site Operating Record and submit these reports to the TCEQ in accordance with 30 TAC §330.675. If the waste acceptance rate exceeds 454,000 tons per year, and the waste increase is not due to a temporary occurrence, the Owner will submit a permit modification in accordance with 30 TAC §305.70(k) as described below to modify the annual waste acceptance rate. The permit modification proposing a revised maximum annual waste acceptance rate will be submitted within 90 days of the exceedance and will be established by the sum of the previous four quarterly summary reports. The permit modification will propose changes in the SOP to manage the increased waste acceptance rate and to protect human health and the environment.

If it is determined that a permit modification is appropriate, this SOP, including the following provisions, will be evaluated, and if needed modified, if applicable:

- Number of operating personnel;
- Number and type of equipment;
- Waste compaction procedures;
- Odor prevention plan and control;
- Unloading waste procedures;
- Waste screening procedures;
- Control of windblown waste and litter;
- Soil management, placement, and compaction of daily, intermediate, and final cover; and
- Other provisions, as necessary.

Based on the newly established number of personnel, number and type of equipment and operational procedures, a revised maximum annual waste acceptance rate will be proposed in the permit modification to the TCEQ.

7.3 SLER/GLER SUBMITTALS (30 TAC §330.123)

The Owner will provide to the TCEQ a Soil Liner Evaluation Report (SLER) and Geomembrane Liner Evaluation Report (GLER) as described in 30 TAC §330.341, after the final construction and lining of new disposal cells within 14 days prior to waste placement. Waste disposal operations will not commence in the new cell until either (1) approval of the SLER or GLER has been received from the TCEQ, or (2) the end of the 14th day following the Executive Director's receipt of the SLER and GLER if no comment from the Executive Director is received. No waste will be placed in the initial cell until approval of the SLER and GLER is received from the Executive Director. SLER/GLERs will be maintained in the Site Operating Record at the landfill.