Permit Application

Lea County, New Mexico

C.K. Disposal E & P Landfill and Processing Facility

Permit No. TBD

Volume I

PARKHILLSMITH&COOPER

November 2015

PSC Project # 01058015

PSC
Parkhill, Smith & Cooper, Inc.
Engineers ▪ Architects ▪ Planners

C.K. Disposal, Lea County, New Mexico
E & P Landfill and Processing Facility –Permit No. TBD
Volume I
PSC Project # 01058015

November 2015

Permit Application

Lea County, New Mexico

C.K. Disposal E & P Landfill and Processing Facility

Permit No. TBD

NICHOLAS N. YBARRA
20683

Nicholas N. Ybarra

11/06/2015

PARKHILL SMITH & COOPER
PSC

November 2015
PSC Project # 01058015

District I
1625 N. French Dr., Hobbs, NM 88240
District II
811 S. First St., Artesia, NM 88210
District III
1000 Rio Brazos Road, Aztec, NM 87410
District IV
1220 S. St. Francis Dr., Santa Fe, NM 87505

State of New Mexico
Energy Minerals and Natural Resources

Oil Conservation Division
1220 South St. Francis Dr.
Santa Fe, NM 87505

For State Use Only:

Form C-137
Revised August 1, 2011

Submit 1 Copy to Santa Fe Office

APPLICATION FOR SURFACE WASTE MANAGEMENT FACILITY

A meeting should be scheduled with the Division's Santa Fe office Environmental Bureau prior to pursuing an application for a surface waste management facility in order to determine if the proposed location is capable of satisfying the siting requirements of Subsections A and B of 19.15.36.13 NMAC for consideration of an application submittal.

1 Application: ☒ New ☐ Modification ☐ Renewal

2. Type: ☒ Evaporation ☒ Injection ☐ Treating Plant ☒ Landfill ☐ Landfarm ☐ Other

3. Facility Status: ☒ Commercial ☐ Centralized

4. Operator: C.K. Disposal LLC.

Address: 5909 86th Street, Lubbock, Texas 79424

Contact Person: Bryce Karger Phone: 480-437-0044

5. Location: ____/4 ____/4 Section 5 Township 336 Range 38E

6. Is this an existing facility? ☐ Yes ☒ No If yes, provide permit number ______

7. Attach the names and addresses of the applicant and principal officers and owners of 25 percent or more of the applicant. Specify the office held by each officer and identify the individual(s) primary responsible for overseeing management of the facility.

8. Attach a plat and topographic map showing the surface waste management facility's location in relation to governmental surveys (quarter-quarter section, township and range); highways or roads giving access to the surface waste management facility site; watercourses; fresh water sources, including wells and springs; and inhabited buildings within one mile of the site's perimeter.

9. Attach the names and addresses of the surface owners of the real property on which the surface waste management facility is sited and surface owners of the real property within one mile of the site's perimeter.

10. Attach a description of the surface waste management facility with a diagram indicating the location of fences and cattle guards, and detailed construction/installation diagrams of pits, liners, dikes, piping, sprayers, tanks, roads, fences, gates, berms, pipelines crossing the surface waste management facility, buildings and chemical storage areas.

11. Attach engineering designs, certified by a registered professional engineer, including technical data on the design elements of each applicable treatment, remediation and disposal method and detailed designs of surface impoundments.

12. Attach a plan for management of approved oil field wastes that complies with the applicable requirements contained in 19.15.36.13, 19.15.36.14, 19.15.36.15 and 19.15.36.17 NMAC.

13. Attach an inspection and maintenance plan that complies with the requirements contained in Subsection L of 19.15.36.13 NMAC.

14. Attach a hydrogen sulfide prevention and contingency plan that complies with those provisions of 19.15.3.118 NMAC that apply to surface waste management facilities.

15. Attach a closure and post closure plan, including a responsible third party contractor's cost estimate, sufficient to close surface waste management facility in a manner that will protect fresh water, public health, safety and the environment (the closure and post closure plan shall comply with the requirements contained in Subsection D of 19.15.36.18 NMAC).

16 Attach a contingency plan that complies with the requirements of Subsection N of 19.15.36.13 NMAC and with NMS 1978, Sections 12-12-1 through 12-12-30, as amended (the Emergency Management Act).

17. Attach a plan to control run-on water onto the site and run-off water from the site that complies with the requirement Subsection M of 19.15.36.13 NMAC.

18. In the case of an application to permit a new or expanded landfill, attach a leachate management plan that describes anticipated amount of leachate that will be generated and the leachate's handling, storage, treatment and disposal, inclu final post closure options.

19. In the case of an application to permit a new or expanded landfill, attach a gas safety management plan that compli the requirements of Subsection O of 19.15.36.13 NMAC

20. Attach a best management practice plan to ensure protection of fresh water, public health, safety and the environm

21. Attach a demonstration of compliance with the siting requirements of Subsections A and B of 19.15.36.13 NMAC

22. Attach geological/hydrological data including:

(a) a map showing names and location of streams, springs or other watercourses, and water wells within o the site;

(b) laboratory analyses, performed by an independent commercial laboratory, for major cations and anion toluene, ethyl benzene and xylenes (BTEX); RCRA metals; and total dissolved solids (TDS) of ground water sa shallowest fresh water aquifer beneath the proposed site;

(c) depth to, formation name, type and thickness of the shallowest fresh water aquifer;

(d) soil types beneath the proposed surface waste management facility, including a lithologic description rock members from ground surface down to the top of the shallowest fresh water aquifer;

(e) geologic cross-sections;

(f) potentiometric maps for the shallowest fresh water aquifer; and

(g) porosity, permeability, conductivity, compaction ratios and swelling characteristics for the sediment the contaminated soils will be placed.

23. In the case of an existing surface waste management facility applying for a minor modification, describe the p change and identify information that has changed from the last C-137 filing.

24. The division may require additional information to demonstrate that the surface waste management facility' will not adversely impact fresh water, public health, safety or the environment and that the surface waste manage will comply with division rules and orders

25. CERTIFICATION

I hereby certify that the information submitted with this application is true, accurate and complete to the best of and belief.

Name: Bryce Karger

Title: Owner

Signature:

Date: 5.1.16

E-mail Address: bryceKarger

Permit Application

Lea County, New Mexico

C.K. Disposal E & P Landfill and Processing Facility

Permit No. TBD

November 2015

PSC Project # 01058015

PARKHILLSMITH&COOPER

NMAC 19.15.36.8 – SURFACE WASTE MANAGEMENT FACILITY PERMITS AND APPLICATION REQUIREMENTS

NMAC 19.15.36.9 - NOTICE REQUIREMENTS FOR NEW SURFACE WASTE MANAGEMENT FACILITIES, MAJOR MODIFICATIONS OR RENEWALS AND ISSUANCE OF A TENTATIVE DECISION

NMAC 19.15.36.10 – COMMENTS AND HEARING ON APPLICATION

NMAC 19.15.36.11 – FINANCIAL ASSURANCE REQUIREMENTS

NMAC 19.15.36.12 - PERMIT APPROVAL, DENIAL, REVOCATION, SUSPENSION, MODIFICATION OR TRANSFER

NMAC 19.15.36.13 - SITING AND OPERATIONAL REQUIREMENTS APPLICABLE TO ALL PERMITTED SURFACE WASTE MANAGEMENT FACILITIES

NMAC 19.15.36.14 - SPECIFIC REQUIREMENTS APPLICABLE TO LANDFILLS

NMAC 19.15.36.15 – SPECIFIC REQUIREMENTS APPLICABLE TO LANDFARMS

NMAC 19.15.36.15 – SMALL LANDFARMS

NMAC 19.15.36.17 – SPECIFIC REQUIREMENTS APPLICABLE EVAPORATION, STORAGE, TREATMENT, AND SKIMMER PONDS

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ATTACHMENT B – ENGINEERED DESIGN PLAN

ATTACHMENT C- SOIL AND LINER QUALITY CONTROL PLAN (SLQCP)

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TABLES

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Permit Application

Lea County, New Mexico
C.K. Disposal E & P Landfill and Processing Facility
Permit No. TBD

New Mexico Administration Code
19.15.36.8 through 19.15.36.20

PARKHILLSMITH&COOPER

PSC

November 2015
PSC Project # 01058015

1.0 NMAC 19.15.36.8 - INTRODUCTION

C.K. Disposal, LLC proposes to develop a surface waste management facility consisting of a landfill, liquid processing area, and deep well injection per NMAC 19.15.36. An approved permit will be issued by the Oil Conservation Division (OCD) of the New Mexico Energy, Minerals and Natural Resources Department. The proposed hereon known as "C.K. Facility", is located 0.05-miles south of State Highway 234, approximately 4.16-miles southeast of Eunice, New Mexico, in Lea County. The C.K. Facility will encompass a 316.97-acres broken down into individual sections as listed below in Table 1 – C.K. Facility.

Table 1 – C.K. FACILITY

Area	**Acres**
C.K. Disposal E&P Landfill and Processing Facility	316.97
Landfill	141.5
Liquid Processing	51.75
Saltwater Disposal	5.1

1.1 NMAC 19.15.36.8.A – Permit Required

Prior to construction and use of the proposed C.K. Facility, C.K. Disposal, LLC will submit a permit meeting requirements set forth in NMAC 19.15.36 and the Oil Conservation Division (OCD) of the New Mexico Energy, Minerals, and Natural Resource Department.

1.2 NMAC 19.15.36.8.B – Permitting Requirements

C.K. Disposal, LLC is requesting a permit per NMAC 19.15.36. The new commercial C.K. Facility permit will provide all information on facility design, volume capacity, and operational plans. All activities at the landfill will be pursuant to NMAC 19.15.36. To assist in the review of this permit, each subsection of NMAC 19.15.36 will be answered individually and attachments at the end of the permit will provide documentation backup.

1.3 NMAC 19.15.36.8.C – Application Requirements for New Facilities

OCD form C-137 has been included with the submission of the permit. All documentation requested in form C-137 is included in the permit write-up or as attachments at the end of the permit.

A NMAC 19.15.36.8.C(1) – Applicant Information

The principal owner of the facility is C.K. Disposal, LLC. There is no other owner that has more than 25% ownership of the site and/or permit. Below is the principal and mailing address for C.K. Disposal, LLC.

Principal Address:
3 Canjilon Court
Santa Fe, NM 87508

Mailing Address:
5909 86th Street
Lubbock, TX 79424

B NMAC 19.15.36.8.C(2) – Plat and Topographic Maps

The following maps are provided in Attachment A - General Facility Maps and Site Drawings. The maps show highways and roads providing access to the surface waste management facility site; watercourses; fresh water sources, including wells and springs; and inhabited buildings within one mile of the site's perimeter.

- Figure A.1 – Site Location Map
- Figure A.2 – Site Development Plan
- Figure A.3 – Topographic Map

Figure A.1 – Site Location Map provides the C.K. Facility and a 1-mile offset plotted on the most current United States Geological Survey (USGS) quadrangle map. Figure A.2 – Site Development Plan details the build out of the site and location of the landfill units, processing area, and stabilization and solidification area within the permitted boundary. Figure A.3 – Topographic Map is a detailed existing site topography, land description, easements, and boundary survey. The original survey is provided in Attachment A.

C NMAC 19.15.36.8.C(3) – Names and Address of Adjacent Land Owners

Table 2 provides a list of all land owners within 1-mile of the permitted boundary. Information was provided by the Lea County, NM Assessor's Office, New Mexico State Land Office, and Andrews County, TX Appraisal District. Figure A.4, located in Attachment A, provides an adjacent landowners map and list of owners.

TABLE 2 - Adjacent Landowners (1-Mile from Permit Boundary) and Notification List

Owner/Office	Mailing Address
Walco Ranch LLC(1)	P.O. Box 790 Hobbs, NM 88241
Paddock Buddy Metal(1)	1613 Clark Rd Crowley, TX 76036
Lea County Solid Waste Authority(1)	Lea County Courthouse Lovington, NM 88260
Waste Control Specialists LLC(2)	PO Box 1129 Andrews, TX 79714
Lea County(1)	100 North Main Ste 4 Lovington, NM 88260
URENCO USA(1)	P.O. Box 1789 Eunice, NM 88231
Louisiana Energy Services LLC(1)	P.O. Box 1789 Eunice, NM 88231
Andrews County(2)	201 N. Main Andrews, TX 79714

C.K. Disposal, LLC(1)	5909 86th Street Lubbock, TX 79424
New Mexico State Land Office	P.O. Box 1148 Santa Fe, NM 87504-1148
New Mexico Bureau of Land Management	620 E. Greene Street Carlsbad, NM 88220
Lea County Commission	100 N. Main Street Lovington, NM 88260
Note: (1) Data for New Mexico properties provided by the Lea County Assessor's Office - http://emaps.emapsplus.com/standard/leaconm.html & the New Mexico State Land Office - http://landstatus.nmstatelands.org/LandStatus.aspx	
(2) Data for Texas properties provided by the Andrews County Central Appraisal District. https://propaccess.trueautomation.com/Map/View/Map/53	

D NMAC 19.15.36.8.C(4) – Surface Waste Management Facility Diagram

Figure A.2 - Site Development Plan provides a layout of the C.K. Facility. The figure includes the layouts for the scale and gate house, the location of roads, pipeline crossings, fences, gates, landfill units, liquid processing area, and stabilization and solidification area. Attachment B – Engineered Design Plans provides detailed construction and installation drawings for the C.K. Facility. Plans include details on grading, drainage, liner and leachate collection installation, and final cover.

E NMAC 19.15.36.8.C(5) – Engineering Designs

The engineered design plans included in Attachment B are provided to establish the engineered design criteria for the C.K. Facility. The engineer design plans provide a design for the landfill units, liquid processing area and stabilization and solidification areas. Full size (22-inch x 34-inch) drawings are included at the end of the permit and will be submitted along with the permit to OCD. The design plans have been signed and sealed by a Professional Engineer registered in the State of New Mexico.

Nicholas N. Ybarra, P.E.
New Mexico Professional Engineer #20683
Parkhill Smith & Cooper, Inc.
501 W. San Antonio
El Paso, Texas 79901
(915) 543-3357 Phone
(915) 544-2059 Fax

F NMAC 19.15.36.8.C(6) – Management Plan for Approved Oil Field Waste

An oil field waste management plan has been included in Attachment K - Site Operating Plan (SOP). The plan covers all requirements listed in NMAC 19.15.36.13, 14, 15, and 17. The plan provides details on-site operation hours, requirements for accepting waste, prohibited wastes and inspection and management. In addition the oil field waste management plan provides the owner/operator a plan for dealing H_2S gas on incoming waste.

G NMAC 19.15.36.8.C(7) – Inspection and Maintenance Plan

Attachment K - Site Operating Plan covers the operations, inspection and maintenance plan for the C.K. Facility. The operations, inspection, and maintenance cover all requirements listed in NMAC 19.15.36.13.L.

H NMAC 19.15.36.8.C(8) – Hydrogen Sulfide Prevention and Contingency Plan

The Hydrogen Sulfide (H_2S) Prevention and Contingency Plan are included in Attachment K – Site Operating Plan. The plan provides the C.K. Facility operators information to inspect, monitor, and treat hydrogen sulfide on site. The contingency plan provides a plan to evacuate, notify, and treat for excessive levels of H_2S. Both plans ensure that requirements listed in NMAC 19.15.11 and 19.15.36 are met in Attachment K – Site Operating Plan.

I NMAC 19.15.36.8.C(9) – Closure and Post-Closure Plan

The closure and post-closure plan will be included in the permit as Attachment L. The closure plan includes drawings that depict the final cover details and final contour plan for the C.K. Facility. The closure plan includes the procedures to be taken for sequential closure of cells following final acceptance of waste. The plan will include:

- A description of the final cover design, including methods and procedures used to install the cover.
- An estimate of the largest area requiring final cover at any time during the active life of the landfill.
- A schedule for completing all activities
- A detailed, written estimate of the cost of hiring a third party to close the largest area of the landfill during its active life.

The closure plan meets all requirements listed in NMAC 19.15.36.18

J NMAC 19.15.36.8.C(10) – Contingency Plan

A contingency plan is included in Attachment K – Site Operating Plan. It follows the requirements listed in NMAC 19.15.36.13. The contingency plan provides the owner a plan to minimize the effects of fires, explosions, and unplanned release of contaminants if these occur. The contingency plan is supplemented with the hydrogen sulfide prevention and contingency plan.

K NMAC 19.15.36.8.C(11) – Drainage Study

This drainage study was prepared as a part of the permit application and is located in Attachment J. All drainage analysis and design is in accordance with NMAC regulations.

Existing and proposed hydrologic and hydraulic conditions of the site are detailed herein, as well as hydraulic structures design, erosion stability and the management of storm water run-on and run-off from the C. K. Facility site in the event of a 25-Year, 24-Hour storm event. All hydrologic computations were performed using United States Army Corps HEC-HMS software and SCS unit hydrograph hydrology.

L NMAC 19.15.36.8.C(12) – Leachate Management Plan

A leachate management plan is included in Attachment K – Site Operating Plan. It follows the requirements listed in NMAC 19.15.36.13. The leachate management plan provides details on anticipated leachate volumes, leachate collection, storage, treatment and disposal on site. The HELP model was used to determine the amount of leachate that would be generated on site. The HELP model shown in Attachment E supplements the leachate management plan.

M NMAC 19.15.36.8.C(13) – Gas Safety Management Plan

The gas safety management plan is provided in Attachment K – Site Operating Plan. The gas safety management plan complies with all requirements listed in NMAC 19.15.36.13. Due to the nature of waste, most gas that will be dealt with on-site will be Hydrogen Sulfide (H_2S). The gas safety management plan is supplemented with the hydrogen sulfide prevention and contingency plan.

N NMAC 19.15.36.8.C(14) – Best Management Practice Plan

Attachment B – Engineered Design Plans design plans provides the best management practice structures and construction methods to provide protection of fresh water, public health, safety, and the environment.

O NMAC 19.15.36.8.C(15) – Geological/Hydrological Data

A geology and hydrogeology study was performed for the C.K. Facility by Kevin T. Carel, P.G. The report is provided as Attachment G. The C.K. Facility was selected due to the absence of groundwater within 100-feet of the deepest excavation. In addition, the site rests on a red bed formation with acts as an aquitard minimizing the potential for groundwater contamination. Based on the finding of this report, a Vadose Monitoring Plan and Sampling and Analysis Plan are supplemental to this report and provided in Attachments H and I, respectively.

i NMAC 19.15.36.8.C(15)(a) – Water Courses Map

Figure IV.2.2 in Attachment G provides a map showing local streams, springs and water wells.

ii NMAC 19.15.36.8.C(15)(b) – Groundwater Laboratory Analysis

During initial site investigation five (5) soil bores were taken on site to a depth of 175-feet below ground surface. No groundwater was observed in the cuttings obtained, nor was there any observed in the bore holes after a 24-hour period. No groundwater is present within the upper 175-feet of the Ogallala Formation or Chinle Formation because they rise above the saturated zone of the Ogallala Formation. Therefore, no laboratory analysis was done on groundwater samples. Additional information on groundwater is in located in Attachment G – Hydrogeology Report.

iii NMAC 19.15.36.8.C(15)(c) – Shallowest Fresh Water Aquifer

A well drilled for Waste Control Specialists in 2008 located approximately 580-feet northeast of the proposed Site encountered the Santa Rosa Formation at a depth of 1,092-feet below ground surface (bgs). The depth to which groundwater was first encountered is listed on the well log as 1,092-feet bgs. The well log indicates the Santa Rosa is 292-feet thick and describes it as a gray, fine sandstone with interbedded reddish brown and weak red siltstone and claystone. Additional information on local aquifers is in located in Attachment G – Hydrogeology Report.

iv NMAC 19.15.36.8.C(15)(d) – Soil Types

A detailed description of soils obtained from the site borings is located in Attachment G – Hydrogeology Report. The soil laboratory testing was conducted in accordance with guidance provided by OCD. The hydrogeology report also includes lithologic descriptions of the soil borings drilled at the site.

v NMAC 19.15.36.8.C(15)(e) – Geologic Cross-Sections

Four (4) geologic cross-sections of the site are provided as Figures G.5, G.7, G.8, and G.9 in Attachment G. The cross sections are based on soil bores taken on site and local geologic research.

vi NMAC 19.15.36.8.C(15)(f) – Geologic Cross-Sections

The underlying geologic units and groundwater saturations in the vicinity of the C.K. Facility shown in the hydrogeology cross-sections in Attachment G – Hydrogeology Report.

vii NMAC 19.15.36.8.C(15)(g) – Geologic Cross-Sections

Hyraulic properties of regional aquifers located below or near the C.K. Facility are located in Table G.2.2 of Attachment G – Hydrogeology Report.

viii NMAC 19.15.36.8.C(16) – Certification of True, Accurate and Complete Information

By signing form C-137, the Engineer certifies that all information submitted in the application is true, accurate, and complete to the best of the applicant’s knowledge.

ix NMAC 19.15.36.8.C(17) – Additional Information Per Request

C.K. Disposal, LLC will provide any applicable information requested by the OCD to demonstrate that the surface waste management facility operation will not adversely impact fresh water, public health, safety, or the environment. In addition, C.K. Disposal, LLC will comply with applicable Rules and Orders issued by OCD.

1.4 NMAC 19.15.36.8.D – Application Requirements for Minor Modifications

C.K. Disposal, LLC will submit the C-137 form if a minor modification is ever required. Currently form C-137 is being submitted with this new permit application.

1.5 NMAC 19.15.36.8.E – Determination that Application is Administratively Complete

This is the initial submittal of the application. If any changes are required, they will be made per comments provided by OCD and submitted along with form C-137.

1.0 NMAC 19.15.36.9 - NOTICE REQUIREMENTS FOR NEW SURFACE WASTE MANAGEMENT FACILITIES, MAJOR MODIFICATIONS OR RENEWALS AND ISSUANCE OF A TENTATIVE DECISION

1.1 NMAC 19.15.36.9.A – Application for a New Surface Waste Management Facility Permit, Permit Renewal or Major Modification

Upon receipt of notification of the division's determination that the application is administratively complete, Parkhill, Smith & Cooper, Inc. (PSC) will send out written notice of the application and determination on behalf of C.K. Disposal, LLC to landowners and other members on the notification list. Table 1 below provides the list of landowners within ½-mile from the permit boundary and other entities to be notified. Information was provided by the Lea County, NM Assessor's Office, New Mexico State Land Office, and Andrews County, TX Appraisal District. Figure A.4, located in Attachment A, provides an adjacent landowners map and listed of owners.

TABLE 1 –Landowners (1/2-Mile from Permit Boundary) and Notification List

Owner/Office	Mailing Address
Walco Ranch LLC(1)	P.O. Box 790 Hobbs, NM 88241
Paddock Buddy Metal(1)	1613 Clark Rd Crowley, TX 76036
Lea County Solid Waste Authority(1)	Lea County Courthouse Lovington, NM 88260
Waste Control Specialists LLC(2)	PO Box 1129 Andrews, TX 79714
URENCO USA(1)	P.O. Box 1789 Eunice, NM 88231
Louisiana Energy Services LLC(1)	P.O. Box 1789 Eunice, NM 88231
C.K. Disposal LLC(1)	5909 86th Street Lubbock, TX 79424
Lea County Commission	100 N. Main Street Lovington, NM 88260
Note: (1) Data for New Mexico properties provided by the Lea County Assessor's Office - http://emaps.emapsplus.com/standard/leaconm.html & the New Mexico State Land Office - http://landstatus.nmstatelands.org/LandStatus.aspx	

(2) Data for Texas properties provided by the Andrews County Central Appraisal District. https://propaccess.trueautomation.com/Map/View/Map/53

1.2 NMAC 19.15.36.9.B– Division Application Notice

No major modification, renewals or issuance of a tentative decision is submitted at this time, therefore no action is required.

1.3 NMAC 19.15.36.9.C – Application Comments

The facility is aware that a person wishing to comment on an application prior to the division's preliminary consideration of the application may file comments within 30 days, or at a later date when the applicant mails the notice.

1.4 NMAC 19.15.36.9.D – Tentative Decision After Comments

The facility is aware that a tentative decision will be made by the division, by the end of 60 days, and the decision will be made public.

1.5 NMAC 19.15.36.9.E – Notice of the Tentative Decision

PSC on behalf of C.K. Disposal, LLC will comply with the notification requirements identified in NMAC 19.15.36.9 upon receiving the division's tentative decision. PSC will coordinate with both the Albuquerque Journal and Hobbs News Sun to publish notification of OCD's tentative decision. Both the Albuquerque Journal and the Hobbs News Sun are in general circulation in the State of New Mexico and Lea County.

1.6 NMAC 19.15.36.9.F – Application Notice Requirements

PSC on behalf of C.K. Disposal, LLC will publish notification upon receiving OCD's tentative decision. Notification will have the following items listed.

1. Applicant's name and address;
2. Surface waste management facility's location, including a street address, and sufficient information to locate the surface waste management facility with reference to surrounding roads and landmarks;
3. Brief description of the proposed surface waste management facility;
4. Depth to and TDS concentration of the ground water in the shallowest aquifer beneath the surface waste management facility site;
5. Statement that the division's tentative decision is available on the division's website, or, upon request, from the division clerk, including the division clerk's name, address and telephone number;

6. Description of alternatives, exceptions, or waivers that may be under consideration in accordance with Subsection G of 19.15.36.18 NMAC or 19.15.36.19 NMAC;
7. Statement of the comment period and of the procedures for requesting a hearing on the application; and
8. Brief statement of the procedures the division shall follow in making a final decision.

1.0 NMAC 19.15.36.10 – COMMENTS AND HEARING ON APPLICATION

1.1 NMAC 19.15.36.10.A – File Comments or Requesting a Hearing

C.K. Disposal, LLC and Parkhill Smith & Cooper Inc. understand that a person may request a hearing within 30-days after the date public notice is issued on OCD's decision. The division will decide if a hearing is required based on criteria stated in 19.15.36.10.A(1) – (4).

1.2 NMAC 19.15.36.10.B – If Scheduled, Hearing Shall be Conducted According to 19.15.14.1206 through 19.15.14.1215 NMAC.

C.K. Disposal, LLC and Parkhill Smith & Cooper Inc. understand that if a hearing is scheduled it will be conducted according to 19.15.14.1206 through 19.15.14.1215.

1.0 NMAC 19.15.36.11 – FINANCIAL ASSURANCE REQUIREMENTS

1.1 NMAC 19.15.36.11.A – Financial Assurance Requirements for Centralized Facilities

The C.K. Facility is a proposed commercial facility as defined in NMAC 19.15.36.7.A(2). No response is required.

1.2 NMAC 19.15.36.11.B – Financial Assurance Requirements for New Commercial Facilities

Upon notification by the division that it has approved a permit for the C.K. Facility, C.K. Disposal, LLC shall submit financial assurance for $2,311,912. This amount covers the estimated closure of one landfill unit, the entire liquid processing area and 30-years of post-closure care for the entire facility. A breakdown of costs is provided in Attachment L - Closure and Post-Closure Care Plan.

1.3 NMAC 19.15.36.11.C – Terms of Financial Assurance

C.K. Disposal, LLC provided the State of New Mexico financial assurance on the prescribed form and made payable to the state. C.K. Disposal, LLC shall notify the State of New Mexico and OCD within 30 days if there is to be a design change that will alter the financial assurance.

1.4 NMAC 19.15.36.11.D – Forfeiting Financial Assurance

C.K. Disposal, LLC understand that the division shall give them 20-days' notice and an opportunity for a hearing prior to forfeiting financial assurance.

1.5 NMAC 19.15.36.11.E – Forms of Financial Assurance

Once the Permit is approved, C.K. Disposal, LLC will select a financial assurance mechanism listed in NMAC 19.15.36.11.E. Financial assurance may be accepted in the following forms: surety bonds, letters of credit, and cash accounts. Documentation of financial insures will be attached to the approved permit. The financial assurance amount covers the estimated closure of one landfill unit, the entire liquid processing area and 30-years of post-closure care for the entire facility. A breakdown of costs is provided in Attachment L - Closure and Post-Closure Care Plan.

1.6 NMAC 19.15.36.11.F – Replacement of Financial Assurance

If C.K. Disposal, LLC decides to replace its financial assurance with another form listed in NMAC 19.15.36.11.E, it will comply with requirements listed in NMAC 19.15.36.11.E.

1.7 NMAC 19.15.36.11.G – Review of Adequacy of Financial Assurance

C.K. Disposal, LLC understands that the division may at any time after five years after initial acceptance review the adequacy of the C.K Facility's financial assurance. C.K. Disposal, LLC will comply with all request made by the division per NMAC 19.15.36.11.F.

1.0 NMAC 19.15.36.12 - PERMIT APPROVAL, DENIAL, REVOCATION, SUSPENSION, MODIFICATION OR TRANSFER

1.1 NMAC 19.15.36.12.A – Granting of Permit

Prior to construction and use of the proposed C.K. Facility, C.K. Disposal, LLC will submit a permit meeting requirements set forth in NMAC 19.15.36 and per the Oil Conservation Division (OCD) of the New Mexico Energy, Minerals, and Natural Resource Department.

A NMAC 19.15.36.12.A(1) Permit Issuance for A New Surface Waste Management Facility or Major Modification

C.K. Disposal, LLC will adhere to all notice requirements for a new surface waste management facility per NMAC 19.15.36.9. Adjacent landfill owners and notification list recipients, shown in section 19.15.36.9, will be informed of the permit approval. In addition C.K. Disposal, LLC will submit appropriate financial assurance per requirements in NMAC 19.15.36.11. Backup documentation on closure and post-closure costs can be found in Attachment L. Both public notification and financial assurance must be completed and submitted to the division prior to final approval of the permit. The following permit provides Attachment B - Engineered Design Plan and Attachment K - Site Operation Plan, which discuss the protection of fresh water, public health, safety, and the environment.

B NMAC 19.15.36.12.A(2) Permit Effective Time of 10 Years

When approved, the permit will be effective for 10-years from the date of approval. If a major modification is approved for the C.K. Facility, the updated permit will be effective for 10-years from the major modification date of approval. Permit renewal will be submitted to OCD at least 120-days prior to the expiration date of the permit. Renewal will be completed in per NMAC 13.15.36.

i NMAC 19.15.36.12.A(2)(a) Permit Effective Time Addition for A Successive 10 Years

The C.K. Facility permit may be renewed for successive 10-year terms. C.K. Disposal, LLC shall submit the permit renewal at least 120-days before the permit expires and the owner/operator shall not be in violation during the renewal or date of expiration. If the facility or owner/operator is in violation, they may be in the process of diligently pursuing procedures to remedy the violation to continue the permit renewal procedure.

ii NMAC 19.15.36.12.A(2)(b) – Application Renewal Information

If C.K. Disposal, LLC requests the renewal of its permit, it will provide accurate information requested in NMAC 19.15.36.8.

iii NMAC 19.15.36.12.A(2)(c) – Permit Renewal Public Notice

If C.K. Disposal, LLC applies for permit renewal it shall comply with notification requirements set forth in NMAC 19.15.36.8 and financial assurance requirements set forth in NMAC 19.15.36.11. Once these two items are met and the permit has been approved, the C.K. Facility may continue operation and ensure fresh water, public health, safety, and the environment will be protected.

C NMAC 19.15.36.12.A(3) – Facility Permit 10-Year Review

C.K. Disposal, LLC will make available all necessary operational, compliance, financial assurance and other technical documents to OCD at any time during the 10 year permit period for the completion of a mid-term review. C.K. Disposal, LLC will respond to OCD requests for updates to address changes in regulatory standards.

1.2 NMAC 19.15.36.12.B – Denial of Permit

C.K. Disposal, LLC understand that the division may deny their permit renewal or major modification per 19.15.36.12.B.

1.3 NMAC 19.15.36.12.C – Additional Requirements

C.K. Disposal, LLC will comply with any additional requirements or conditions imposed by OCD during the permit renewal process.

1.4 NMAC 19.15.36.12.D – Revocation, Suspension or Modification of a Permit

C.K. Disposal, LLC understand that the division may revoke, suspend, or modify the permit at any time per 19.15.36.12.D.

1.5 NMAC 19.15.36.12.E – Transfer of a Permit

C.K. Disposal, LLC shall not transfer a permit without the division's prior written approval and review per 19.15.36.12.E.

1.0 NMAC 19.15.36.13 - SITING AND OPERATIONAL REQUIREMENTS APPLICABLE TO ALL PERMITTED SURFACE WASTE MANAGEMENT FACILITIES: EXCEPT AS OTHERWISE PROVIDED IN NMAC 19.15.36 - INTRODUCTION

Siting documentation is detailed to demonstrate that the operation of the Facility will protect public health and the environment. This section confirms the remote location, absence of any residential housing within 1-mile of the Facility boundary, absence of churches, schools, parks or other unrelated business in the area. With open pasture and oil field production facilities surrounding the C.K. Facility, the location is ideally suited for development as a surface waste management facility.

1.1 NMAC 19.15.36.13.A. Depth to Ground Water

Groundwater is demonstrated to be more than 100 -feet below the lowest elevation of the design depth of the landfill where oil field waste will be placed. Additional detail is provided in Attachment G.

A NMAC 19.15.36.13.(2) Landfarm Soil or Drill Cutting Requirements

Not Applicable. C.K. Disposal, LLC does not propose to operate a landfarm permitted under 19.15.36.15 NMAC.

B NMAC 19.15.36.13.(3) Landfarm Soil or Drill Cutting Requirements

Not Applicable. C.K. Disposal, LLC does not propose to operate a landfarm permitted under 19.15.36.15 NMAC.

C NMAC 19.15.36.13.(4) Landfarm Ground Water

Not Applicable.

D NMAC 19.15.36.13.(5) Waste Management Facility Groundwater

Groundwater is not located less than 50 ft below the lowest elevation of the processing area where oil field waste will be placed. Additional detail is provided in Attachment G.

1.2 NMAC 19.15.36.13.B. No Surface Waste Management Facility Shall be Located:

A NMAC 19.15.36.13.(1) within 200 feet of a watercourse, lakebed, sinkhole or playa lake;

The Facility is not located within 200-feet of a watercourse, lakebed, and sinkhole or playa lake.

Documentation regarding the locations of watercourses, lakebeds, sinkholes and playa lakes with respect to the C.K. Facility is provided in Attachment J.

B NMAC 19.15.36.13(2) within an existing wellhead protection area or 100-year floodplain;

The Facility is not located within an existing wellhead protection area or 100-year floodplain. Documentation regarding wellhead protection areas and 100-year floodplains is provided in Attachment J.

C NMAC 19.15.36.13(3) within, or within 500 feet of, a wetland;

The Facility is not located within 500-feet of a wetland. Documentation regarding wetlands in the vicinity of the Facility site is provided in Attachment A, Figure A.26.

D NMAC 19.15.36.13(4) within the area overlying a subsurface mine;

The Facility is not located in an area overlying a known subsurface mine. Documentation of mines, mills, and quarries is provided in Attachment A, Figure A.20.

E NMAC 19.15.36.13(5) within 500 feet from the nearest permanent residence, school, hospital, institution or church in existence at the time of initial application; or

The Facility is not located within 500-feet of the nearest permanent residence, school, hospital, institution, or church. Land use setback documentation is provided in Attachment A, Figure A.21.

F NMAC 19.15.36.13.(6) within an unstable area

Unstable area means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the landfill structural components responsible for preventing releases from a landfill. Examples of unstable areas are poor foundation conditions, areas susceptible to mass movements, and Karst terrain areas where Karst topography, with its characteristic surface and subterranean features, is developed as a result of dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographic features present in Karst terrains include, but are not limited to, sinkholes, sinking streams, caves, large springs, and blind valleys. Thin lenses or caliche material were encountered onsite, but due to the small nature of the caliche, it is not deemed an unstable area. Based on site visits and borings onsite, there is no evidence of any unstable area within the facility boundary.

1.3 NMAC 19.15.36.13.C. No Surface Waste Management Facility Shall Exceed 500 Acres

The C.K. Facility will not exceed 500-acres. Total acreage for the Facility site is 317 ± acres. A copy of the Boundary Survey for the C.K Facility site, which describes the size of the site and the site boundary is provided in Attachment I.C. Note that the Survey Description included on the Boundary Survey provides the description for the 317 acre ± C.K. Facility. Table I.1 provides details regarding site facilities and acreages.

1.4 NMAC 19.15.36.13.D. The Operator Shall Not Accept Oil Field Wastes Transported by Motor Vehicle

C.K. Disposal, LLC will comply with this requirement. The Oil Field Waste Management Plan provided requires that, prior to acceptance of any liquid waste, the transporter must provide the Facility with a Division-approved Form C-138.

1.5 NMAC 19.15.36.13.E. The Operator Shall Not Place Oil Field Waste Containing Free Liquids in a Landfill or Landfarm Cell

C.K. Disposal, LLC will comply with this requirement. The Oil Field Waste Management requires that, prior to acceptance of any oil field waste in the landfill portion of the Facility, the material will pass the paint filter test. Solidification, if necessary, will be accomplished in the Mixing/Solidification Area located in the lined stabilization and solidification area and described in Operation, Inspection, and Maintenance Plan.

1.6 NMAC 19.15.36.13.F. Surface Waste Management Facilities Shall Accept Only Exempt or Non-Hazardous Waste

C.K. Disposal, LLC will comply with this requirement. The Oil Field Waste Management Plan provides a detailed description of oil field waste acceptance protocol. Included in this Plan are Form C-138 certification, certification frequency. C.K. Disposal, LLC will maintain and make documentation of this available for OCD inspection.

A NMAC 19.15.36.13(1) Exempt oil field wastes

C.K. Disposal, LLC will comply with this requirement. The Oil Field Waste Management provides a detailed description of oil field waste acceptance protocol. Included in this Plan is the Form C-138 certification and additional documentation that the oil field waste is Resource Conservation and Recovery Act (RCRA) exempt.

B NMAC 19.15.36.13(2) Non-exempt, non-hazardous, oil field wastes.

C.K. Disposal, LLC will comply with this requirement. The Oil Field Waste Management Plan provides a detailed description of oil field waste acceptance protocol. Included in this Plan is the Form C-138 certification and additional documentation that any non-exempt oil field waste is nonhazardous.

C NMAC 19.15.36.13(3) Emergency non-oil field wastes.

C.K. Disposal, LLC will comply with this requirement by following Section 4.3 in Attachment K.

1.7 NMAC 19.15.36.13.G. Operator of a Commercial Facility Records

C.K. Disposal, LLC will comply with this requirement. The Oil Field Waste Management provides a detailed description of oil field waste acceptance recordkeeping forms. The forms in this Plan include the information required in this subsection and will be maintained and retained for a period of not less than five years following Facility closure. C.K. Disposal, LLC will make these records available for OCD inspection upon request.

1.8 NMAC 19.15.36.13.H. Disposal at a Commercial Facility

Disposal operations at C.K. Disposal, LLC will only be conducted when an attendant is on duty. C.K. Disposal, LLC may conduct Facility operations 24-hours a day, 7-days a week. The Facility will be secured with barbed wire fencing, cattle guards, and locking gates to prevent any unauthorized access or disposal when an attendant is not on duty.

1.9 NMAC 19.15.36.13.I. Migratory Bird Projection

C.K. Disposal, LLC herein requests an exception to 19.15.36.13.I NMAC. The Migratory Bird Protection Plan presented as describes an alternate methodology to the screening requirement of the storage ponds. This Plan describes visual inspections and migratory bird retrieval and clean up procedures should bird(s) require decontamination. In addition, the Engineering Design provides a process design for produced waters and other liquids that will remove the oils present in these materials prior to discharge through the evaporation ponds. Plan can be found in Section NMAC 19.15.36.17, Section 1.3C of this permit application.

1.10 NMAC 19.15.36.13.J. Surface Waste Management Sign

The proposed Site Entrance Sign is provided as Figure I.4. The sign was designed in compliance with the requirements of 19.15.36.13.J NMAC. A 4-foot by 8-foot sign with 3-inch lettering will identify the Facility operator as C.K. Disposal, LLC and will include the Facility permit number, location and emergency phone numbers.

1.11 NMAC 19.15.36.13.K. The Operators Shall Comply with the Spill Reporting and Corrective Action Provisions of 19.15.30 NMAC or 19.15.29 NMAC.

The C.K. Facility is specifically designed to prevent pollutants from entering surface and groundwater, as demonstrated in Attachments A, B, and C. Successful implementation of the engineering design and operational programs will ensure compliance with 19.15.30 NMAC. The C.K. Disposal Contingency Plan (Appendix B in Attachment K) is designed to comply with the notification and corrective action as required in 19.15.29 NMAC.

1.12 NMAC 19.15.36.13.L. Operator Inspection and Maintenance Plan

The Operations, Inspection, and Maintenance Plan for the C.K. Facility is provided. The Plan describes in detail the methods and frequency for inspections, sampling, recordkeeping, and maintenance for the leak detection sumps, and containment berms.

1.13 NMAC 19.15.36.13.M. Operator Plan to Control Run-On Water onto the Site and Run-Off Water from the Site

Engineering Design and Calculations provides the design for berms, conveyance channels, and detention capacity to control run-on/run-off for at least the peak discharge from a 25-year 24-hour storm. C.K. Disposal, LLC will prevent discharge of pollutants to the waters of the State or United States in violation of state water quality standards through adherence to the Operations, Inspection, and Maintenance Plan in Attachment K, and construction of the detention ponds described in Attachment J. If required after consultation with New Mexico Environment Department (NMED), C.K. Disposal, LLC will obtain a permit under the Multi-Sector General Permit for Stormwater Discharges (promulgated September 29, 2008).

1.14 NMAC 19.15.36.13.N. Contingency Plan

The Contingency Plan included in Attachment K, Appendix B and provides detailed information in response to 19.15.36.13.N.1 through 14 NMAC.

1.15 NMAC 19.15.36.13.O. Gas Safety Management Plan

C.K. Disposal, LLC does not believe that this Section applies to the proposed Facility. Landfill Gas (LFG) is typically produced when there is a significant supply of readily putrescible organic material, moisture; and a lack of oxygen in the fill. Oil field wastes do not contain significant amounts of putrescible wastes and will not provide a suitable environment for LFG production. Typical oil field wastes will not generate significant quantities of LFG, nor the requisite pressure to promote migration. Conventional LFG monitoring and control systems would not be necessary or effective; and the waste matrix itself would inhibit migration or collection if it contained primarily soils and less than 5% degradable organics.

However, a gas monitoring program consisting of testing incoming vehicles during unloading will be utilized to ensure that hydrogen sulfide (H_2S) gas concentrations do not exceed 10 parts per million (ppm) on-site or at the property boundary. Areas around the landfill disposal cells, treating plant, liquid solidification, and evaporation ponds will utilize monitors that issues a visual and audible signal at 10-ppm H_2S to ensure compliance with regulatory alert levels.

Routine gas monitoring of the proposed vadose zone monitoring wells will also be conducted.

Monitoring points may be added or replaced as necessary. Gas safety management details are presented, and the H_2S Prevention and Contingency Plan.

1.16 NMAC 19.15.36.13.P. Training Program

C.K. Disposal, LLC will comply with this requirement. The Operation, Inspection, and Maintenance Plan describes in detail the training programs for site personnel. Training records will be maintained by C.K. Disposal, LLC for OCD inspection for a period of not less than five years.

1.0 NMAC 19.15.36.14 - INTRODUCTION

C.K. Disposal, LLC proposes to develop a commercial surface waste management facility consisting of a landfill, liquid processing area, and deep well injection per NMAC 19.15.36. This section provides the general design and operating requirements as provided in NMAC 19.15.36.14. The proposed C.K. Facility is located 0.05-miles south of State Highway 234, approximately 4.16-miles southeast of Eunice, New Mexico, in Lea County. The C.K. Facility will encompass a 316.97-acres broken down into individual sections as listed below in Table 1 – C.K. Facility.

Table 1 –C.K. FACILITY

Area	**Acres**
C.K. Disposal E&P Landfill and Processing Facility	316.97
Landfill	141.5
Liquid Processing	51.75
Saltwater Disposal	5.1
Buffer Areas, Site Structures and Access Roads	118.62

1.1 NMAC 19.15.36.14.A(1) – Working Face and Compaction

The C.K. Facility will keep its working face to the smallest practical areas while accepting waste on a daily basis. The working face will be minimized, provide a safe unloading area for trucks, and a safe working area for site equipment. To compact the waste to the smallest practical volume, the lifts will be spread in layers approximately 2-foot thick and worked by high ground-pressure bulldozer, compactor, or equivalent.

A minimum 2-foot thick protective cover will be placed over the geomembrane and act as a leachate collection system. The protective cover will be comprised of site soils. Protective cover does not require compaction control; however, it should be stable and capable of supporting site equipment and disposal traffic. Care will be exercised during placement so as not to shift, wrinkle, or damage the underlying geosynthetic layers, and placement methods will be documented. Protective cover will be placed such that the top surface, while spreading, is at least 2-feet above the geosynthetic layers at all times, unless low-ground pressure dozers are used (i.e. track pressure less than 5-psi). At least 1-foot should be retained between the low-ground pressure dozer and the geosynthetic layer. A greater thickness will be maintained to support loaded hauling trucks and trailers and for turning areas. Drivers will proceed with caution when on the overlying soil and prevent spinning of tires on sharp turns. Placement of protective cover is discussed in full detail in Attachment C - Soil Liner Quality Control Plan.

1.2 NMAC 19.15.36.14.A(2) - Access Control

The site employees will control access and monitor all vehicles entering and exiting the site. Access to the landfill is limited to the entrance road on the northeast corner of the facility that connects to State Highway 234. Unauthorized access to the landfill will be controlled by a perimeter fence located along the facility boundary and a gate at the access road. The perimeter fence will consist of a 4-strand barbed wire fence. Although the facility will operate 24-hours a day, the gate will be locked when no landfill personnel are on site. A cattle guard will be placed at the entrance along with a gate to prevent animals from entering the site. All persons accessing the site, including customers, visitors, and employees will check-in at the scale house area or gate house.

1.3 NMAC 19.15.36.14.A(3) – Fire Prevention and Extinguishing

A Fire Prevention

If a fire occurs, the landfill manager will be notified immediately. The customer service representatives, inspectors, equipment operators, and spotter will be on alert for signs of hot loads, such as smoke, steam, or heat being released from incoming waste loads. Suspected hot loads will not be allowed at the active working face. The driver will be directed to discharge or unload in an area that is located away from waste, vegetation, other vehicles and structures. The hot load or fire will be quenched or extinguished using soil, extinguishers, water, or other appropriate means. If the fire cannot be extinguished by onsite personnel within 10 minutes of detection, the local fire department will be notified via 911. In addition to these hot load procedures, the following fire prevention measures shall be enforced on-site:

- Smoking on site is not permissible, and smoking cannot occur within 20-feet of an entrance to the C.K. Facility.
- Fuel spills will be contained and cleaned up immediately, regardless of their location.
- Open burning is not allowed.
- Proper compaction will be utilized at the working face.
- Proper cover application will be utilized to create firebreaks within the buried waste mass.
- No landfill equipment will remain on the immediate active area of the site overnight.
- Staff will be trained when hired, as well as annually thereafter, regarding the Fire Prevention, Fire Control, General Rules for Fires, Specific Fire Fighting Procedures, and Notification requirements.

Table 2 provides contact information for reference and use during an emergency.

Table 2 - Emergency Contacts

Agency/Organization	Emergency Number
1. Fire	
Eunice Fire Department	911 or (575) 394-3258
2. Police	
Eunice County Police Department	911 or (575) 394-2112
Lea County Sheriff's Department	911 or (575) 396-3611
New Mexico State Police	911 or (575) 392-5580
3. Medical/Ambulance	
Eunice Fire Department	911 or (575) 394-3258
Lea Regional Medical Center 5419. N. Lovington Highway Hobbs, NM 88240	(575) 492-5000
4. Response Firm	
Phoenix Environmental, LLC. 2113 French Drive Hobbs, NM 88240	(575) 391-9685
5. OCD Emergency Response Contacts	
Oil Conservation Division - District 1 1625 N. French Drive Hobbs, NM 88240	(575) 393-6161 (office) (575) 370-3186 (mobile)
Oil Conservation Division - Main Office 1220 South St. Francis Drive Santa Fe, NM 87505	(505) 476-3440
6. State Emergency Response Contacts	
Environmental Emergency 24 hr. (NMED)	(505) 827-9329
New Mexico Environment Department Solid Waste Bureau, Santa Fe	(505) 827-0197
7. Local Emergency Response Contacts	
Lea County Emergency Management	(575) 391-2983
8. Federal Emergency Response Contacts	
National Emergency Response Center (U.S. Coast Guard)	(800) 424-8800
Region VI Emergency Response Hotline (USEPA)	(214) 665-2200

B Fire Control

The City of Eunice Fire Department will be contacted any time a fire occurs which onsite staff cannot extinguish within 10 minutes of detection. The following rules will be implemented in the event of a fire at the proposed facility.

- If fire cannot be extinguished in 10 minutes, call the Fire Department at 911.
- Do not attempt to fight fire alone.
- Be familiar with the use and limitations of firefighting equipment onsite.
- Alert other facility personnel.
- Do not attempt to fight fire without adequate personal protective equipment.
- Assess extent of fire and possibilities for the fire to spread.
- Attempt to contain or extinguish the fire until arrival of the Fire Department if it appears the fire can be safely fought with available firefighting devices.

C Specific Fire-Fighting Procedures

If fire occurs on or within a vehicle or piece of equipment, the equipment operator should bring the vehicle to a safe stop. The vehicle should be parked away from fuels, supplies, uncovered waste, and other vehicles, if safety of personnel will allow. The engine will be shut off and the brake engaged or other methods will be used to prevent subsequent movement of the vehicle. Firefighting methods for fires involving waste material include smothering with soil, separating burning material from other waste, and spraying with water from a water truck (if fire is not oil related). If detected soon enough, a small fire may be fought with an ABC rated hand-held extinguisher. If fire is in the working face, the burning area should be isolated or pushed away from the working face quickly before fire is spread throughout the working face. If this is not possible or unsafe, efforts to cover the working face with soil must be initiated immediately to smother the fire.

D Stockpiling Fire-Fighting Materials

i Earthen Material Coverage

Landfill fires normally will be extinguished by smothering with cover soil material spread by a dozer or other suitable equipment. A minimum of 667-cubic yards of soil or enough soil to cover the working face with at least six inches of compacted soil will be stockpiled within 2,500-feet of the working face for this purpose. Earthen material coverage calculations are included below.

Maximum size of working face= 30,000 square feet

Contingency=20 %

Volume of soil required for a six-inch cover on a 30,000 square foot maximum working face with a 20 percent contingency included is calculated as follows:

Maximum size of working face= 30,000 sq. ft.

Required stockpile= 30,000 sq. ft. x 0.5 ft. ÷ (27 cy/sf) * 1.2 (20% contingency) = 667-cubic yards

A daily log will be maintained to document the location of the stockpile, the distance of the stockpile from the working face, the volume of the stockpile, the use and replacement of soil for fire control, and demonstration of the amount of stockpiled soil will be adequate to cover the largest working face in use on that day. The operator will, at all times, maintain sufficient equipment for moving the soil stockpile and placing a six-inch soil cover over the working face within one hour of detecting a fire at the working face.

1.4 NMAC 19.15.36.14.A(4) – Litter and Odor Control

A Litter Control

Windblown waste and litter will be controlled through several methods, including proper unloading, compaction, and cover procedures. The placement of screening berms, stockpiles, and adequate staffing will also provide control of windblown waste and litter. Personnel will patrol the landfill site, including fences, access roads, and the entrance gate every operating day to pick up and return windblown waste and litter to the active working face and perform other litter control measures as necessary. Daily cover will be placed on top of the waste lift as soon as practical for any portion of the lift that reaches recommended lift height. The working face will be covered daily.

B Odor Control

Facility personnel will ensure the municipal solid waste facility does not violate any applicable air quality requirements per the NMAC. Odors will be controlled at the site, and if they occur, will be reduced in accordance with the Odor Management Plan. Sources of odor and potential odor sources associated with this landfill facility include wastes containing high levels of hydrogen sulfide (H_2S) gas, the open working face, and ponded water. All wastes which arrive onsite will undergo visual inspection and be screened for H_2S. If waste contains concentrations of 10-parts per million (ppm) or higher of H_2S, the load will be treated with calcium hypochlorite ($Ca(ClO)_2$), also referred to as bleach powder, until H_2S concentration is below 1-ppm. If the hauler refuses to comply with this treatment, the load will be rejected and taken offsite.

The size of the working face will be minimized thereby exposing as little waste as possible to open air. Waste transported to the facility for disposal will be spread and compacted promptly into the working face of the landfill. Waste will be covered on a daily basis with 6-inches of clean soil or an alternate daily cover. If landfill closes for more than 24 hours, the working face will be covered with a minimum of 6-inches of clean soil. Leachate generated by this landfill will be placed in the produced water tanks for separation and then evaporation ponds. If H_2S levels in the evaporation ponds exceed 10-ppm, bleach will be added until H_2S concentration is below 1-ppm. Leachate risers are constructed with caps to minimize exposure to open air and diffusion of gas.

1.5 NMAC 19.15.36.14.A(5) – Prohibited Excavation of Closed Cells

Closed cells onsite will remain closed and not excavated without approval from the Oil Conservation Division (OCD) of the Energy, Minerals and Natural Resources Department.

1.6 NMAC 19.15.36.14.A(6) – Daily Cover Requirements

The C.K. Facility will apply an alternate daily cover or 6-inches of well-compacted earthen material not previously mixed with rubbish or other solid waste at the end of each day to control dust, debris, odors, other nuisances, fires, windblown litter or waste, and scavenging, unless a more frequent interval is required.

1.7 NMAC 19.15.36.14.A(7) – Intermediate Cover Requirements

The C.K. Facility will cover all areas that have received waste but will be inactive for longer than 30-days, and have not reached the final waste elevation with intermediate or final cover. Intermediate cover will be placed over existing daily cover, and will include 6-inches of suitable earthen material capable of sustaining native plant growth and will be seeded or sodded following its application in order to control erosion. This intermediate cover will be graded to prevent ponding of water. Plant growth or other erosion control features will be inspected and maintained as needed. Placement of intermediate and final cover are discussed in Attachment C and Attachment D.

1.8 NMAC 19.15.36.14.A(8) – Closure Requirements

As each landfill unit reaches its final top of waste elevation, the unit will undergo the closure process. The operator shall notify the division’s environmental bureau at least three working days prior to landfill unit closure. Closure plan is provided in the NMAC 19.15.36.18 section below. The plan provides detailed procedures for closure and post-closure care.

1.9 NMAC 19.15.36.14.B(1)&(2) – Vadose Monitoring Program

A Proposed Vadose Zone Monitoring System

During initial site investigation five (5) soil bores were taken onsite to a depth of 175-feet below ground surface. No groundwater was observed in the cuttings, nor in the bore holes after a 24-hour period. No groundwater was present within the upper 175-feet of the Ogallala Formation or Chinle Formation because they rise above the saturated zone of the Ogallala Formation. Therefore, a vadose monitoring system has been designed for the facility based on onsite specific technical information. The design considered the thickness, stratigraphy, lithology, and hydraulic characteristics of the geologic units, as well as the depth to groundwater, TDS concentration, critical receptors, and the contaminant migration pathway analysis.

The presence of groundwater in the vadose zone monitoring wells may not be the result of leakage from the facility. Other sources such as infiltration of surface water during excavation of the landfill cells or infiltration from proximal storm water detention ponds may cause temporary saturation and water to be detected in down-slope vadose zone wells. Chemical analysis of water samples and comparison to leachate samples and/or samples from a leak detection system will be used to determine if the water is a result of a release from the facility.

B Proposed Monitoring Well Locations

Nine (9) vadose zone monitoring wells have been designed and identified along a point of compliance on the site perimeter. The compliance monitoring well locations are generally located down-slope of the leachate collection sumps. In addition, two background (up-slope) monitoring wells have been designed along the north side of the facility. The background wells represent the quality of background or up-slope water not affected by leakage from a landfill.

During initial construction of the landfill unit, wells VW-1, VW-2 and VW-3 will be constructed. An initial sample of water, if present, will be collected prior to acceptance of any waste at the facility. Other vadose zone monitoring wells will be installed upon progression of the landfill units and samplings will be collected prior to acceptance of waste in these stated landfill units. The hydrogeology study, vadose monitoring plan and sampling and analysis plan can be found in Attachments D, E and F.

1.10 NMAC 19.15.36.14.C – Landfill Design Specifications

A Introduction

The C.K. Facility will encompass 316.97-acres, with a landfill footprint of 141.50-acres. The six (6) waste cells will have a combined disposal capacity of approximately 24,585,056-cubic yards. Volume and Site Life Calculations are provided in Attachment K. The landfill method will be below-grade fill with 4H:1V side slopes and aerial fill with 5H:1V final cover side slopes, with a maximum 3.5% final cover top slope. The drainage system as described in Attachment J – Drainage Study, will be designed to meet or exceed NMAC requirements for run-on and runoff.

Per NMAC 19.15.36.14.C(1), the landfill will have an alternate liner design due to no groundwater present within 100-feet of the deepest excavation. The site also has a red bed clay layer that acts like a barrier between the site and groundwater. The alternate liner system will consist of, from bottom to top.

- 6-inches of compacted subgrade
- A Geosynthetic Clay Liner (GCL)
- 60-mil High Density Polyethylene (HDPE) Geomembrane Liner
- 200-mil HDPE Geonet (floor)/200-mil HDPE Geocomposite (side slopes)
- 60-mil HDPE Geomembrane Liner
- 200-mil HDPE Geocomposite (floor/slope)
- 24-inches of Protective Soil Layer

Engineered site drawings and liner cross sections can be found in Attachment B – Engineering Design Plans.

1.11 NMAC 19.15.36.14.C(1) – Base Layer

The base layer of the landfill liner will consist of 6-inches of compacted subgrade overlain by a geosynthetic clay liner (GCL). The GCL will comprise of a uniform layer of granular sodium bentonite encapsulated between two geotextile layers. The GCL will have a maximum hydraulic conductivity of 5 x 10^{-9} cm/sec, which is below the 1 x 10^{-7} cm/sec allowed in the NMAC. The GCL shall be BENTOLINER products as produced by GSE Environmental or an equivalent pre-approved by the Geotechnical Professional. Details on quality control, storage, installation, and reporting can be found in Attachment C - Soil Liner Quality Control Plan.

1.12 NMAC 19.15.36.14.C(2) – Lower Geomembrane Liner

The lower geomembrane liner will consist of a 60-mil HDPE material.

1.13 NMAC 19.15.36.14.C(3) – Geonet/Geocomposite

A geonet (floor) and geocomposite (sideslopes) will comprise the leak detection of the liner system at the C.K. Facility. The geonet component will be used on the floor and the geocomposite will be placed on the side slopes. The geocomposite consists of a geonet heat laminated on both sides with an 8-ounce nonwoven geotextile. The geocomposite will be used on the side slopes to provide a higher interface friction with the textured HDPE liner. The geonet/geocomposite are designed to transfer fluid horizontally though the anticipated landfill loads. The geonet and geocomposite have a transmissivity of 2 x 10^{-3}-m/s and 1 x 10^{-2}-m/s, respectively. Since soil will not be used, leachate will be transported through the geonet/geocomposite layers at the rate listed above. The geonet and geocomposite materials shall be as manufactured by GSE Environmental or an equivalent pre-approved by the Geotechnical Professional. Additional information on installation, testing and reporting can be found in Attachment C - Soil Liner Quality Control Plan.

The geonet/geocomposite system will channel leachate directly to the sump and leak detection piping. The slope of the landfill sub-grade, drainage pipes and laterals will be at 2% as shown in Attachment B – Engineered Design Plans. The leachate collection system will be comprised of 6 & 24-inch SDR 11 pipe. The SDR 11 pipe has a larger wall thickness than the minimum schedule 80 pipe in the NMAC. The operator shall seal a solid drainage pipe to transport collected liquids to a corrosion-proof sump or sumps located outside the landfill’s perimeter for observation, storage, treatment or disposal. The sump and pipe layout is shown in Attachment B – Engineering Design Plans.

1.14 NMAC 19.15.36.14.C(4) – Upper Geomembrane Liner

The upper geomembrane liner will consist of a 60-mil HDPE material.

1.15 NMAC 19.15.36.14.C(5) – Leachate Collection and Removal System

A leachate collection system (LCS) will be placed above the upper geomembrane liner. The LCS will consist of a heat bonded HDPE geonet/geotextile drainage composite (geocomposite) on the floor and side slopes with granular (gravel) embedded leachate collection pipes in the sump and pipe trench areas. The leachate collection pipes will consist of six-inch diameter pipe with 3/8-inch diameter holes on six-inch centers. To avoid gravel entering into the collection pipes, the granular drainage layer shall consist of rounded, river-run gravel meeting the requirements of ASTM C-33 for coarse aggregate.

Crushed material will not be acceptable. The gravel should meet gradation requirements of No. 6 (Nominal size ¾ inch to 3/8 inch) or coarser. The maximum gravel size shall not exceed two-inches.

"Leachate chimneys" will be installed through the protective cover to allow a direct hydraulic conduit between the lowest waste layers and the LCS. A minimum 8-ounce geotextile will completely encase the pipe embedment gravel layer with a full-width geotextile overlap where the chimney daylights through the protective cover. The geotextile overlap will be covered by a maximum six-inch thick layer of the granular material used as the pipe embedment. Leachate pipes will be placed at a minimum slope of 2% to aid in leachate removal.

The geotextile materials will include an 8-ounce fabric around the leachate chimneys and a minimum 8-ounce nonwoven fabric on both sides of the geonet forming the geocomposite layer. The geotextile will be bonded on both sides of the geonet. Additional information on installation, testing and reporting is located in the Attachment C - Soil Liner Quality Control Plan.

Leachate will be pumped out of sumps into tanker trucks and transferred to the produced water receiving tanks and then evaporation ponds.

1.16 NMAC 19.15.36.14.C(6) – Protective Soil Layer

A minimum 2-foot thick protective cover will be placed above the LCS. The protective cover will consist of site soils in combination with the leachate chimneys described above. The maximum gravel size shall not exceed two inches. Pre-construction and conformance testing for the protective cover soils will include gradation analysis with a minimum conformance testing frequency of one grain-size analysis (ASTM D422) per 5,000-cubic yards (or fraction thereof) of in-place material. Protective cover does not require compaction control; however, it should be stable and capable of supporting site equipment and disposal traffic. A greater thickness will be maintained to support loaded hauling trucks and trailers, and for turning areas. Additional information on installation, testing and reporting is located in the Attachment C – Soil Liner Quality Control Plan.

1.17 NMAC 19.15.36.14.C(7) – Placement of Waste

Upon approval of construction of the landfill liner system, the Owner/Operator shall place oil field waste over the leachate collection and removal system protective layer.

1.18 NMAC 19.15.36.14.C(8) & (9) – Landfill Final Cover Design

As each cell progresses through aerial fill and reaches its final top of waste elevations, final cover will be applied, as shown in Attachment B – Engineered Design Plans. The final cover will be placed in phases as a cell reaches its designed top of waste elevation. Final cover application will generally consist of the following:

- Reach approved final waste elevation with solid waste, place 6-inches of daily cover and 6-inches of intermediate cover.
- Perform a baseline topographic survey to act as the control for thickness verification during the placement of the final cover.

- Construct the final cover layers, and perform testing in accordance with the Attachment D - Final Cover Quality Control Plan (FCQCP).
- Final cover evaluation report and as-built survey will be prepared by an independent licensed professional engineer in the State of New Mexico and will be maintained in the site operating records and the final cover log will be updated to reflect the area where the final cover has been placed.

The final cover system will be a combination two performance based liner systems. One design is for the top cap and the other for the side slopes.

The top cap design will follow the design outlined in the NMAC but will replace the drainage layer with a geocomposite drainage layer. Water collected by the geocomposite will be transported to articulated block channels which run around the perimeter of the cap diverting runoff from the side slopes. The perimeter channels will discharge to one (1) of four (4) articulated block channels of the landfill corner. Although collecting water from the geocomposite, the articulated blocks do not encroach into the overall thickness of final cover on either the cap or side slopes. Drainage design is shown in Attachment B – Engineered Design Plans and backup information in Attachment J – Drainage Study. The design for the cap is as follows from bottom to top:

- 12-inch Foundation Layer
- 60-mil High Density Polyethylene (HDPE) Geomembrane Liner
- Geocomposite Drainage Layer
- 24-inch Infiltration Layer
- 12-inch Soil Erosion Layer

The side slope final cover design will be a performance based water balance cover. With the assistance of 5 to 1 slopes, the majority of water will run off the side slopes to drainage channels around the perimeter of the landfill base. The design of the side slope final cover is as follows from bottom to top:

- 12-inch Foundation Layer
- 24-inch Infiltration Layer
- 12-inch Soil Erosion Layer

Both performance final covers have been modeled using the Hydrologic Evaluation of Landfill Performance (HELP) Model. The final covers demonstrate meeting permeability criteria listed in the NMAC. The two cap designs will not create a “bathtub effect” since the final cover has an equivalent or lower permeability than the liner system installed. The HELP model results can be found in Attachment E.

The final cover system will be maintained consistent with those defined in Attachment D – Final Cover Quality Control Plan. All soil placed on the final cap will be compacted to a minimum of 80 percent Standard Proctor Density. The Owner/Operator shall install the top landfill cover within one year of achieving the final landfill cell waste elevation. Prior to installation of the final cover, the Owner/Operation will provide three (3) working days' notice to the division, to allow a member of the division to witness the final cover installation. Additional information on installation, testing and reporting is located in Attachment D - Final Cover Quality Control Plan.

1.19 NMAC 19.15.36.14.C(10) – External Piping

The C.K. Facility has been designed to use HDPE pipe based on its ability to resist chemical attack and degradation. The leachate collection and sump removal systems will not penetrate the liner but will run along the landfill side slopes placed against the geocomposite liner. The geotextile layer of the geocomposite along with the 2-foot protective cover will protect the pipes and liner system from accidental damage from landfill waste or landfilling activities.

The leak detection pipe will be the only pipe penetrating the liner system. The leak detection pipe will be placed between the upper geomembrane and leak detection geonet/geocomposite. An HDPE boot with pipe clamps will be placed around the pipe at the penetration. The HDPE boot will be welded to the upper geomembrane, to create a leak free seal. The location of the pipe in the sump allows inspection of the leak detection system by the Owner/Operator, while maintaining the integrity of the liner system. Design drawings of the pipe penetration can be found in Attachment B – Engineered Design Plans.

1.20 NMAC 19.15.36.14.D(1)(a)-(c) – Liner Specifications and Requirements

The 60-HDPE liner has a hydraulic conductivity less than the maximum 1 x 10^{-7}-cm/sec allowed in the NMAC. The HDPE material has chemical and ultraviolet resistance properties, listed in Attachment F, and is compatible with and resistant to chemical attack from the oil field waste and leachate. The 2-feet of protective cover will assist the HDPE liner to withstand the projected loading stresses, setting and disturbances from oil field waste, and cover material and equipment. The geomembrane liner (GML) materials shall be as manufactured by GSE Environmental or an equivalent pre-approved by the Geotechnical Professional. Details on quality control and storage can be found in Attachment C - Soil Liner Quality Control Plan.

When installed on the floor, the HDPE liner will be placed at a minimum of 2% slope to promote positive drainage for leachate collection and leak detection. The side slopes are designed at a 4 to 1 slope to minimize tensile stresses on the liner material. Interface friction test reports are provided in Attachment F, which provide a maximum friction angle of 19.4-degrees, well above the 4 to 1 slope being used on side slopes.

Field seams between sheets of GML material will be made using approved fusion welding systems, equipment, and techniques. Approved fusion welding systems include fillet welds using extrudate, lap welds using extrudate, and lap welds using single or double wedge (double track) welder. The welds will either be pressure or vacuum tested. Additional information on installation, testing, and reporting is located in Attachment C - Soil Liner Quality Control Plan.

1.21 NMAC 19.15.36.14.E – Requirements for the Soil Component

A NMAC 19.15.36.14.E(1) – (2) – Subgrade Placement

The subgrade shall be prepared in a manner consistent with proper subgrade preparation techniques for the installation of geosynthetic materials and as recommended by the GCL manufacturer. The subgrade shall be compacted to 90-percent standard proctor density or greater (if required by GCL manufacturer). The subgrade shall be properly compacted so as to prevent post construction settlement, causing excessive strains in the GCL or other synthetic liner materials. Prior to installation, ensure a surface free of debris, roots, or angular stones larger than ½-inch. The subgrade must be rolled with a smooth-wheeled roller. During installation, ensure rutting or raveling is not caused by installation equipment. Additional information on installation, testing and reporting is located in Attachment C - Soil Liner Quality Control Plan.

B NMAC 19.15.36.14.E(3) – Clay Soil Component Placement

The alternate liner designed for the C.K. Facility will use a GCL instead of compacted clay soil. The GCL has a uniform layer of sodium bentonite encase between two geotextile fabrics. The sodium bentonite clay utilized in the GCL is a naturally occurring clay mineral that swells as liquid enters between its clay platelets. During installation, the needle-punched fibers hold the bentonite in place and prevent the GCL from separating. The GCL, at minimum, will have 0.75-lb/ft^2 of sodium bentonite. Each GCL panel will have an overlay of 6-inches to create a uniform clay layer. Additional information on installation, testing, and reporting is located in the Attachment C - Soil Liner Quality Control Plan.

1.22 NMAC 19.15.36.14.F – Leachate Collection and Removal System Placement

The leachate collection and removal system is comprised of 2-foot protective cover overlaying a geocomposite. The protective soil layer is comprised of excavated onsite soils. Prior to placement, the soil will be screened to remove organic material. The geocomposite will consist of a heat bonded HDPE geonet/geotextile drainage composite. The geotextile fabric acts as a barrier between the soil and geonet to prevent clogging of the geonet. The geocomposite has a transmissivity of 1 x 10^2-cm/s. This transmissivity will provide transport of the leachate to the sumps for removal. The geonet is made from the same HDPE material as the geomembrane liner and provides the same chemical resistivity properties. Chemical resistivity property documentation is provided in Attachment F.

Sumps will have high water level sensors which will inform the operator if leachate is reaching unauthorized levels. The operator will drain the sumps and transfer the leachate to the produced water tanks for disposal.

1.23 NMAC 19.15.36.14.G – Landfill Gas Control System

Typically landfill gas is generated during the natural process of bacterial decomposition of organic material. Numerous factors influence the quantity of gas generated at a landfill. The factors include types and age of waste, the quantity and types of organic compounds in the waste, moisture content and waste temperature. Organic wastes include food, garden waste, street sweepings, textiles, and wood and paper products. Oil field wastes do not contain significant amounts of organic compounds. Factoring the type of waste and the arid climate in the area, no landfill gas monitoring is proposed at the C.K. Facility.

The C.K. Facility will monitor gas by inspection of vehicles with incoming waste and evaporation ponds. Incoming loads will be inspected at either the scale or gate house. Loads will be monitored for hydrogen sulfide (H_2S). H_2S monitors will be placed throughout the site. This includes the scale and gate houses, landfill working face, evaporation ponds, liquid processing area, stabilization and solidification area, and the saltwater disposal area. Monitors will alarm staff if concentrations of H_2S exceed 10-parts per million (ppm). If H_2S levels exceed 10-ppm on incoming waste and evaporation ponds, loads will be treated with calcium hypochlorite ($Ca(ClO)_2$), aka chlorine or bleach powder, until H_2S concentration is below 1-ppm. A minimum of 1,000-gallons of calcium hypochlorite will be kept onsite for H_2S treatment.

Habitable onsite buildings and structures will be monitored at a minimum quarterly with either a portable combustible gas indicator or a continuous LFG monitor/alarm that will provide an audible alarm if methane concentration exceed 1.25 percent by volume. In the event allowable methane concentration limits are exceeded, the building will be immediately evacuated and ventilated by opening doors and windows. Immediate necessary steps to be taken include notifying the respective officials listed in Table 2.

1.24 NMAC 19.15.36.14.H(1)–(4) – Landfill Gas Response Plan

The purpose of the response plan is to address necessary procedures to be taken if methane concentrations exceed allowable concentrations in structures or facility boundary matrices, to ensure protection of fresh water, public health, safety and the environment. The response plan will include initial response measures and notification procedures. The emergency response differs between buildings and facility boundaries as will be discussed.

A Emergency Action

i Buildings/Structures

If the monitoring device in a facility structure is triggered and/or gas monitoring equipment indicates H_2S concentrations have exceeded allowable concentrations, the facility will be evacuated of all personnel immediately and the site manager notified. Personnel will not be allowed to reenter the affected structure until additional measures are taken. Only authorized monitoring personnel will be allowed reentry into the structure.

ii Facility Boundary

The site manager will be notified if H_2S concentrations exceed allowable concentrations. The immediate course of action for the site manager will be to determine if any nearby structures (including off-site) are at risk and if evacuation of the structures is required.

B Notification Procedures

When H_2S concentrations exceed allowable concentrations in monitoring points, or within any onsite structure, the monitoring personnel will notify the site manager who will immediately take all necessary steps to ensure the protection of human health. Notification will be made to New Mexico Environmental Department (NMED), OCD district office and the appropriate city, county, and local government and emergency officials; and any residents, tenants and owners of the property within ¼-mile (1,320 feet) of the reading. Within seven days of detection, the site manager will place in the site operating record the concertation of H_2S levels detected and a description of the steps taken to protect human health. Also, within seven days, written notification will be sent to the OCD district office. Within 30 days of detection, the Owner/Operator will submit a remediation plan for the H_2S release(s), which is described below. Within 60 days of detection, implement a remediation plan for the H_2S release(s) as discussed in the Remediation Plan.

C Remediation Plan

If H_2S concentrations exceed allowable concentrations in monitoring points or within any onsite structures, remediation actions will be implemented within 60 days of detection. The Remediation Plan will begin by investigating the cause of these levels. Authorized personal will continue monitoring downstream of the exceedance. Once the source of the exceedance is determined, the affected area will be treated with calcium hypochlorite until H_2S concentrations are <1-ppm.

1.0 NMAC 19.15.36.15 – SPECIFIC REQUIREMENTS APPLICABLE TO LANDFARMS

The permit submitted by Parkhill, Smith & Cooper, Inc. on behalf of C.K. Disposal, LLC. does not propose to permit or operate a landfarm.

1.0 NMAC 19.15.36.16 – SMALL LANDFARMS

The permit submitted by Parkhill, Smith & Cooper, Inc. on behalf of C.K. Disposal, LLC. does not propose to permit or operate a small landfarm.

1.0 NMAC 19.15.36.17 - INTRODUCTION

C.K. Disposal, LLC. proposes to develop a Commercial surface waste management facility consisting of a landfill, liquid processing area, and deep well injection per NMAC 19.15.36. This section provides the general design and operating requirements as provided in NMAC 19.15.36.14. The proposed C.K. Facility is located 0.05-miles south of State Highway 234, and approximately 4.16-miles southeast of Eunice, New Mexico, in Lea County. The C.K. Facility will encompass 316.97-acres broken down into individual sections as listed below in Table 1 – 19.15.36.14 – C.K Facility Acreage.

Table 1 – 19.15.36.14: C.K. FACILITY ACREAGE

Area	Acres
C.K. Disposal E&P Landfill and Processing Facility	316.97
Landfill	141.50
Liquid Processing	51.75
Saltwater Disposal	5.10
Buffer Areas, Site Structures and Access Roads	118.62

1.1 NMAC 19.15.36.17.A – Engineered Design Plans

Plans for the C.K. Facility evaporation ponds, tank holding area, stabilization, and solidification area have been designed by Parkhill, Smith and Cooper, Inc. (PSC) under New Mexico Registered Professional Engineer, Nicholas Ybarra. The sections listed below provide backup documentation for design, operation, construction, and closure of the above mentioned structures designed per requirements listed in NMAC 19.15.36.17.

- Attachment B - Engineered Design Plans
- Attachment C - Soil Liner Quality Control Plan
- Attachment G - Hydrogeology Report
- Attachment H - Vadose Monitoring Plan
- Attachment K - Operating and Maintenance Procedures
- Attachment L - Closure and Post-Closure Plan

The site operating plan provides a plan to prevent the H_2S accumulation in the evaporation ponds and a contingency plan if the levels go above critical levels listed in the NMAC.

1.2 NMAC 19.15.36.17.B – Construction Standards

A. NMAC 19.15.36.17.B(1) – General Liner

The C.K. Facility will have evaporation ponds, receiving and processing tanks, containment areas, and a stabilization and solicitation area. Each has an individual liner design based on requirement listed in NMAC 19.15.36.17. Although each liner system is different, Attachment C – Soil Liner Quality Control Plan (SLCQP) provides construction details for each layer of the liner system. The SLQCP also provides requirements for manufacture quality control testing and third party testing. Below are the liner systems for each area at the C.K. Facility.

The evaporation pond liner system will consist of (from bottom to top):

- 6-inch compacted soil subgrade.
- GCL under the leak detection sumps.
- 60-mil HDPE primary upper liner.
- 200-mil HDPE geonet leak detection layer.
- 60-mil HDPE secondary liner.

The receiving tank liner system will consist of (from bottom to top):

- 6-inches compacted soil subgrade.
- 60-mil HDPE liner.
- 6- to 12-inches of gravel.

The stabilization and solidification area liner system will consist of (from bottom to top):

- 6-inch compacted soil subgrade.
- GCL under the leak detection sumps.
- 60-mil HDPE secondary liner.
- 200-mil HDPE geonet leak detection layer.
- 60-mil HDPE primary liner.

B. NMAC 19.15.36.17.B(2) – Liner Requirements

The evaporation ponds and stabilization and solidification area liner system each have a lower and upper liners systems as required by NMAC 19.15.36.17.B(2). The lower and upper geomembrane liner will consist of a HDPE 60-mil liner.

C. NMAC 19.15.36.17.B(3) – Liner Specifications

The 60-HDPE liner has a hydraulic conductivity less than the maximum 1 x 10 - 9-cm/sec allowed in the NMAC. The HDPE material has chemical and ultraviolet resistance properties, listed in Attachment F, and is compatible with and resistant to chemical attack from the oilfield waste and leachate. The 2-feet of protective cover will assist the HDPE liner to withstand the projected loading stresses, setting, and disturbances from oilfield waste, cover material, and equipment. The GML materials shall be as manufactured by GSE Environmental or an equivalent pre-approved by the Geotechnical Professional (GP). Details on quality control and storage can be found in the Attachment C - Soil Liner Quality Control Plan.

D. NMAC 19.15.36.17.B(4) – Alternate Liner Media

The C.K. Facility will only be permitted to use 60-mil HDPE geomembrane liner. The GML materials shall be as manufactured by GSE Environmental or an equivalent pre-approved by the GP. Details on quality control and storage can be found in the Attachment C - Soil Liner Quality Control Plan.

E. NMAC 19.15.36.17.B(5) – Pit Construction

The subgrade shall be prepared in a manner consistent with proper subgrade preparation techniques for the installation of geosynthetic materials and as recommended by the GCL manufacturer. The subgrade shall be compacted to 90% standard proctor density or greater (if required by GCL manufacturer). The subgrade shall be properly compacted so as to prevent post construction settlement, causing excessive strains in the GCL or other synthetic liner materials. Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 0.5-inch. The subgrade must be rolled with a smooth-wheeled roller. During installation, ensure that rutting or raveling is not caused by installation equipment. Additional information on installation, testing and reporting is located in the Attachment C - Soil Liner Quality Control Plan.

The alternate liner designed for the C.K. Facility will use a GCL instead of compacted clay soil. The GCL has a uniform layer of sodium bentonite encase between two (2) geotextile fabrics. The sodium bentonite clay utilized in the GCL is a naturally occurring clay mineral that swells as liquid enters between its clay platelets. During installation, the needle-punched fibers hold the bentonite in place and prevent the GCL from separating. The GCL, at minimum, will have 0.75-lb/ft^2 of sodium bentonite. Each GCL panel will overlay each other 6-inches to create a uniform clay layer. Additional information on installation, testing and reporting is located in the Attachment C - Soil Liner Quality Control Plan.

The GML shall be placed to minimize seams during placement. Field seams between sheets of GML material will be made using approved fusion welding systems, equipment, and techniques. Approved fusion welding systems include fillet welds using extrudate, lap welds using extrudate, and lap welds using single or double wedge (double track) welder. The welds will either be pressure or vacuum tested. Additional information on installation, testing and reporting is located in the Attachment C - Soil Liner Quality Control Plan.

F. NMAC 19.15.36.17.B(6) – Point of Discharge

At a point of discharge or suction from the lined pit, the liner shall be protected from excessive hydrostatic force or mechanical damage, and external discharge lines shall not penetrate the liner.

G. NMAC 19.15.36.17.B(7) – Primary Liners

The C.K. Facility will only be permitted to use 60-mil HDPE geomembrane liner. The GML materials shall be as manufactured by GSE Environmental or an equivalent preapproved by the GP. Details on quality control and storage can be found in the Attachment C - Soil Liner Quality Control Plan.

H. NMAC 19.15.36.17.B(8) – Secondary Liners

The secondary liner will consist of a 60-mil HDPE liner. The GML materials shall be as manufactured by GSE Environmental or an equivalent preapproved by the GP. Details on quality control and storage can be found in the Attachment C - Soil Liner Quality Control Plan.

The liner will be laid upon a GCL layer. The GCL acts as a compacted clay reducing the hydraulic conductivity at the base of the liner system. Both GML and GCL have a hydraulic conductivity less than 1 x 10^{-9}-cm/s. Documentation for both materials is provided in Attachment F. Additional information on installation, testing and reporting is located in the Attachment C - Soil Liner Quality Control Plan.

I. NMAC 19.15.36.17.B(9) – Leak Detection System

A geonet will comprise the leak detection system of the liner system for the evaporation ponds and stabilization and solidification areas. The geonet component will be used on both floor and side slopes of the liner systems. The geonet is designed to transfer fluid horizontally though the anticipated site loads. The geonet has a transmissivity of 2 x 10^{-3}-m/s. Since soil will not be used, leachate will be transported through the geonet at the rate listed above. The geonet material shall be as manufactured by GSE Environmental or an equivalent preapproved by the GP. Additional information on installation, testing and reporting is located in the Attachment C - Soil Liner Quality Control Plan.

The geonet will channel leachate directly to the sump and leak detection piping. The slope of the ponds and stabilization and solidification area will be a minimum of a 2% slope as shown in Attachment B – Engineered Design Plans. The leachate collection system be comprised of 6-inch HDPE SDR 11 pipe. The SDR 11 pipe has a larger wall thickness than the minimum schedule 80 pipe required in the NMAC. The operator shall seal a solid drainage pipe to convey collected liquids to a corrosion-proof sump or sumps located outside the landfill perimeter for observation, storage, treatment or disposal. The sump and pipe layout is shown in Attachment B – Engineering Design Plans.

J. NMAC 19.15.36.17.B(10) – Notification of Installation

The C.K. Facility will notify the division a minimum of three (3) days prior to the installation of the leak detection system. The division may inspect all installation procedures on the leak detection system.

K. NMAC 19.15.36.17.B(11) – Pond and Pit Freeboard

The ponds have been sized to maintain a minimum of 3-feet of freeboard at all times during operation. The owner/operator must remove excess water if water reaches above this level.

L. NMAC 19.15.36.17.B(12) – Pond Sizing

All evaporation ponds onsite have a minimum sizing of 9.73-acre/feet in capacity. Pond grading and cross sections are provided in Attachment B – Engineered Design Drawings.

1.3 NMAC 19.15.36.17.C – Operating Standards

A. NMAC 19.15.36.17.C(1) – Operating Standards

The operator at the C.K. Facility shall ensure that only produced water that has gone through the processing tanks is discharged in to the evaporation ponds. All oil should be removed during the separation process within the four (4) produced water tanks. Any visible oil in the evaporation pond tanks will be removed immediately and returned to either an oil recovery tank or produced water tank for treatment. Tank and evaporation pond inspection are provided in Attachment K – Site Operating Plan.

B. NMAC 19.15.36.17.C(2) – Leak Detection Monitoring

The operator at the C.K. Facility shall monitor the leak detection system per NMAC requirements. All monitoring records will be kept onsite and readily available for review by OCD. Monitoring and maintenance is outlined in Attachment K – Site Operating Plan. If leaks are detected in the system, the C.K. Facility operator will notify OCD of findings.

C. NMAC 19.15.36.17.C(3) – Fencing and Netting

The C.K. Facility will construct and maintain perimeter fencing around the site. The 4-strand barbed wire fencing will run along the permit boundary and keep prevent trespassers. In addition, a cattle guard and gate will be placed at the entrance to assist in managing animals from entering the site. The C.K. Facility requests an exemption to not place screening material over ponds for migratory bird protection. The C.K. Facility will inspect the evaporation ponds daily for birds and if a recurring problem, the C.K. Facility with either submit a migratory bird plan or place screening over the ponds.

D. NMAC 19.15.36.17.C(4) – Spray System

The C.K. Facility proposes installing a spray system to each of the evaporation ponds. The spray system will utilize mechanical evaporators to aid in the evaporation of liquids in the proposed ponds. The proposed mechanical evaporator system is designed to maintain spray-borne suspended and dissolved solids within the liner boundary of the ponds. The site maintenance plan will contain the inspection schedule for all evaporators. Documentation and evaporation calculations are provided in Attachment K, Appendix D.

E. NMAC 19.15.36.17.C(4) – Jet Out Pits and Tanks

The C.K. Facility is designed to use both jet out pits and settling tanks. The setting tanks will receive produced water, leachate, and oil containing excessive water. After arriving onsite, the liquid will be placed in a receiving tank which drains into a series of four (4) setting tanks. The liquid will have up to five (5) days to settle in the tanks with one (1) day having heat introduced to assist in settling. Oil removed from the setting tanks will be transferred to either the oil recovery tanks or oil sales tanks. Water will be transferred through a mechanical separator to the evaporation ponds.

The jet out pits will be used to collect waste from tanks and allow it to separate within the settling pits. Oil removed from the setting tanks will be transferred to either the oil recovery tanks or oil sales tanks. Water will be transferred through a mechanical separator to the evaporation ponds.

The process diagram for tanks and pit is shown in Attachment A. The layout of the setting tanks and pit is shown in Attachment B – Engineered Design Plans.

1.4 NMAC 19.15.36.17.D – Below-grade Tanks and Sumps

The C.K. Facility does not propose to construct or operate below-grade tanks and sumps.

1.5 NMAC 19.15.36.17.E – Closure Required

The C.K. Facility shall properly close all pits, tanks, and ponds within six (6) months after cessation of use. Attachment L - Closure and Post-Closure Plan provides instructions and costs for closure of the operation.

1.0 NMAC 19.15.36.18 - INTRODUCTION

C.K. Disposal LLC., proposes to develop a commercial surface waste management facility consisting of a landfill, liquid processing area and deep well injection per NMAC 19.15.36. This section provides the general design and operating requirements as provided in NMAC 19.15.36.14. The proposed C.K. Facility is located 0.05-miles south of State Highway 234, approximately 4.16-miles southeast of Eunice, New Mexico, in Lea County. The C.K. Facility will encompass 316.97-acres broken down into individual sections as listed below in Table 1 – C.K Facility.

TABLE 1 – C.K. Facility

Area	Acres
C.K. Disposal E&P Landfill and Processing Facility	316.97
Landfill	141.5
Liquid Processing	51.75
Saltwater Disposal	5.1
Buffer Areas, Site Structures and Access Roads	118.62

Based on the daily tonnage received, the C.K. Facility landfill will have an active life between 38 – 115-years. Table 2 –Site Life, below provides the expected site life based on three different daily tonnages.

TABLE 2 – Site Life

Estimated Incoming Waste	Years
500 cubic yards per day	115 years
1,000 cubic yards per day	57 years
1,500 cubic yards per day	38 years

Once the landfill has reached its maximum capacity closure procedures will commence per NMAC 19.15.36.18. A closure and post-closure plan is provided in Attachment L providing instructions on closure procesdures for the site including the landfill, liquid processing area, and saltwater injection.

1.1 NMAC 19.15.36.18.A – Surface Waste Management Facility Closure by Operator

A NMAC 19.15.36.18.A(1) – Notification to the Division

C.K. Disposal, LLC will notify the division's environmental bureau a minimum of 60-days prior to the cessation of operations at the facility. Attached to the notification will be a schedule for closure activities. C.K. Disposal, LLC will not proceed with closure until 60-days after the division has received the notice for closure, allowing time for comments.

B NMAC 19.15.36.18.A(2) – Division's Notification to the Owner

The division's environmental bureau will notify the owner/operator, C.K. Disposal, LLC, within 60-days after it receives notice of cessation of operations with any additional requirements for closure of the facility. C.K. Disposal, LLC will proceed with closure if no notice or additional requirements are received within 60-days of notice to the division.

C NMAC 19.15.36.18.A(3) – No Additional Requirements or Notification

If the division's environmental bureau does not notify C.K. Disposal, LLC of additional requirements within 60-days of receiving notification, C.K. Disposal, LLC will proceed with closure activities.

D NMAC 19.15.36.18.A(4) – No Additional Requirements

C.K. Disposal, LLC acknowledges that it is entitled to a hearing concerning a modification to its closure plan or additional requirements the division is requesting. The owner/operator must submit the request within 10-days of receiving notice from the division.

E NMAC 19.15.36.18.A(5) – Closure by Approved Plan

C.K. Disposal, LLC will close the facility based on the approved closure plan to ensure the protection of fresh water, public health, safety and the environment.

F NMAC 19.15.36.18.A(6) – Site Revegetation

Upon closure the operator will revegetate the site, although vegetation does not affect the performance of our final cap. The cap will be seeded with native grasses and bushes.

1.2 NMAC 19.15.36.18.B – Release of Financial Assurance

A NMAC 19.15.36.18.B(1) – Release of Financial Assurance

The owner/operator understands that when the division deems the site closed per the closure plan, the division will release the financial assurance except for the amount needed to maintain post-closure activities.

B NMAC 19.15.36.18.B(2) – Release of Financial Assurance

After the applicable post-closure care period is completed the division will release the remainder financial assurance to the owner.

C NMAC 19.15.36.18.B(3) – Revegetation of Site

The owner understand that the division shall not release financial assurance until it determines the site has been successfully revegetated.

1.3 NMAC 19.15.36.18.C – Closure Initiated by Division & Forfeiture of Financial Assurance

A NMAC 19.15.36.18.C(1) – Closure Initiated by Division & Forfeiture of Financial Assurance

For good cause, the division may, after notice to the operator and an opportunity for a hearing, order immediate cessation of a surface waste management facility’s operation when it appears that cessation is necessary to protect fresh water, public health, safety or the environment, or to assure compliance with statutes or division rules and orders. The division may order closure without notice and an opportunity for hearing in the event of an emergency, subject to NMSA 1978, Section 70-2-23, as amended.

B NMAC 19.15.36.18.C(2) – Closure Initiated by Division & Forfeiture of Financial Assurance

The C.K. Facility will be operated to maintain the protection of fresh water, public health, safety, and the environment. If any anytime the division has a concern on operations, the owner/operator will work with the division to improve their operations. The owner understands that the division can at any time cease operations at the facility.

C NMAC 19.15.36.18.C(3) – Division Allow Surety to Perform Closure

C.K. Facility is aware the division may allow a surety to perform closure if the surety can demonstrate the ability to timely complete the closure and post closure in accordance with the approved plan.

D NMAC 19.15.36.18.C(4) – Closure Initiated by Division & Forfeiture of Financial Assurance

The C.K. Facility will be operated to maintain the protection of fresh water, public health, safety, and the environment. The owner understands the rules listed in this section.

E NMAC 19.15.36.18.C(5) – Abandonment of Facility or Unable to Meet Operation Requirements

The C.K. Facility is aware that if it abandons or cannot fulfill the conditions and obligations of the surface waste management facility permit or division rules, the state of New Mexico, its agencies, officers, employees, agents, contractors, and other entities designated by the state shall have all rights of entry into, over, and upon the surface waste management facility property. This includes all necessary and convenient rights of ingress and egress with all materials and equipment to conduct operation, termination, and closure of the surface waste management facility, including but not limited to the temporary storage of equipment and materials, the right to borrow or dispose of materials, and all other rights necessary for surface waste management facilities operation, termination and closure in accordance with the surface waste management facility permit and to conduct post-closure monitoring.

1.4 NMAC 19.15.36.18.D – Cell Closure and Post-Closure

A NMAC 19.15.36.18.D(1)(a) – (c)– Oil Treatment Plant Closure

C.K. Disposal, LLC will perform closure and post-closure procedures provided in Attachment D – Final Cover Quality Control Plan and Attachment L – Closure and Post-Closure Plan. The plans follows all requirements listed in NMAC 19.15.36.

B NMAC 19.15.36.18.D(2)(a) – Closure of Landfill Units

C.K. Disposal, LLC will perform closure and post-closure procedures provided in Attachment D – Final Cover Quality Control Plan and Attachment L – Closure and Post-Closure Plan. The plans follows all requirements listed in NMAC 19.15.36. The closure system will be comprised of two final covers. The top cap grades will have a minimum slope of 2% with the maximum being approximately 4%. The top cap final cover will consist of the following:

- 12” Foundation Layer
- 60-mil High Density Polyethylene (HDPE) Liner
- Geocomposite Liner
- 24” Infiltration Layer
- 12” Soil Erosion Layer

The side slopes will have a maximum slope of 25% or 4H to 1V slopes. The side slope final cover will consist of the following:

- 12” Foundation Layer
- 24” Infiltration Layer
- 12” Soil Erosion Layer

C NMAC 19.15.36.18.D(2)(b) – Vegetation

C.K. Disposal, LLC will perform closure and post-closure procedures provided in Attachment D – Final Cover Quality Control Plan and Attachment L – Closure and Post-Closure Plan. The plans follows all requirements listed in NMAC 19.15.36. The site will be vegetated with native grasses and bushes. The post-closure costs included in the attachment provide funds to maintain grasses and reseeding if necessary.

D NMAC 19.15.36.18.D(3)(a) – (b) – Post-Closure Care

C.K. Disposal, LLC will perform closure and post-closure procedures provided in Attachment D – Final Cover Quality Control Plan and Attachment L – Closure and Post-Closure Plan. The plans follows all requirements listed in NMAC 19.15.36.

E NMAC 19.15.36.18.D(4) – Landfarm Closure

C.K. Disposal, LLC does not propose to have a landfarm on its facilities. These requirements are not applicable.

1.5 NMAC 19.15.36.18.E – Pond and Pit Closure

C.K. Disposal, LLC will perform closure and post-closure procedures provided in Attachment L – Closure and Post-Closure Plan. The plans follows all requirements listed in NMAC 19.15.36.

1.6 NMAC 19.15.36.18.F – Landfarm, Pond and Pit Post-Closure

C.K. Disposal, LLC will perform closure and post-closure procedures provided in Attachment L – Closure and Post-Closure Plan. The plans follows all requirements listed in NMAC 19.15.36.

1.7 NMAC 19.15.36.18.G – Alternates to Revegetation

C.K. Disposal, LLC will revegetate the site until vegetation is established to requirements listed in 19.15.36.18.

1.0 NMAC 19.15.36.19 - EXCEPTIONS AND WAIVERS

1.1 NMAC 19.15.36.19.A - Alternatives to Requirements

C.K. Disposal, LLC. requests alternatives to the requirements consistent with the flexibility provided for:

- LFG control requirements per NMAC 19.15.36.13.O.
- Groundwater monitoring per NMAC 19.15.36.14.B(1-2).
- Geonet detection and drainage layers per NMAC 19.15.36.14.C.
- Final cover per NMAC 19.15.36.14.C(9).
- Bird control alternatives per NMAC 19.15.36.19.

Demonstrations and justifications are provided in the referenced sections and associated technical documentation.

1.2 19.15.36.19.B - Exceptions to, Waivers of, or Approved Alternatives to Requirements in an Emergency without Notice or Hearing

C.K. Disposal, LLC. will comply and is aware the division may grant exceptions to, or waivers of, or approve alternatives to requirements of 19.15.36 NMAC in an emergency without notice or hearing. The operator requesting an exception or waiver, except in an emergency, shall apply for a surface waste management facility permit modification in accordance with Subsection C of 19.15.36.8 NMAC. If the requested modification is major, the operator shall provide notice of the request in accordance with 19.15.36.9 NMAC.

1.0 NMAC 19.15.36.20 - TRANSITIONAL PROVISIONS

The C.K. Facility is a proposed new Surface Waste Management Facility. No response required.

Permit Application

Lea County, New Mexico

C.K. Disposal E & P Landfill and Processing Facility

Permit No. TBD

Attachment A

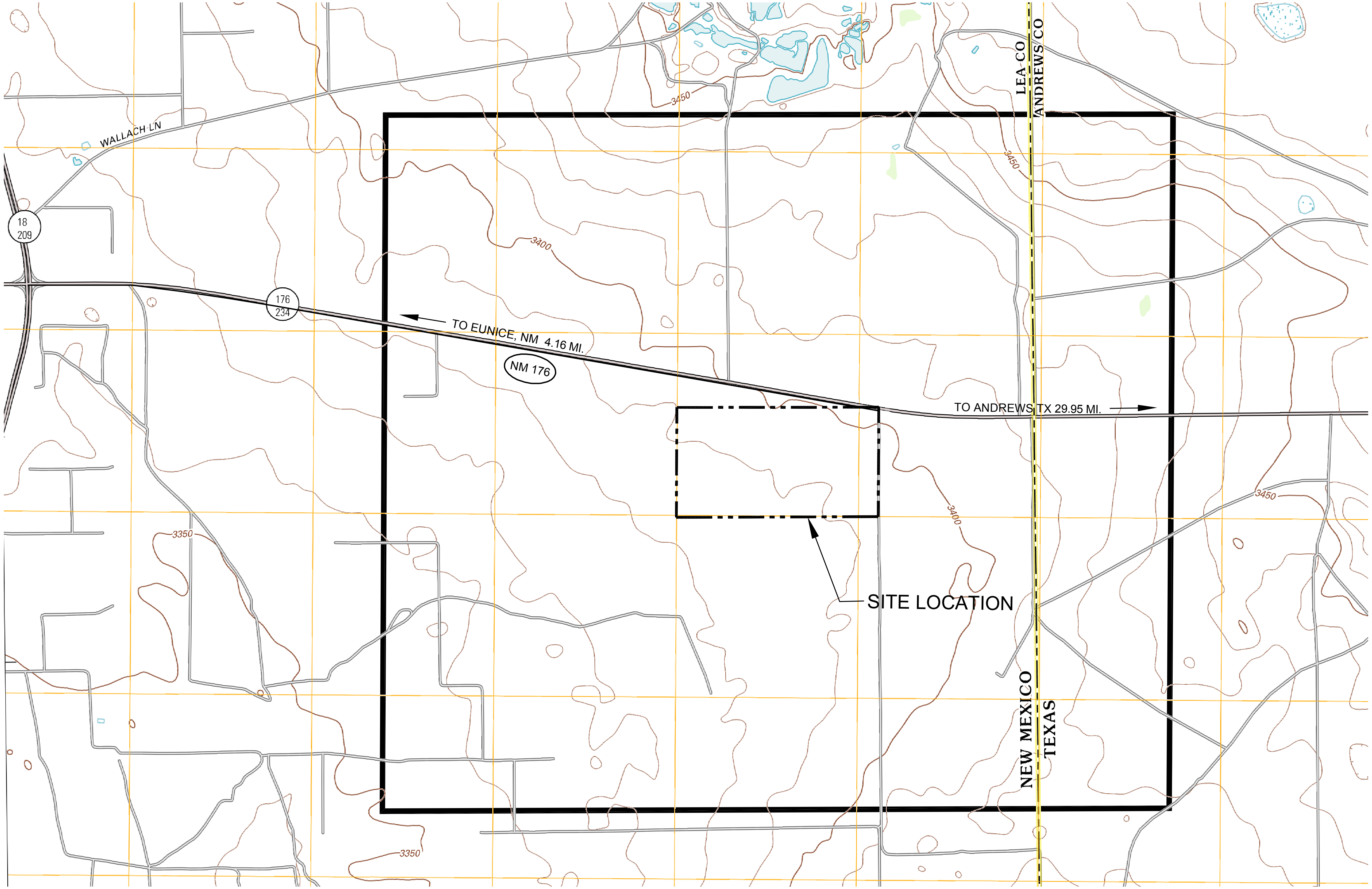
General Facility Maps and Site Drawings

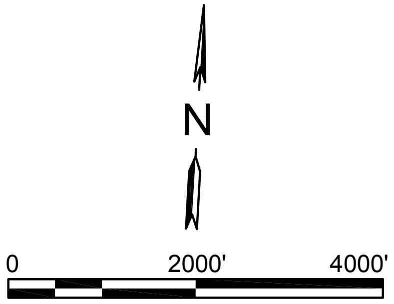
November 2015

PSC Project # 01058015

PARKHILLSMITH&COOPER

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.1-SITE LOCATION MAP.dwg LAYOUT NAME: FIG.A.1 PRINTED: Thursday, November 05, 2015 - 8:31pm USER: TKrueger





NICHOLAS N. YBARRA
20683

Nicholas N. Ybarra
11/6/2015

MAP REFERENCE

United States Geological Survey

North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid: Universal Transverse Mercator, Zone 13S
10 000-foot ticks: Texas Coordinate System of 1983 (north central zone), New Mexico Coordinate System of 1983 (east zone)

North American Vertical Datum of 1998
Eunice NE, TX-NM
2012

(EDITED BY PARKHILL, SMITH & COOPER, INC.)

LEGEND

— - - —	SITE BOUNDARY
━━━	1 MILE OFFSET FROM SITE

PSC PARKHILL SMITH & COOPER

C. K. DISPOSAL E & P LANDFILL & PROCESSING FACILITY

NMED PERMIT NO. __

NEW LANDFILL SITE & PROCESSING FACILITY

LEA COUNTY, NEW MEXICO

KEY PLAN

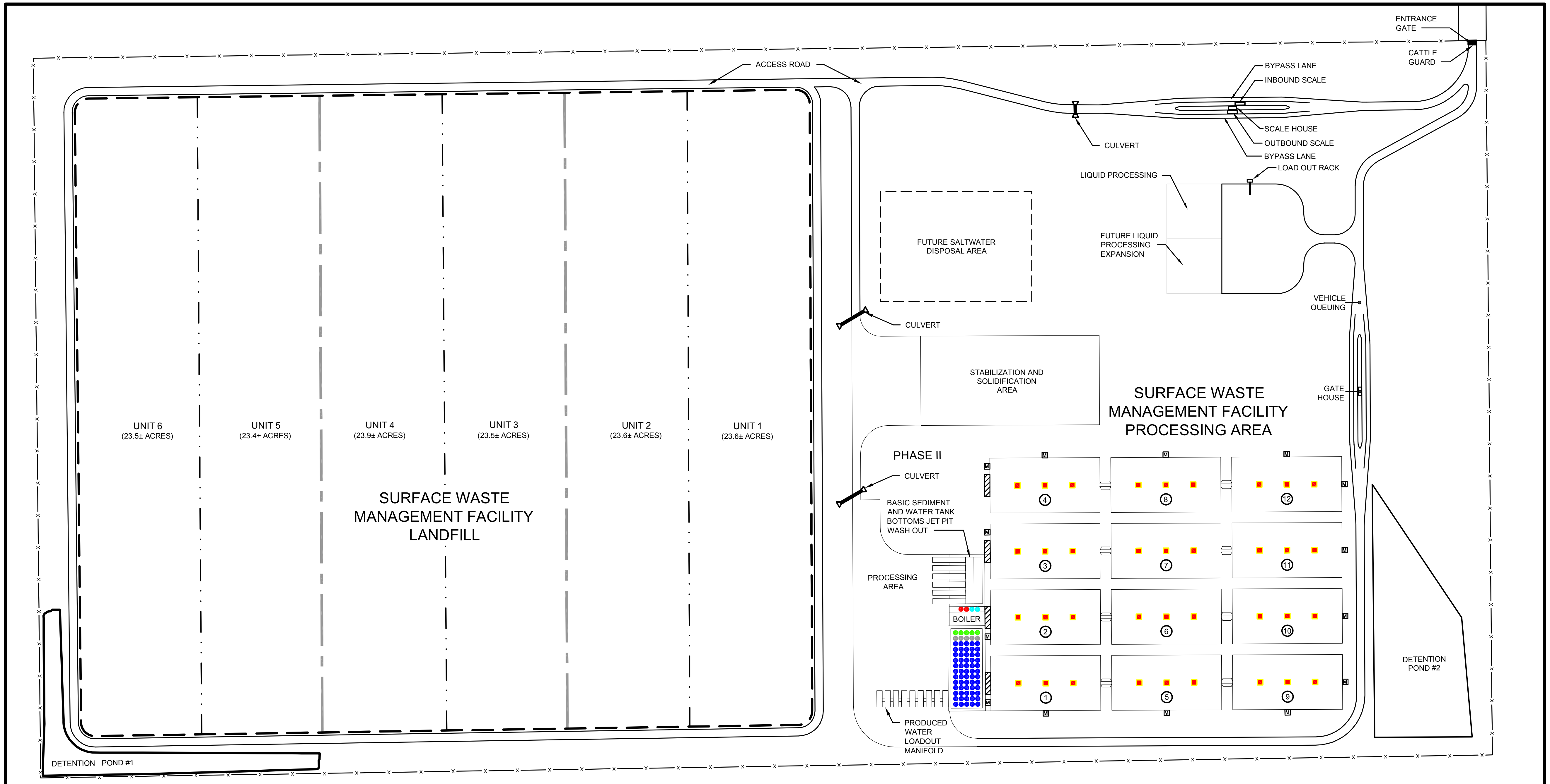
NO	DATE	DESCRIPTION
1	09/23/15	ISSUE FOR REVIEW

ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

SITE LOCATION MAP

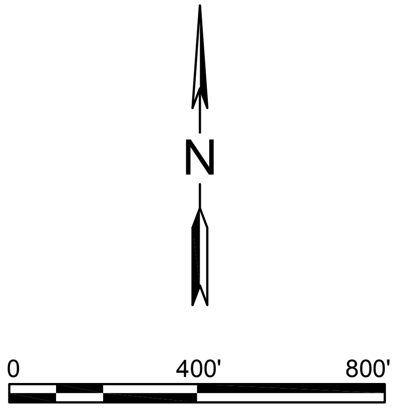
FIG.A.1

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.2 -SITE DEVELOPMENT.dwg LAYOUT NAME: FIG.A.2 PRINTED: Thursday, November 05, 2015 - 8:32pm USER: TKrueger



LEGEND

- ——x——x—— FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
- — — — LANDFILL FOOTPRINT
- — – — LANDFILL PHASE LINE
- —— · · —— UNIT LIMITS
- ▨ MECHANICAL OIL/WATER SEPARATOR
- 🟥 EVAPORATOR
- ■ MONITORING POINTS
- ⊟ LOW WATER CROSSING
- ● PRODUCED WATER SETTING TANK
- ● OIL RECOVER TANK
- ● OIL SALES TANK
- ● CHEMICAL TANK
- ● JET OUT WATER TANK
- ⑤ EVAPORATION POND NUMBER



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11/6/2015

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LEA COUNTY, NEW MEXICO

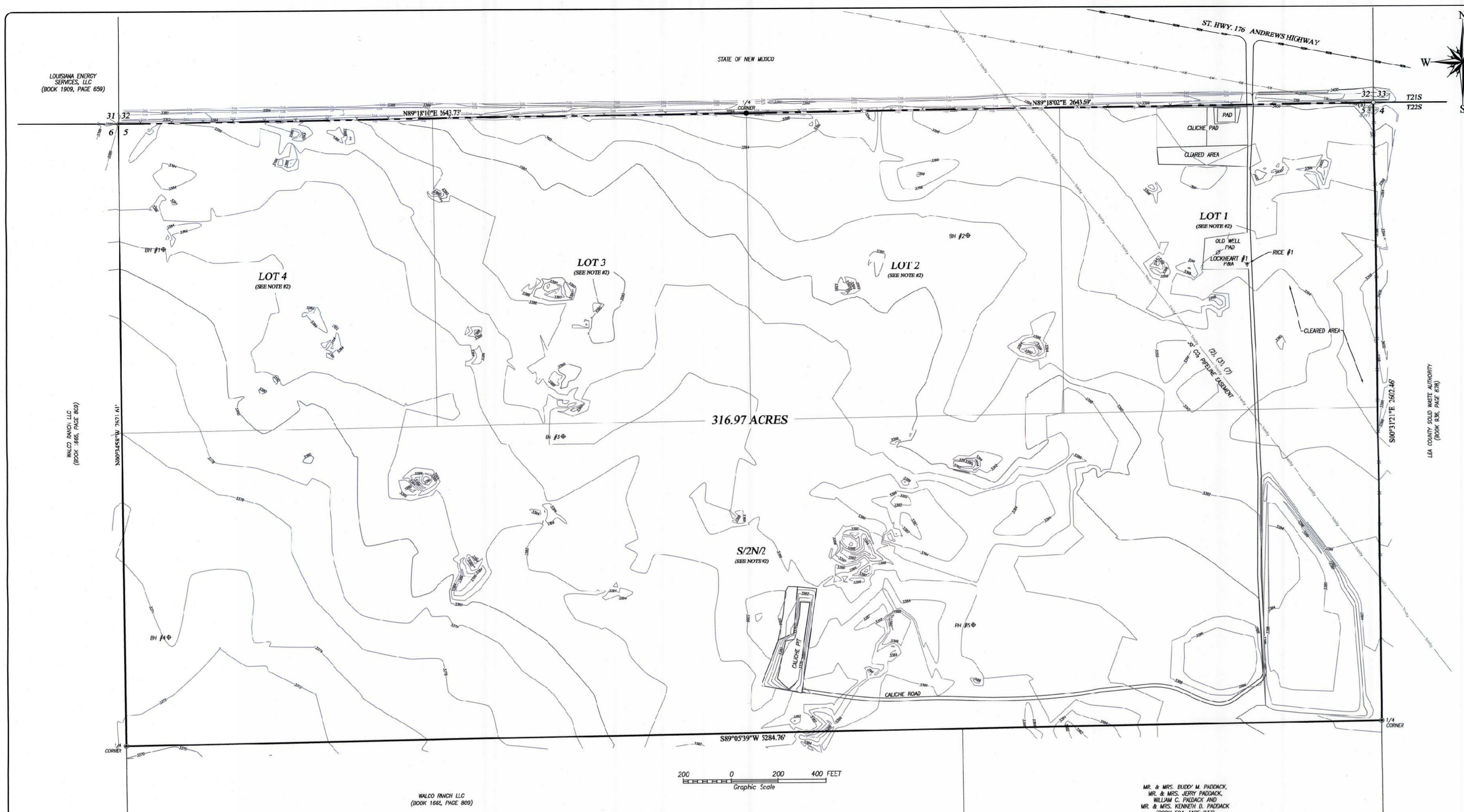
KEY PLAN

NO	DATE	DESCRIPTION
1	09/23/15	ISSUE FOR REVIEW

ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

SITE DEVELOPMENT PLAN

FIG.A.2



DESCRIPTION:

LOTS 1, 2, 3, 4 AND S/2N/2 OF SECTION 5, TOWNSHIP 22 SOUTH, RANGE 38 EAST, N.M.P.M., LEA COUNTY, NEW MEXICO, TOGETHER WITH APPURTENANCES THERETO INCLUDING ANY INTEREST OF GRANTOR IN SAND, GRAVEL OR CALICHE. SUBJECT TO RESERVATIONS, RESTRICTIONS AND EASEMENTS APPEARING OF RECORD.

NOTE:

A) OWNER OF RECORD: A. BRYCE KARGER, WARRANTY DEED BOOK 1956, PAGE 831
AND JOHNNY D. COPE, WARRANTY DEED BOOK 1961, PAGE 265

B) MEASURED BEARINGS SHOWN ARE MERCATOR GRID AND CONFORM TO THE NEW MEXICO COORDINATE SYSTEM "NEW MEXICO EAST ZONE" NORTH AMERICAN DATUM 1983. DISTANCES ARE SURFACE VALUES. AREAS DIVDED BY "LOT" AND "S/2N/2" ARE FOR GRAPHICAL PURPOSES ONLY.

C) NO EASEMENT WAS PROVIDED DESCRIBING ACCESS ACROSS SECTION 22 FROM STATE HIGHWAY 176.

LEGEND:

◉	– DENOTES FOUND USCLO 1911 BRASS CAP
⊙	– DENOTES FOUND 1/2" STEEL ROD
●	– DENOTES FOUND 2-1/2" ALUMINUM CAP MARKED "MUTH PLS #13239"
Ø	– DENOTES PLUGGED & ABANDONED WELL
BH #1 Φ	– DENOTES BORE HOLE LOCATION
⊞	– DENOTES MANHOLE WITH VALVE
▼	– DENOTES WOOD LATHE WITH HUB & TACK
—3400—	– DENOTES CONTOUR LINE WITH ELEVATION
—top— —toe—	– DENOTES TOP/TOE OF DITCH
—Trinity—	– DENOTES TRINITY CO2 PIPELINE
—ROW—ROW—	– DENOTES HIGHWAY RIGHT-OF-WAY
—X—X—	– DENOTES FENCE LINE
—4W—	– DENOTES 4 WIRE OVERHEAD ELECTRIC LINE
UP	– DENOTES UTILITY POLE
GUY	– DENOTES GUY/ANCHOR WIRE

RESERVATIONS, RESTRICTIONS, AND EASEMENTS OF RECORD PROVIDED BY ELLIOTT & WALDRON TITLE AND ABSTRACT COMPANY:

(1) AGREEMENT FOR USE OF CALICHE ROAD, FILED MARCH 6, 1970, IN BOOK 318. PAGE 841, DEED RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY PAT SIMS TO IMPERIAL-AMERICAN MANAGEMENT COMPANY. THE ROAD SHOWN ON EXHIBIT "A" IN THE RECORD DOCUMENT IS NOT ON OR DOES NOT TOUCH SURVEYED PROPERTY.

(2) RIGHT OF WAY AGREEMENT, FILED SEPTEMBER 16, 1985, IN BOOK 422, PAGE 108, DEED RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY KENNETH V. BEER TO BIG THREE INDUSTRIES, INC. A 30 FT. CO_2 PIPELINE EASEMENT WITH A DESCRIPTION THAT IS BLANKET IN NATURE, BUT KNOWN TO BE THAT PIPELINE SHOWN HEREON.

(3) ASSIGNMENT, FILED FEBRUARY 13, 1989, IN BOOK 450, PAGE 453, DEED RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY BIG THREE INDUSTRIES, INC. TO BIG THREE CARBON DIOXIDE COMPANY. A 30 FT. CO_2 PIPELINE EASEMENT WITH A DESCRIPTION THAT IS BLANKET IN NATURE, BUT KNOWN TO BE THAT PIPELINE SHOWN HEREON.

(4) ASSIGNMENT, FILED JUNE 19, 1992, IN BOOK 477, PAGE 461, OIL AND GAS RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY GREENVILLE TRADING COMPANY, INC. TO FIVE STATES 1992-A, LTD., A TEXAS LIMITED PARTNERSHIP (90% INTEREST), MARK L. SHIDLER, INC. (5% INTEREST) ARGUS OIL COMPANY (5% INTEREST). A PRIVATE ROAD EASEMENT BEING THE SAME ROAD DESCRIBED IN ITEM (1).

(5) ASSIGNMENT, BILL OF SALE AND CONVEYANCE, FILED JUNE 25, 1992, IN BOOK 477, PAGE 735, OIL AND GAS RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY AMERICAN EXPLORATION COMPANY TO GREENVILLE TRADING CO. A PRIVATE ROAD EASEMENT BEING THE SAME ROAD DESCRIBED IN ITEM (1).

(6) ASSIGNMENT AND BILL OF SALE, FILED MAY 31, 1994, IN BOOK 499, PAGE 806, OIL AND GAS RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY ARGUS OIL COMPANY TO MARK L. SHIDLER, INC. A PRIVATE ROAD EASEMENT BEING THE SAME ROAD DESCRIBED IN ITEM (1).

(7) ASSIGNMENT, BILL OF SALE AND ASSUMPTION AGREEMENT, FILED DECEMBER 15, 2000, IN BOOK 1052, PAGE 558, OFFICIAL RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY AIR LIQUIDE AMERICA CORPORATION AND BIG THREE INDUSTRIES, INC. TO TRINITY PIPELINE L.P. A 30 FT. CO_2 PIPELINE EASEMENT WITH A DESCRIPTION THAT IS BLANKET IN NATURE, BUT KNOWN TO BE THAT PIPELINE SHOWN HEREON.

(8) ASSIGNMENT, CONVEYANCE AND BILL OF SALE, FILED APRIL 2, 2007, IN BOOK 1505, PAGE 369, OFFICIAL RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY FIVE STATES ENERGY COMPANY, L.L.C., TO ISRAMCO ENERGY, L.L.C. A PRIVATE ROAD EASEMENT BEING THE SAME ROAD DESCRIBED IN ITEM (1).

(9) UTILITY EASEMENT, FILED NOVEMBER 4, 2009, IN BOOK 1654, PAGE 865, OFFICIAL RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY LEO V. SIMS, PERSONAL REPRESENTATIVE OF THE WINNIE KENNANN ESTATE TO SOUTHWESTERN PUBLIC SERVICE COMPANY. AFFECTS SURVEYED PROPERTY AND IS SHOWN HEREON.

(10) MEMORANDUM OF ROAD USE, MAINTENANCE, LICENSE, AND RIGHT-OF-WAY AGREEMENT, FILED JANUARY 26, 2010, IN BOOK 1665, PAGE 627, OFFICIAL RECORDS, LEA COUNTY, NEW MEXICO. EXECUTED BY S&D RANCH LLC AND LEO V. SIMS LLC ("S&D") TO CHEVRON U.S.A. INC. AFFECTS SURVEYED PROPERTY, BLANKET IN NATURE AND NOT SURVEYABLE OR PLOTTABLE.

LEA COUNTY SEAL

STATE OF NEW MEXICO
COUNTY OF LEA
FILED

________, 2015
at ________ o'clock ____M
and recorded in:
Cabinet ______ Slide ______
Book ______ Page ______
Pat Chappelle, Lea County Clerk
By ________ Deputy

PROVIDING SURVEYING SERVICES
SINCE 1946
JOHN WEST SURVEYING COMPANY
412 N. DAL PASO
HOBBS, NEW MEXICO 88240
(575) 393-3117 www.jwsc.biz
TBPLS# 10021000

A. BRYCE KARGER
BOUNDARY SURVEY OF
LOTS 1 THROUGH 4 AND THE SOUTH HALF OF THE NORTH HALF
OF SECTION 5, TOWNSHIP 22 SOUTH, RANGE 38 EAST, N.M.P.M.,
LEA COUNTY, NEW MEXICO

SURVEYOR'S CERTIFICATE:

I, GARY G. EIDSON, NEW MEXICO PROFESSIONAL SURVEYOR No. 12641, DO HEREBY CERTIFY THAT THIS SURVEY PLAT AND THE ACTUAL SURVEY ON THE GROUND UPON WHICH IT IS BASED WERE PERFORMED BY ME OR UNDER MY DIRECT SUPERVISION; THAT I AM RESPONSIBLE FOR THIS SURVEY; THAT THIS SURVEY MEETS THE MINIMUM STANDARDS FOR SURVEYING IN NEW MEXICO; AND THAT IT IS TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

GARY G. EIDSON Gary G. Eidson DATE: 8/20/15

GARY G. EIDSON 12641

Survey Date: 6/22–7/6/15
Work Order No.: 15.11.0650
CAD Drafter & Date: DSS 8/4/15
Revised Date: n/a
DonnaS\Tracts\Boundary Survey\2015\15110650
Disposal Area Lots 1–4 S2 N2 S5 T22 R38 Lea County
Scale: One Inch = Two Hundred Feet

JWSC File No.
E-3461A

PROVIDED BY JOHN WEST SURVEYING COMPANY

PARKHILL SMITH & COOPER

C. K. DISPOSAL E & P LANDFILL & PROCESSING FACILITY

NMED PERMIT NO. __

NEW LANDFILL SITE & PROCESSING FACILITY

LEA COUNTY, NEW MEXICO

KEY PLAN

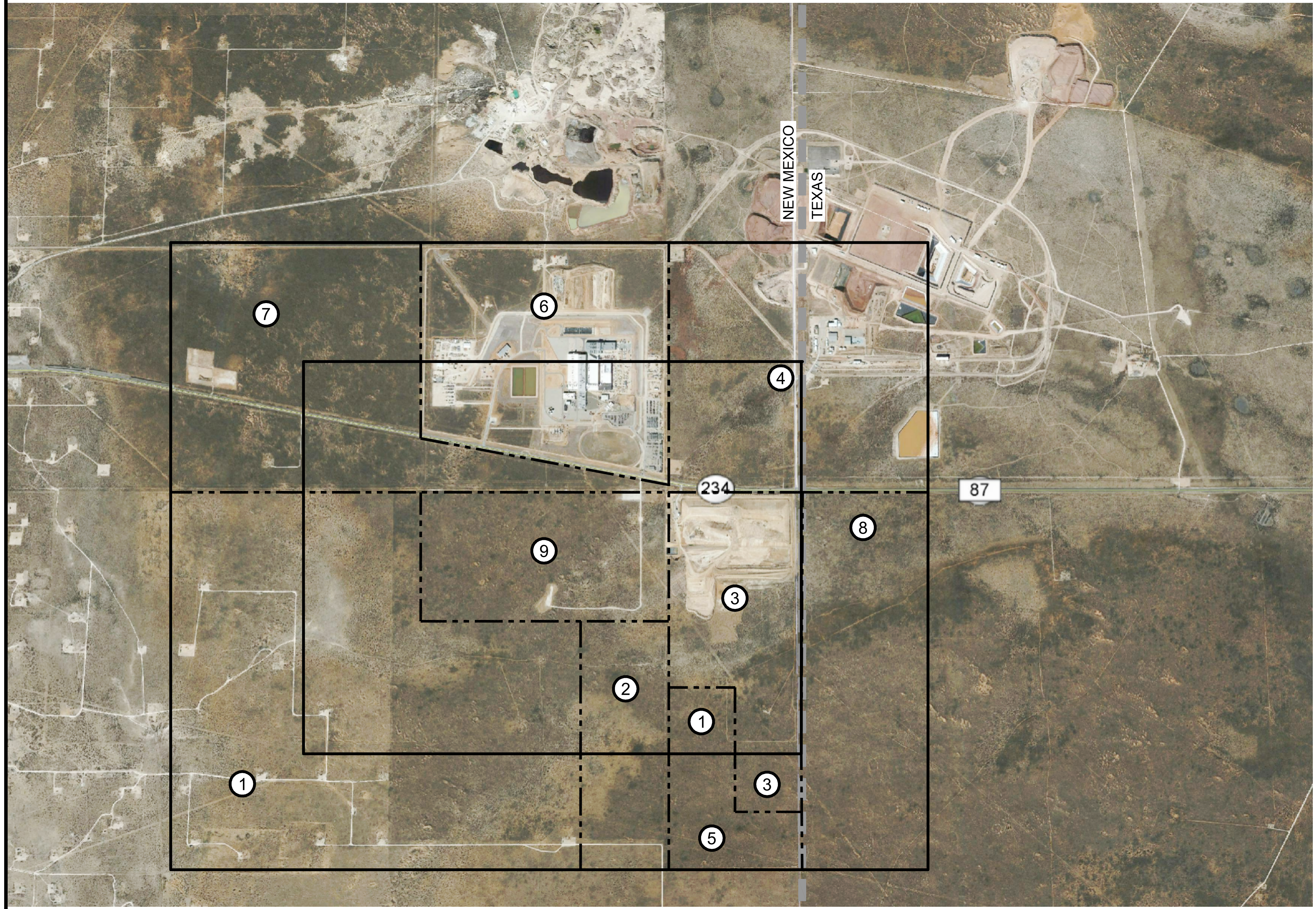
1	09/23/15	ISSUE FOR REVIEW
NO	DATE	DESCRIPTION

ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

TOPOGRAPHIC MAP

FIG.A.3

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.4-ADJACENT LANDOWNERS.dwg LAYOUT NAME: FIG.A.7 PRINTED: Thursday, November 05, 2015 - 8:32pm USER: TKrueger



N

NO SCALE

LANDOWNERS

1. WALCO RANCH LLC
2. PADDOCK BUDDY METAL
3. LEA COUNTY SOLID WASTE AUTHORITY
4. WASTE CONTROL SPECIALIST LLC
5. LEA COUNTY
6. URENCO USA
7. LOUISIANA ENERGY SERVICES LLC
8. ANDREWS COUNTY
9. C.K. DISPOSAL LLC
10. ERENCO (URANIUM ENRICHMENT FACILITY)
11. STATE OF TEXAS

LEGEND

— · · — · · PROPERTY LINE

— — — — STATE LINE

——— $\frac{1}{2}$ MILE AND 1 MILE RADIUS

NICHOLAS N. YBARRA
20683

Nicholas N. Ybarra
11/6/2015

PARKHILL SMITH & COOPER

C. K. DISPOSAL E & P LANDFILL & PROCESSING FACILITY

NMED PERMIT NO. __

NEW LANDFILL SITE & PROCESSING FACILITY

LEA COUNTY, NEW MEXICO

KEY PLAN

NO	DATE	DESCRIPTION
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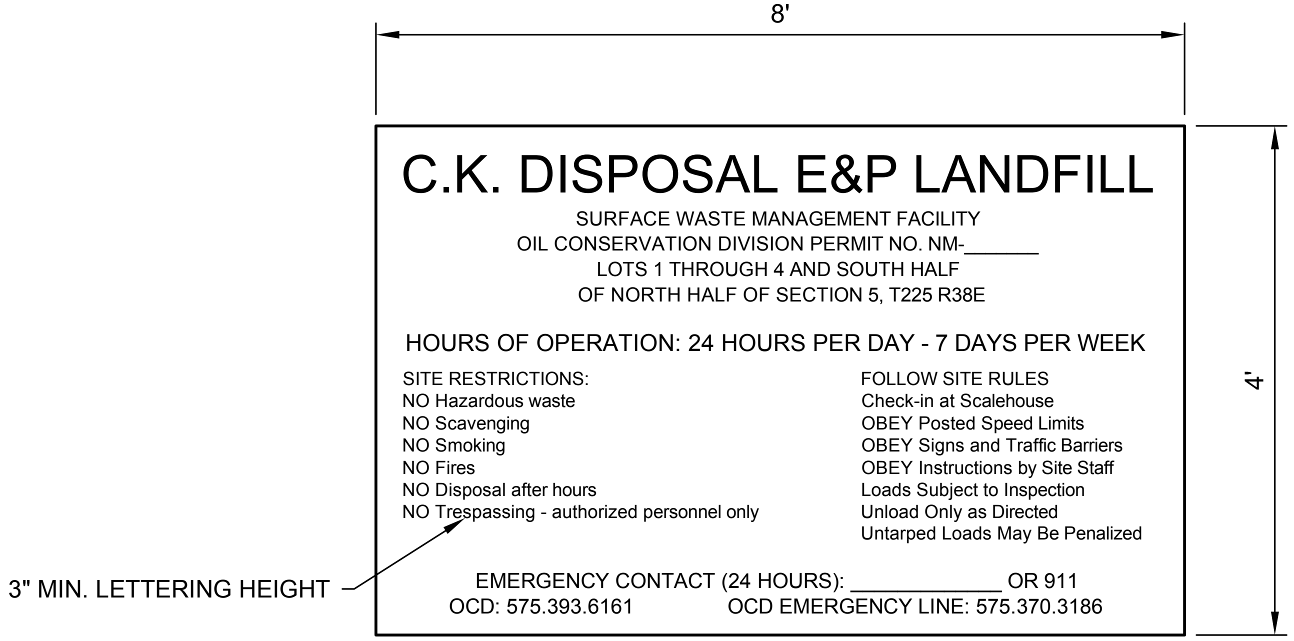
ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

ADJACENT LANDOWNERS MAP

FIG.A.7

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.5-SITE ENTRANCE SIGN.dwg LAYOUT NAME: FIG. A.5 PRINTED: Thursday, November 05, 2015 - 8:33pm USER: TKrueger



C.K. DISPOSAL E&P LANDFILL

SURFACE WASTE MANAGEMENT FACILITY
OIL CONSERVATION DIVISION PERMIT NO. NM-_______
LOTS 1 THROUGH 4 AND SOUTH HALF
OF NORTH HALF OF SECTION 5, T225 R38E

HOURS OF OPERATION: 24 HOURS PER DAY - 7 DAYS PER WEEK

SITE RESTRICTIONS:
NO Hazardous waste
NO Scavenging
NO Smoking
NO Fires
NO Disposal after hours
NO Trespassing - authorized personnel only

FOLLOW SITE RULES
Check-in at Scalehouse
OBEY Posted Speed Limits
OBEY Signs and Traffic Barriers
OBEY Instructions by Site Staff
Loads Subject to Inspection
Unload Only as Directed
Untarped Loads May Be Penalized

EMERGENCY CONTACT (24 HOURS): _____________ OR 911
OCD: 575.393.6161 OCD EMERGENCY LINE: 575.370.3186

NICHOLAS N. YBARRA
20683

Nicholas N. Ybarra
11/6/2015

PSC
PARKHILL SMITH & COOPER

C. K. DISPOSAL E & P LANDFILL & PROCESSING FACILITY

NMED PERMIT NO. ___

NEW LANDFILL SITE
& PROCESSING FACILITY

LEA COUNTY, NEW MEXICO

KEY PLAN

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PROJECT NO: 0580.15

SITE
ENTRANCE SIGN

FIG. A.5

C.K DISPOSAL E&P
LANDFILL & PROCESS
FACILITY

LEA COUNTY, NEW MEXICO

S 1/2 OF THE N1/2
SECTION 5, T225, R38E

OIL CONSERVATION DIVISION PERMIT NO. NM-________

DANGER

NO SMOKING
NO DRUGS
NO FIREARMS
NO CHILDREN

DANGER

THIS MACHINE STARTS AUTOMATICALLY

SPEED
LIMIT
15

DANGER

H_2S
MAY BE PRESENT

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FACILITY

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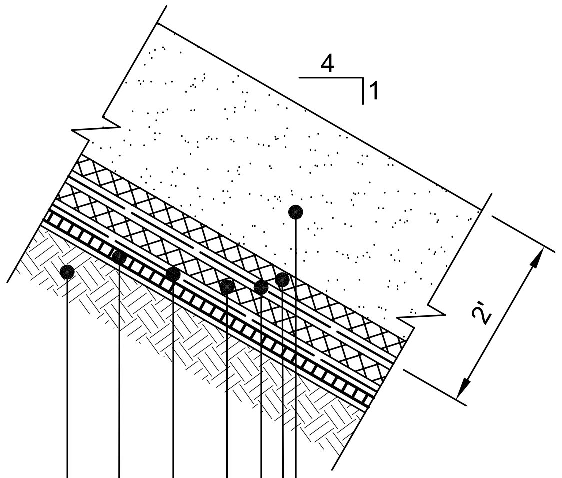
SITE SIGNS
(TYPICAL)

FIG.A.6

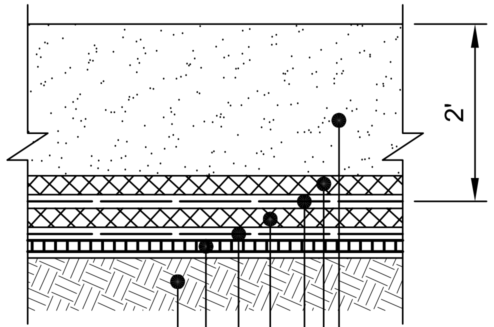
FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.6 -SITE SIGNS.dwg LAYOUT NAME: FIG.A.6 PRINTED: Thursday, November 05, 2015 - 8:33pm USER: TKrueger



MIN. 24" PROTECTIVE SOIL LAYER (ON-SITE SOILS)
200 MIL GEOCOMPOSITE
60 MIL DOUBLE-SIDED TEXTURED HDPE UPPER LINER
200 MIL GEOCOMPOSITE
60 MIL DOUBLE-SIDED TEXTURED HDPE UPPER LINER
REINFORCED GEOSYNTHETIC CLAY LINER
6" PREPARED SUBGRADE COMPACTED TO 90% ASTM D698

A1 SIDEWALL LINER SYSTEM

NO SCALE



PROTECTIVE SOIL LAYER (ON-SITE SOILS)
200 MIL GEOCOMPOSITE
60 MIL SMOOTH HDPE UPPER LINER
200 MIL GEONET
60 MIL SMOOTH HDPE LOWER LINER
REINFORCED GEOSYNTHETIC CLAY LINER
6" PREPARED SUBGRADE COMPACTED TO 90% ASTM D698

A2 FLOOR LINER SYSTEM

NO SCALE

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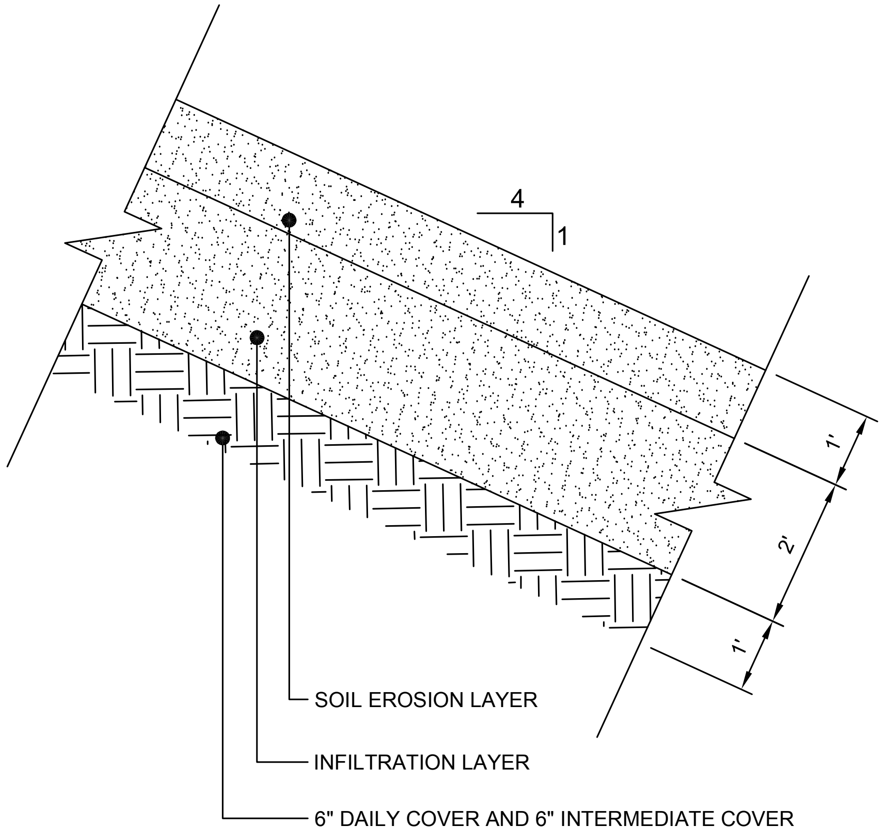
LINER
SCHEMATIC

FIG.A.7

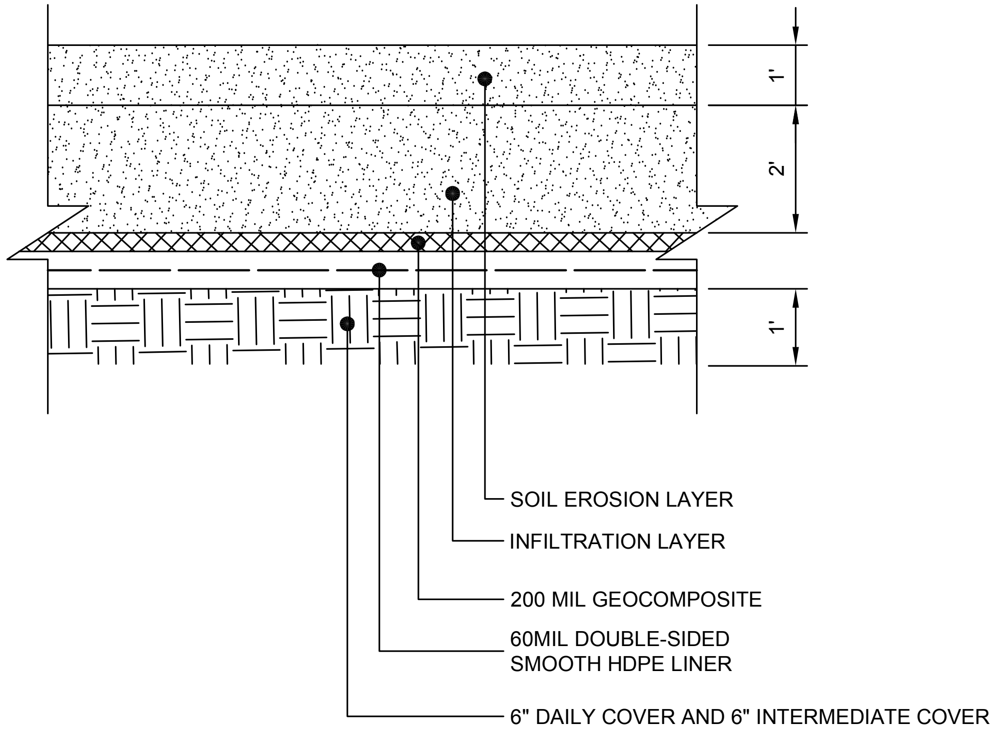
FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.7-LINER SCHEMATIC.dwg LAYOUT NAME: FIG.A.7 PRINTED: Thursday, November 05, 2015 - 8:33pm USER: TKrueger

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.8-FINAL COVER SECTIONS.dwg LAYOUT NAME: FIG.A.8 PRINTED: Thursday, November 05, 2015 - 8:33pm USER: TKrueger



A1 FINAL COVER DETAIL SIDE SLOPE PERFORMANCE DESIGN

NO SCALE



A2 FINAL COVER TOP CAP PERFORMANCE DESIGN

NO SCALE

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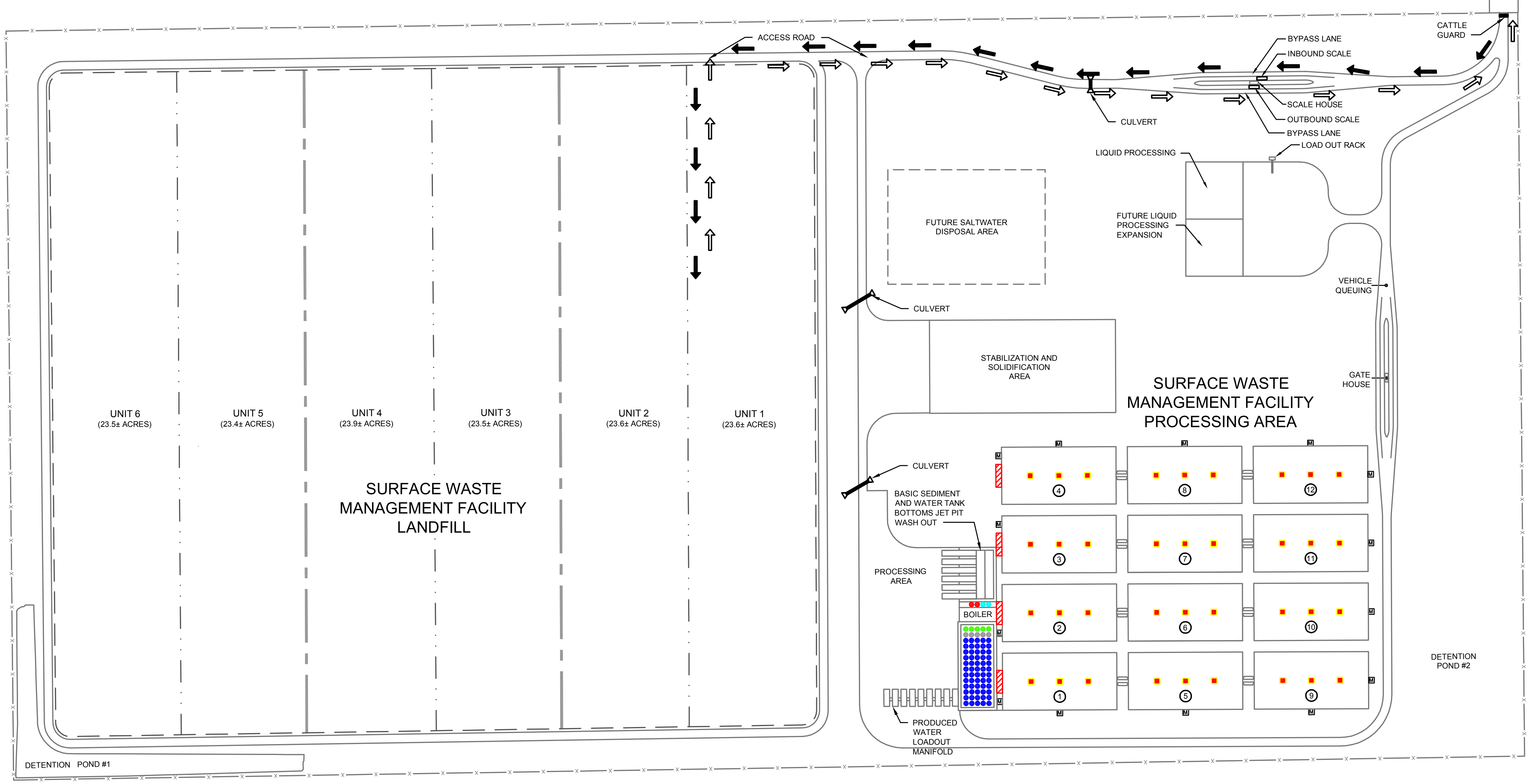
FINAL COVER SECTIONS

FIG.A.8

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.9 -LANDFILL TRAFFIC FLOW PLAN.dwg LAYOUT NAME: FIG.A.9 PRINTED: Thursday, November 05, 2015 - 8:34pm USER: TKrueger



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LEGEND

—x—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— — —	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
M	MONITORING POINTS
⊜	LOW WATER CROSSING
🔵	PRODUCED WATER SETTING TANK
⚪	OIL RECOVER TANK
🟢	OIL SALES TANK
🔴	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER
⬅	INBOUND TRAFFIC
⇨	OUTBOUND TRAFFIC

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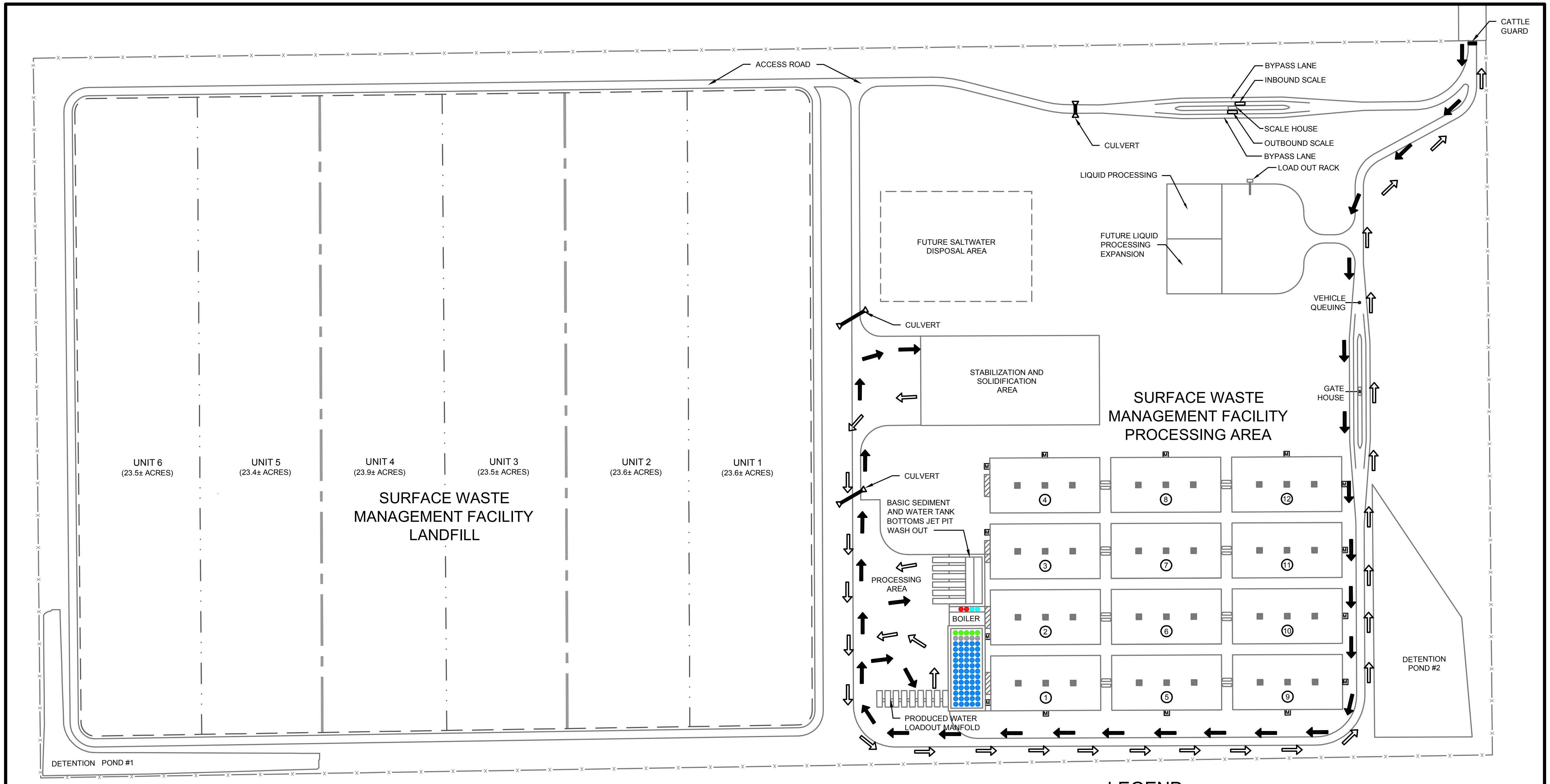
LANDFILL TRAFFIC FLOW PLAN

FIG.A.9

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.10 -PROCESSING AREA TRAFFIC FLOW PLAN .dwg LAYOUT NAME: FIG.A.10 PRINTED: Thursday, November 05, 2015 - 8:34pm USER: TKrueger



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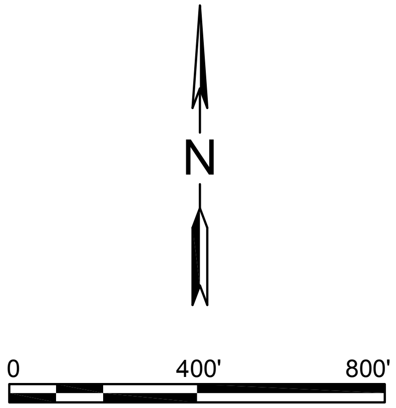

LEGEND

—x—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— — —	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
M	MONITORING POINTS
⊟	LOW WATER CROSSING
●	PRODUCED WATER SETTING TANK
●	OIL RECOVER TANK
●	OIL SALES TANK
●	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER
←	INBOUND TRAFFIC
⇨	OUTBOUND TRAFFIC

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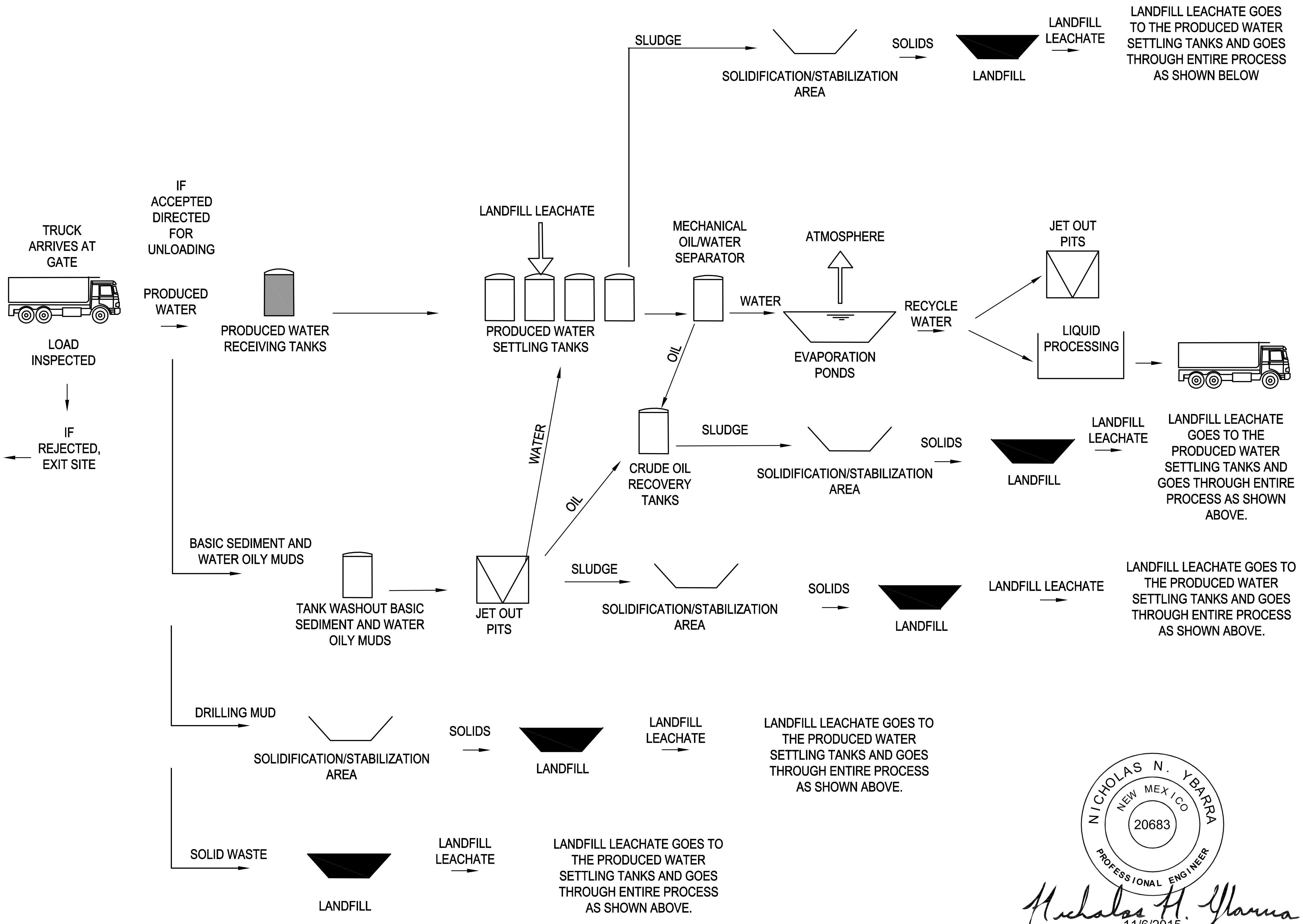
PROCESSING AREA TRAFFIC FLOW PLAN

FIG.A.10

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.11 -PROCESS FLOW DIAGRAM.dwg LAYOUT NAME: FIG.II.1.7 PRINTED: Thursday, November 05, 2015 - 8:35pm USER: TKrueger



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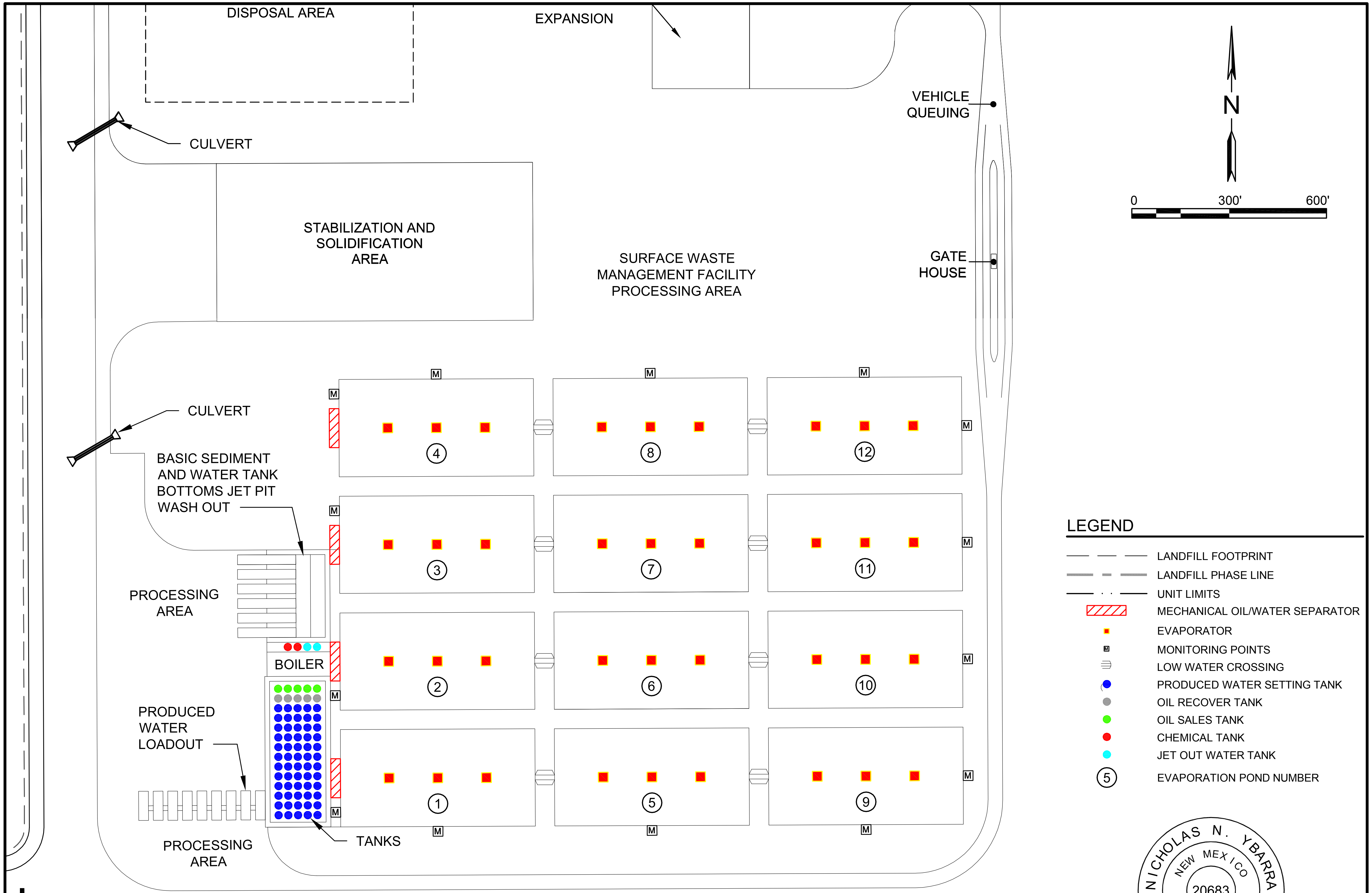
PROCESS FLOW DIAGRAM

FIG.II.1.7

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.12 -EVAPORATION POND STA. MONT.dwg LAYOUT NAME: FIG.A.12 PRINTED: Thursday, November 05, 2015 - 8:35pm USER: TKrueger



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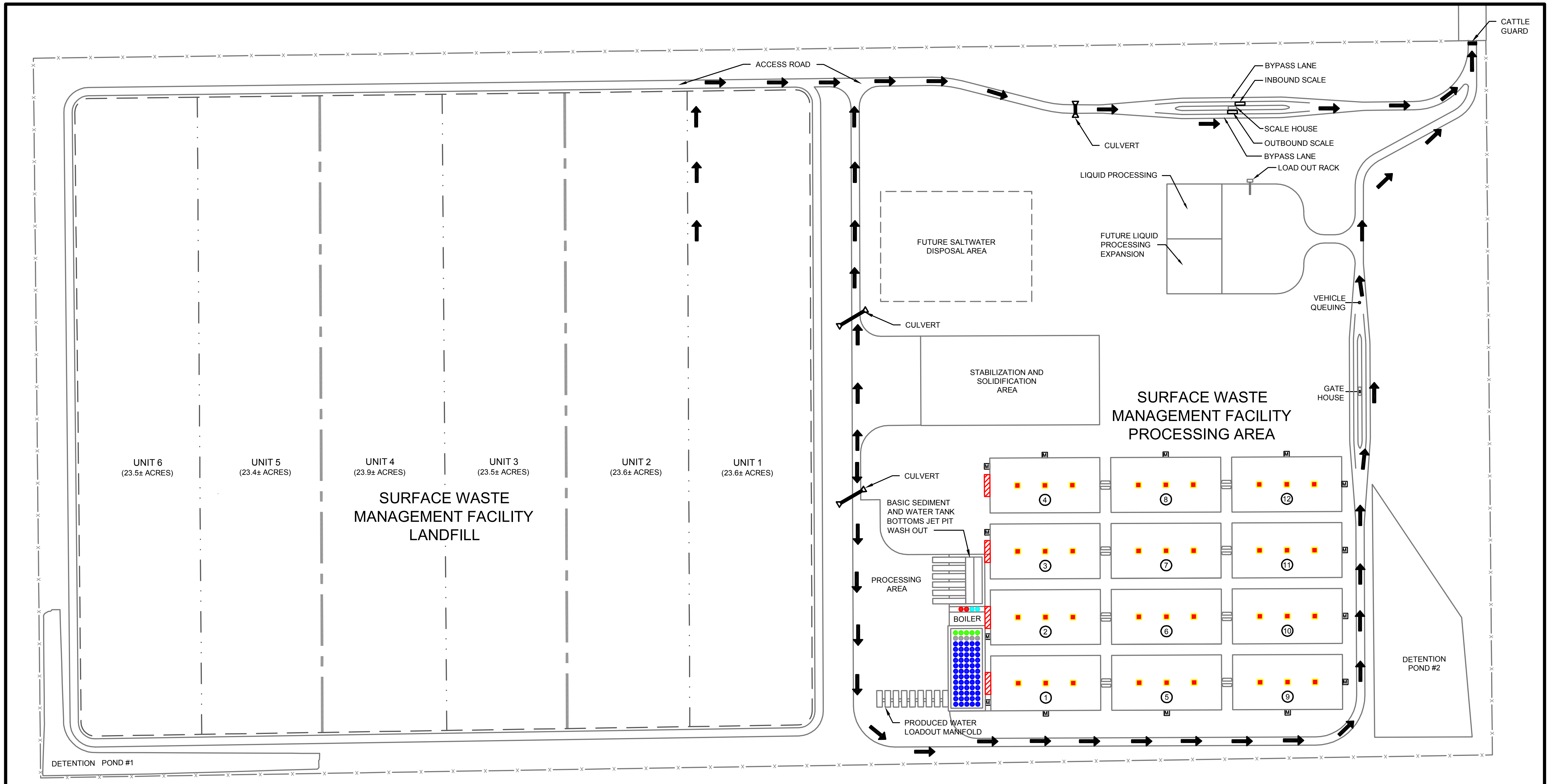
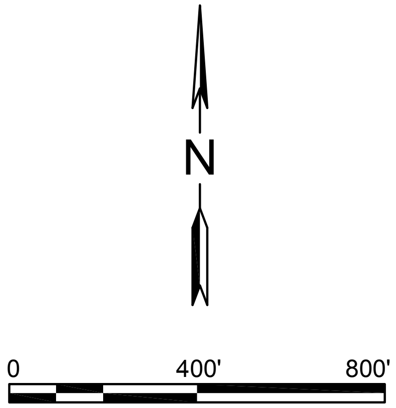
EVAPORATION POND STATIONARY MONITORING

FIG.A.12

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.13 -SITE EVACUATION PLAN.dwg LAYOUT NAME: FIG.A.13 PRINTED: Thursday, November 05, 2015 - 8:36pm USER: TKrueger





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LEGEND

—x—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
━ ━ ━	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
🟥	EVAPORATOR
M	MONITORING POINTS
▤	LOW WATER CROSSING
🔵	PRODUCED WATER SETTING TANK
●	OIL RECOVER TANK
🟢	OIL SALES TANK
🔴	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER
➡	EVACUATION ROUTE

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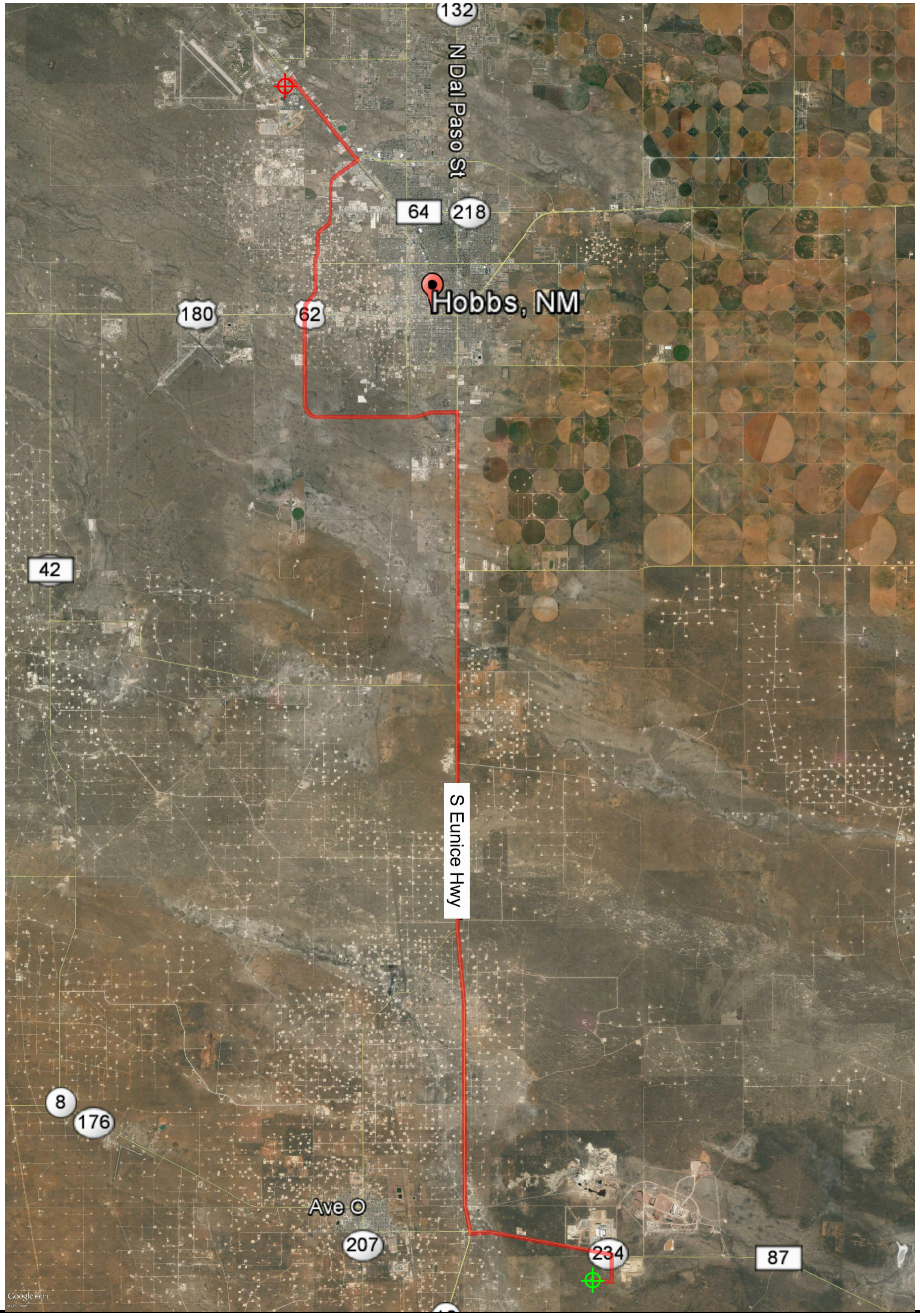
SITE EVACUATION PLAN

FIG.A.13



DIRECTIONS

1. FROM C.K. DISPOSAL E&P LANDFILL & PROCESSING FACILITY
2. HEAD WEST ON NM-176 W/NM234 W (23Mi.)
3. TURN RIGHT ONTO NM-18 N (16.2Mi.)
4. TURN LEFT INTO S BYPASS (4.9Mi.)
5. CONTINUE ONTO NW COUNTY ROAD (3.5Mi.)
6. TURN LEFT ONTO NM-18 N (1.9Mi.)
7. TURN LEFT ONTO GERRY (276 FT)
8. TURN RIGHT AT THE 1ST CROSS STREET (413 FT)
9. TURN LEFT (318 FT)
10. ARRIVE AT LEA REGIONAL MEMORIAL CENTER (5419 N. LOVINGTON HWY.)

NOTES

A. ESTIMATED DISTANCE: 29 MILES
B. ESTIMATED TRAVEL TIME: 33 MINUTES

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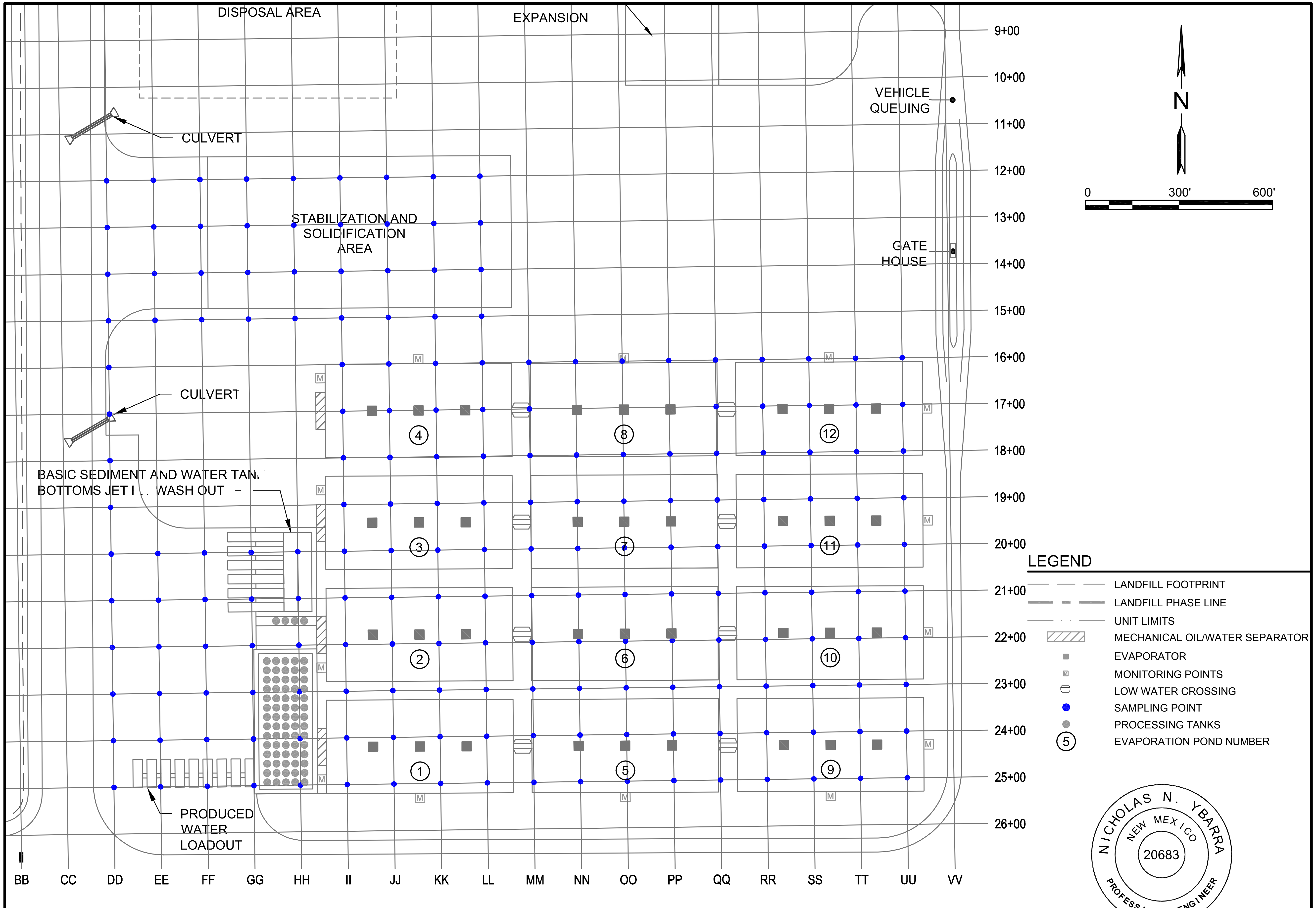
HOSPITAL LOCATION MAP

FIG.A.14

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.14 -HOSPITAL LOCATION.dwg LAYOUT NAME: FIG.A.14 PRINTED: Thursday, November 05, 2015 - 8:36pm USER: TKrueger

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.15 -EVAPORATION POND STA. MONT.dwg LAYOUT NAME: FIG.A.15 PRINTED: Thursday, November 05, 2015 - 8:37pm USER: TKrueger



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SURFACE WASTE
MANAGEMENT FACILITY
PROCESSING AREA

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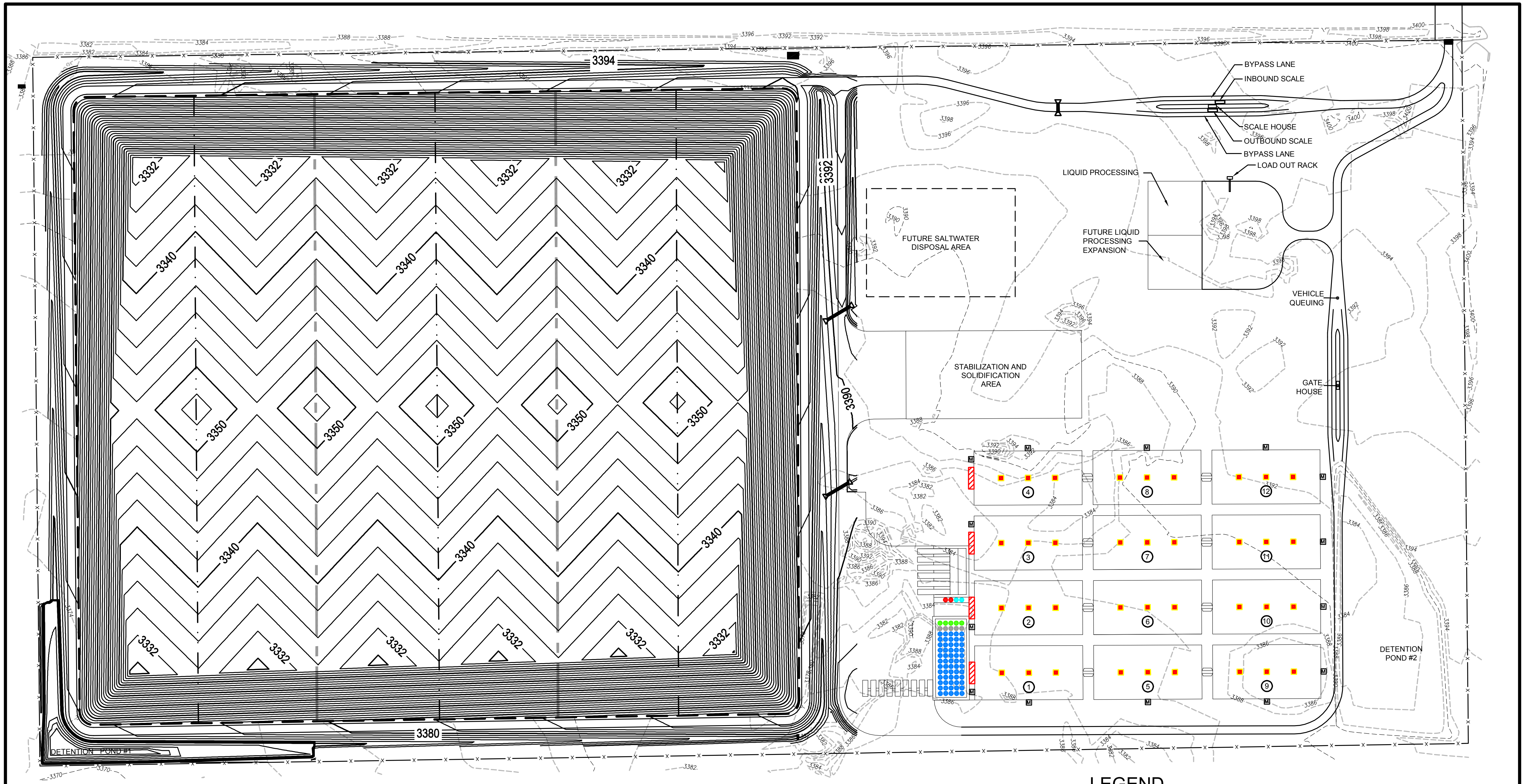
LIQUID PROCESSING AREA SAMPLING GRID

FIG.A.15



LEGEND

- - - 3392 - - -	EXISTING CONTOUR
—3340—	2' LINER CONTOUR
—x—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— — —	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
▣	MONITORING POINTS
⊜	LOW WATER CROSSING
●	PRODUCED WATER SETTING TANK
●	OIL RECOVER TANK
●	OIL SALES TANK
●	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER

N

0 400' 800'

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FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.16 - LANDFILL BASE GRADING PLAN.dwg LAYOUT NAME: FIG.A.16 PRINTED: Thursday, November 05, 2015 - 8:37pm USER: TKrueger

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LEA COUNTY, NEW MEXICO

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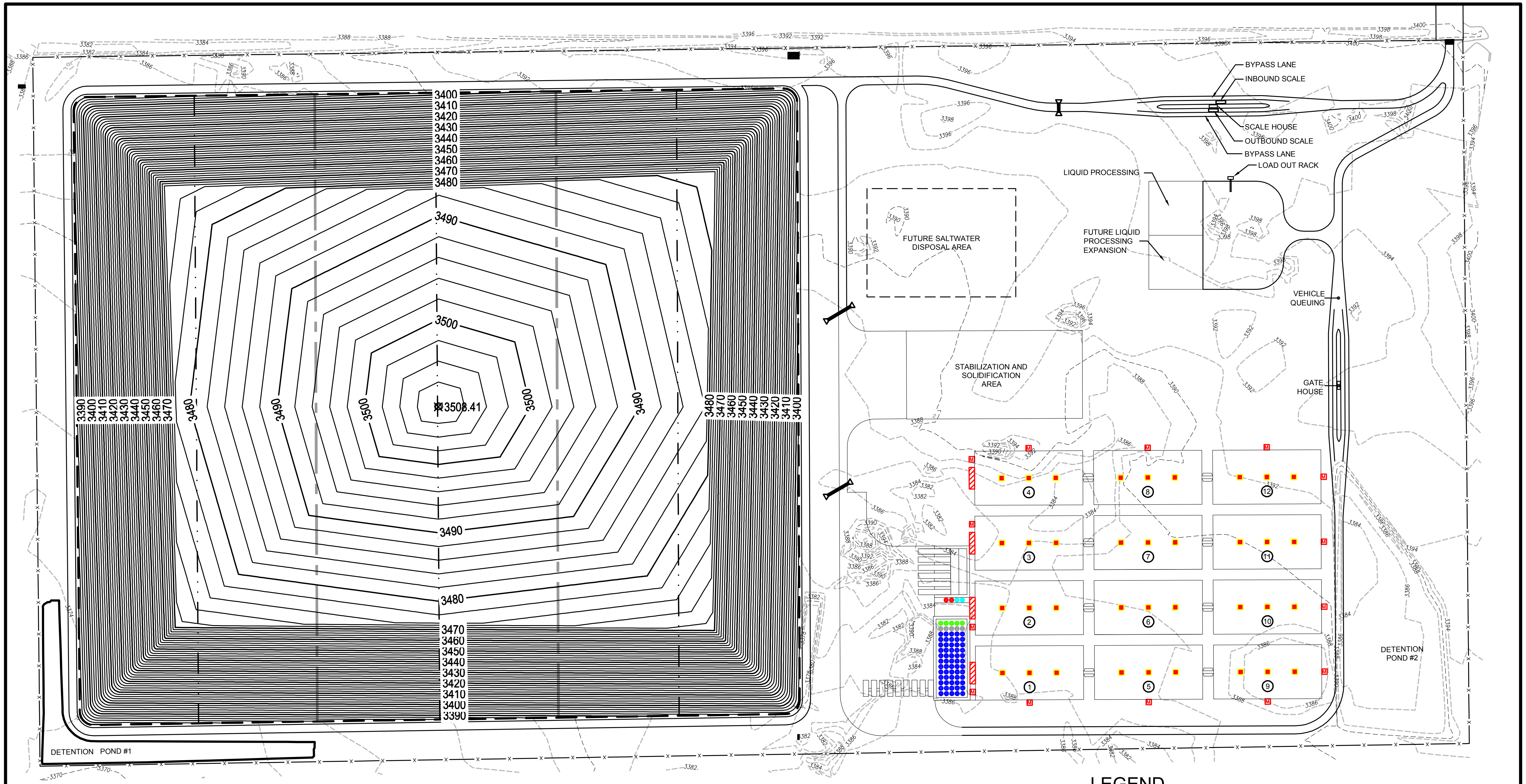
LANDFILL
BASE GRADING PLAN

FIG.A.16

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.17 - LANDFILL FINAL GRADING PLAN.dwg LAYOUT NAME: FIG.A.17 PRINTED: Thursday, November 05, 2015 - 8:37pm USER: TKrueger



LEGEND

- - 3392 - -	EXISTING CONTOUR
—3340—	2' LINER CONTOUR
—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— - —	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
▣	MONITORING POINTS
⊖	LOW WATER CROSSING
●	PRODUCED WATER SETTING TANK
●	OIL RECOVER TANK
●	OIL SALES TANK
●	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER

N

0 400' 800'

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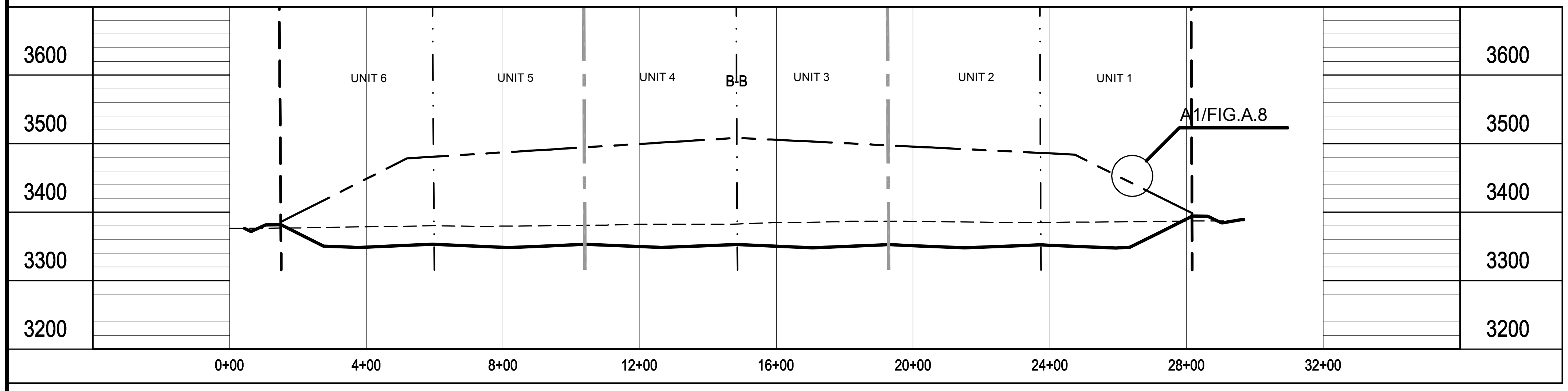
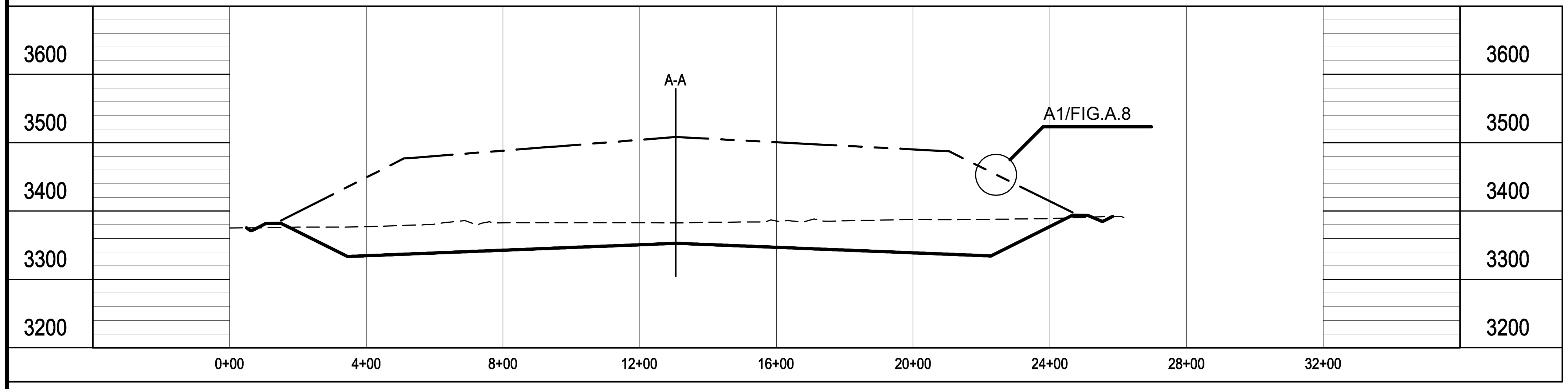
LANDFILL
FINAL GRADING PLAN

FIG.A.17

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.18 - LANDFILL CROSS SECTIONS.dwg LAYOUT NAME: FIG.A.18 PRINTED: Thursday, November 05, 2015 - 8:38pm USER: TKrueger



A SECTION A-A
SCALE: 1" = 400'



B SECTION B-B
SCALE: 1" = 400'

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SCALES:

HORIZONTAL
0 400' 800'

VERTICAL
0 200' 400'

LEGEND

— — —	LANDFILL PHASE BOUNDARY
— · · — · · —	LANDFILL UNIT BOUNDARY
- - - - - - - -	EXISTING GRADE
———	BASE GRADE
—— — — ——	FINAL GRADE

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LEA COUNTY, NEW MEXICO

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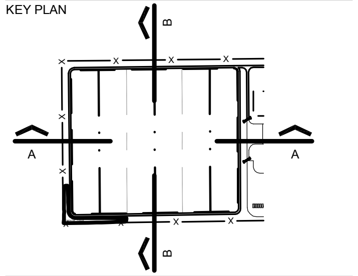

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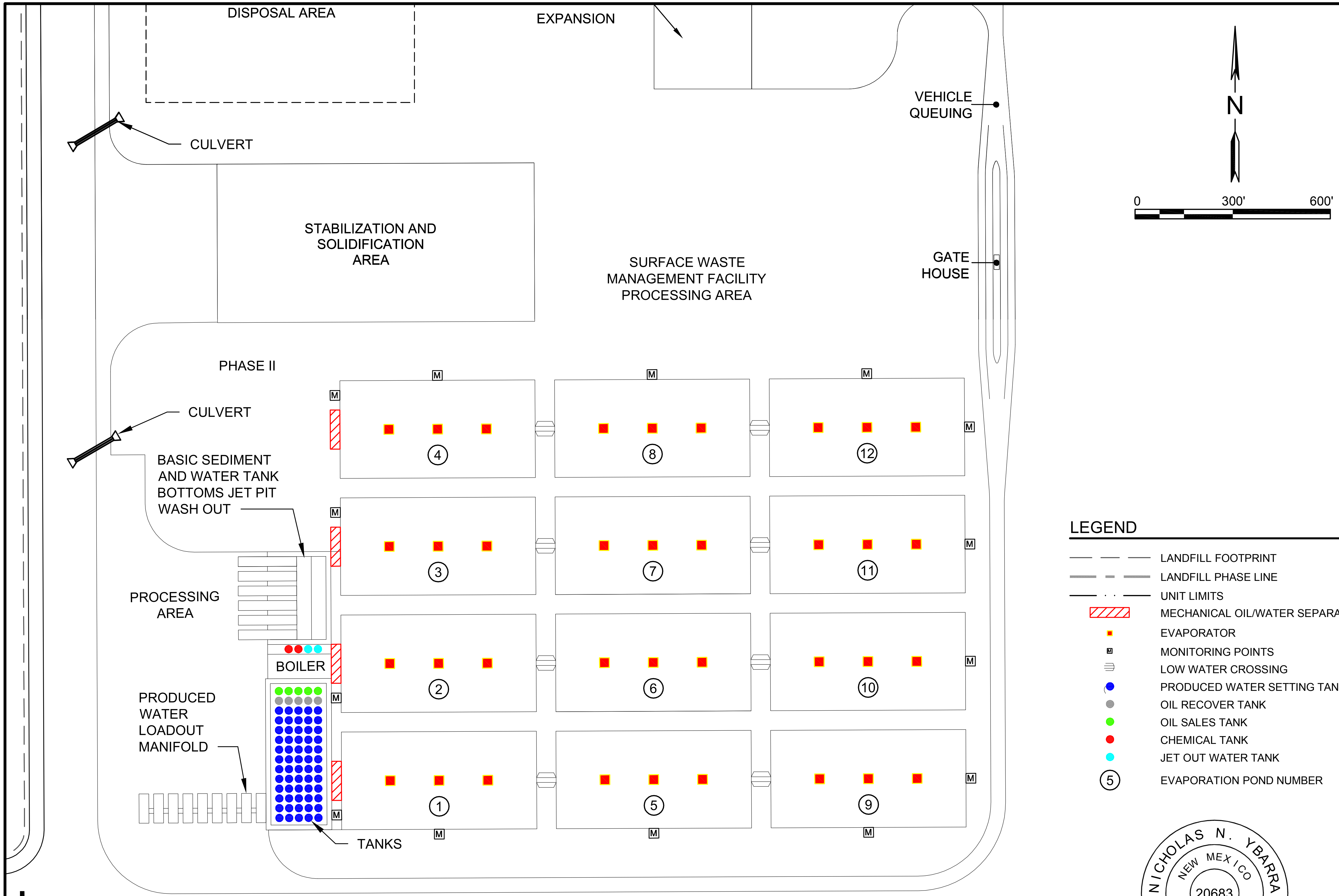
LANDFILL CROSS SECTIONS

FIG.A.18

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.19 -EVAPORATION POND MECHANICAL EVAPORATOR LOCATIONS.dwg LAYOUT NAME: FIG.A.19 PRINTED: Thursday, November 05, 2015 - 8:38pm USER: TKrueger



LEGEND

- — — — LANDFILL FOOTPRINT
- — - — LANDFILL PHASE LINE
- — · · — UNIT LIMITS
- ▨ MECHANICAL OIL/WATER SEPARATOR
- ■ EVAPORATOR
- ◘ MONITORING POINTS
- ≡ LOW WATER CROSSING
- ● PRODUCED WATER SETTING TANK
- ● OIL RECOVER TANK
- ● OIL SALES TANK
- ● CHEMICAL TANK
- ● JET OUT WATER TANK
- ⑤ EVAPORATION POND NUMBER

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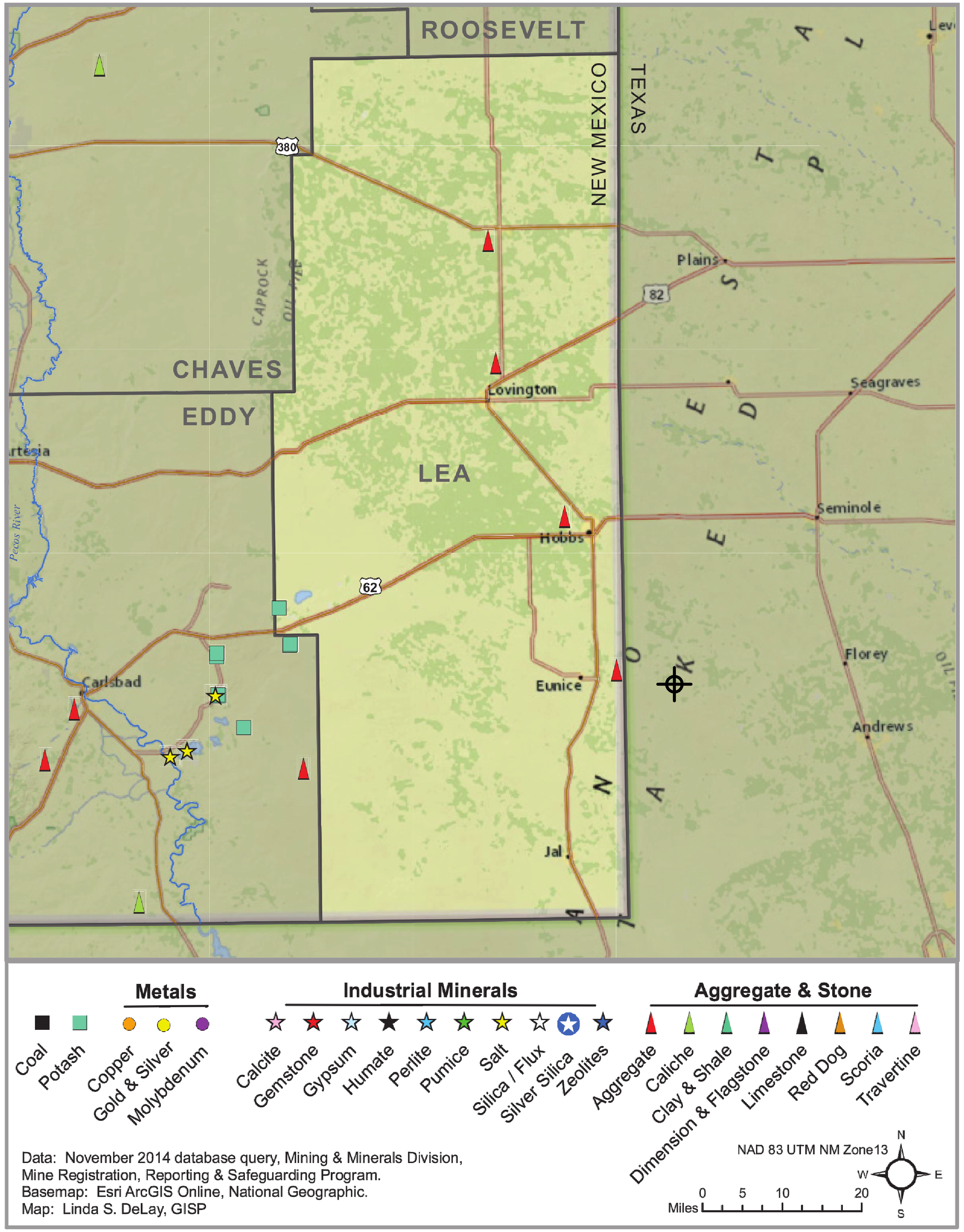
EVAPORATION POND
MECHANICAL EVAPORATOR
LOCATIONS

FIG.A.19

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.20-MINES MILLS QUARRIES.dwg LAYOUT NAME: FIG.A.20 PRINTED: Thursday, November 05, 2015 - 8:39pm USER: TKrueger

Active Mines in Lea County, New Mexico, November 2014



Data: November 2014 database query, Mining & Minerals Division,
Mine Registration, Reporting & Safeguarding Program.
Basemap: Esri ArcGIS Online, National Geographic.
Map: Linda S. DeLay, GISP

LEGEND

⌖ C.K. DISPOSAL SITE

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C. K. DISPOSAL E & P LANDFILL & PROCESSING FACILITY

NMED PERMIT NO. __

NEW LANDFILL SITE & PROCESSING FACILITY

LEA COUNTY, NEW MEXICO

KEY PLAN

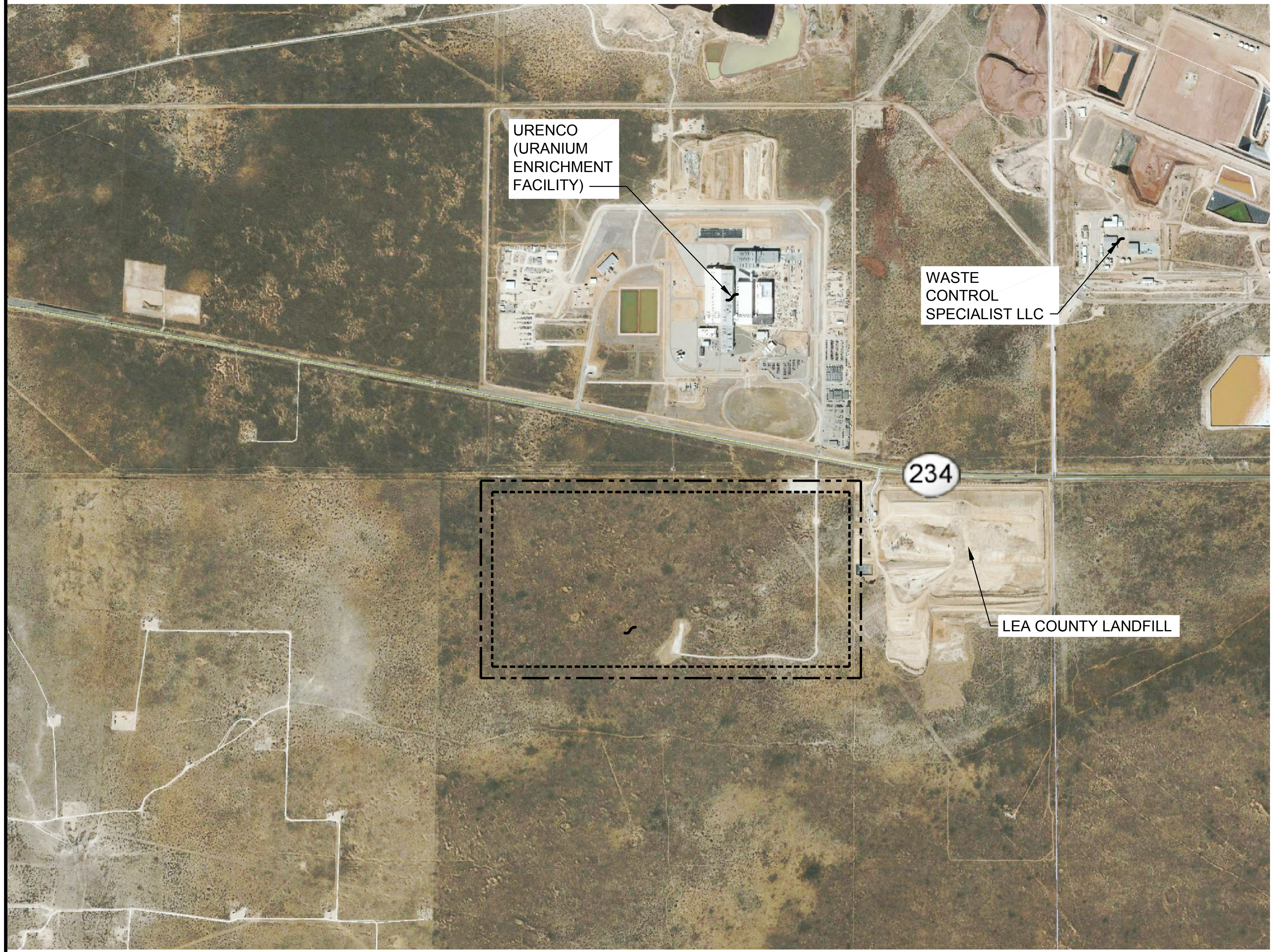
NO	DATE	DESCRIPTION
1	09/23/15	ISSUE FOR REVIEW

ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

MINES, MILLS, & QUARRIES

FIG.A.20

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.21 -AERIAL PHOTOGRAPH.dwg LAYOUT NAME: FIG.A.21 PRINTED: Thursday, November 05, 2015 - 8:39pm USER: TKrueger



N
NO SCALE

LEGEND

— - - —— - - —— PROPERTY LINE
- - - - - - - - - - - - - - 150' SETBACK

NICHOLAS N. YBARRA
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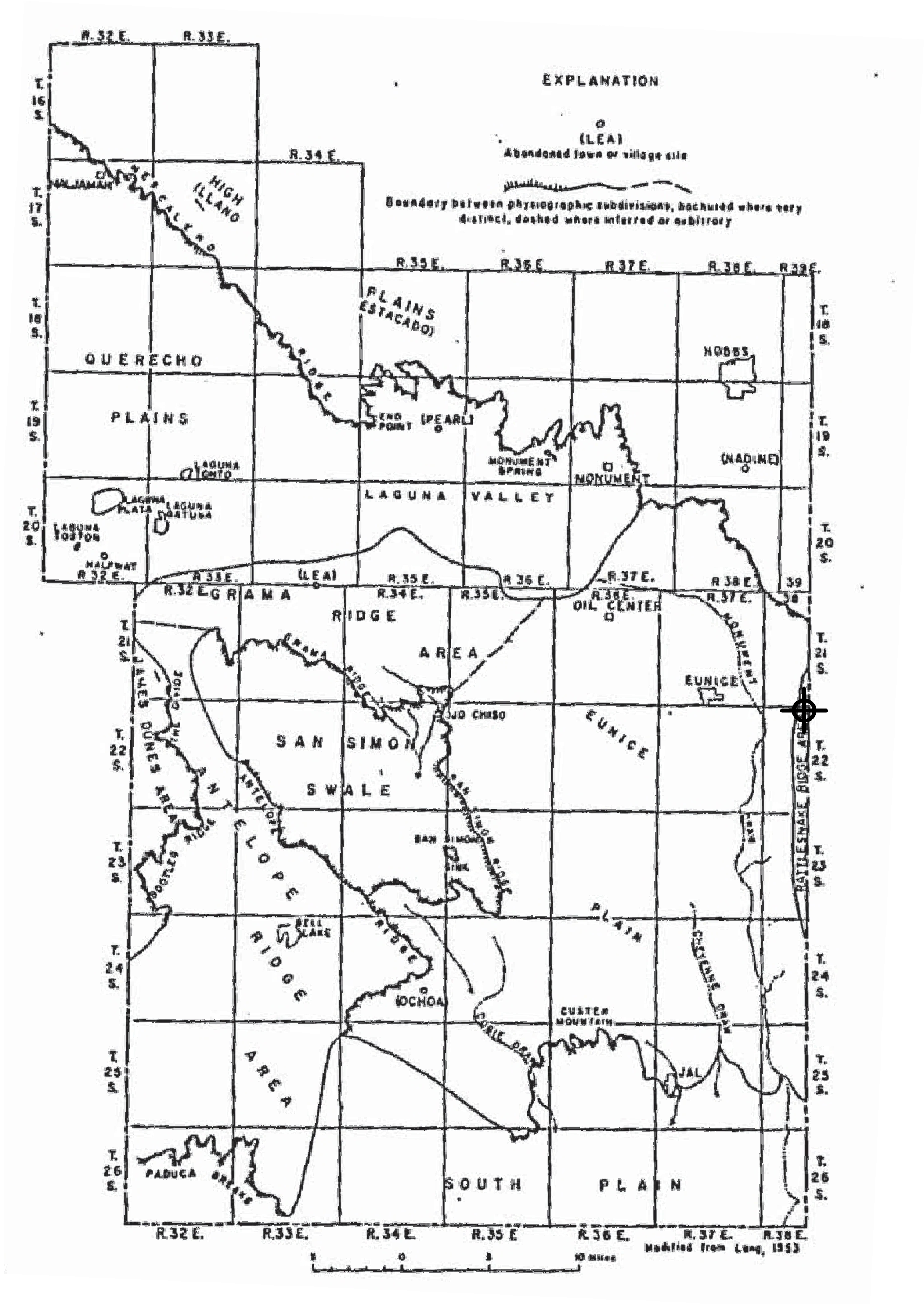
AERIAL
PHOTOGRAPH

FIG.A.21

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.22-PHYSIOGRAPHY OF SOUTHERN LEA COUNTY.dwg LAYOUT NAME: FIG.A.22 PRINTED: Thursday, November 05, 2015 - 8:39pm USER: TKrueger



* NO SUBSIDENCE FEATURES IN THE VICINITY OF THE CK FACILITY

REFERENCE:
NICHOLSON AND CLEBSCH (1961, LEA COUNTY)

LEGEND

⌖ C.K. DISPOSAL SITE

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20683

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PHYSIOGRAPHY OF SOUTHERN LEA COUNTY, NEW MEXICO

FIG.A.22

LEGEND

🟧	FAULTS
⌖	C.K. DISPOSAL SITE

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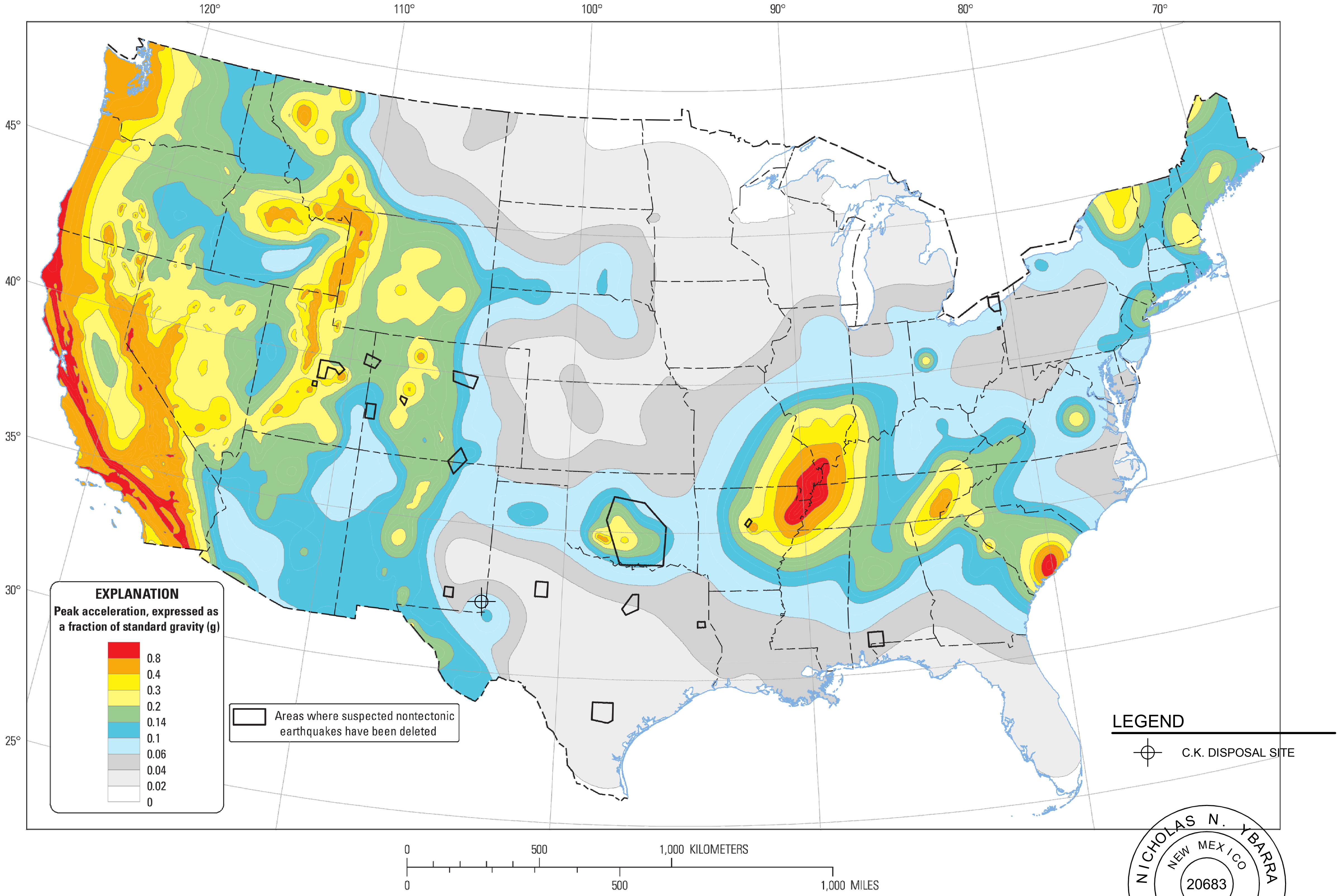
FAULTS
MAP

FIG.A.23

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.23 -FAULTS MAP.dwg LAYOUT NAME: FIG.A.23 PRINTED: Thursday, November 05, 2015 - 8:40pm USER: Tkrueger

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.24 -SIESMIC IMPACT ZONE.dwg LAYOUT NAME: FIG.A.24 PRINTED: Thursday, November 05, 2015 - 8:40pm USER: TKrueger



Two-percent probability of exceedance in 50 years map of peak ground acceleration

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SEISMIC IMPACT ZONE

FIG.A.24

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.25 -MAJOR STRUTURES OF SE NEW MEXICO.dwg LAYOUT NAME: FIG.A.25 PRINTED: Thursday, November 05, 2015 - 8:41pm USER: TKrueger

N

LEGEND

⌖ C.K. DISPOSAL SITE

MAP REFERENCE

HARTMAN, J.R. AND L.R. WOODWARD
FUTURE PETROLEUM RESOURCES IN
POST-MISSISSIPPIAN STRATA OF
NORTH, CENTRAL, AND WEST TEXAS,
AND EASTERN NEW MEXICO, IN
FUTURE PETROLEUM PROVINCES OF
THE UNITED STATES- THEIR
GEOLOGY AND POTENTIAL, 1971

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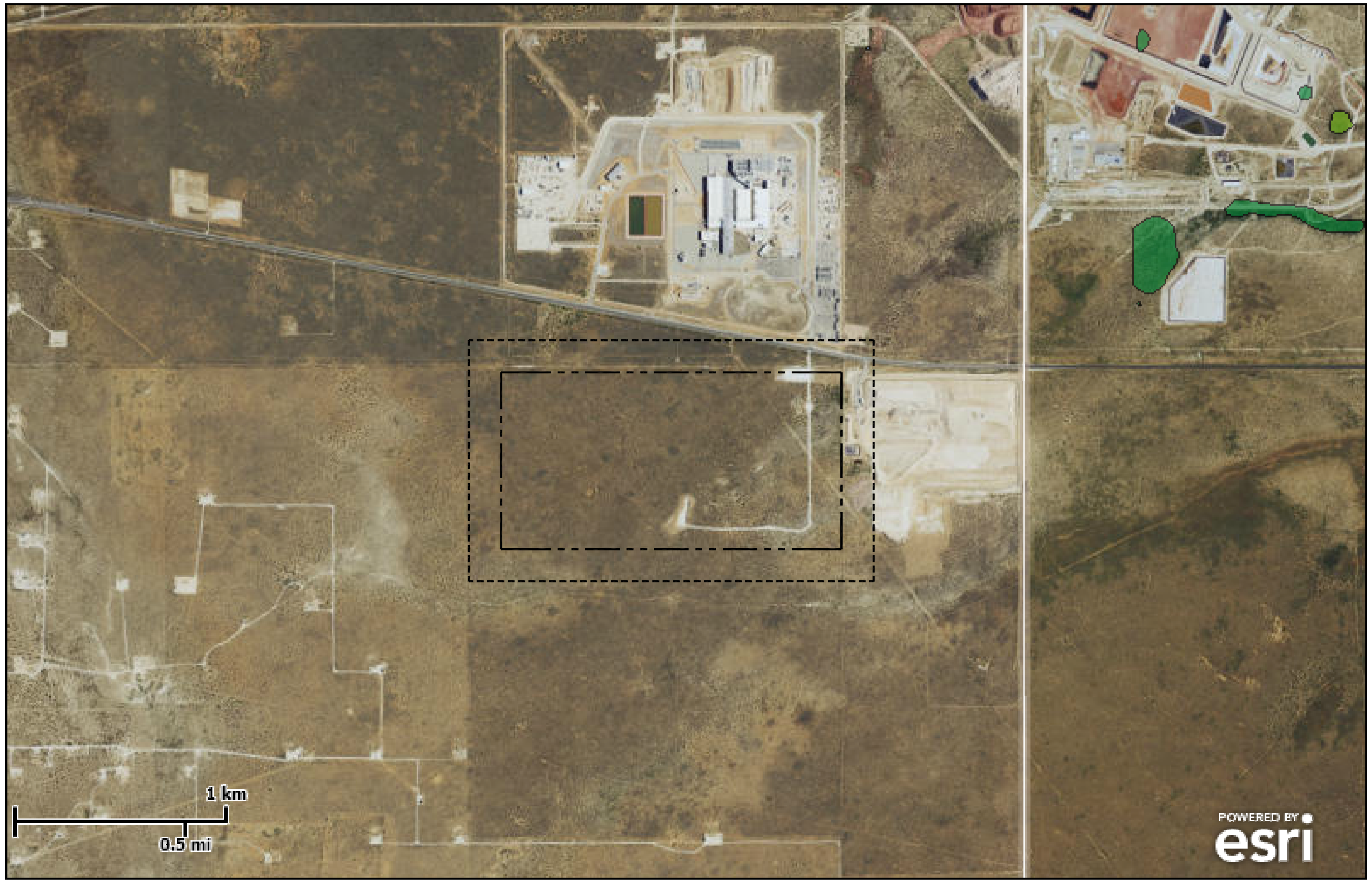
MAJOR STRUCTURES
OF SOUTHEAST
NEW MEXICO

FIG.A.25

U.S. Fish and Wildlife Service

National Wetlands Inventory

Wetlands Map



Wetlands

- 🟩 Freshwater Emergent
- 🟩 Freshwater Forested/Shrub
- 🟦 Estuarine and Marine Deepwater
- 🟩 Estuarine and Marine
- 🟦 Freshwater Pond
- 🟦 Lake
- 🟦 Riverine
- 🟫 Other

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

N

NO SCALE

LEGEND

— - - — - - — PROPERTY LINE

---------------- 500' FROM PROPERTY

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LEA COUNTY, NEW MEXICO

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WETLANDS
MAP

FIG.A.26

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-A\FIG.A.26 -WETLANDS.dwg LAYOUT NAME: FIG.A.26 PRINTED: Wednesday, November 11, 2015 - 10:13am USER: TKrueger

Permit Application

Lea County, New Mexico
C.K. Disposal E & P Landfill and Processing Facility
Permit No. TBD

Attachment B
Engineered Design Plan

November 2015
PSC Project # 01058015

PARKHILLSMITH&COOPER

C.K. DISPOSAL
E&P LANDFILL & PROCESSING FACILITY
CONSTRUCTION DOCUMENTS
LEA COUNTY, NEW MEXICO

PARKHILL SMITH & COOPER

4222 85th Street
Lubbock, Texas 79423
806.473.2200

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Nicholas N. Ybarra
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PARKHILL SMITH & COOPER

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E & P LANDFILL &
PROCESSING
FACILITY**

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**NEW LANDFILL SITE
& PROCESSING FACILITY**

LEA COUNTY, NEW MEXICO

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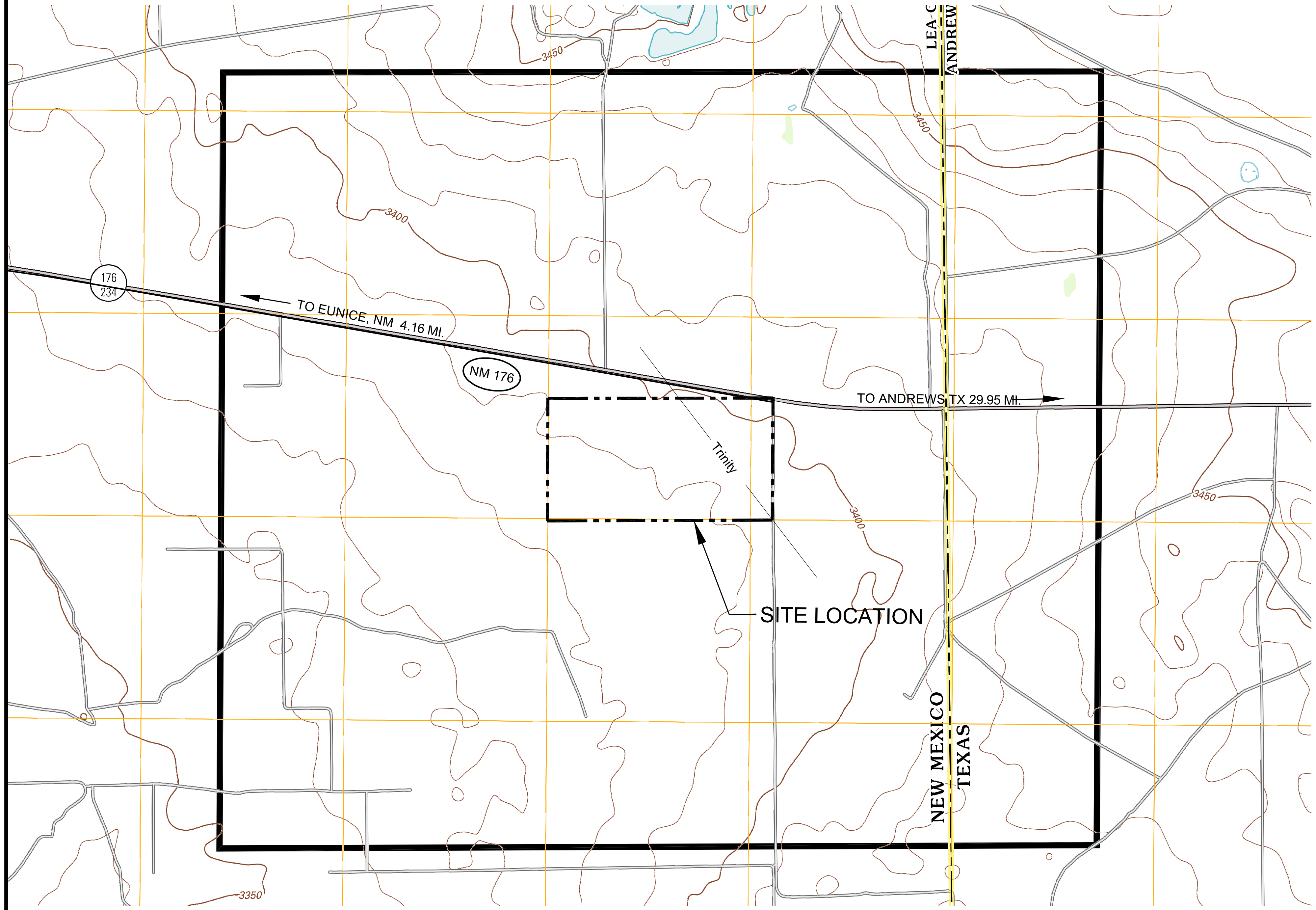
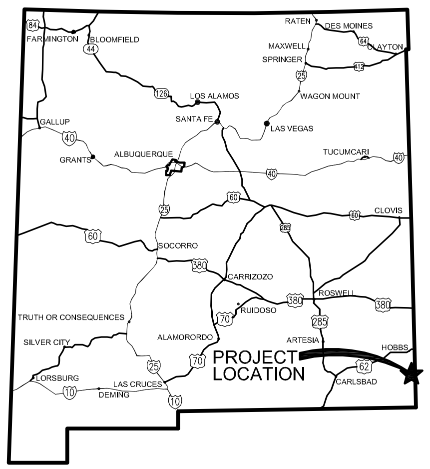
PROJECT NO: 0580.15

**COVER
SHEET**

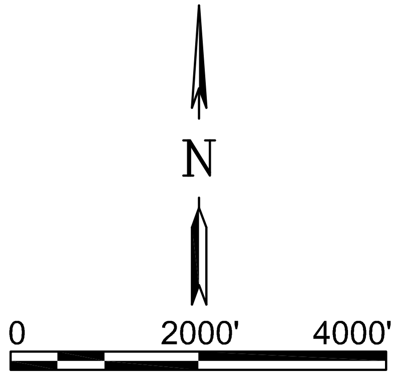
G-001

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\G-001 -COVER SHEET.dwg LAYOUT NAME: G-001 PRINTED: Friday, November 06, 2015 - 8:16am USER: TKrueger





VICINITY MAP



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20683
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Nicholas N. Ybarra
11/6/2015

OWNER:
C.K. DISPOSAL E&P LANDFILL
LEA COUNTY, NEW MEXICO

ENGINEER:
PARKHILL, SMITH & COOPER, INC.
4222 85TH STREET
LUBBOCK, TEXAS 79423
(806)473-2200

PIPELINE OWNER:
TRINITY
401 W. WALL
MIDLAND, TEXAS 79701
(432) 683-8267

"ONE CALL UTILITY LOCATING COMPANIES:
1-800-321-ALERT
NEW MEXICO ONE CALL: 811

MAP REFERENCE

United States Geological Survey

North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid: Universal Transverse Mercator, Zone 13S
10 000-foot ticks: Texas Coordinate System of 1983 (north central zone), New Mexico Coordinate System of 1983 (east zone)

North American Vertical Datum of 1998
Eunice NE, TX-NM
2012

(EDITED BY PARKHILL, SMITH & COOPER, INC.)

SHEET INDEX

SHEET #	DESCRIPTION
G-001	COVER SHEET
G-002	SITE LOCATION MAP, VICINITY MAP & SHEET INDEX
G-003	EXISTING SITE CONDITIONS
G-004	SITE DEVELOPMENT PLAN
G-005	BEST MANAGEMENT PRACTICES
C-101	LANDFILL BASE GRADING PLAN
C-102	LANDFILL FINAL GRADING PLAN
C-103	LANDFILL COMPLETION DRAINAGE PLAN
C-104	FINAL COVER PROFILE
C-105	LANDFILL CROSS SECTIONS
C-106	EVAPORATION POND AND STABILIZATION/SOLIDIFICATION AREA
	CROSS SECTIONS
C-107	PROCESSING AREA LAYOUT CROSS SECTIONS
C-501	LINER & LEACHATE COLLECTION DETAILS
C-502	LEACHATE SUMP PLAN & PROFILE DETAILS
C-502A	LEAK DETECTION PROFILE DETAILS
C-503	POND LEACHATE COLLECTION SYSTEM DETAILS
C-504	EVAPORATION POND DETAILS
C-505	TYPICAL RECEIVING TANK LINER CONTAINMENT DETAILS
C-506	DETENTION POND & DETAILS
C-507	DEVELOPED DRAINAGE STRUCTURES PLAN
C-508	STABILIZATION AND SOLIDIFICATION AREA

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LEA COUNTY, NEW MEXICO

KEY PLAN

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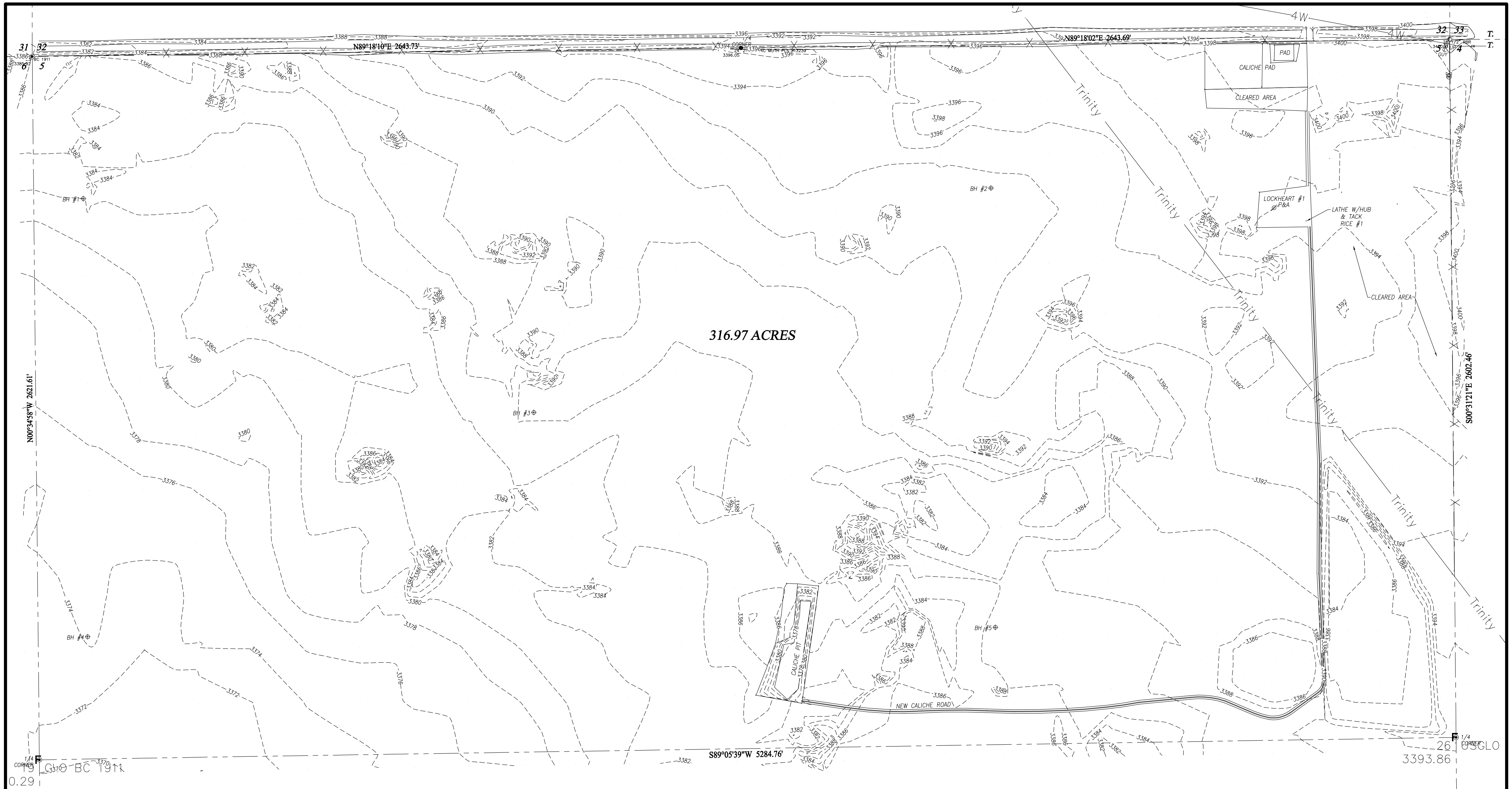
**SITE LOCATION,
VICINITY MAP,
& INDEX SHEET**

G-002

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\G-002 - PROJECT LOCATION.dwg LAYOUT NAME: G-002 PRINTED: Wednesday, November 11, 2015 - 10:26am USER: TKrueger

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\G-003 - EXISTING SITE CONDITIONS.dwg LAYOUT NAME: G-003 PRINTED: Friday, November 06, 2015 - 8:17am USER: TKrueger



LEGEND:

◉ – DENOTES FOUND USGLO 1911 BRASS CAP
○ – DENOTES FOUND 1/2" STEEL ROD
● – DENOTES FOUND 2–1/2" ALUMINUM CAP MARKED "MUTH PLS #13239"
Ø – DENOTES PLUGGED & ABANDONED PRODUCTION WELL
BH #1 ⊕ – DENOTES BORE HOLE LOCATION
MH – DENOTES MANHOLE WITH VALVE
——Trinity——Trinity—— – DENOTES TRINITY CO_2 PIPELINE
——ROW——ROW——ROW——ROW—— – DENOTES HIGHWAY RIGHT–OF–WAY
——x——x——x——x—— – DENOTES FENCE LINE
——4W——4W——4W—— – DENOTES 4 WIRE OVERHEAD ELECTRIC LINE
UPØ – DENOTES UTILITY POLE
GUY← – DENOTES GUY/ANCHOR WIRE
———— – – ———— LANDFILL PROPERTY/PERMIT BOUNDARY

NOTE:

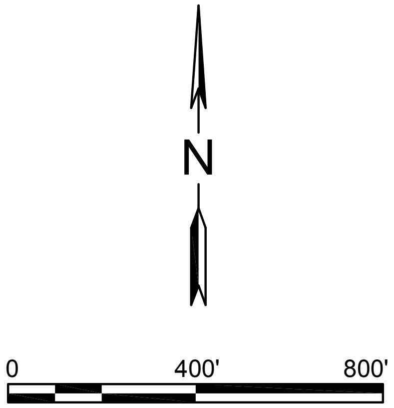
1) OWNER OF RECORD: A. BRYCE KARGER, WARRANTY DEED BOOK 1956, PAGE 831.

2) ELEVATIONS ARE RELATIVE TO NAVD88 (GEOID 12A).

3) THIS IS NOT A BOUNDARY SURVEY, APPARENT PROPERTY CORNERS AND PROPERTY LINES ARE SHOWN FOR INFORMATION PURPOSES ONLY. SECTION LINE DATA HEREON ARE MERCATOR GRID AND CONFORM TO THE NEW MEXICO COORDINATE SYSTEM "NEW MEXICO EAST ZONE" NORTH AMERICAN DATUM 1983. DISTANCES ARE SURFACE VALUES.

4) UTILITIES SHOWN WERE LOCATED FROM OBSERVED EVIDENCE. CONTRACTOR SHALL FIELD VERIFY ALL UTILITIES.

PROVIDING SURVEYING SERVICES
SINCE 1946
JOHN WEST SURVEYING COMPANY
412 N. DAL PASO
HOBBS, NEW MEXICO 88240
(575) 393-3117 www.jwsc.biz
TBPLS# 10021000



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LEA COUNTY, NEW MEXICO

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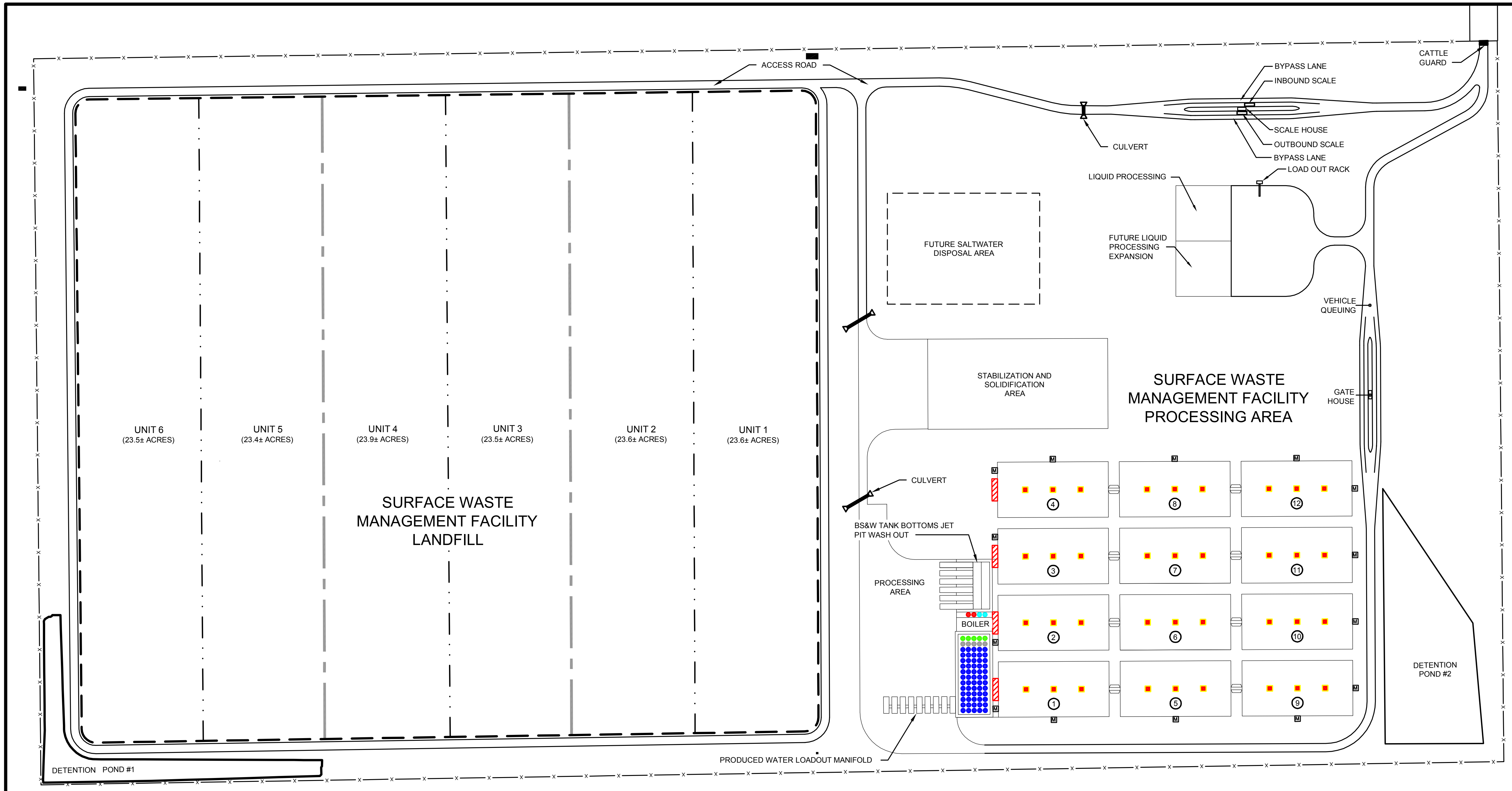
SITE SURVEY

G-003

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\G-004 - SITE DEVELOPMENT PLAN.dwg LAYOUT NAME: G-004 PRINTED: Friday, November 06, 2015 - 8:18am USER: TKrueger



NICHOLAS N. YBARRA
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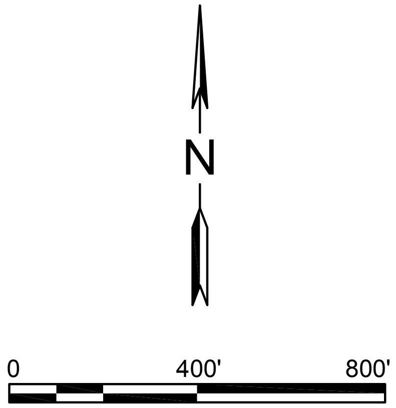

LEGEND

—x—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— - —	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
▣	MONITORING POINTS
▤	LOW WATER CROSSING
●	PRODUCED WATER SETTING TANK
●	OIL RECOVER TANK
●	OIL SALES TANK
●	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER

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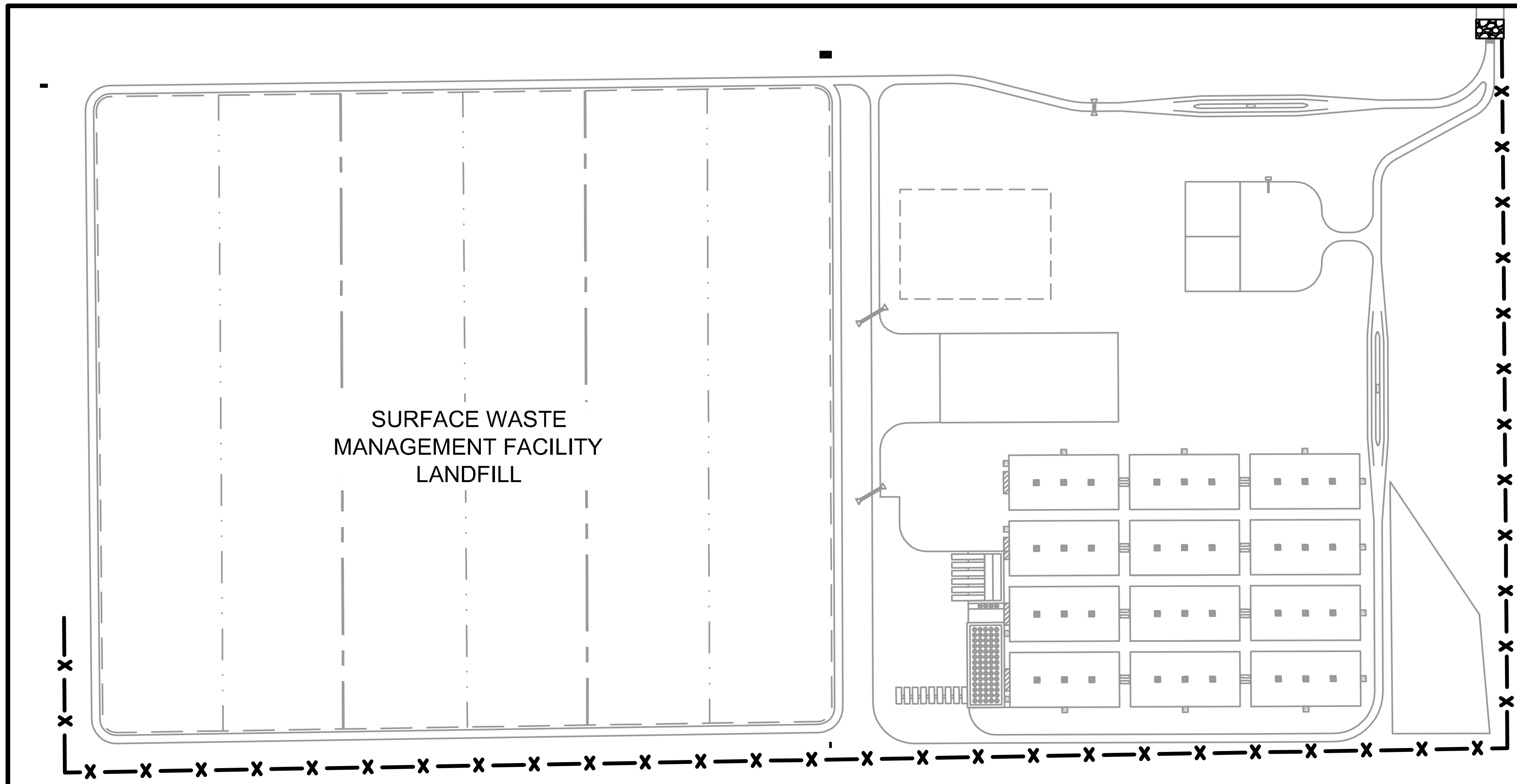
SITE DEVELOPMENT PLAN

G-004



LEGEND

┌ ─ ┐	AREA AFFECTED BY PROJECT (APPROX. 316.97 ACRES)
—X—	SILT FENCE
▩	STABILIZED CONSTRUCTION ENTRANCE

BEST MANAGEMENT PRACTICES

1. STRUCTURAL MEASURES SHALL BE MAINTAINED THROUGHOUT THE LIFT OF THE PROJECT IN EFFECTIVE OPERATING CONDITIONS.

2. DOCUMENTATION OF MAINTENANCE ACTIVITIES INCLUDING FREQUENCY, LOT DESIGNATION, INSPECTION OF STRUCTURAL CONTROLS, MATERIAL STORAGE AREAS, VEHICLES ENTRANCE AND EXITS: ACTIONS TAKEN AND INSPECTORS NAME.

3. CONSTRUCTION SITE NOTICE WILL BE MAINTAINED ON SITE.

4. COPY OF SWPPP SHALL BE KEPT ON SITE.

5. PERIMETER MUST RETAIN THE

A. WASTE MATERIALS
ALL WASTE MATERIALS INCLUDING CONSTRUCTION DEBRIS, SHALL BE COLLECTED AND STORED IN A SECURED LIDDED METAL DUMPSTER, NO CONSTRUCTION MATERIAL SHALL BE BURIED ON SITE. THE DUMPSTER SHALL BE EMPTIED AS NECESSARY OR AS AND THE TRASH BE HAULED TO A LICENSED LANDFILL.

B. HAZARDOUS WASTE
AT A MINIMUM, ANY PRODUCTS IN THE FOLLOWING CATEGORIES SHALL BE CONSIDERED HAZARDOUS PAINT, ACIDS FOR CLEANING MASONRY SURFACE, CLEANING SOLVENTS, ASPHALT PRODUCTS, CHEMICAL ADDITIVES FOR SPILL STABILIZATION, CURING COMPOUNDS AND ADDITIVES, IN EVENT OF SPILL WHICH MAY BE HAZARDOUS THE CONTRACTOR SHALL TAKE IMMEDIATE ACTION AND CONTACT THE FIRE DEPARTMENT, OCD AND NMED.

C. SANITARY WASTE
ALL SANITARY WASTE SHALL BE COLLECTED FROM THE CONSTRUCTION PORTABLE UNITS AS NECESSARY BY A LICENSED SANITARY WASTE MANAGEMENT CONTRACTOR. ALL WASTE MATERIAL SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR.

D. SPILL PREVENTION
THE FOLLOWING PRACTICES SHALL BE USED TO REDUCE THE RISK OF SPILLS OR OTHER ACCIDENTAL EXPOSURES OR MATERIALS TO STORM WATER RUNOFF.

E. GOOD HOUSEKEEPING
1. STORE ONLY ENOUGH PRODUCTS REQUIRED TO DO THE JOB
2. NEATLY STORE MATERIAL ON-SITE IN A SECURELY MANNER
3. KEEP PRODUCTS IN THEIR ORIGINAL CONTAINER
4. DO NOT MIX SUBSTANCES WITH ANOTHER, UNLESS OTHERWISE RECOMMENDED BY THE MANUFACTURER.
5. USE ENTIRE CONTENTS OF A PRODUCT BEFORE DISPOSING OF THE CONTAINER
6. FOLLOW MANUFACTURER'S RECOMMENDATIONS FOR PROPER USE AND DISPOSAL

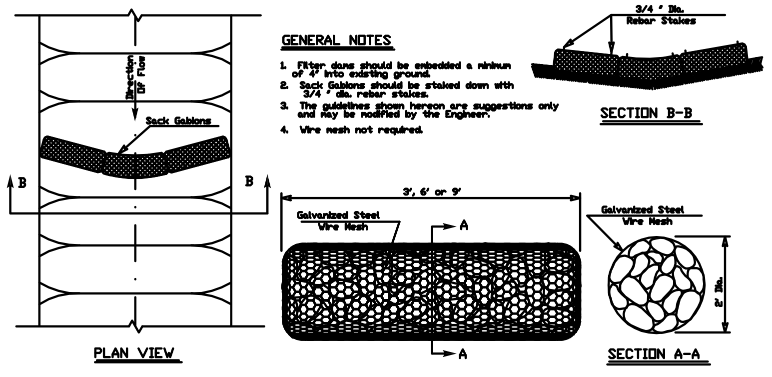
F. HAZARDOUS CONDITIONS
PRACTICES TO REDUCE RISKS:
1. KEEP PRODUCTS IN THEIR ORIGINAL CONTAINER IF AT ALL POSSIBLE
2. RETAIN ORIGINAL LABELS, PRODUCT INFORMATION AND MATERIAL SAFETY DATA SHEETS (MSDS)
3. DISPOSE SURPLUS PRODUCTS IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.

G. PETROLEUM PRODUCTS
PRODUCTS SHALL BE STORED IN TIGHTLY SEALED CONTAINERS WHICH ARE CLEARLY LABELED ANY ASPHALT SUBSTANCES USED ON-SITE SHALL BE APPLIED ACCORDING TO THE MANUFACTURER RECOMMENDATIONS

H. SPILL CONTROL PRACTICES
1. MANUFACTURER RECOMMENDED METHODS FOR SPILL CLEAN UP SHALL BE CLEARLY POSTED AND SITE PERSONNEL SHALL BE MADE WARE OF THE PROCEDURE
2. MATERIALS AND EQUIPMENT NECESSARY FOR SPILL CLEANUP SHALL BE KEPT IN THE MATERIAL STORAGE AREA ON-SITE
3. ALL SPILLS SHALL BE CLEANED UP IMMEDIATELY AFTER DISCOVERY
4. SPILL AREA SHALL BE WELL VENTILATED AND APPROPRIATE CLOTHING WILL BE WORN.
5. ANY SPILL SHALL BE REPORTED TO THE APPROPRIATE GOVERNMENTAL AGENCY.
6. MEASURES SHALL BE TAKEN TO PREVENT A SPILL FROM REOCCURRING.

I. MAINTENANCE AND INSPECTION PROCEDURES
ALL POLLUTION PREVENTION MEASURES SHALL BE INSPECTED AT LEAST EVERY 14-DAYS AND FOLLOWING A STORM EVENT OF 0.5 INCHES OR MORE BEST MANAGEMENT PRACTICES AND POLLUTION CONTROL PROCEDURES SHALL BE INSPECTED FOR ADEQUACY. A RECORD OF THE RESULTS OF THE INSPECTION OF THE SITE SHALL BE KEPT ON-SITE

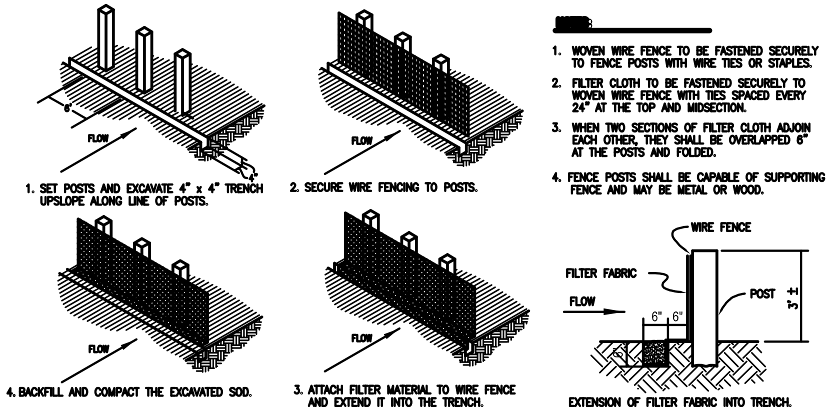
J. REMARKS
DISPOSAL AREAS, STOCKPILES, AND HAUL ROADS SHALL BE CONSTRUCTED IN A MANNER THAT WILL MINIMIZE AND CONTROL THE AMOUNT OF SEDIMENT THAT MAY ENTER RECEIVING WATERS, CONSTRUCTION STAGING AREAS AND VEHICLE MAINTENANCE AREAS SHALL BE CONSTRUCTED BY THE CONTRACTOR IN A MANNER TO MINIMIZE THE RUNOFF OF POLLUTANTS.



GENERAL NOTES

1. Filter dams should be embedded a minimum of 4" into existing ground.
2. Sack Gabions should be staked down with 3/4 " dia. rebar stakes.
3. The guidelines shown hereon are suggestions only and may be modified by the Engineer.
4. Wire mesh not required.

B1 ROCK FILTER DAM – TYPE 4 (SACK GABIONS)
NO SCALE



1. SET POSTS AND EXCAVATE 4" x 4" TRENCH UPSLOPE ALONG LINE OF POSTS.
2. SECURE WIRE FENCING TO POSTS.
3. ATTACH FILTER MATERIAL TO WIRE FENCE AND EXTEND IT INTO THE TRENCH.
4. BACKFILL AND COMPACT THE EXCAVATED SOD.

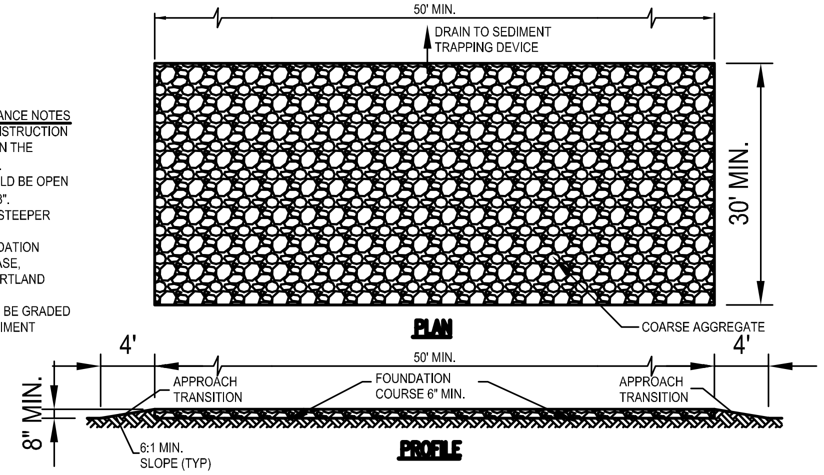
EXTENSION OF FILTER FABRIC INTO TRENCH.

NOTES:

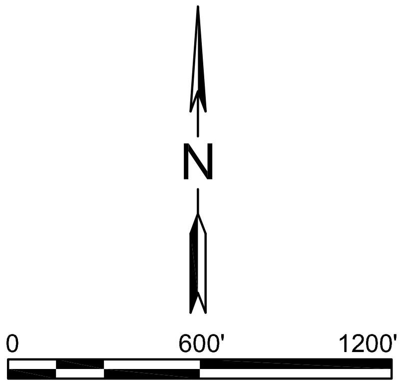
1. WOVEN WIRE FENCE TO BE FASTENED SECURELY TO FENCE POSTS WITH WIRE TIES OR STAPLES.
2. FILTER CLOTH TO BE FASTENED SECURELY TO WOVEN WIRE FENCE WITH TIES SPACED EVERY 24" AT THE TOP AND MIDSECTION.
3. WHEN TWO SECTIONS OF FILTER CLOTH ADJOIN EACH OTHER, THEY SHALL BE OVERLAPPED 6" AT THE POSTS AND FOLDED.
4. FENCE POSTS SHALL BE CAPABLE OF SUPPORTING FENCE AND MAY BE METAL OR WOOD.

B2 FILTER FABRIC BARRIER (SILT FENCE)
NO SCALE

STABILIZED CONSTRUCTION ENTRANCE NOTES
1. THE LENGTH OF THE TYPE 1 CONSTRUCTION EXIT SHALL BE AS INDICATED ON THE PLANS, BUT NOT LESS THAN 50'.
2. THE COARSE AGGREGATE SHOULD BE OPEN GRADED WITH A SIZE OF 4" TO 8".
3. THE APPROACH SHOULD BE NO STEEPER THAN 6:1.
4. THE CONSTRUCTION EXIT FOUNDATION COURSE SHALL BE FLEXIBLE BASE, BITUMINOUS CONCRETE OR PORTLAND CEMENT CONCRETE.
5. THE CONSTRUCTION EXIT SHALL BE GRADED TO ALLOW DRAINAGE TO A SEDIMENT TRAPPING DEVICE.



A1 STABILIZED CONSTRUCTION ENTRANCE & EXIT (TYPE 1)
NO SCALE



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Nicholas N. Ybarra
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PROCESSING
FACILITY

NMED PERMIT NO. __

NEW LANDFILL SITE
& PROCESSING FACILITY

LEA COUNTY, NEW MEXICO

KEY PLAN

NO	DATE	DESCRIPTION
1	09/23/15	ISSUE FOR REVIEW

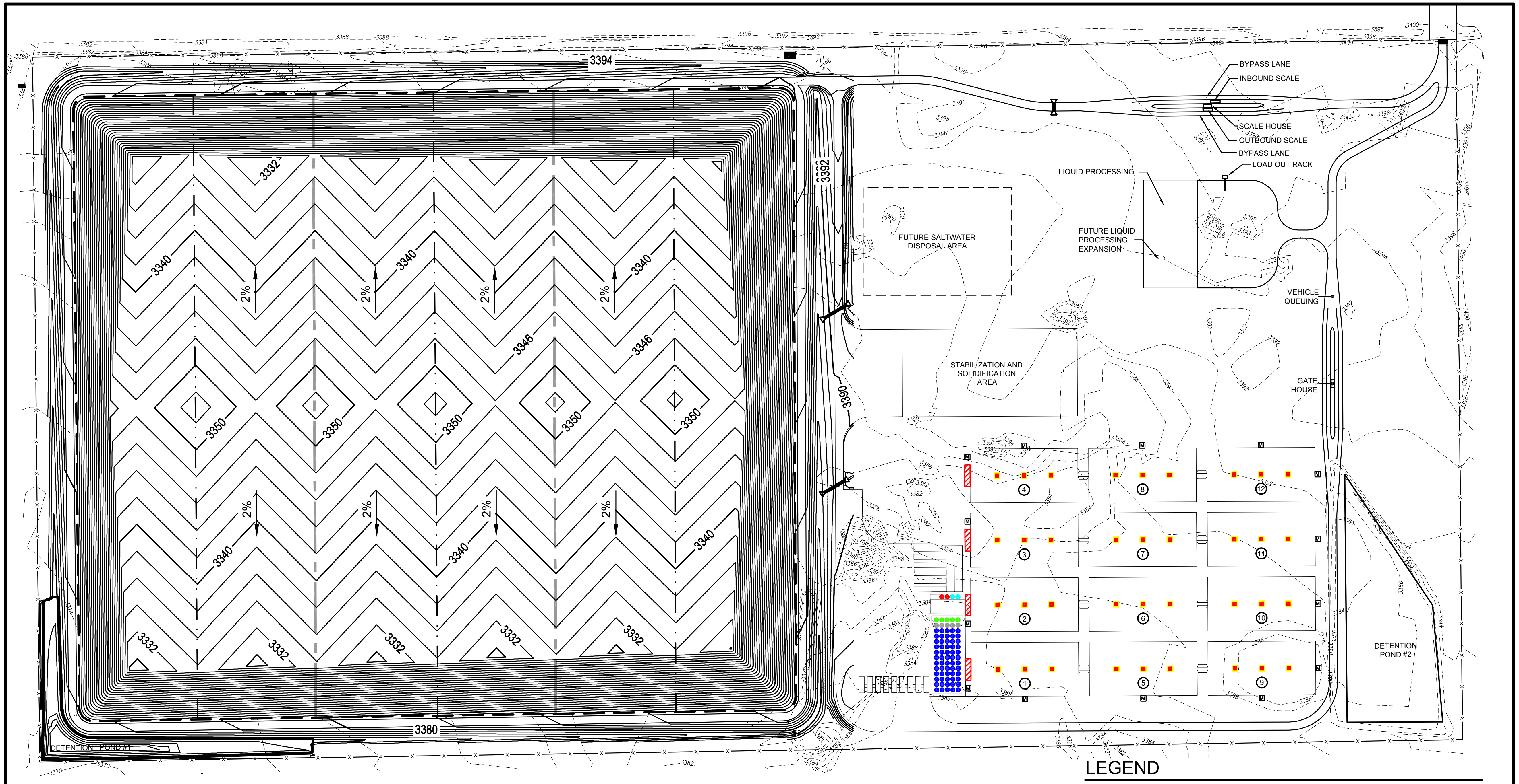
ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

SITE DEVELOPMENT
PLAN

G-005

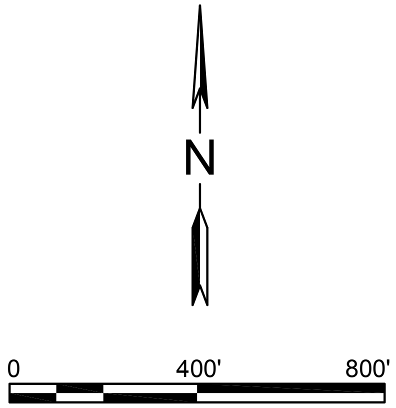
FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\G-005 - BEST MANAGEMENT PRACTICES.dwg LAYOUT NAME: G-005 PRINTED: Wednesday, November 11, 2015 - 11:17am USER: TKrueger

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-101 - LANDFILL BASE GRADING PLAN.dwg LAYOUT NAME: C-101 PRINTED: Friday, November 06, 2015 - 8:18am USER: TKrueger



LEGEND

- - 3392 - -	EXISTING CONTOUR
—3340—	2' LINER CONTOUR
← 2%	OIL RECOVER TANK
—x—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— — —	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
▣	MONITORING POINTS
⊜	LOW WATER CROSSING
●	PRODUCED WATER SETTING TANK
●	SLOPE
●	OIL SALES TANK
●	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER



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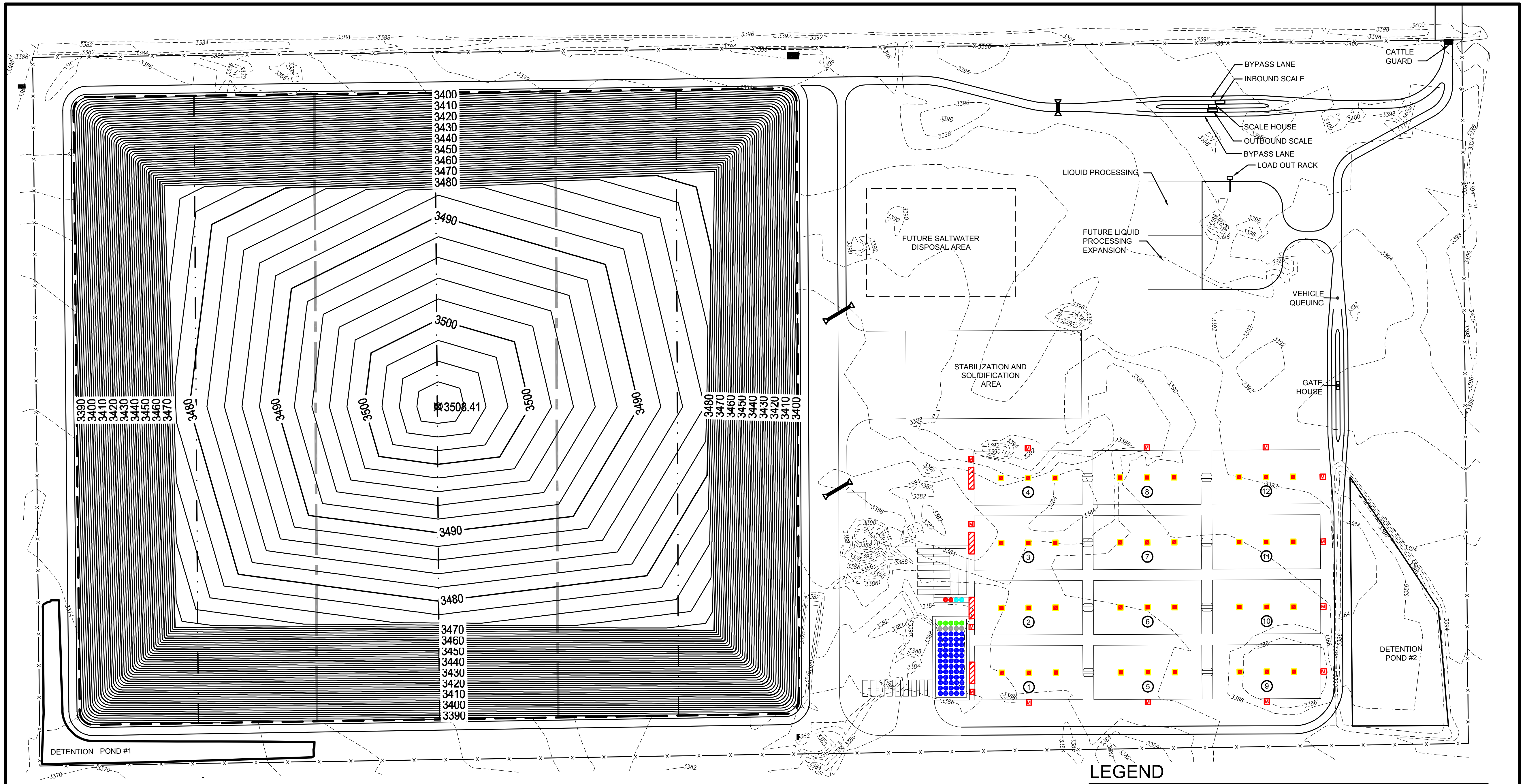
LANDFILL BASE GRADING PLAN

C-101

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-102- LANDFILL FINAL GRADING PLAN.dwg LAYOUT NAME: C-102 PRINTED: Friday, November 06, 2015 - 8:18am USER: TKrueger



LEGEND

- - - 3392 - - -	EXISTING CONTOUR
—3340—	2' LINER CONTOUR
← 2%	OIL RECOVER TANK
——x——x——	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— — —	LANDFILL PHASE LINE
— · · —	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
▣	MONITORING POINTS
⊜	LOW WATER CROSSING
●	PRODUCED WATER SETTING TANK
●	SLOPE
●	OIL SALES TANK
●	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER

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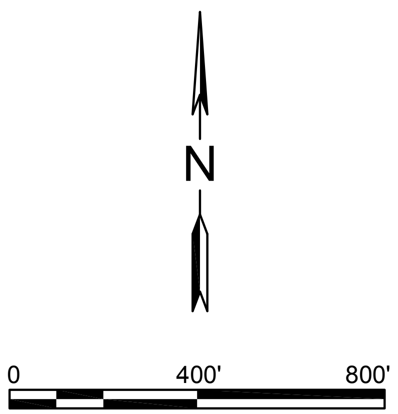

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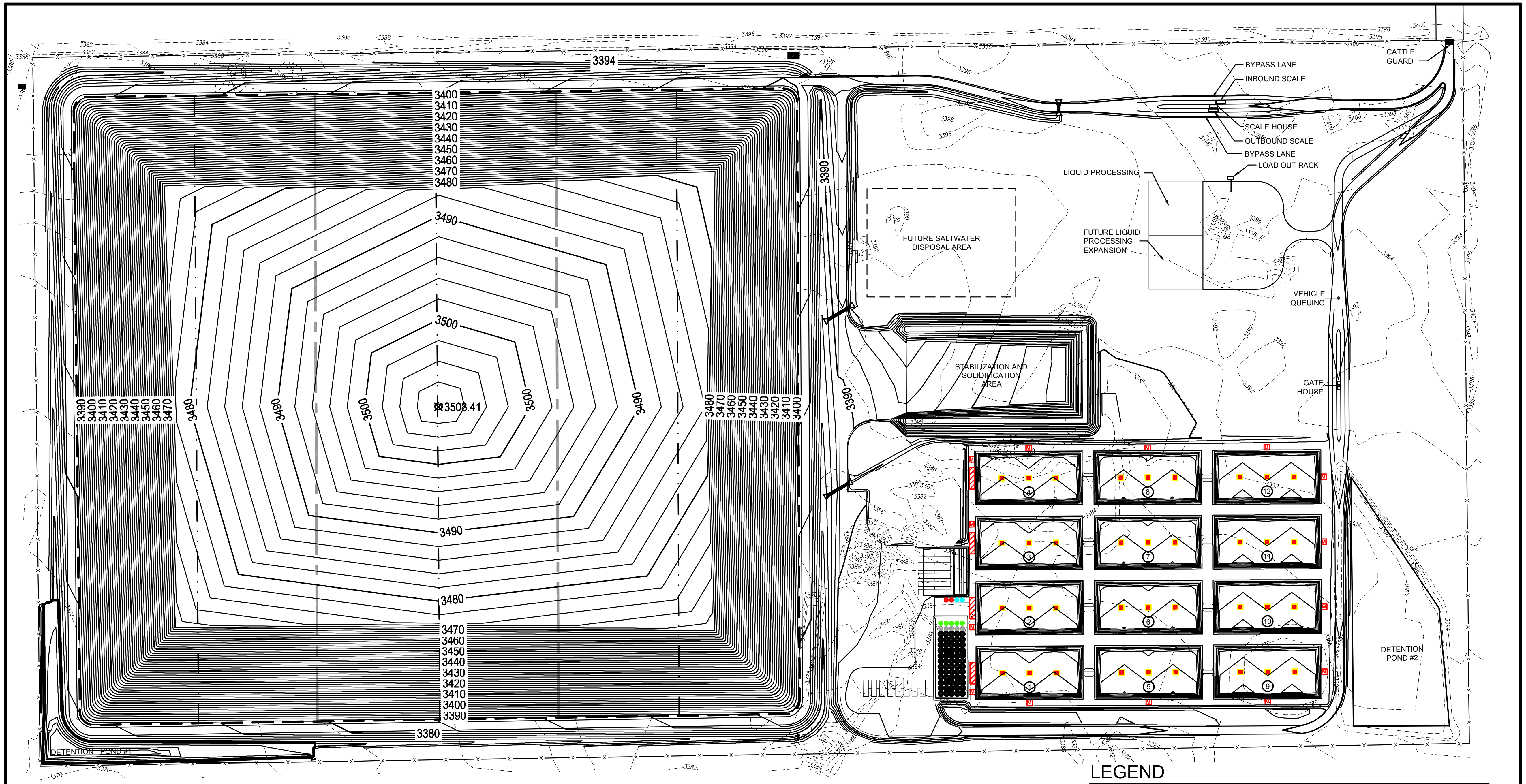
LANDFILL FINAL GRADING PLAN

C-102

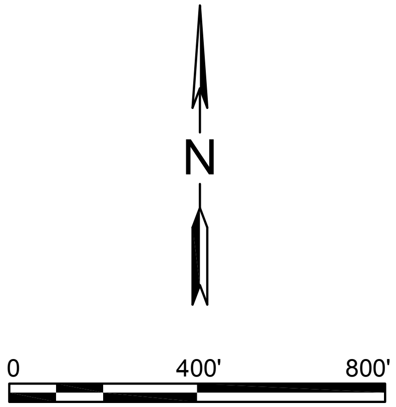


LEGEND

- - 3392 - -	EXISTING CONTOUR
—3340—	2' LINER CONTOUR
2% ←	OIL RECOVER TANK
—x—x—	FENCE/LANDFILL PROPERTY/PERMIT BOUNDARY
— — —	LANDFILL FOOTPRINT
— — —	LANDFILL PHASE LINE
- · · -	UNIT LIMITS
▨	MECHANICAL OIL/WATER SEPARATOR
■	EVAPORATOR
▣	MONITORING POINTS
⊜	LOW WATER CROSSING
●	PRODUCED WATER SETTING TANK
●	SLOPE
●	OIL SALES TANK
●	CHEMICAL TANK
●	JET OUT WATER TANK
⑤	EVAPORATION POND NUMBER

NOTES

1. REFER TO SHEET C-505 FOR FURTHER DETAIL OF DRAINAGE STRUCTURES



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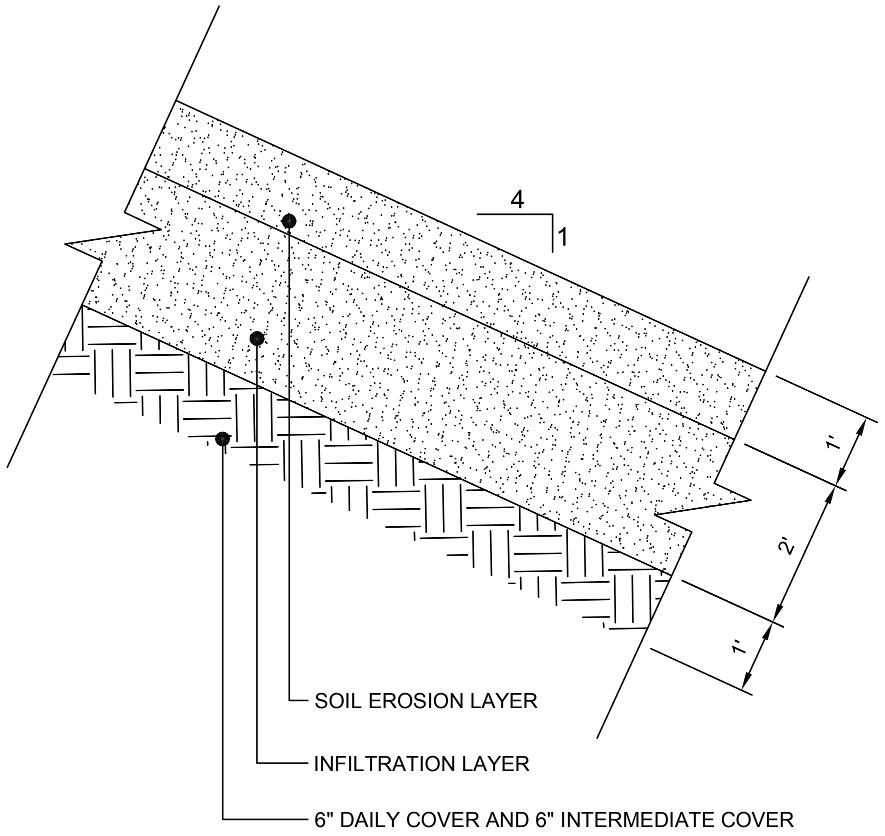
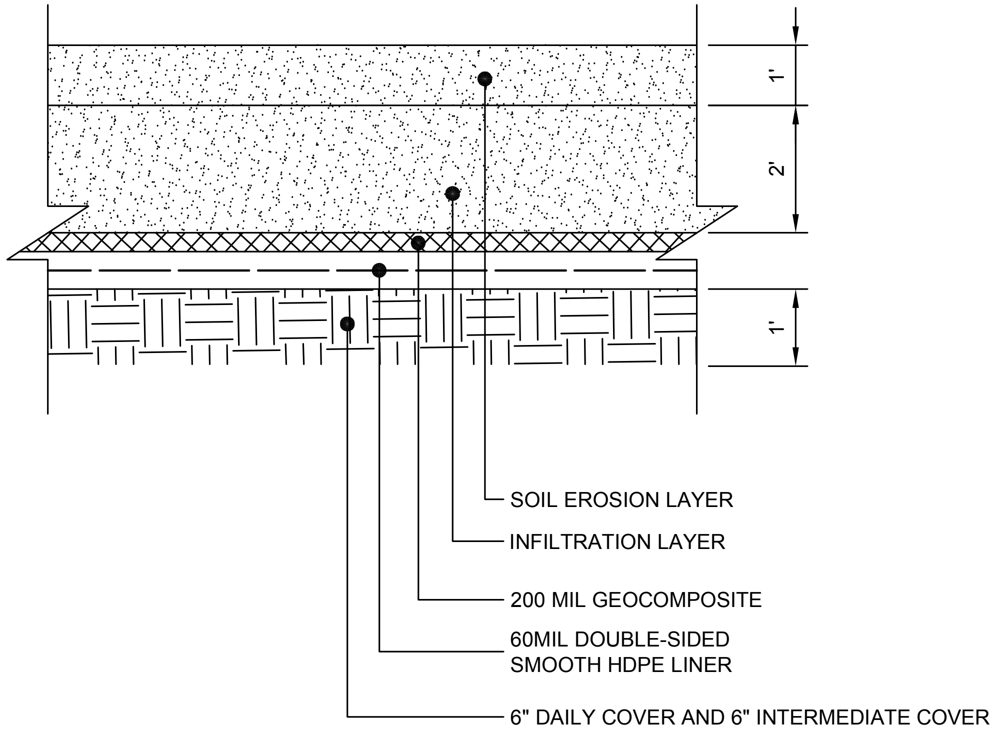
LANDFILL COMPLETION DRAINAGE PLAN

C-103

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-104 - FINAL COVER SECTIONS.dwg LAYOUT NAME: C-104 PRINTED: Friday, November 06, 2015 - 8:19am USER: TKrueger





A1 FINAL COVER DETAIL SIDE SLOPE PERFORMANCE DESIGN

NO SCALE

A2 FINAL COVER TOP CAP PERFORMANCE DESIGN

NO SCALE

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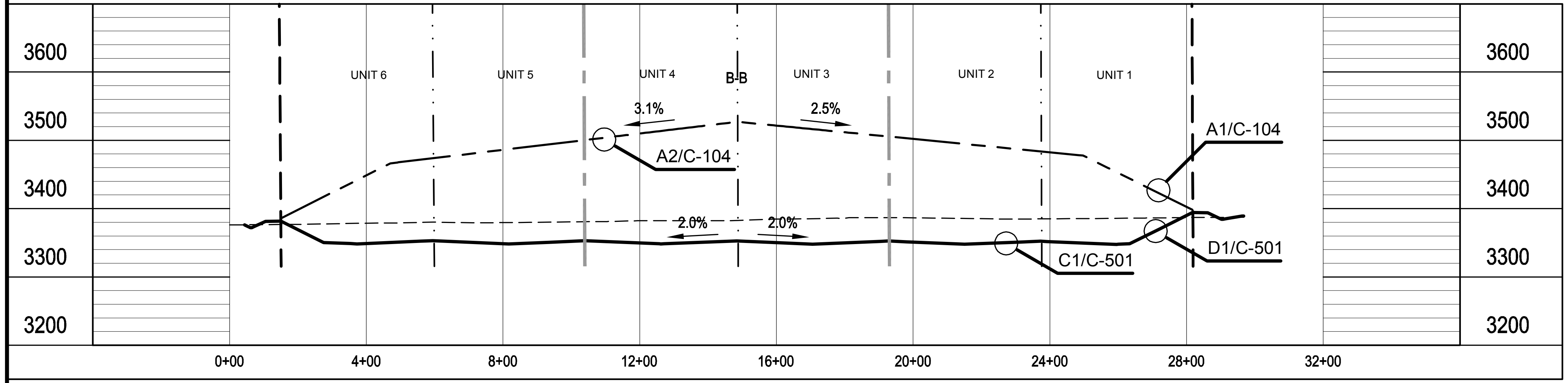
FINAL COVER
SECTIONS

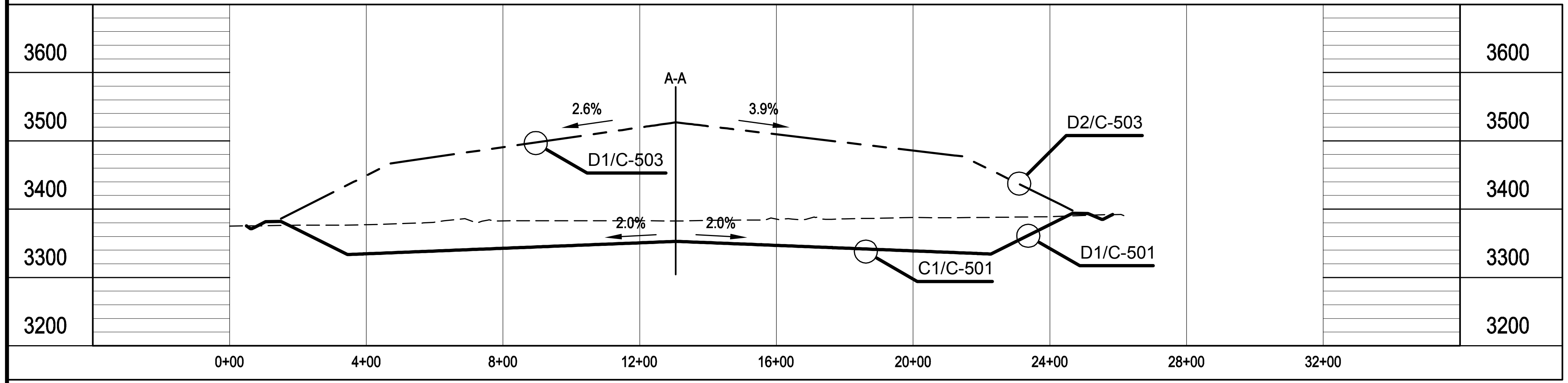
C-104

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-105 - LANDFILL CROSS SECTIONS.dwg LAYOUT NAME: C-105 PRINTED: Friday, November 06, 2015 - 8:19am USER: TKrueger



A SECTION A-A

SCALE: 1" = 400'



B SECTION B-B

SCALE: 1" = 400'

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11/6/2015

SCALES:

HORIZONTAL

0 400' 800'

VERTICAL

0 200' 400'

LEGEND

▬ ▬ ▬	LANDFILL PHASE BOUNDARY
— · · — · · —	LANDFILL UNIT BOUNDARY
- - - - - - -	EXISTING GRADE
━━━━━	BASE GRADE
— — —	FINAL GRADE

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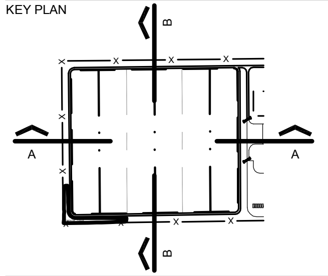
LEA COUNTY, NEW MEXICO

KEY PLAN



NO	DATE	DESCRIPTION
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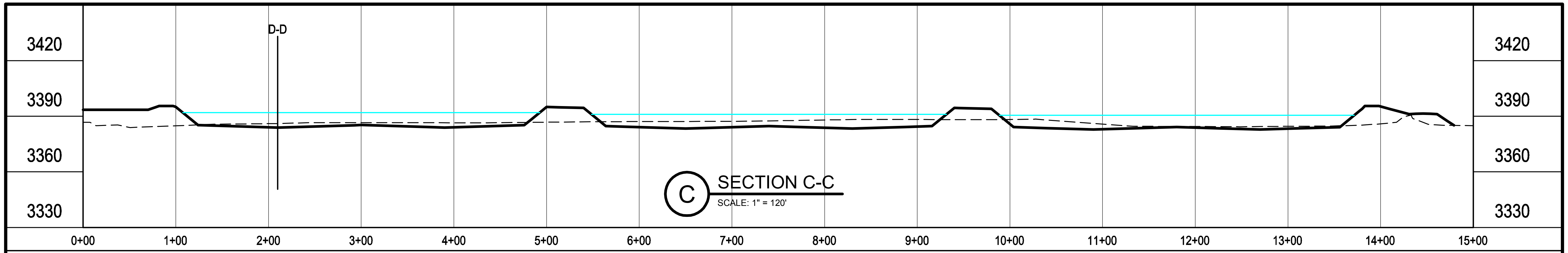
ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

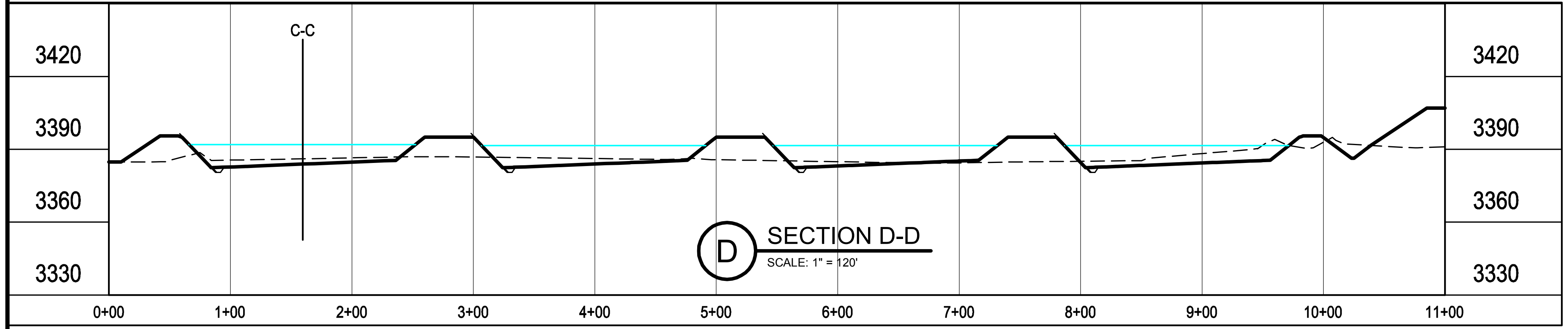
LANDFILL
CROSS SECTIONS

C-105

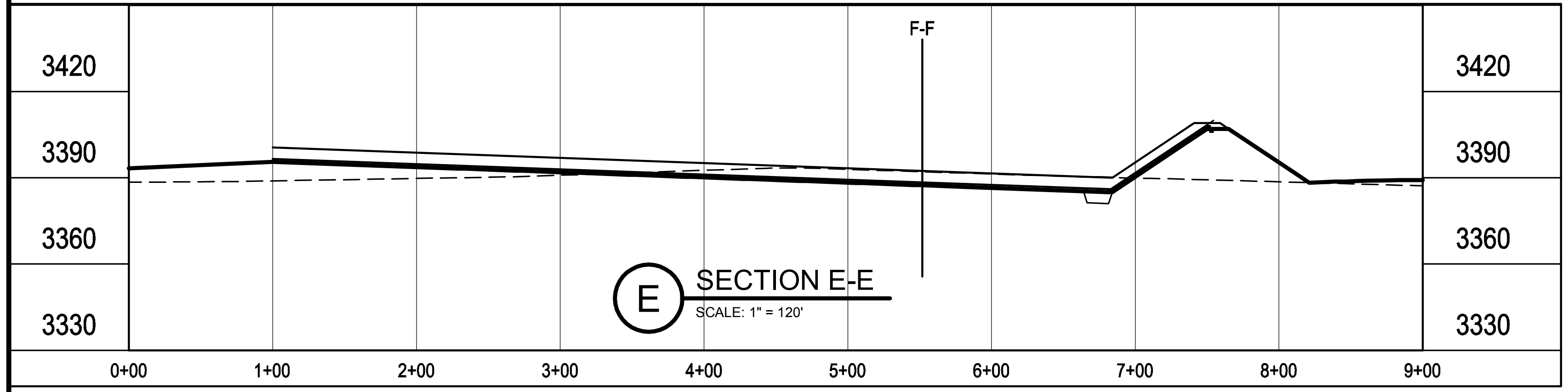
FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-106 - EVAP-POND-SOLIDIFIC AREA CROSS SECTIONS.dwg LAYOUT NAME: C-106 PRINTED: Friday, November 06, 2015 - 8:20am USER: TKrueger



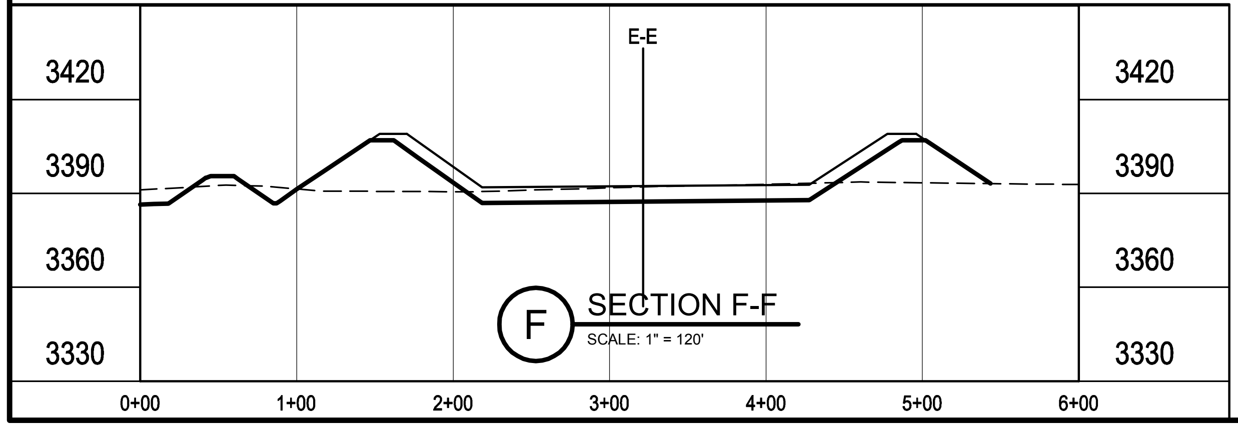
C SECTION C-C
SCALE: 1" = 120'



D SECTION D-D
SCALE: 1" = 120'

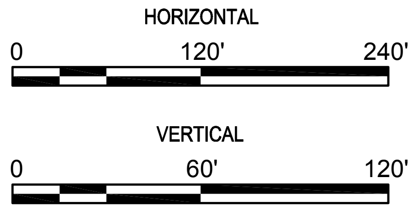


E SECTION E-E
SCALE: 1" = 120'



F SECTION F-F
SCALE: 1" = 120'

SCALES:



LEGEND

- LANDFILL PHASE BOUNDARY
- LANDFILL UNIT BOUNDARY
- LIMIT OF WASTE
- EXISTING GRADE
- BASE GRADE
- WATER SURFACE LEVEL

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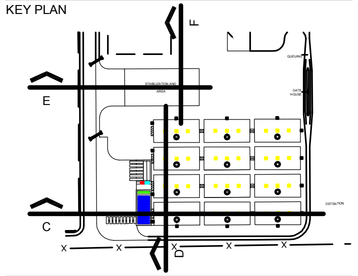
LEA COUNTY, NEW MEXICO



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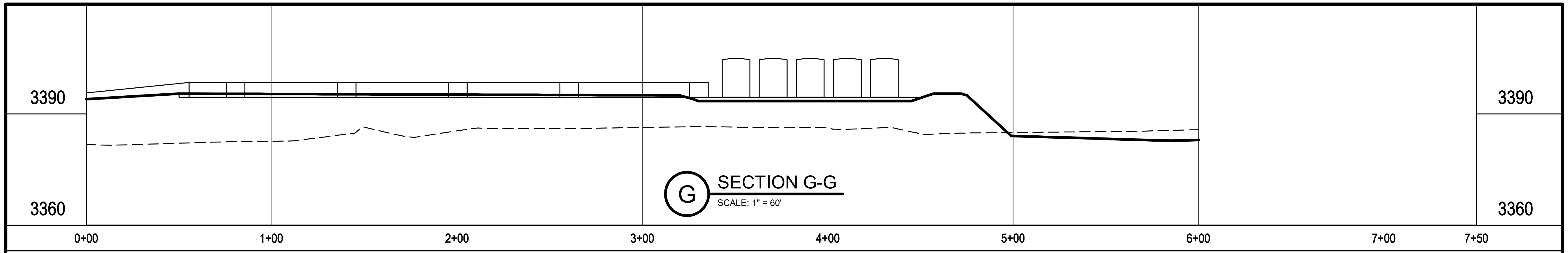
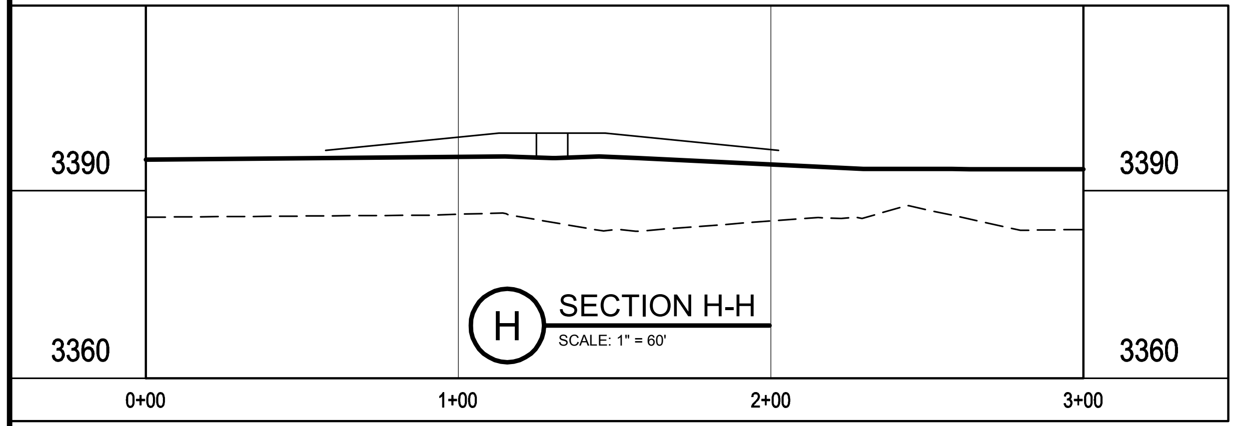
EVAPORATION POND AND STABILIZATION/ SOLIDIFICATION AREA CROSS SECTIONS

C-106

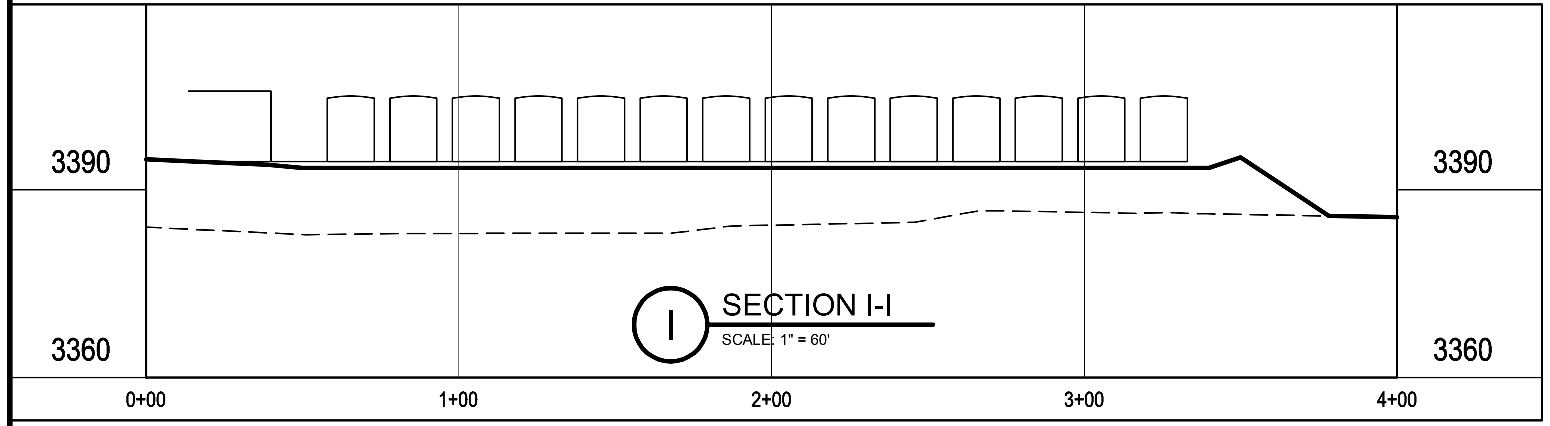
FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-107 - PROCESSING AREA LAYOUT CROSS SECTIONS.dwg LAYOUT NAME: C-107 PRINTED: Friday, November 06, 2015 - 8:20am USER: TKrueger



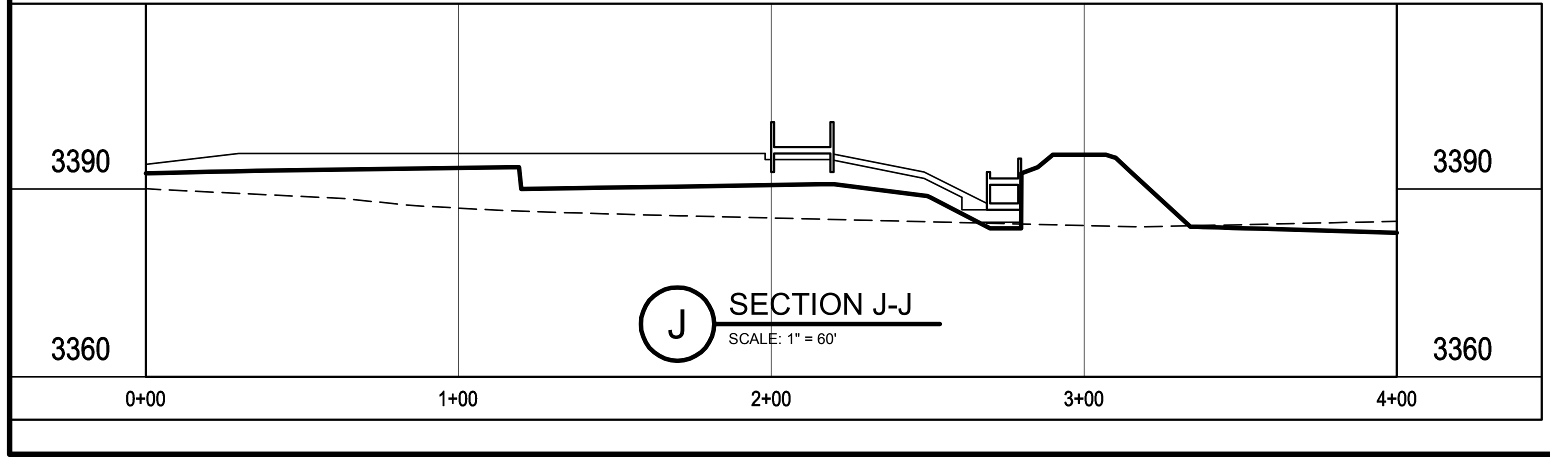
SECTION G-G
SCALE: 1" = 60'



SECTION H-H
SCALE: 1" = 60'



SECTION I-I
SCALE: 1" = 60'



SECTION J-J
SCALE: 1" = 60'

SCALES:

HORIZONTAL
0 60' 120'

VERTICAL
0 30' 60'

LEGEND

LANDFILL PHASE BOUNDARY
LANDFILL UNIT BOUNDARY
LIMIT OF WASTE
EXISTING GRADE
BASE GRADE

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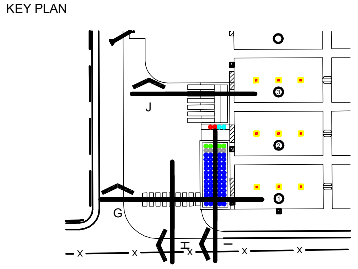

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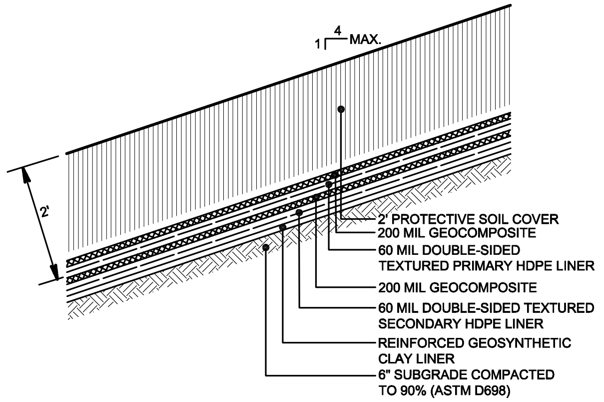
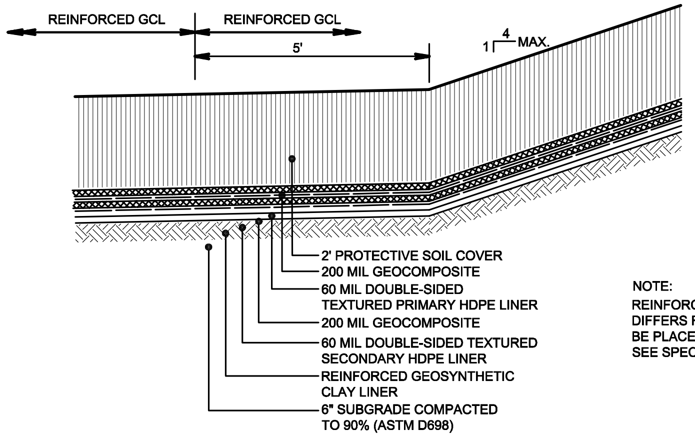
PROCESSING AREA LAYOUT CROSS SECTIONS

C-107



D1 TYPICAL SIDE SLOPE LINER DETAIL
1/2"=1'-0"



D2 LINER TRANSITION
1/2"=1'-0"

NOTE:
REINFORCED GCL FOR SIDE SLOPES DIFFERS FROM REIN- FORCED GCL TO BE PLACED ON FLOOR. SEE SPECIFICATION SECTION 02240.

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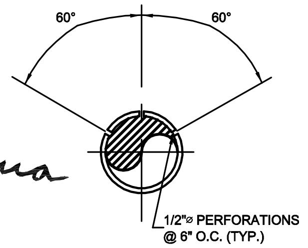
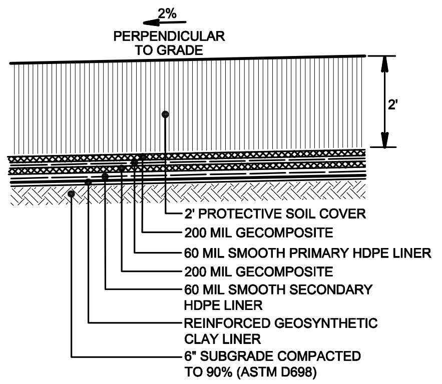
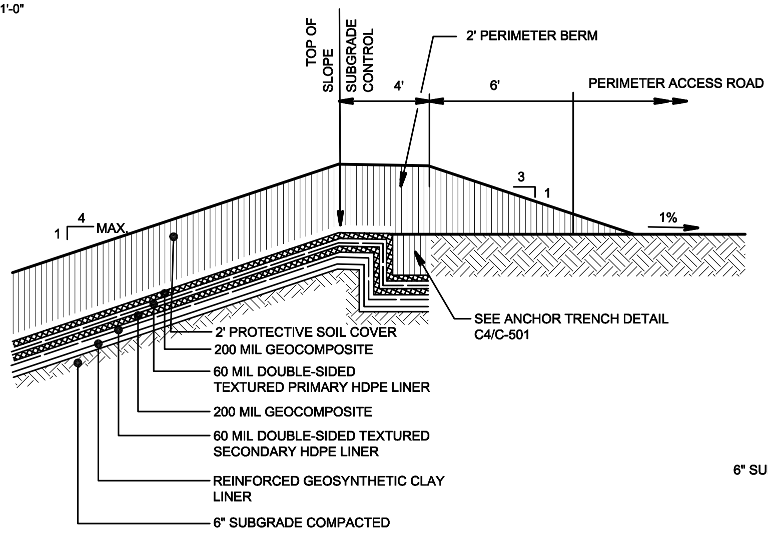


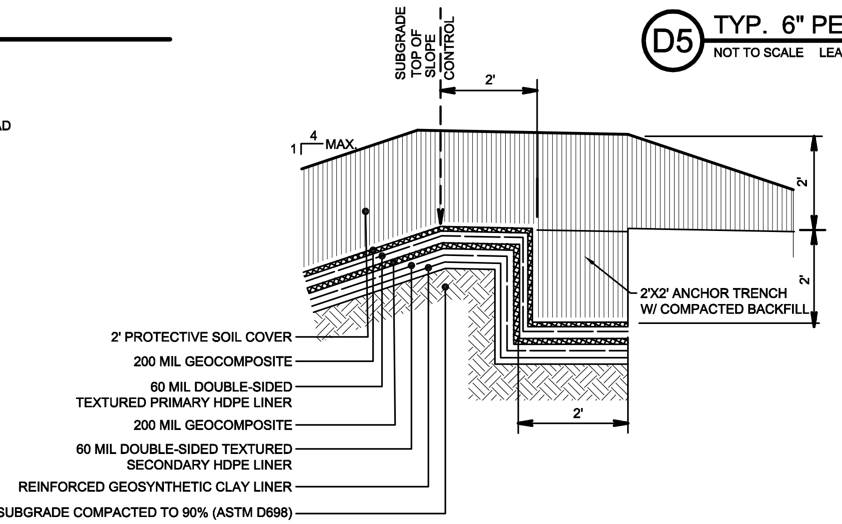
D5 TYP. 6" PERFORATED LEACHATE COLLECTION PIPE
NOT TO SCALE



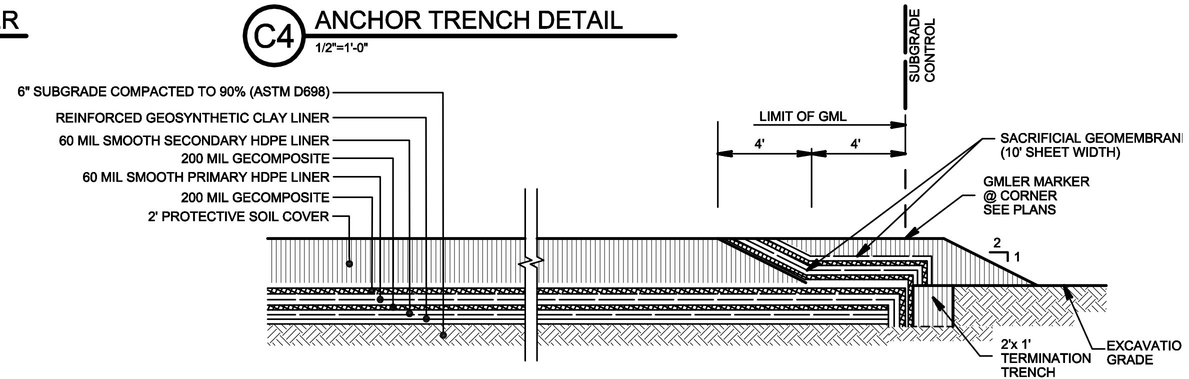
C1 TYPICAL BOTTOM LINER DETAIL
1/2"=1'-0"



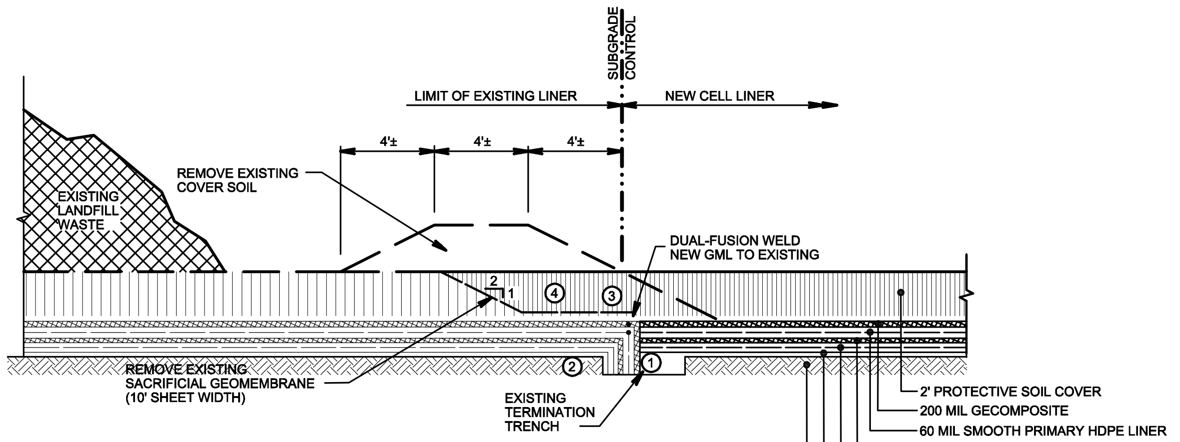
C2 TYPICAL ANCHOR TRENCH AT PERIMETER
1"=5'-0"



C4 ANCHOR TRENCH DETAIL
1/2"=1'-0"



B4 LINER TERMINATION - LANDFILL SIDESLOPE
1/4"=1'-0"



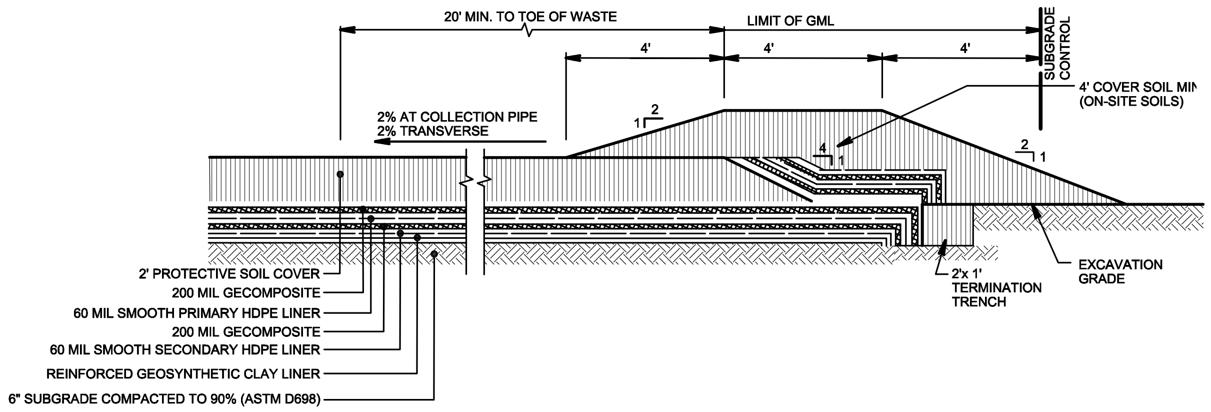
① REMOVE EXISTING LINER FROM TERMINATION TRENCH. REPLACE SOIL AND COMPACT TO SMOOTH GRADE.

② RAISE EXISTING GML AND OVERLAP NEW GCL 12-INCHES OVER EXISTING GCL. ADD GRANULAR BENTONITE AT SPECIFIED RATE.

③ CLEAN EXISTING GML AND DUAL FUSION WELD NEW GML TO EXISTING GML.

④ OVERLAP NEW GEONET/GEOTEXTILE DRAINAGE COMPOSITE 12-INCHES OVER EXISTING GEONET/GEOTEXTILE DRAINING COMPOSITE.

A1 LINER WELD TO EXISTING LINER
1/4"=1'-0"



A4 LINER TERMINATION - LANDFILL BOTTOM
1/4"=1'-0"

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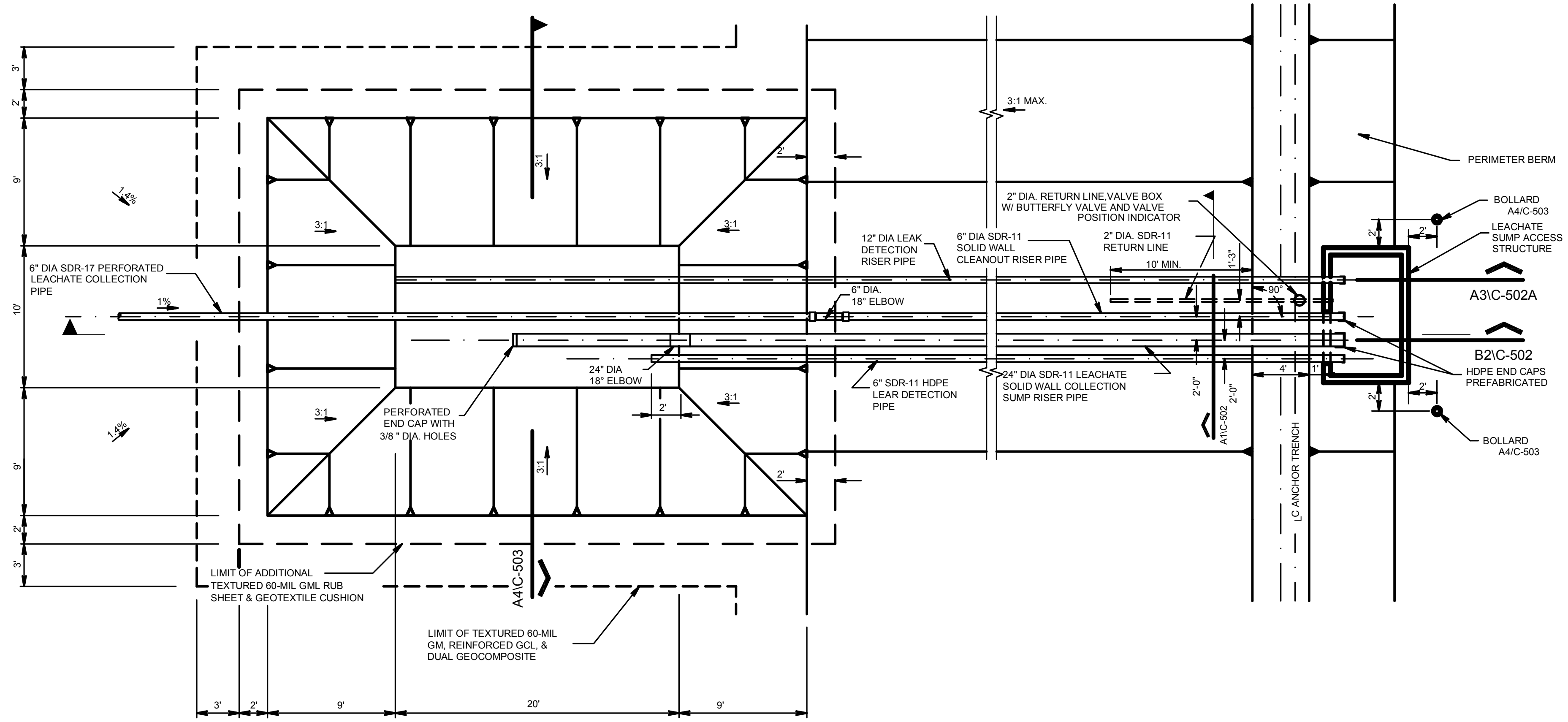
PROJECT NO: 0580.15

LINER & LEACHATE COLLECTION DETAILS

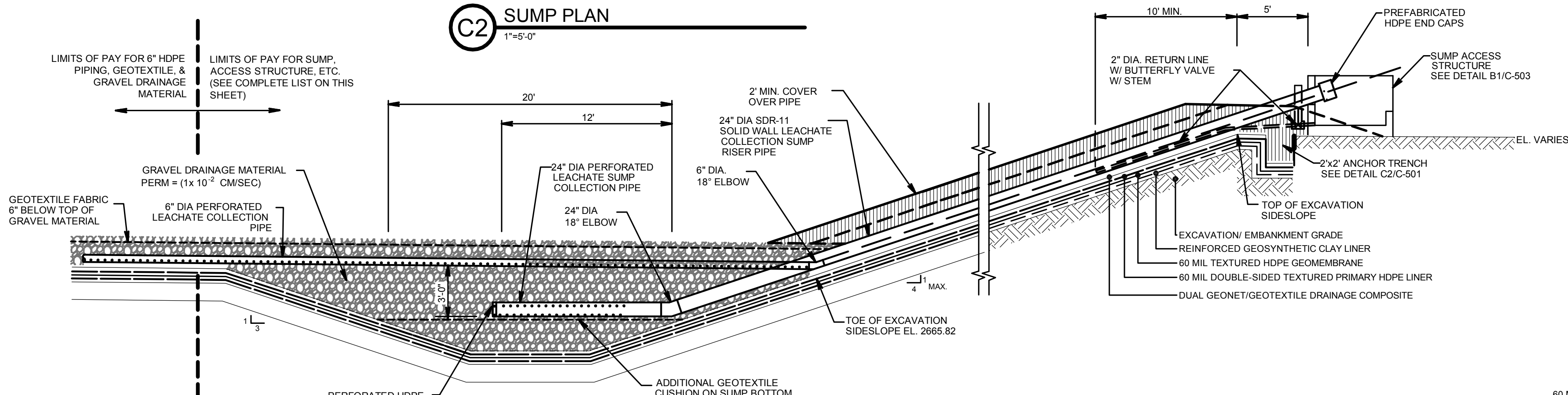
C-501

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-501 - LINER & LEACHATE COLL DETAILS.dwg LAYOUT NAME: C-501 PRINTED: Friday, November 06, 2015 - 8:20am USER: TKrueger

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-502 - LEACHATE SUMP PLAN & PROFILE DETAILS.dwg LAYOUT NAME: C-502 PRINTED: Friday, November 06, 2015 - 8:20am USER: TKrueger



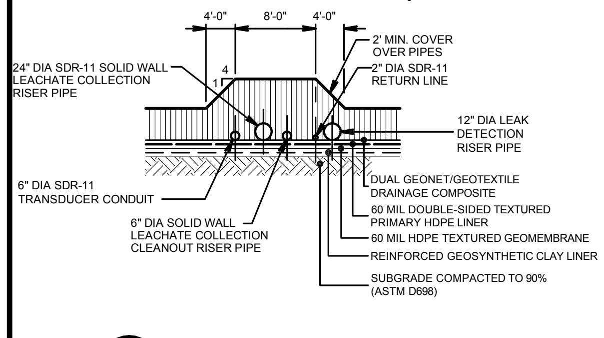
C2 SUMP PLAN
1"=5'-0"



LIMITS OF PAY FOR 6" HDPE PIPING, GEOTEXTILE, & GRAVEL DRAINAGE MATERIAL

LIMITS OF PAY FOR SUMP, ACCESS STRUCTURE, ETC. (SEE COMPLETE LIST ON THIS SHEET)

B2 SUMP PROFILE
1"=5'-0"



A1 LEACHATE RISER SECTION
NOT TO SCALE

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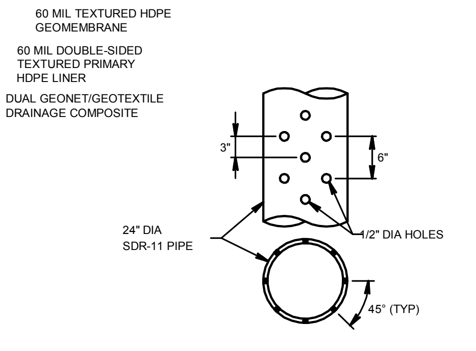
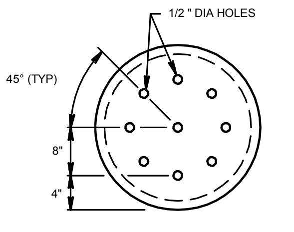
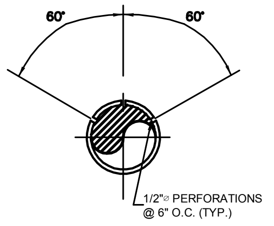


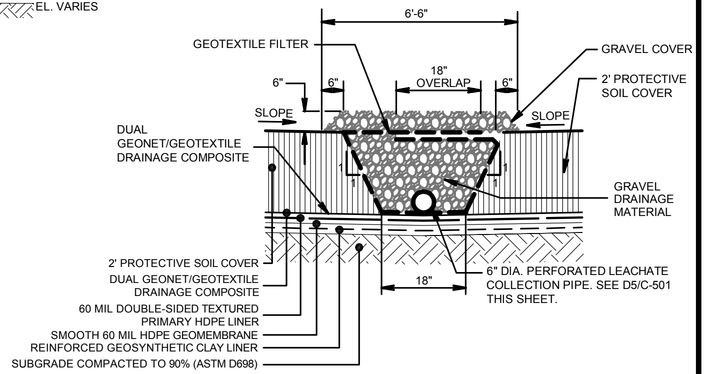
A4 LEACHATE COLLECTION SUMP
NOT TO SCALE PERFORATION DETAIL



A5 END CAP
NOT TO SCALE PERFORATION DETAIL



C5 TYP. 6" PERFORATED
NOT TO SCALE LEACHATE COLLECTION PIPE



B5 LEACHATE COLLECTION PIPE
1/2"=1'-0"

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LEACHATE SUMP PLAN & PROFILE DETAILS

C-502

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-502A - LEAK DETECTION PROFILE DETAILS.dwg LAYOUT NAME: C-502A PRINTED: Friday, November 06, 2015 - 8:21am USER: TKrueger

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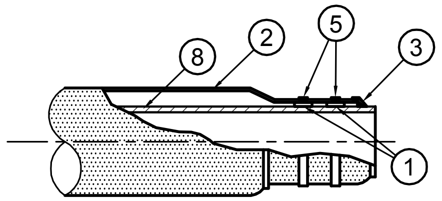
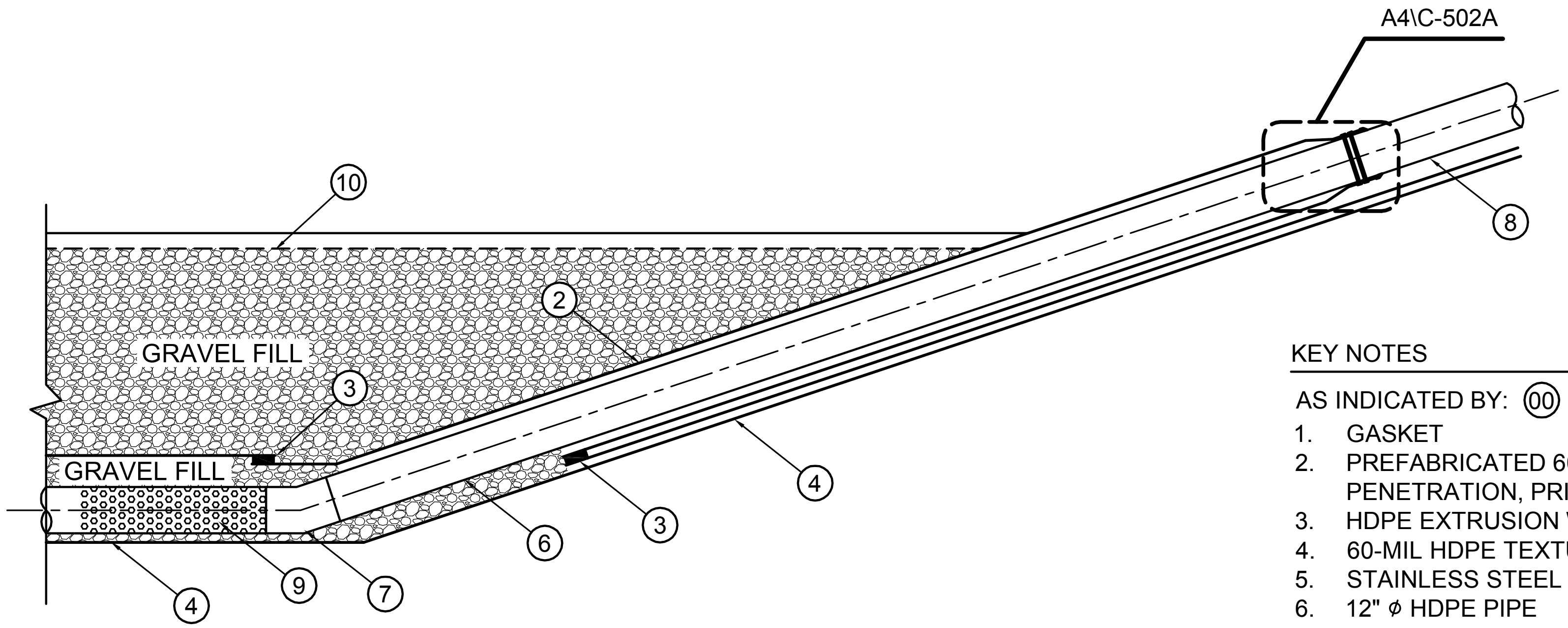


C5 SECTION
1-1/2" = 1'-0"
PIPE PENETRATION SEAL



A3 SECTION
1/2"=1'-0"
LEAK DETECTION LINER PENETRATION

KEY NOTES

AS INDICATED BY: (00)

1. GASKET
2. PREFABRICATED 60-MIL HDPE PIPE BOOT PENETRATION, PRIMARY
3. HDPE EXTRUSION WELDS
4. 60-MIL HDPE TEXTURED LINER, SECONDARY
5. STAINLESS STEEL BANDING
6. 12" ϕ HDPE PIPE
7. FABRICATED ELBOW
8. 12" DETECTOR RISER
9. PERFORATED HDPE PIPE
10. GEOTEXTILE

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LEAK DETECTION PROFILE DETAILS

C-502A

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-503 - POND LEACHATE COLLECTION SYSTEM DETAILS.dwg LAYOUT NAME: C-503 PRINTED: Friday, November 06, 2015 - 8:21am USER: TKrueger

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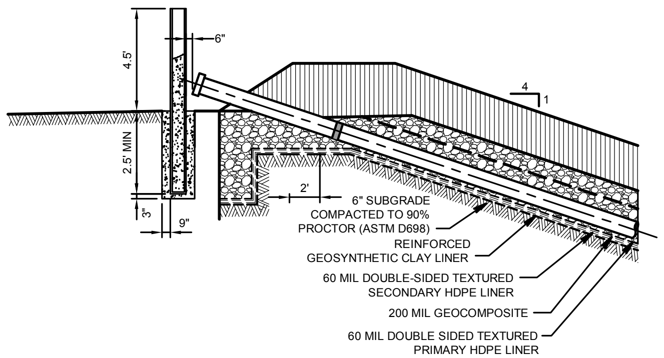

D3 RISER PIPE TERMINATION
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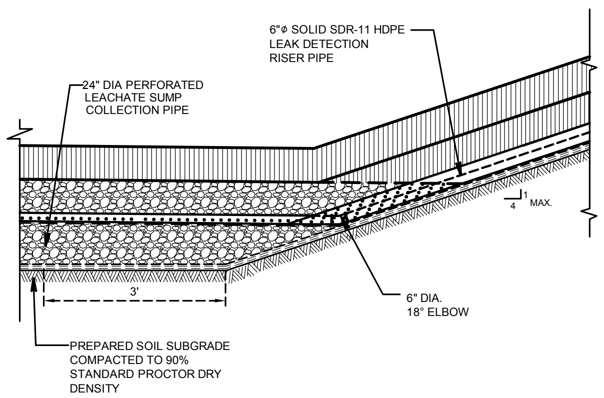

D4 LEACHATE EXTRACTION RISER PIPE
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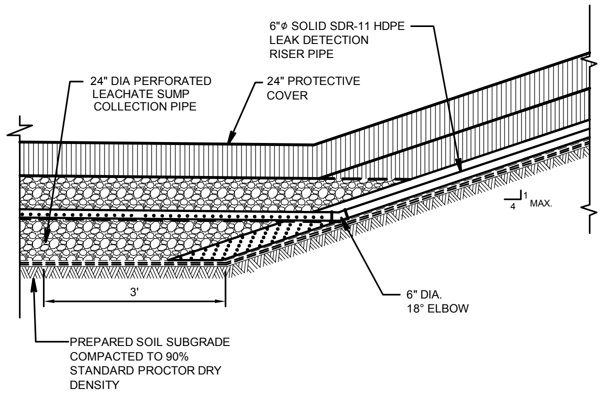

C4 LEAK DETECTION RISER PIPE
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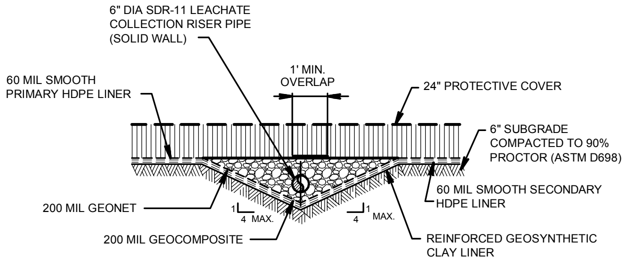
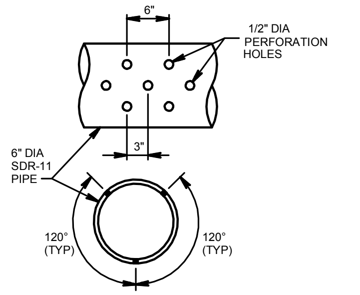
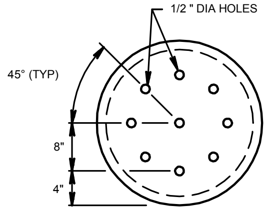


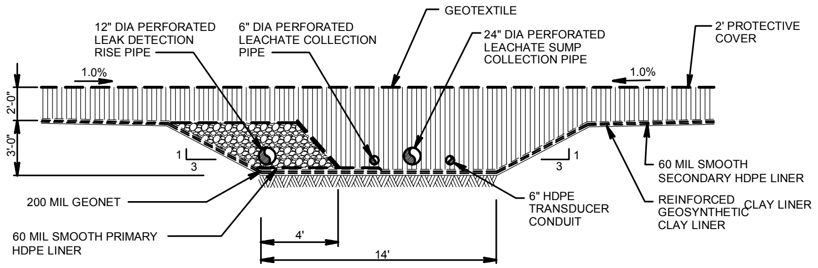
B4 LEAK DETECTION SUMP RISER PIPE CROSS SECTION A-A
NOT TO SCALE



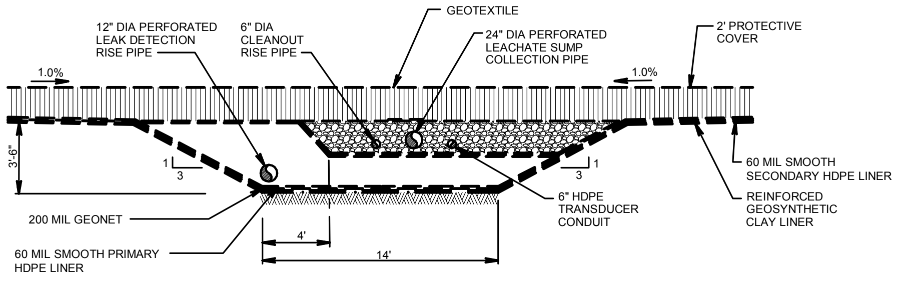
A1 LEACHATE COLLECTION SUMP
NOT TO SCALE PERFORATION DETAIL



A2 END CAP
NOT TO SCALE PERFORATION DETAIL



A3 LEACHATE SUMP SECTION
1"=5'-0"



A4 LEACHATE SUMP SECTION
1"=5'-0"

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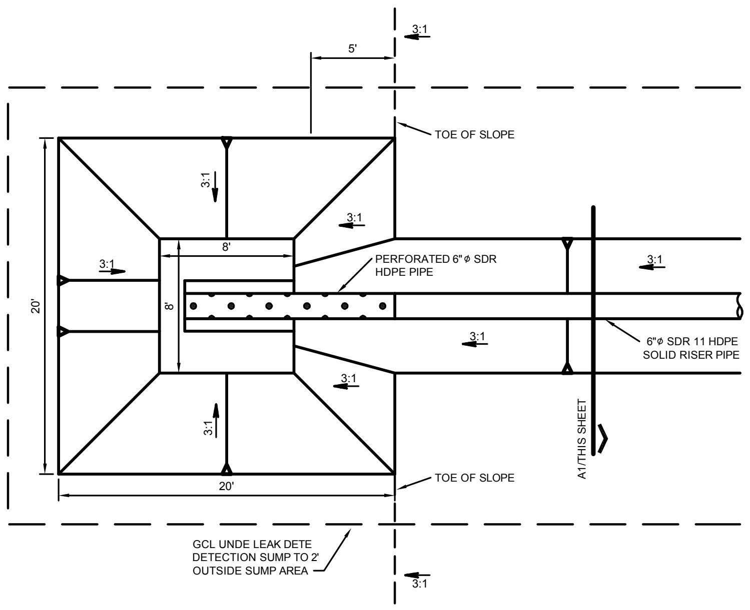
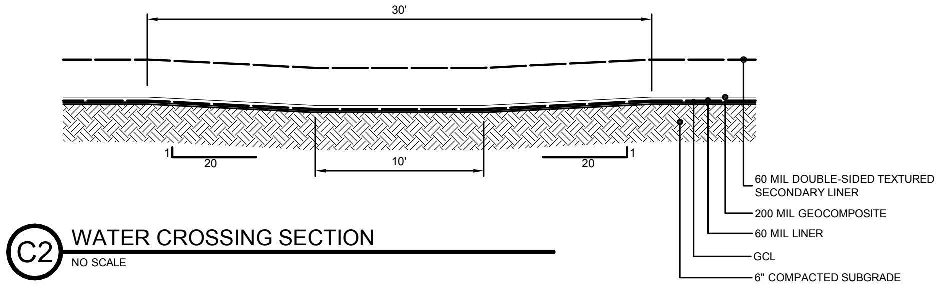
LEACHATE SUMP PLAN & PROFILE DETAILS

C-503



C1 SUMP PLAN

NO SCALE



C2 WATER CROSSING SECTION

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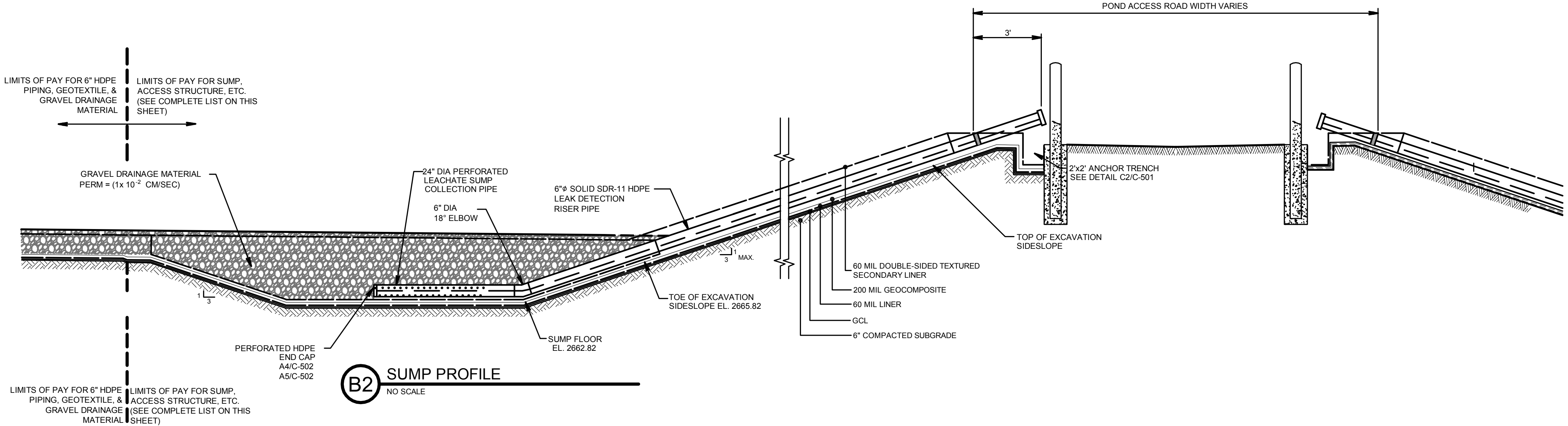

B2 SUMP PROFILE

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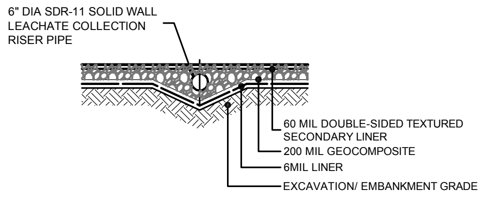

A1 LEAK DETECTION SUMP RISER PIPE CROSS SECTION A-A

NOT TO SCALE

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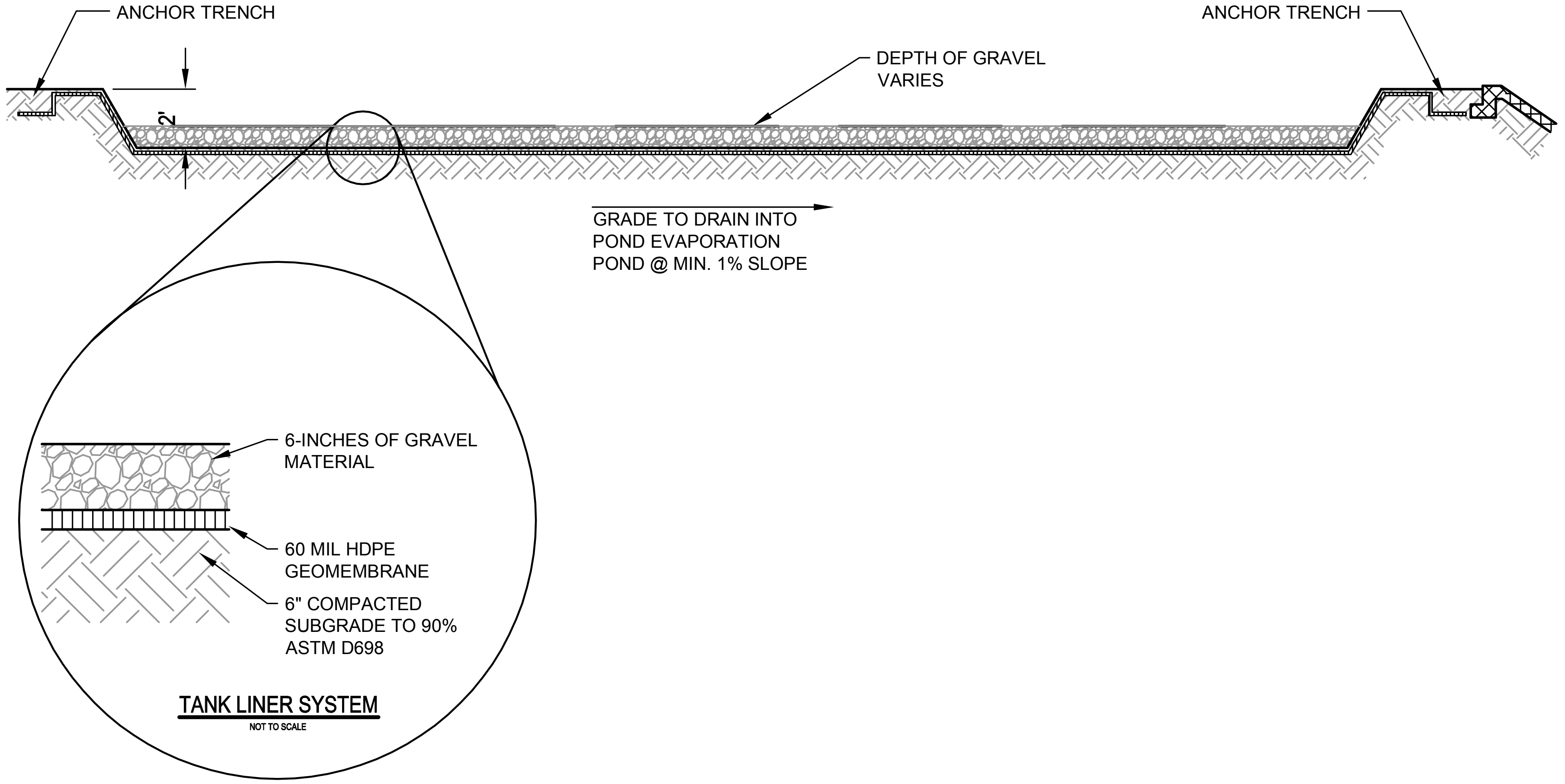
EVAPORATION POND DETAILS

C-504

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-505 - TYPICAL RECEIVING TANK INSTALLATION DETAILS.dwg LAYOUT NAME: C-505 PRINTED: Friday, November 06, 2015 - 8:21am USER: TKrueger



A1 ELEVATION SECTION

NO SCALE

NICHOLAS N. YBARRA
20683

Nicholas N. Ybarra
11/6/2015

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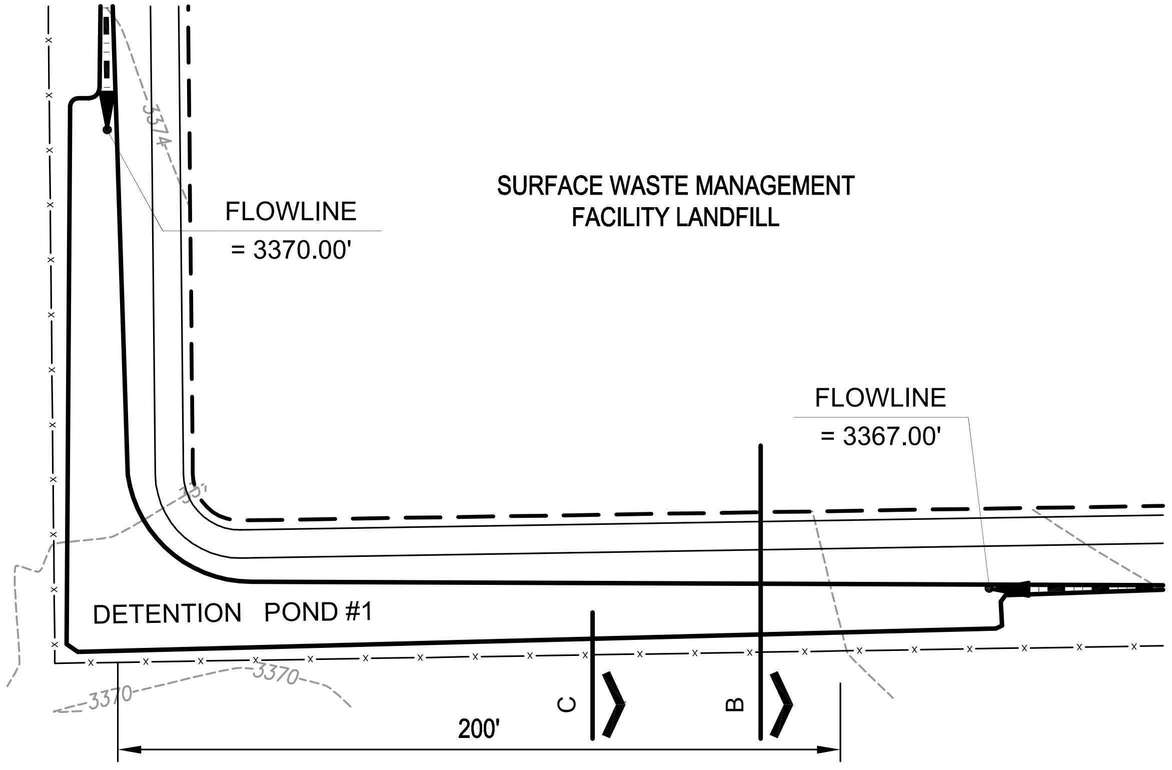
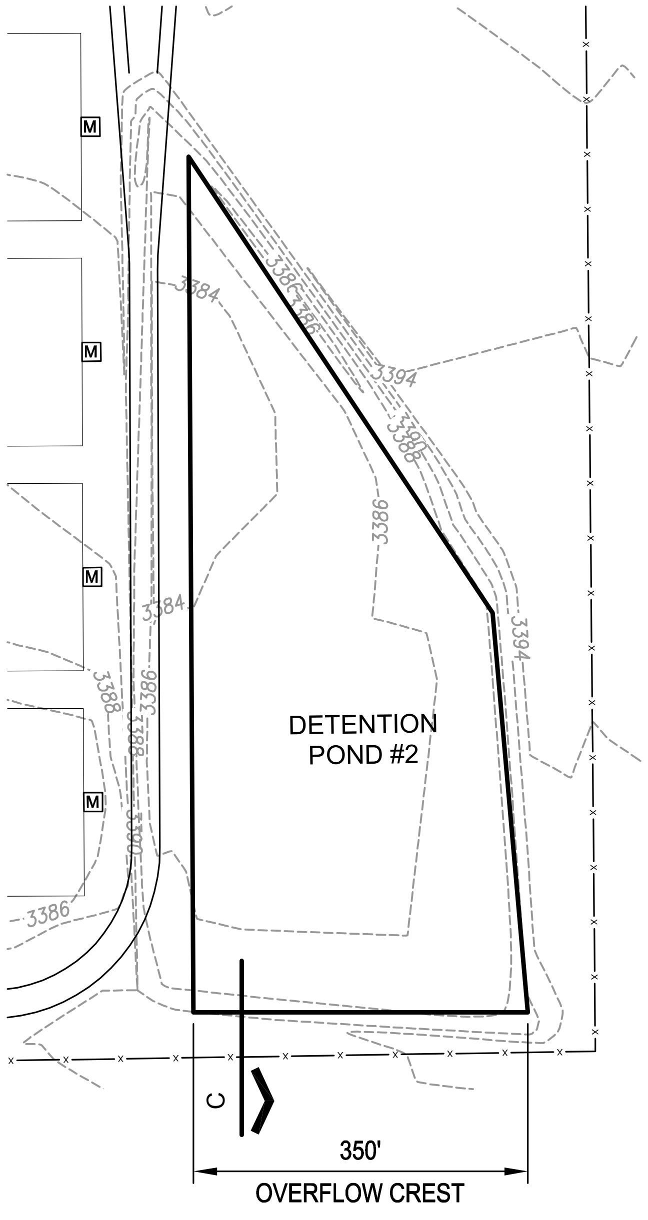
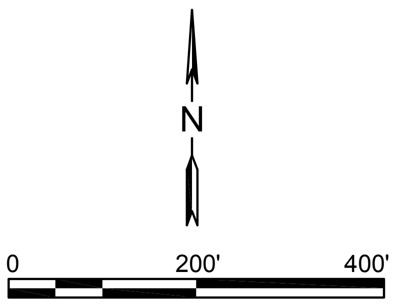
TYPICAL RECEIVING TANK LINER CONTAINMENT DETAILS

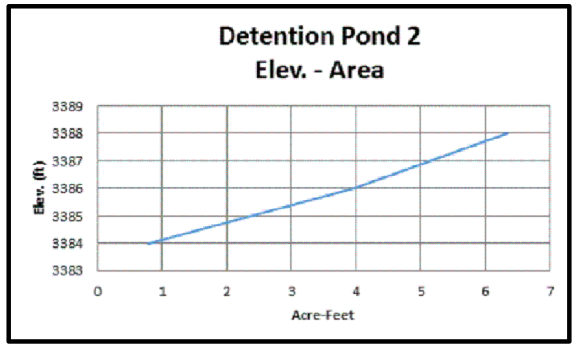
C-505

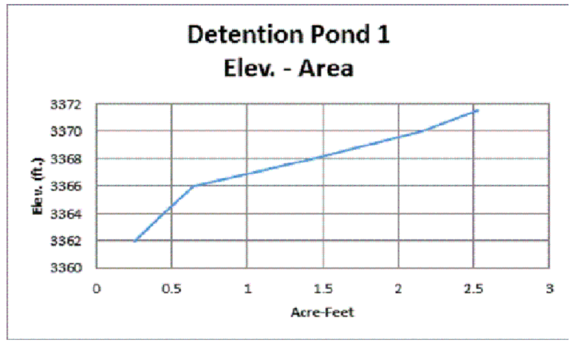
FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-506 - DETENTION POND & DETAILS.dwg LAYOUT NAME: C-506 PRINTED: Friday, November 06, 2015 - 8:22am USER: TKrueger











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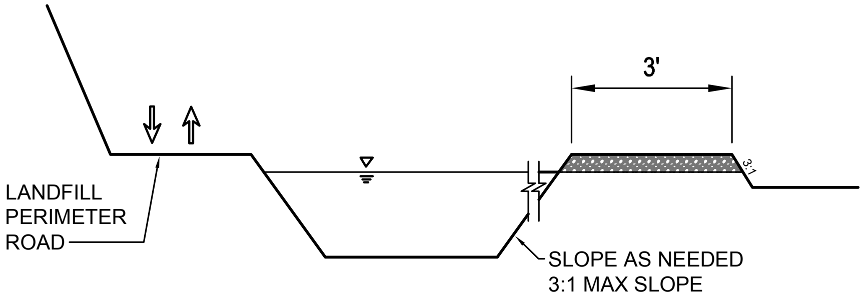

B SECTION
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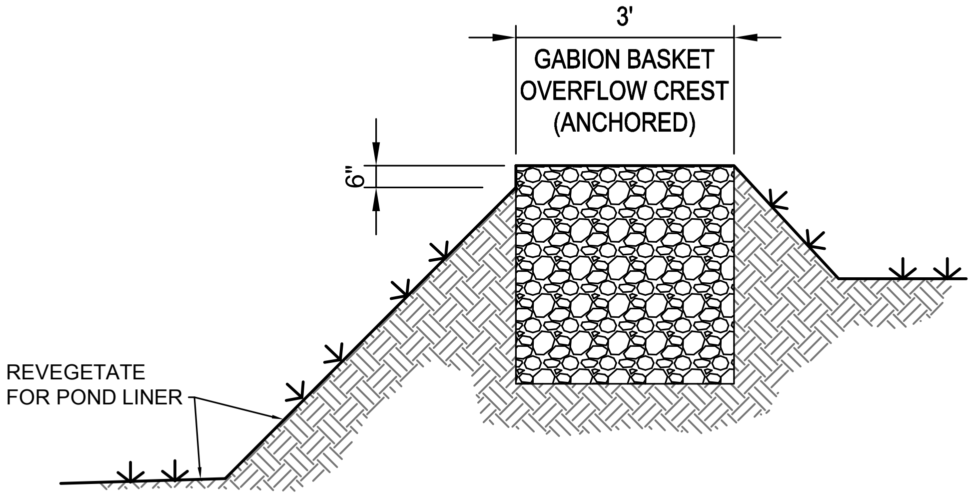

C SECTION
NO SCALE

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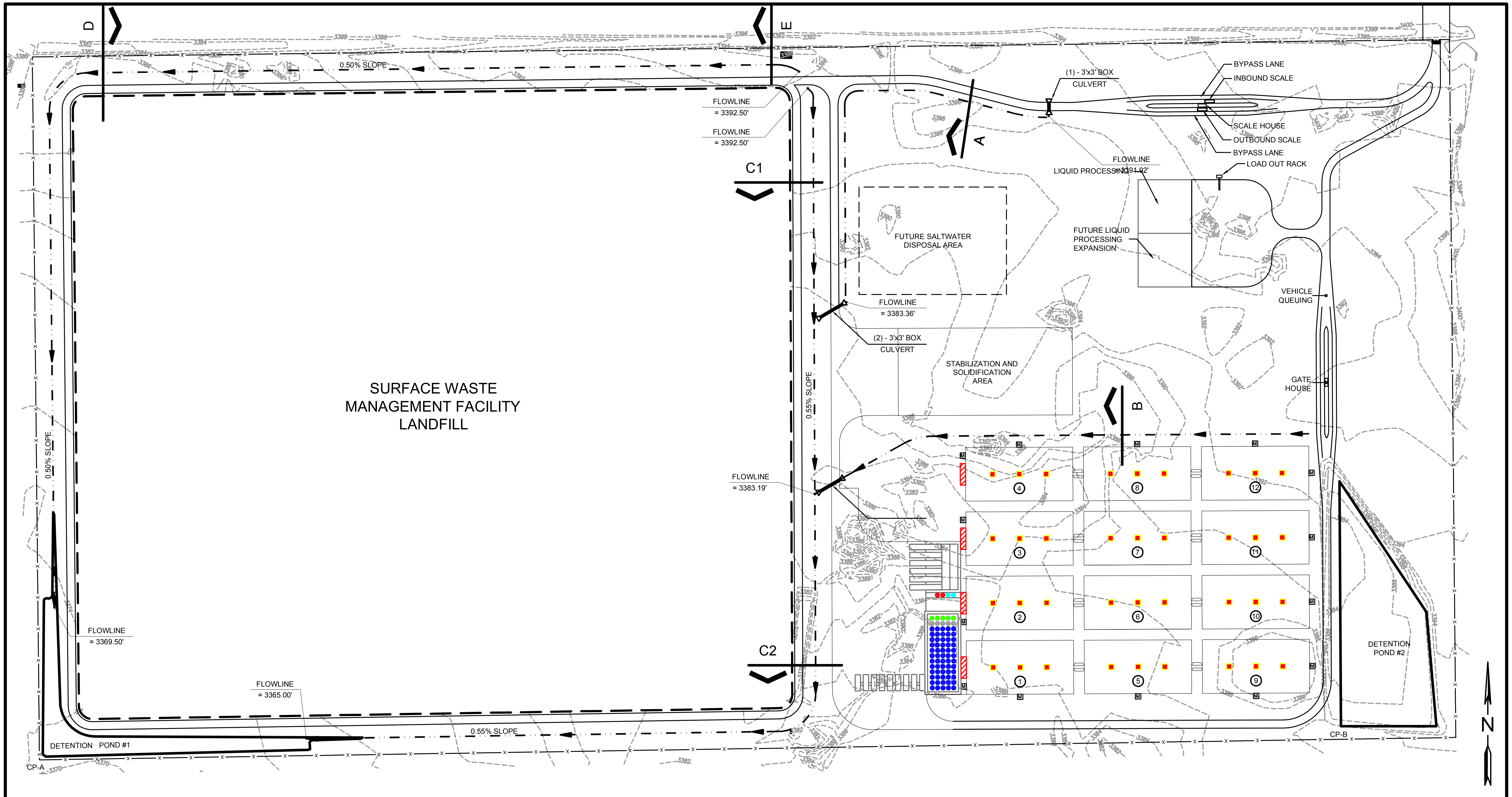
DETENTION POND & DETAILS

C-506

FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-507 - DEVELOPED DRAINAGE STRUCTURES PLAN.dwg LAYOUT NAME: C-507 PRINTED: Friday, November 06, 2015 - 8:22am USER: TKrueger

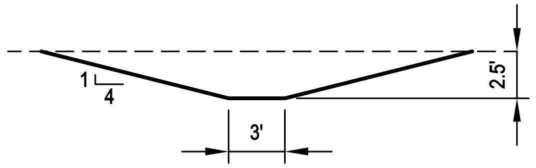


0 400' 800'

LEGEND

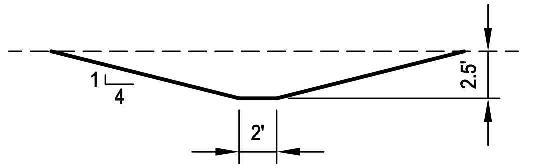
LANDFILL FOOTPRINT

CHANNEL CENTERLINE / DIRECTION OF FLOW



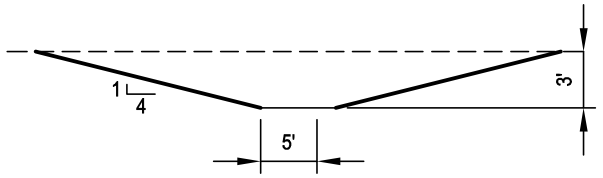
Ⓐ DRAINAGE CHANNEL A

SCALE: 1" = 10'



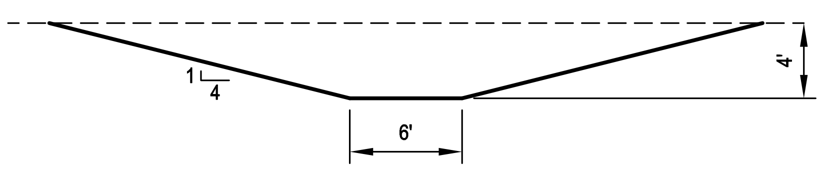
Ⓑ DRAINAGE CHANNEL B

SCALE: 1" = 10'



(C1) DRAINAGE CHANNEL C1

SCALE: 1" = 10'



(C2) DRAINAGE CHANNEL C2

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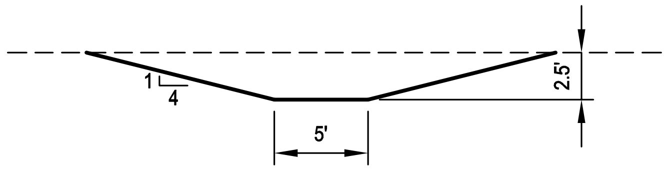
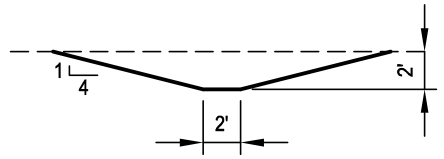


Ⓓ DRAINAGE CHANNEL D

SCALE: 1" = 10'



Ⓔ DRAINAGE CHANNEL E

SCALE: 1" = 10'

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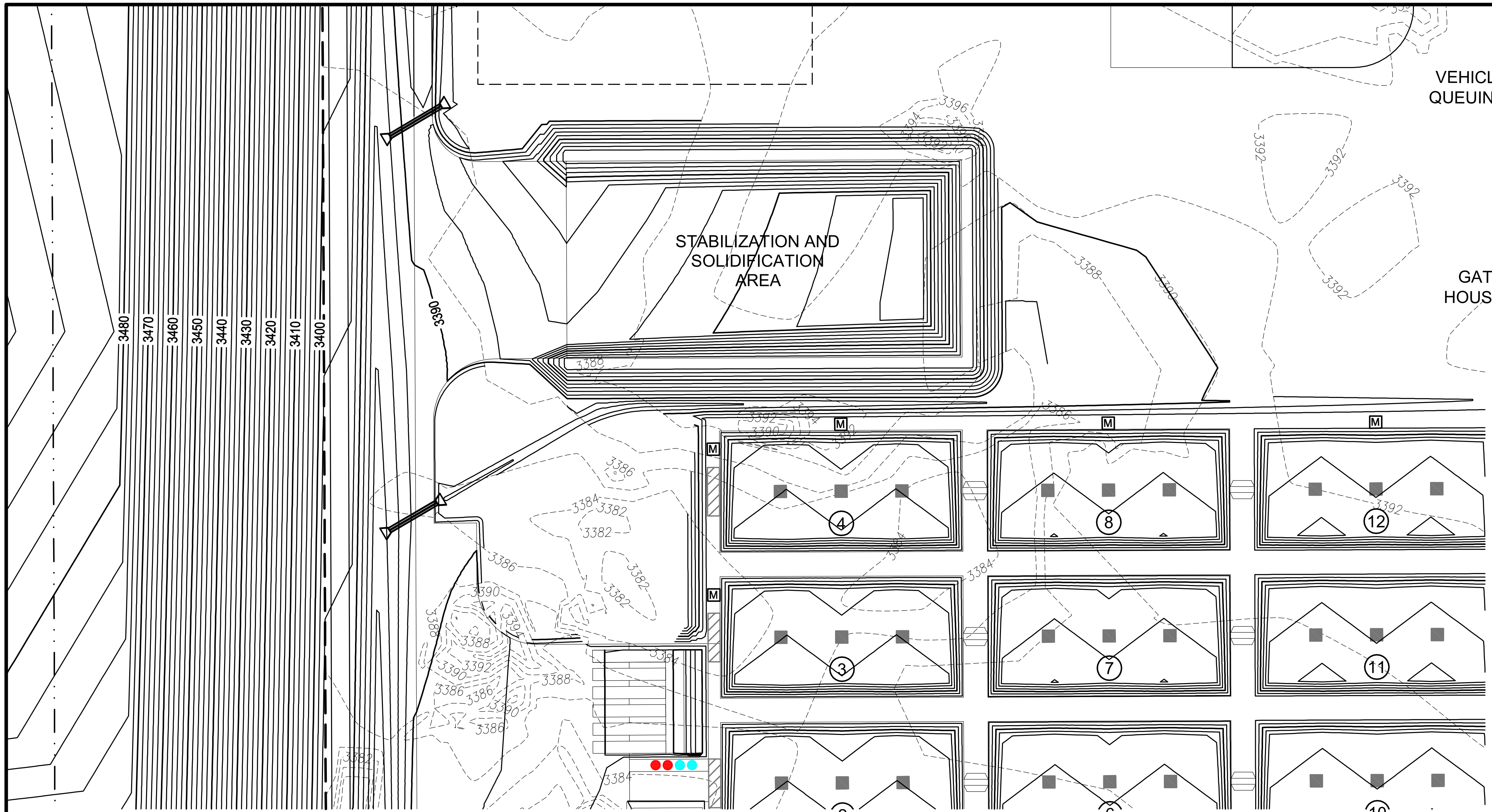
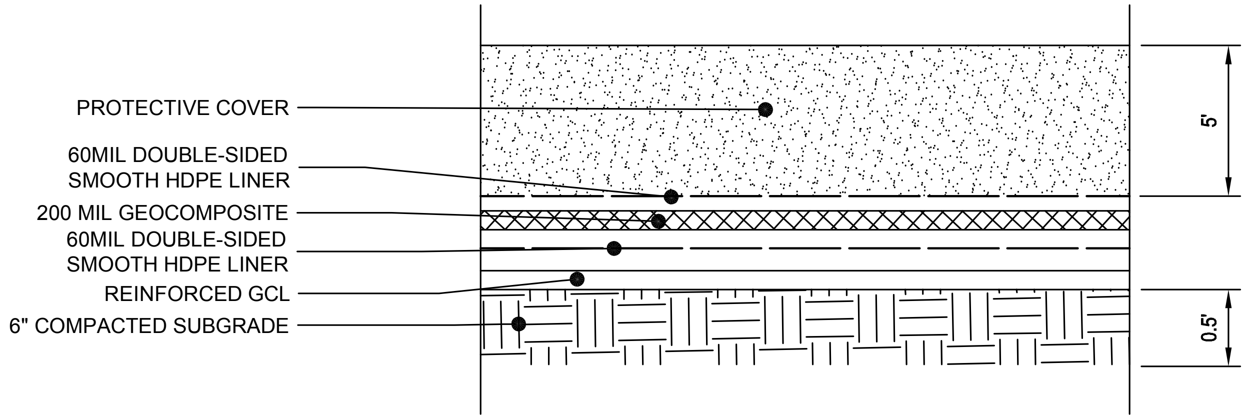
DEVELOPED DRAINAGE STRUCTURES PLAN

C-507

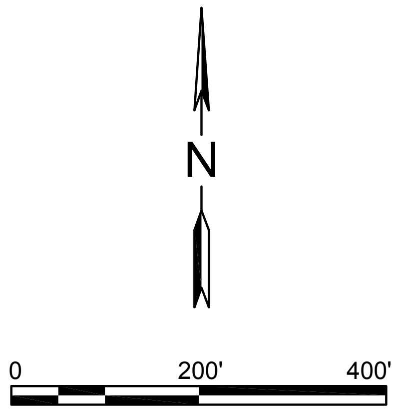
FILE NAME: \\Data1\Projects\2015\0580.15\BIM_CAD\09_PERMIT\ATT-B\C-508 - STABILIZATION AND SOLIDIFICATION AREA.dwg LAYOUT NAME: C-508 PRINTED: Friday, November 06, 2015 - 8:22am USER: TKrueger





A1 SOLIDIFICATION AND STABILIZATION LINER DETAIL

NO SCALE



LEGEND

------3392------	EXISTING CONTOUR
——3340——	2' LINER CONTOUR
—— · · ——	UNIT LIMITS

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STABILIZATION AND
SOLIDIFICATION AREA

C-508

Permit Application

Lea County, New Mexico

C.K. Disposal E & P Landfill and Processing Facility

Permit No. TBD

Attachment C

Liner Construction Quality Assurance (CQA) Plan

NMAC 19.15.36

November 2015

PSC Project # 01058015

PARKHILLSMITH&COOPER

ATTACHMENT C – SOIL AND LINER QUALITY CONTROL PLAN (SLQCP)

FIGURES

TABLES

1.0 INTRODUCTION

The Soil and Liner Quality Control Plan (SLQCP) presents engineering and quality control requirements for liner, final cover, and leachate collection system construction for the C.K. Facility to protect fresh water, public health, safety, and the environment. The SLQCP follows the requirements listed in NMAC 19.15.36. The SLQCP shall be used in conjunction with Attachment K - Site Operating Plan, Attachment B - Engineered Design Plan, and specifications provided during construction. The SLQCP shall address the following:

- A Quality Assurance Program and the Quality Assurance Procedures to be implemented during the liner and final cover construction include field observation, laboratory and field testing, and acceptance criteria for constructed work.
- Recording and documenting procedures to demonstrate the liner meets the requirements listed in the NMAC.
- Lines of communication, responsibilities and role of quality assurance team and other related project personnel.

The landfill liner system will consist of (from bottom to top):

- 6-inches of compacted subgrade
- Geosynthetic clay liner (GCL)
- 60-mil high density polyethylene (HDPE) geomembrane (GML) upper liner
- 200-mil HDPE geonet (floor)/200-mil HDPE geocomposite (side slopes)
- 60-mil HDPE geomembrane lower liner
- 200-mil HDPE geocomposite (floor/slope)
- 24-inches of protective soil layer

The evaporation pond liner system will consist of (from bottom to top):

- 6-inches of compacted soil subgrade
- Geosynthetic clay liner (GCL)
- 60-mil HDPE lower liner
- 200-mil HDPE geonet leak detection layer
- 60-mil HDPE upper liner

The stabilization and solidification area liner system will consist of (from bottom to top):

- 6-inches of compacted soil subgrade
- Geosynthetic clay liner (GCL)
- 60-mil HDPE lower liner
- 200-mil HDPE geonet leak detection layer

- 60-mil HDPE upper liner
- 5-feet of protective soil and operational layer.

The Owner/Operator shall notify the division a minimum of 72-hours before construction and installation of any liner system, to allow the division to witness installation.

1.1 DEFINITIONS

This section provides the definitions for terms used in this SLQCP.

A. Quality Control (QC)

Actions taken by the geosynthetic manufacturers and geosynthetic and soil contractor to ensure the geosynthetics materials and workmanship meet the requirements of project plans and specifications.

B. Quality Assurance (QA)

Actions taken by the Geotechnical Professional (GP) to assure conformity of the liner system production and installation with the Quality Assurance Plan, drawings, and specifications. QA is provided by a party independent of installation.

C. Work

All tools, equipment, supervision, labor, and material or supplies necessary to complete the project as specified herein and shown on the plans.

D. Geosynthetics

A generic classification given to synthetic (man-made plastic) materials used in geotechnical engineering applications. Included are geomembrane lining, geotextiles, geonets, geogrids, geocomposites and geocells.

E. Geomembrane Liner (GML)

Essentially an impermeable synthetic material used as an integral part of a lining system, sometimes referred to as a geomembrane, sheet, or panel. On the project, the GML will consist of a 60-mil, high density polyethylene (HDPE) material.

F. Geotextile

A permeable synthetic textile used with soil, rock, sand, gravel, or any other similar materials as an integral part of the composite lining system. This textile provides protection to the GML as a geosynthetic cushion and serves as a filter interface between two (2) types of soil materials.

G. Geosynthetic Clay Liners (GCL)

Geosynthetic clay liners (GCL) are factory-manufactured, hydraulic barriers typically consisting of bentonite clay or other very low permeability clay materials, supported by geotextiles and/or geomembranes held together by needling, stitching and/or chemical adhesives.

H. Manufacturer

Firm(s) responsible for the production of GML, GCL, geotextiles, geonets, and geocomposites.

I. Earthwork Contractor

The firm responsible for excavation and subgrade preparation under the liner and final cover installation. This firm may also be responsible for placing protective cover and granular drainage materials over the installed lining system.

J. GML Contractor

The firm responsible for handling, storing, placing, seaming, and other aspects of the installation of the GML, geosynthetics cushion, and geotextiles as part of the lining system.

K. Geotechnical Professional (GP)

Person(s) or firm(s) authorized by Owner to manage and oversee execution of the work. May also be referred to as the Professional of Record (POR). For work-related to clay liner construction, this includes a professional engineer registered in this state who possesses professional experience in geotechnical engineering, testing, and interpretations. The GP is responsible for observing, testing, and documenting activities related to liner quality assurance during the installation of the lining system, and for issuing the final report. All completed work is subject to approval of the GP. For liner construction work involving geosynthetics, the GP must be a professional engineer with experience in geosynthetics.

The GP or representative should be onsite for all liner construction and testing for soils, geosynthetic clay liners, geomembrane liners, geotextiles, and geocomposite materials. 100% of all non-destructive testing of seams for geomembrane liners should be directly observed by the GP or representative.

L. Owner

C.K. Disposal, LLC.

M. Qualified Engineering Technician

The qualified representative of the GP who is certified in Geotechnical Engineering Technology (NICET) at Level 2 or higher, an engineering technician with a minimum of four (4) years of directly-related experience, or graduate engineer/geologist with one (1) year of directly related experience.

N. Quality Assurance Laboratory

The firm responsible for conducting tests on samples of liner system components taken from the site. The laboratory shall be independent of the Owner, Manufacturer, Lining Contractor, and any party involved with the manufacturing and/or installation of any of the geosynthetics.

O. Project Plans and Specifications

All project-related plans and specifications including design modifications and "as-built" plans.

P. Project Documents

All contractor submittals, construction plans, "as-built" plans, construction specifications, QA plan, safety plan, and project schedule.

2.0 GEOSYNTHETIC CLAY LINER (GCL)

2.1 General

This section includes the requirements for selection, installation, and protection of GCL.

2.2 Submittals

A. Pre-installation

Submit the following to the GP for approval prior to GCL deployment.

1. Supplier of the GCL manufacturer results for standard tests described in Table C.1.
2. Written certification the GCL meets the properties listed in Table C.1.
3. Written certification that GCL manufacturer has continuously inspected each roll of GCL for the presence of needles and other defects and found GCL defect-free.
4. Written certification from the GCL manufacturer the bentonite will not shift during transportation or installation thereby causing thin spots in the body of the GCL.
5. QC certificates signed by a responsible party of the GCL manufacturer for each roll delivered to the site. Each certificate shall include roll identification numbers and results of all QC tests. At a minimum, results shall be given for tests corresponding to Table C.1. The bentonite and textile suppliers shall each certify the respective properties under Manufacturer's Quality Control. The GCL manufacturer shall also perform the bentonite tests described under Manufacturer's Quality Control and third party tests.

Table C.1 - STANDARD TESTS ON GEOSYNTHETIC CLAY LINER MATERIAL

Test	Item	Type of Test	Standard Test Method	Frequency of Testing
Manufacturer's Quality Control	Bentonite[(A)]	Swell Index[(A)]	ASTM D5890	per 100,000-lbs and every truck or railcar
		Moisture Content[(A)]	ASTM D4643	per 100,000-lbs and every truck or railcar
		Fluid Loss[(A)]	ASTM D5891	per 100,000-lbs and every truck or railcar
	Geotextile	Grab Tensile Strength[(B)]	ASTM D6496	per 200,000-ft^2
		Mass/Unit Area	ASTM D5261	per 200,000-ft^2
	GCL Product	Grab Tensile Strength[(B)]	ASTM D6496 ASTM D4632	per 200,000-ft^2
		Clay Mass/Unit Area[(C)]	ASTM D5993	per 40,000-ft^2
		Permeability[(D)]	ASTM D5084	per week for each production line[(E)]
		Lap Joint Permeability[(D)(F)]	ASTM D5084	per each material and lap type
Conformance Testing by 3rd Party Independent Laboratory	GCL Product	Clay Mass/Unit Area[(C)]	ASTM D5993	at least one (1) test per 100,000-ft^2 and ASTM D4354 procedure A
		Permeability[(D)(F)]	ASTM D5084	per 100,000-ft^2
		Direct Shear[(F)(G)]	ASTM D5321	Per GCL/adjoining material type

Notes:

A - Tests performed on bentonite before incorporation into GCL. Free swell shall have a minimum test value of 24-ml. Fluid loss shall have a maximum value of 18-ml.

B - Geotextiles shall meet minimum manufacturer criteria.

C - Minimum Test value - 0.75-lb/in MARV at 0% moisture content.

D - 1 x 10^{-8} m^3/m^2/sec or as required by the permit.

E - Report last twenty (20) permeability values, ending on production data of supplied GCL.

F - Test at confining/consolidating pressures simulating field conditions.

G - Not applicable for slopes of 7H:1V or flatter. Testing must be on material in hydrated state unless GCL includes geomembrane on both sides of GCL.

B. Installation

The GCL installation Contractor shall submit to the GP a Subgrade Surface Acceptance Form, signed by the GCL installation Contractor, for each covered directly by GCL as installation proceeds.

2.3 Delivery, Storage, and Handling

A. Packing and Shipping

The GCL shall be supplied in rolls wrapped individually in relatively impermeable and opaque protective covers. The GCL rolls shall be marked or tagged with the following information:

1. Manufacturer's name.
2. Product identification.
3. Roll number.
4. Roll dimensions.
5. Roll weight.

B. Storage and Protection

The Contractor will provide an onsite storage area for GCL rolls from the time of delivery until installed as recommended by the GCL Manufacturer. After Contractor mobilization, he shall store and protect GCL from dirt, water, ultraviolet light exposure, and other sources of damage. Contractor shall preserve integrity and readability of GCL roll labels. Rolls must not be stacked higher than recommended by the manufacturer to preclude thinning of bentonite at contact points.

2.4 Materials

The active ingredient of the GCL shall be natural sodium bentonite and encapsulated between two (2) geotextiles. The geotextile-backed GCL shall provide sufficient internal shear strength of the slopes to be lined. All GCLs shall be evaluated for stability prior to use onsite and the evaluation included in the GCLER/GMLER submittal. The GCL shall have a coefficient of permeability of 1 x 10^7-centimeters/second (cm/sec) or less.

The bentonite shall be continuously adhered to both geotextiles to ensure the bentonite will not be displaced during handling, transportation, storage, and installation, including cutting, patching, and fitting around penetrations. The bentonite sealing compound or bentonite granules used to seal penetrations and make repairs shall be made of the same natural sodium bentonite as the GCL and recommended by the GCL manufacturer. The permeability of the GCL seams shall be equal to or less than the permeability of the body of the GCL sheet.

2.5 Manufacturer

A. Acceptable Manufacturers

The GCL shall be Bentoliner products as produced by GSE or an equivalent pre-approved by the GP.

B. Manufacturing Experience

The GCL manufacturer shall have a minimum of two (2) years of continuous experience in the manufacture of similar GCL products. The Manufacturer must demonstrate, by submitting a list of previous projects, a minimum of 5-million sq.ft. of manufacturing experience of similar GCL products.

2.6 Warranty

The Manufacturer shall provide a 5-year warranty to the Owner against manufacturing defects. The warranty shall include defective product found in compliance with SLQCP requirements. The warranty shall include the supply of the replacement GCL material and shall not include the cost of re-installation, defects, or failures due to improper installation.

2.7 Execution

A. Examination

The GP or his representative will collect samples of delivered material to the site or designated by the Manufacturer by roll number to be delivered to the site for conformance testing.

B. Subgrade Preparation

The subgrade shall be prepared in a manner consistent with proper subgrade preparation techniques for the installation of geosynthetics materials and as recommended by the GCL manufacturer. The subgrade shall be properly compacted to a minimum of 95% Standard Proctor Density per ASTM D698, so as not to settle and cause excessive strains in the GCL or other synthetic liner materials. Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 0.5-inch. The subgrade must be rolled with a smooth-wheeled roller. During installation, ensure rutting or raveling is not caused by installation equipment.

C. Installation

i. GCL Deployment

Handle GCL in a manner to ensure it is not damaged as recommended by the GCL Manufacturer. At a minimum, comply with the following:

1. On slopes, anchor the GCL securely and deploy it down the slope in controlled manner.
2. Weight the GCL with sandbags or equivalent in the presence of wind.
3. Cut GCL with a cutter (hook blade), scissors, or other approved device.
4. Prevent damage to underlying layers during placement of GCL.
5. During GCL deployment, do not entrap in or beneath GCL stones, trash, or moisture that could damage GCL.
6. Visually examine entire GCL surface. Ensure no potentially harmful foreign objects such as needles are present.
7. Do not place GCL in the rain or at times of impending rain.
8. Do not place GCL in areas of ponded water.
9. Replace GCL that is hydrated before placement of overlying geomembrane and cover soil.
10. In general, only deploy GCL that can be covered during the day by geomembrane.
11. For needle-punched GCLs, add granular bentonite to the overlapped areas at the manufacturer’s specified rate.

12. Protective soil cover (including leachate collection media) shall be placed over the liner as soon as practicable.
13. Avoid dragging GCL on the subgrade.
14. Vehicular traffic other than low contact pressure vehicles such as smooth-tired ATV's or glove carts must be allowed on deployed GCL.
15. Installation personnel shall not smoke or wear damaging shoes when working on GCL.

ii. Overlaps

Overlap GCL to the manufacturer's recommendations that will vary according to seam location and climatic conditions. For needle-punched GCLs, apply granular bentonite to the overlapped area at a rate required by the manufacturer. At sumps, overlapped GCL shall be a minimum of 1-foot. At bottom of collection and leak detection sumps, unroll an extra layer of GCL on top of previously installed GCL. Avoid placing seams on top of underlying seams. Horizontal seams and mid-slope anchor trenches are not allowed on side slopes.

iii. Defects and Repairs

Repair all flaws or damaged areas by placing a patch of the same material extending at least 1-foot beyond the flaw or damaged area. Add granular bentonite to the overlapped edges of the patch at the manufacturer's specified rate.

iv. Interface with Other Products

Ensure the following when deploying overlying material:

1. GCL and underlying materials are not damaged.
2. Minimal slippage of GCL on underlying layers occurs.
3. No excess tensile stresses occur in GCL.
4. If necessary, approved adhesive can be used to keep overlap seams and patches in place during placement of overlying materials.

2.8 Equipment

A. Storage

Use wooden pallets for above ground storage of GCL and heavy, waterproof tarpaulin for protecting unused GCL unless otherwise specified by GCL manufacturer.

B. Installation

1. Use front-end loader, crane, or similar equipment for GCL deployment with a spreader bar to prevent slings from damaging edges.
2. A 15-foot long, 3-inch outer diameter schedule 120 steel pipe will be inserted into roll core for lifting.
3. Use 3-inch wide grips for moving GCL panels into place for each installation technician.
4. Place bentonite between overlapped panels, or as directed by project needs requirements.

5. Bentonite sealing compound and/or granular bentonite for securing around penetrations and structures as shown on the contract documents.
6. Anchor bolts for securing around concrete structures, if required.
7. Use sand bags for securing tarpaulin when being stored and to secure GCL prior to placement of GML.
8. Use utility knives with cutter, hook blade, or other approved device. Keep replacement blades onsite to maintain clean cuts in GCL.

3.0 GEOMEMBRANE LINING (GML)

3.1 General

This section covers the work necessary to construct and test the geomembrane lining (GML) system which will consist of 60-mil HDPE material. The objective is to provide an effective lining system at the completion of the work. The GML shall generally conform to the testing requirements of GRI Standard GM13 – Test Properties, Testing Frequency and Recommended Warrant for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes, (Geosynthetic Research Institute; Folsom, PA; November 2014) except as modified herein. Textured GML will be used on the side slopes. Smooth GML will be used on floor.

3.2 Submittals

A. Manufacturer Certification of SLQCP Conformance

The Contractor shall submit written certification by the Manufacturer that the lining materials conform to the requirements of the SLQCP, are similar and of the same formulation as that for which certification is submitted, and demonstrated by actual usage to be satisfactory for the intended application.

B. Contractor and Manufacturer QC Program

The Manufacturer and the Contractor, shall each submit a complete description of the quality control program as applicable, for manufacturing, handling, installing, testing, repairing, and providing a completed lining in accordance with requirements of the SLQCP. The description shall include but not be limited to polymer resin supplier, product identification, acceptance testing, fabrication and production testing, installation testing, documentation of changes, alterations and repairs, retests, and acceptance. Each shall present documented evidence of its ability and capacity to perform this Work.

C. Contractor Installation Plan

The Contractor shall submit installation drawings, descriptions of installation procedures, and a schedule for performing/completing the Work. Installation drawings shall show a lining panel layout with proposed size, number, position, and sequence of placing all panels and indicating the location of all field seams. Installation drawings shall also show complete details and/or methods for anchoring the lining at the perimeter, making field seams, and making anchors/seals to pipes and structures.

The Contractor shall submit a complete description of welding procedures for making field seams and repairs. The welding procedures shall conform to the latest procedures recommended by the lining Manufacturer and to the SLQCP.

The Contractor shall submit for approval by the GP certification that the surface(s) on which the lining will be placed is acceptable. Installation of the lining shall not commence until certification is furnished to the GP.

D. Manufacturer's Warranty

The lining Manufacturer shall furnish a written lining material warranty as described in GRI GM13. The warranty shall be against manufacturing defects or workmanship and against deterioration due to ozone, ultraviolet, or other normal weather aging. The warranty shall be limited to replacement of material only and shall not cover installation of said material. The warranty shall not cover damage due to vandalism, acts of animals, or supernatural acts of God. The warranty shall be for 5 years from the date of GML installation.

E. Contractor's Warranty

The Contractor shall furnish a written guarantee that the entire lining work constructed by him is free of defects in material and workmanship and installed pursuant to the SLQCP for 2 years following the date of acceptance of the work by the GP. During the 23rd month, a pre-guarantee expiration inspection will be conducted to identify any necessary repair work covered by the guarantee. The Contractor shall agree to make any repairs or replacements made necessary by defects in materials or workmanship in the Work which become evident within said guarantee period. The Contractor shall make repairs and/or replacements promptly, the Owner may do so, and the Contractor shall be liable to the Owner for the cost of such repairs and/or replacements.

3.3 Quality Assurance

Prior to start of work, the lining Manufacturer and the Contractor shall each submit for approval by the GP documented evidence of the ability and capacity to perform this Work. Each shall have successfully manufactured and/or installed a minimum of 2-million/sq/ft of similar lining material in waste and/or liquid processing containment structures. The Contractor can meet these criteria by teaming with a subcontractor who is identified in the bid and the firm's experience.

The Contractor shall submit the name and qualifications of the project superintendent on the project whenever lining materials are being handled/installed plus the names and qualifications of senior installation personnel on the project.

The Quality Control Plan(s) to be implemented for the Work by the lining Manufacturer and the Contractor shall be in accordance with applicable paragraphs of the SLQCP.

The Manufacturer shall provide onsite technical supervision and assistance at all times during installations of the lining system. The Manufacturer and Contractor, as applicable to each, shall submit for approval by the GP written certification that the lining system was installed in accordance with the Manufacturer's recommendation, the SLQCP, project specification and drawings, and approved submittals.

The GP will initiate a pre-installation meeting with the Manufacturer and Contractor prior to installation of the lining system. Topics for review/discussion shall include, as a minimum, project plans and specifications, approved submittals, training and qualification procedures for Contractor personnel, and demonstration of making field-welded seam(s) included peel and shear tests.

Prior to installation of the lining system, the Contractor shall instruct the hazards of installation workers on handling sheets of lining material in high winds, use of equipment, application of solvents, adhesives and caulks, and walking on lining surfaces. Work gloves, safety glasses, hard hats, and smooth-soled shoes are minimum safety wear requirements when working on the GML. Safety shoes must be worn when handling heavy objects.

The GP shall have authority to order an immediate work stoppage because of improper installation procedures, safety infractions, or for any reason resulting in a defective liner.

3.4 Deliver, Storage, and Handling

The Contractor shall submit for approval by the GP method(s) for handling and storage of lining material(s) delivered to the project site. These materials shall be stored in accordance with the Manufacturer's recommendation. Lining materials delivered to the site shall be inspected for damage, unloaded, and stored with a minimum of handling. Materials shall not be stored directly on the ground. The storage area shall be such that all materials are protected from mud, soil, dirt, and debris. The stacking of lining shall not be higher than two (2) rolls. Under no circumstances shall the lining be subjected to materials, sandbags, equipment, or other items dragged across the surface. Nor shall workers and others slide down slopes atop the lining. All scuffed surfaces resulting from abuse of any kind caused by the Contractor in performance of the work shall be repaired at GP direction.

The Contractor shall be completely responsible for shipping storage, handling, and installation of all lining materials in compliance with SLQCP.

3.5 Products

HDPE lining materials shall be new, first quality products designed and manufactured specifically for the purposes of the Work and have satisfactorily demonstrated by prior use to be suitable and durable for such purposes. The geomembrane shall be unmodified HDPE containing no plasticizers, fillers, chemical additives, reclaimed polymers, or extenders. For ultraviolet resistance, the GML material shall contain not less than 2.0% carbon black as determined by ASTM D1603. The only other compound ingredients added to the GML shall be antioxidants and heat stabilizers required for manufacturing. The GML shall be supplied as a single-ply continuous sheet with no factory seams and in rolls with a minimum width of 15-feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest field seams.

The GML lining materials shall be as manufactured by GSE Lining Systems, Inc., Houston, Texas; Poly-America, Inc., Grand Prairie, Texas; National Seal Company, Galesburg, Illinois; or approved equal.

The standard tests described in Table C.2 will be performed on the GML material.

Table C.2 - STANDARD TESTS ON HDPE GML MATERIAL

Test	Type of Test	Standard Test Method	Frequency of Testing
Resin	Melt Flow Index	ASTM D1238	per 100,000-ft^2 and every resin lot
	Specific Gravity/Density	ASTM D1505	per 100,000-ft^2 and every resin lot
Manufacturer Quality Control	Thickness	ASTM D5199 or ASTM D5994	per 100,000-ft^2 and every resin lot
	Specific Gravity/Density	ASTM D1505	per 100,000-ft^2 and every resin lot
	Carbon Black Content	ASTM D1603	per 100,000-ft^2 and every resin lot
	Carbon Black Dispersion	ASTM D5596	per 100,000-ft^2 and every resin lot
	Tensile Properties	ASTM D6693, Type IV	per 100,000-ft^2 and every resin lot
	Tear	ASTM D1004	per 100,000-ft^2 and every resin lot
	Puncture	ASTM D4833	per 100,000-ft^2 and every resin lot
Conformance Testing by 3rd Party Independent Laboratory	Thickness	ASTM D5199 or ASTM D5994	per 100,000-ft^2 and every resin lot
	Specific Gravity/Density	ASTM D1505	per 100,000-ft^2 and every resin lot
	Carbon Black Content	ASTM D1603	per 100,000-ft^2 and every resin lot
	Carbon Black Dispersion	ASTM D5596	per 100,000-ft^2 and every resin lot
	Tensile Properties	ASTM D6693, Type IV	per 100,000-ft^2 and every resin lot

Note: NSF 54 modified with 2-inch initial gauge length assumed for elongation at break.

Extrusion resin used for fusion welding with extrudate to make field seams between GML sheets and for repairs shall be HDPE-produced and the same as HDPE sheet resin. Physical properties shall be same as HDPE lining sheets.

3.6 Installation Procedures

Prior to installation of the GML, a site inspection will be conducted by the GP and Contractor to verify measurements, structures, and surface conditions to support the GML. The Contractor will provide written documentation to the GP that surfaces to receive the GML have been inspected and acceptable for installation of the lining.

Before the work begins, the Contractor will inspect all lining materials for damage from transit. Materials that cannot be repaired will be rejected and removed from the work area and site. During unwrapping of lining materials for use and placement, the Contractor will visually inspect all materials, particularly surfaces of lining sheets, for imperfections and faulty areas. All such defective places will be marked and repaired in accordance with approved methods.

The GML will be installed as shown on the project plans and approved installation drawings. Placement of the GML will be done such that good fit, without bridging, is a provided on all covers and grade changes. Excessive slack will be avoided to minimize rippling during the soil cover operation. Sheets of GML materials will be of such lengths and widths and will be placed in such a manner as to reduce field seaming to a minimum. The lining will be anchored according to details shown on approved plans and drawings. The lining will be anchored and sealed to structures, pipes, and other types of penetrations, (if any), in accordance with details shown on approved plans and drawings. All changes in approved installation drawings and procedures must be approved by the GP.

Extreme care will be taken during installation of the lining to be certain no damage is done to any part of the lining. Dragging of the GML material on the GCL or subgrade will be avoided. Installation personnel are prohibited from smoking. All handling and installation procedures will be performed by workers wearing shoes with smooth soles. Shoes with patterned soles in relief are prohibited. No foot traffic is allowed on lining. All motor-driven equipment using fuel will have spark arrestors. No gasoline-driven generators or cans of gas or solvent will be place directly on the lining material. Under no circumstances will the lining be used as a work area to prepare patches or to store tools and supplies. If needed, a tarpaulin of approved material will be spread out as a work area.

During installation, the Contractor will be responsible for protecting the lining against adverse effects of high winds such as uplift. Sand bags with sufficiently close-knit to preclude fines from working through the bottom, sides or seams, will be used as required to hold the lining material in position during installation. Paper bags used as sand bags, whether or not lined with plastic, will not be permitted. Burlap bags, if used, must be lined with plastic. Bags will contain not less than 40-pounds, nor more than 60-pounds of sand having 100% passing a number 8 screen and tied closed after filling, using only plastic ties. Bags that are split, torn, or otherwise losing the contents will be immediately removed from the work area and any spills immediately cleaned up. Metal or wire tires will not be used.

During installation, water shall not be allowed to pond on the GML material. The Contractor shall have available appropriate pumps to immediately remove ponding water.

The GML material will not be installed under adverse climatic conditions, unless Contractor can demonstrate his installation techniques adequately compensate for such adverse conditions and quality of workmanship is not compromised. Adverse climatic conditions occur when the air temperature measured 6-inches above the GML surface is less than 32°F and decreasing or more than 90°F, when relative humidity is more than 80%, when raining or frost on the ground, or during conditions of excessive winds.

GML field seams will be lap seams as shown on approved plans and drawings. The lap seams will be formed by lapping the edges of GML sheets a minimum of 4-inches. The contact surfaces of the sheets will be wiped clean to remove dirt, dust, moisture, and other foreign materials. For fillet weld seams, bevel edge of GML and clean oxidation from surfaces to extrudate by disk grinding or equivalent not more than one (1) hour before seaming. Lap seam intersections involving more than three (3) thicknesses of lining material will be avoided and all seam intersections will be offset at least 2-feet. Non-horizontal field seams will be allowed on the slope and sheets of lining material on the slopes will extend down slope out onto bottom a minimum of 5-feet from the toe of slope. Field seams between sheets of GML material will be made using approved fusion welding systems, equipment, and techniques. Approved fusion welding systems include fillet weld using extrudate, lap weld using extrudate, and lap weld using single or double wedge welder. If the wedge welder is used, excess free edge of the seam (wider than 3-inches) of the top sheet will be removed without affecting the integrity of the seam. Any necessary repairs to the GML will be made with the lining material itself, using approved fusion welding systems, equipment, and techniques. The patch size will be 4-inches larger in all directions than the area to be patched. All corners of the patch will be rounded with a 1-inch minimum radius. All seams and seals of the GML will be tightly bonded on completion of the work. Any lining surface showing injury due to scuffing or penetration by foreign objects or showing distress will be replaced or repaired as directed by the GP.

Cleanup within the work area will be an ongoing responsibility of the Contractor. Particular care will be taken to ensure no trash, tools, or other unwanted materials are trapped beneath the lining. Care will be taken to guarantee all scraps of lining materials are removed from the work area prior to completion of the installation.

3.7 Field Quality Control

Inspection and testing will involve fulltime observation of the installation of the GML, including the making and testing of lining seams, patches, and period measurement of the liner material thickness to ensure compliance. Field thickness measurements must be taken for each panel before seamed. The material thickness shall be checked using a micrometer at a minimum frequency of one (1) measurement per 5-feet along the leading edge of each panel with a minimum of five (5) measurements along the leading edge of the panel. No single measurement shall be less than 10% below the required nominal thickness for the panel to be accepted. In addition, the average of all measurements along the edge must be at least 60-mils.

Test seams will be made to verify that adequate conditions exist for field seaming to proceed. Each seamer will produce a test seam at the beginning of each shift to determine the peel and tensile strength of the seam. The GP may require a sample field seam be made at any time during seaming production to verify equipment/operator performance and seam integrity. In addition, if a seaming operation is suspended for more than 0.5-hour or if a breakdown of seaming equipment occurs, a test seam will be produced prior to resumption of seaming operations.

The trial weld sample must be a minimum of 3-feet long and 1-foot wide with the seam centered lengthwise The GP must observe all trial welding operations, quantitatively test each trial weld for peel and shear, and record the results. A minimum of two (2) peel and two (2) shear tests will be performed per trial seam. Double wedge weld trial seams shall have a minimum of four (4) peel tests performed. The trial weld shall be completed under the same conditions for which the panels will be welded. The trial weld must meet the requirements for peel and shear as stated in the following paragraph and the break must be ductile or a film tearing bond (FTB) for a wedge weld or extrusion weld.

During the field seaming operation, destructive samples will be removed from field seams by the Contractor at locations selected by the GP. Field seam repairs will be made according to repair procedures specified in the SLQCP. The samples will have a width of 12-inches plus the seam width and length of 42- to 48-inches. A minimum of one (1) stratified sample per 500-feet of field seam will be made. All field seams will have a film tear bond in peel and shear and a minimum 1-pound/inch width seam strength in shear when tested as specified in this SLQCP. At the very least, the peel adhesion and bonded shear strength must be 62% and 95% respectively of the strength of the parent material, but not less than 78-ppi and 120-ppi respectively. A sufficient amount of the seam must be removed to conduct field testing, independent laboratory testing, and archiving of enough material to retest the seam when necessary. The archived material will be kept at the independent laboratory. Field testing shall include at least two (2) peel tests per sample, but four (4) when possible for testing both tracks on dual-track fusion welded seams. Destructive seam-testing locations shall be cap-stripped and the cap completely seamed by extrusion welding to the GML. Capped sections shall be non-destructively tested. Additional destructive test samples may be taken if deemed necessary by the GP or his representative.

All field-tested samples from a destructive-test location must be passing in both shear and peel for the seam to be considered passing in both shear and peel. The independent laboratory testing must confirm these field results. The passing criterion for independent laboratory testing is four (4) of five (5) samples from each dual track fusion welded seam, when possible to test each seam, must be passing before the seam is considered as passing. Sample testing conducted by an independent testing agency will save all test samples including specimens tested until notified by the GP relative to the disposal. All specimens which have failed under test will be shipped immediately by express delivery to the GP for determination or corrective measure to be taken, including retest or repair of failed section.

For destructive samples which failed the passing criterion, the Contractor will reconstruct all field seams between any two (2) previously-passed seam locations which include the failed seam, or will go on both sides of the failed seam location (10-feet minimum), take samples from each side, and test both. If both pass, the Contractor will repeat the process of taking samples for test. In all cases, acceptable field seams must be bound by two (2) passed test locations. The GP decision will be final.

If capping of a field seam is required, the Contractor will use a cover strip of the same thickness as the lining (and from the same roll, if available) and of 8-inches minimum width. It will be positioned over the center of the field seam and welded to the lining using a fillet weld on each side.

All GML sheets, seams, anchors, seals, and repairs will be visually inspected by the Contractor for defects. In addition, all seams and repairs will be further checked by a metal probe. Depending on seam welding equipment used, all seams and repairs will be tested by a vacuum testing device, a spark testing device and/or air pressure. A visual inspection of the lining sheets, seams, anchors, and seals will be made by the Contractor as the installation progresses and again on completion of the installation. Defective and questionable areas will be clearly marked and repaired. Final approval of repairs will be given by the GP.

The Contractor will run a metal probe, such as a dull-pointed ice pick, along the length of all seams and repairs to ensure the seam is continuous and absent of leak paths. Defects will be clearly marked and repaired.

If the fillet weld, extrusion lap weld, or single hot-wedge fusion weld is used to weld seams, the Contractor will further test all seams and repairs in the GML by vacuum box. All vacuum box testing will be done in the presence of the GP. The testing area will be cleaned of all dust, debris, dirt, and other foreign matter. A soap solution will be applied to the test area with a paint roller and the vacuum of 3-psi air pressure will be induced and held at least ten (10) seconds to mark for repair of any suspicious areas as evidenced by bubbles in the soap solution.

If the fillet weld is used to weld seams, the Contractor will further test all seams and repairs in the GML by using a high voltage spark detector if vacuum box or air pressure methods cannot be performed. The setting of the detector will be 20,000-volts. To conduct this test, all test seams will be provided with not less than gauge 24-30 copper wires properly embedded in the seams and grounded. All spark testing will be done in the presence of the GP and all defective areas marked for repair.

If the double hot-wedge is used, the Contractor will further test all seams in the GML by using the air pressure test which consists of inserting a needle with gauge in the air space between the welds. Air will be pumped into space to 35-psi and held for 5-minutes. If pressure is not maintained, then the seam is unacceptable.

All costs of retesting of the GML including reruns of field weld tests and all repairs is at the Contractor’s expense.

The Contractor will retain responsibility for the integrity of the GML system until acceptance by the GP. The GML will be accepted by the GP when:

a) Written certification letters including “as built” drawings are received by the GP.
b) Installation is completed.
c) Documentation of completed installation, including all reports, is complete.
d) Verification of adequacy of field seams and repairs, including associated testing, is complete.

Acceptance of the competed work will include receipt of all submittals and all work completed to the satisfaction of the GP.

4.0 LEACHATE COLLECTION SYSTEM

4.1 Granular Drainage Media

A leachate collection system (LCS) will be placed above the GML. The LCS will consist of a heat bonded HDPE geonet/geotextile drainage composite (geocomposite) on the floor and side slopes with granular (gravel) embedded leachate collection pipes in the sump and pipe trench areas. The leachate collection pipes will consist of 6-inch diameter pipe with 3/8-inch diameter holes on 6-inch centers. To avoid piping losses into the collection pipes, the granular drainage layer shall consist of rounded, river-run gravel meeting the requirements of ASTM C33 for coarse aggregate. Crushed material will not be acceptable. The gravel should meet gradation requirements of Sine No. 6 (nominal size 3/4-inch to 3/8-inch) or coarser. The maximum gravel size shall not exceed 2-inches. The required thickness of drainage materials will be verified by survey methods on an established grid system with not less than one (1) verification point per 5,000-sq/feet of surface area.

The gravel will have a permeability of $1\text{x}10^{-2}$ cm/sec and the percent calcium carbonate by weight shall not exceed 15%. A minimum 8-ounce non-woven geotextile will be placed around the gravel drainage components to prevent intrusion of fines. All geotextile materials will be hand placed.

4.2 Geocomposite Drainage Materials

The geocomposite will be formed of two (2) non-woven geotextiles heat bounded to a geonet core. The geotextile on both sides of the geonet will be a minimum 8-ounce non-woven material meeting the standard test requirements in Table C.3. The protective cover will be carefully spread on top of the geocomposite to avoid damage to the liner system.

4.3 Leachate Chimneys

Leachate chimneys will be installed through the protective cover to allow a direct hydraulic conduit between the lowest waste layers and the LCS. A minimum 8-ounce geotextile will completely encase the pipe embedment gravel layer with a full-width geotextile overlap where the chimney daylights through the protective cover. The geotextile overlap will be covered by a maximum 6-inch thick layer of the granular material used as the pipe embedment.

4.4 Drainage Layer Placement

Placement of granular drainage materials over GML will generally not proceed at ambient temperatures below 32°F or above 104°F, but should not be conducted at the coolest part of the day to minimize the development of wrinkles or folding of the geosynthetic materials. A minimum of 1-foot of material is required between low ground pressure dozers (i.e. track pressure less than 5-psi) and the geomembrane. Greater material thickness must be maintained above the geomembrane to support heavier spreading equipment and hauling vehicles. In such cases, a minimum of 2-feet of drainage material thickness will be used unless otherwise specified in the design. The placement of the LCS will be controlled to avoid damage to the liner; however, the drainage layer does not need to be density controlled.

Granular drainage materials will be selected to meet the described specifications. At least one (1) set of pre-construction tests will be conducted for each drainage media from each proposed source. Gravel and sand sources will include a complete grain-size analysis, including Minus No. 200 sieve, by ASTM D4222. Hydraulic conductivity may be correlated from the grain-size distribution to determine the gravel or sand suitability. Granular drainage materials selected for use will be tested at regular interval for conformance during construction. Minimum testing frequency will be on grain-size analysis for every 3,000-cubic/yards, or portion thereof, for each material being used.

The geotextile materials will include an 8-ounce fabric around the leachate chimneys and a minimum 8-ounce nonwoven fabric on both sides of the geonet forming the geocomposite layer. The following tests described in Table C.3 will be required on the geotextile materials. The geotextile will be bonded on both sides of the geonet. Geonet tests are described in Table C.4.

Table C.3 - STANDARD TESTS ON GEOTEXTILE MATERIALS

Test	**Type of Test**	**Standard Test Method**	**Frequency of Testing**
Manufacturer's Quality Control	Mass per Unit Area	ASTM D5261	per 100,000-ft^2
	Grab Tensile Strength (%)(MD/CD)[1]	ASTM D4632	per 100,000-ft^2
	Grab Elongation (%)(MD/CD)[1]	ASTM D4632	per 100,000-ft^2
	Puncture Strength	ASTM D4833	per 100,000-ft^2
	Trapezoidal Tear Strength	ASTM D4533	per 100,000-ft^2
	Apparent Opening Size	ASTM D4751	per 100,000-ft^2
	Permittivity	ASTM D4491	per 100,000-ft^2
	UV Light Resistance	ASTM D4355	per 100,000-ft^2
	Burst Strength	ASTM D3786	per 100,000-ft^2
Conformance Testing by 3rd Party Independent Laboratory	Thickness	ASTM D5199	per 100,000-ft^2
	Mass per Unit Area	ASTM D5261	per 100,000-ft^2
	Grab Tensile Strength (%)(MD/CD)[1]	ASTM D4632	per 100,000-ft^2
	Grab Elongation (%)(MD/CD)[1]	ASTM D4632	per 100,000-ft^2
	Puncture Strength	ASTM D4833	per 100,000-ft^2
	Trapezoidal Tear Strength	ASTM D4533	per 100,000-ft^2
	Apparent Opening Size	ASTM D4751	per 100,000-ft^2
	Permittivity	ASTM D4491	per 100,000-ft^2
	Burst Strength	ASTM D3786	per 100,000-ft^2

Note: MD/CD = MD - Machine Direction/CD - Cross Direction

Table C.4 - STANDARD TESTS FOR GEOCOMPOSITE MATERIALS

Test	Type of Test	Standard Test Method	Frequency of Testing
Manufacturer's Quality Control	Thickness	ASTM D5199	per manufacturer's quality control specifications
	Mass per Unit Area	ASTM D3776 (Option C)	per 100,000-ft^2 and every resin lot
	Ply Adhesion	ASTM D7005	per 100,000-ft^2 and every resin lot
	Transmissivity	ASTM D4716	per 100,000-ft^2 and every resin lot
Conformance Testing by 3rd Party Independent Laboratory	Thickness	ASTM D5199	per 100,000-ft^2 and every resin lot
	Mass per Unit Area	ASTM D3776 (Option C)	per 100,000-ft^2 and every resin lot
	Carbon Black Content	ASTM D4218	per 100,000-ft^2 and every resin lot
	Tensile Strength	ASTM D7179	per 100,000-ft^2 and every resin lot

Note: Geotextiles used in Geocomposite shall be tested in accordance to Table C.3

5.0 LEAK DETECTION SYSTEM

A leak detection system (LDS) will be placed between the upper and lower GML layers. The LDS consists of an HDPE geonet on the floor and a geocomposite on the side slopes. A 6-inch leak detection pipe will be placed at each sump between the two GML layers. An HDPE boot will be placed around the leak detection pipe above the upper GML penetration and extrusion welded to the GML to create a seal and maintain the integrity of the liner system. The geonet and geocomposite will meet the requirements listed above in Section 4.0.

5.1 Installation

On the side slopes, the geocomposite material shall be anchored in the anchor trench then rolled down the slopes, ensuring no excessive slack is maintained in the geocomposite. The geocomposite shall extend 5-feet onto the floor before transitioning to the geonet. All panels (geonet/geocomposite) shall overlap a minimum of 6-inches. A plastic cable tie shall connect geocomposite and geonet panels at an interval of one (1) per every five (5) feet in the machine direction and one (1) per every foot in the transverse direction. Overlapping geocomposite panels shall have their upper geotextile component sewn or heat bonded to one another per project specifications.

6.0 BALLAST/PROTECTIVE COVER

6.1 General

This section addresses the need for soil or waste ballast at the landfill and covers the work necessary for construction of the protective cover system over the LCS. The protective cover system proposed for use at the landfill uses available soil onsite as the cover material, as described in Section 6.3.

6.2 Ballast

Based on the measured groundwater depths, the excavated landfill cells will be well above the seasonal high water table. As a result, ballasting of the cells against hydrostatic uplift will not be required at this facility.

6.3 Protective Cover

A minimum 2-foot thick protective cover will be placed above the LCS. The protective cover may use onsite soils in combination with the chimneys described in Section 4.3. The maximum gravel size shall not exceed 2-inches. Pre-construction and conformance testing for the protective cover soils will include maximum size gradation with a minimum conformance testing frequency of one grain-size analysis (ASTM D422) per 5,000-cubic/yards (or fraction thereof) of in-place material.

Protective cover does not require compaction control; however, it should be stable for construction and disposal after traffic. Care will be used in placement so as not to shift, wrinkle, or damage the underlying geosynthetic layers, and placement methods will be documented. Protective cover will be placed such that the top surface, while spreading, is at least 2-feet above the geosynthetic layers at all times, unless low-ground pressure dozers are used (i.e. track pressure less than 5-psi). 1-foot minimum should be retained between the low-ground pressure dozer and the geosynthetic layer. A greater thickness will be maintained to support loaded hauling trucks and trailers for turning areas. Drivers will proceed with caution when on the overlying soil and prevent spinning of tires on sharp turns.

Protective cover will generally be placed in an up-slope direction for sidewalls as long as the same material is being used. Where the top few feet of sidewalk (typically less than 5-feet vertically) is to be protected by a different soil type, (such as clay for tying in the final cover soil liner), this material may be placed from the top if adequate care is taken to protect the synthetic liner components.

The required thickness of protective cover will be verified by survey methods on an established grid system with not less than on verification point per 5,000-sq/feet of surface.

7.0 GCLER, GMLER, AND CONSTRUCTION DOCUMENTATION

Upon completion of all required liner construction and evaluation, the GP will prepare and submit both the Soil Liner Evaluation Report (GCLER) and Geomembrane Liner Evaluation Report (GMLER) to the division for review and approval. These will be submitted along with a construction documentation report. Multiple submittals of the reports or documentation during the project may be made if they may facilitate review of the project. The GCLER and GMLER will be signed and sealed by Professional Engineer registered in the State of New Mexico and who has applicable expertise in liner engineering.

The construction documentation will contain a narrative describing the conduct of work and testing programs required by the SLQCP, as-built or record drawings, and appendices of field and laboratory data. Because the volume of data of these projects can be quite large, the documents may be subdivided for ease of review. The preferred document format will include the GCLER, GMLER, narrative, as-built drawings, and summaries of test results in a single volume. The remaining appendices will be placed in accompanying volumes. Specifically, the construction documentation report will contain or discuss the following information, at a minimum, for GML:

- Roll shipment and receipt information.
- Manufacturer quality control certificates and results.
- Storage and handling information.
- Conformance test sampling and test results.
- Seamer names and resumes of experience and qualifications.
- Subgrade acceptance.
- Anchor trench preparation and backfilling.
- Seam preparation, orientation, and identification
- Weather and ambient/sheet temperatures.
- Equipment placed or operated on geomembrane.
- 100% visual inspection for defects, damage, etc.
- Trial seam tests for each combination of seaming equipment and personnel.
- Seaming methods, times, temperature, and equipment shutdowns and startups.
- Continuous 100 percent non-destructive seam testing, methods, criteria and results
- Destructive testing methods criteria and results.
- Repairs, including preparation and procedures, failure delineation, patch size and shape, and retesting.
- Material properties and placement of drainage materials and protective covers.

Permit Application

Lea County, New Mexico
C.K. Disposal E & P Landfill and Processing Facility
Permit No. TBD

Attachment D
Final Cover Quality Control Plan
NMAC 19.15.36.14(C)(8)

November 2015
PSC Project # 01058015

PARKHILLSMITH&COOPER

ATTACHMENT D - FINAL COVER QUALITY CONTROL PLAN

TABLES

1.0 INTRODUCTION

This Final Cover Quality Control Plan (FCQCP) has been prepared to provide the Owner, Design Engineer, Construction Quality Assurance Professional of Record, and the Contractor the means to govern the construction quality of the prescriptive final cover and the alternate soil final cover system and to satisfy the environmental protection requirements under New Mexico Administrative Code (NMAC) regulations. Final cover design consists of a prescriptive cover with a geocomposite replacing the gravel drainage layer along the crown of the landfill as well as an alternate cover design to be used on the 4:1 side slopes on the landfill cap. The covers are designed to prevent the "bathtub effect" which occurs when a more permeable cover is placed over a less permeable bottom liner. NMAC 19.15.36.14(C) allows the operator to propose a performance-based landfill design system using geosynthetics, including geocomposites and geosynthetic clay liners, when supported by EPA's "hydrologic evaluation of landfill performance" (HELP) model or other division-approved model preventing the "bathtub effect." Demonstrations of both liner system performances are included in Attachment E – HELP Model.

1.1. Definitions

This section provides the definitions for terms used in this FCQCP.

A. ASTM

American Society for Testing and Materials.

B. Contract Documents

These are the official set of documents issued by the Owner. The documents include bidding requirements, contract forms, contract conditions, specifications, contract drawings, addenda, and contract modifications.

C. Contract Specifications

Qualitative requirements for products, materials, and workmanship upon which the contract is based.

D. Contractor

Person(s), firm, partnership, corporation, or any combination, private or public, who, as an independent contractor, has entered into a contract with the Owner, and who is referred to throughout the contract documents by singular number and masculine gender.

E. Construction Quality Assurance (CQA)

A planned system of activities providing the Owner and permitting agency assurance the facility was constructed as specified in the design (EPA, 1986). Construction quality assurance includes observations and evaluations of materials as well as workmanship necessary to determine and document the quality of the constructed facility. CQA refers to measures taken by the CQA Organization to assess if the installer or contractor is in compliance with the plans and specifications for a project.

F. Construction Quality Assurance (CQA) Monitors

CQA monitors are representatives of the Professional of Record (POR) who work under direct supervision of the POR. The CQA monitor is responsible for quality assurance monitoring and performing onsite tests and observations. The CQA monitor is onsite full-time during construction and reports directly to the POR. The CQA monitor performing daily quality assurance/quality control (QA/QC) observation and testing shall have a minimum of four (4) years of directly related experience or a graduate engineer or geologist with one (1) year of directly related experience. Field observations, testing, or other activities associated with CQA may be performed by the CQA monitor(s) on behalf of the POR. Additional CQA monitors may be used. If working under the direction of a CQA monitor, the second CQA monitor shall have a minimum of one (1) year of directly related experience.

G. Construction Quality Assurance (CQA) Professional of Record (POR)

The POR is an authorized representative of the Owner and has overall responsibility for construction quality assurance to confirm the facility was constructed in general accordance with plans and specifications approved by the permitting agency. The POR must be licensed as a Professional Engineer or Geologist in New Mexico and experienced in geotechnical testing and interpretations. Experience and/or education may include geotechnical engineering, engineering geology, soil mechanics, geotechnical laboratory testing, construction quality assurance, quality control testing, and hydrogeology. The credentials of the POR must meet or exceed the minimum requirements of the permitting agency. Any references to monitoring, testing, or observations to be performed by the POR should be interpreted to mean the POR or CQA monitors working under POR direction. The POR may also be known in applicable regulations as the CQA Engineer or Resident Project Representative.

H. Final Cover Evaluation Report (FCER)

Upon completion of closure activities, the certification will be in the form of the FCER, signed by the POR and include all documentation necessary for certification of closure.

2.0 CONSTRUCTION QUALITY ASSURANCE FOR ALTERNATIVE COVER SYSTEM

2.1. Introduction

This section of the FCQCP Plan addresses the construction of the soil components of the alternative cover system and outlines the program to be implemented with regard to materials selection and evaluation, laboratory test requirements, field test requirements and treatment of problems. The alternative cover system will be used on the sideslopes of the final cap. The scope of earthwork and related construction quality assurance includes the following elements (from bottom to top):

- 6-inch Daily Cover and 6-inch Intermediate Cover Layer
- 24-inch Infiltration Layer
- 12-inch Soil Erosion Layer

The Owner/Operator shall notify the division a minimum of 72-hours before construction of any final cover system installation, to allow the division to witness installation.

2.2. Earthwork Construction

The following paragraphs describe soil properties, general construction procedures, and QA/QC methods used in construction of the various layers of the final cover system.

A. Final and Intermediate Cover Layer

After the landfill reaches the maximum permitted grade of waste, soil will be placed according to the Site Operating Plan. The layer will consist of soil from the landfill site currently used as daily cover. A minimum of two (2) 6-inch layers of soil will be placed over the waste, prior to commencing work on the Final Cover System. The contractor will re-work the soil to provide a smooth surface, free of rocks and material larger than 2-inches in diameter with soils compacted to a minimum 80% Standard Proctor Density. The soils will be graded to an elevation 36-inches below the proposed final contours. QA/QC for preparation of this layer will be performed under the supervision of the CQA POR. Upon completion of grading, the POR will determine that the layer is prepared to provide a uniform surface and that it will adequately serve as the foundation for the overlying infiltration layer. Once the intermediate soil is placed, graded, and approved, a survey will be performed to verify the final and intermediate cover is a minimum 12-inches thick. The layer will be probed every 100-feet in each direction to verify a thickness of 12-inches.

B. Infiltration Layer

The infiltration layer will consist of a 24-inch thick minimum soil layer (measured perpendicular to the final and intermediate cover layer surface) placed on the side slope of the landfill. Material used for this layer will be obtained from the landfill site. It will be placed as two (2) 12-inch lifts, and will be compacted to approximately 85% of standard proctor (ASTM D698) density (+5%), at a moisture content within +/-2% of optimum. The material may be classified as SM, SP, SW or SC according to the Unified

Soil Classification System (USCS). Testing will be completed, as needed, to classify the soil according to the USCS. Over compacted soil in the infiltration layer will be disked or ripped (or any method approved by the POR) and recompacted to a density within the acceptable limits. If a density test fails, additional tests may be performed to define the over compacted area. The area to be reworked, then, will be the area between passing density tests. The infiltration layer construction will be conducted in a systematic and timely fashion. Delays will be avoided in completing the infiltration layer. Placement of the infiltration layer will cease during rainfall events to prevent over-compaction. Before proceeding with construction after a rainfall event greater than 0.5-inches, the Contractor will complete, at a minimum, a 10-foot by 10-foot test pad to verify that over-compaction will not occur as construction continues. A minimum of two (2) field density tests are required per test pad area. Test pad results will be reported in the Final Cover Evaluation Report.

C. Soil Erosion Layer

The soil erosion layer will be placed on top of the infiltration layer over the entire surface of the final cover. The soil will have a minimum thickness of 12-inches and capable of sustaining vegetation. The soil will be placed in 6-inch lifts, at 85% standard proctor (ASTM D698) density and within +/-5% of optimum moisture content. The material may be classified as SM, SP, SW, or SC according to the Unified Soil Classification System (USCS). Testing will be completed, as needed, to classify the soil according to the USCS. Over-compacted soil in the soil erosion layer will be disked, ripped, (or any method approved by the POR), and recompacted to a density within the acceptable limits. If a density test fails, additional tests may be performed to define the over-compacted area. The area to be re-worked, then, will be the area between passing density tests. The surface of the soil cover should be graded to the final grades as shown in Attachment B - Engineered Design Plans, and disked parallel to the proposed contours in preparation for seeding and to prevent excessive erosion after rainfall. The erosion control layer should be placed under the continuous QA/QC observation to ensure a minimum thickness of 12-inches is applied and existing structures are protected. Placement of the erosion control layer will be stopped during rainfall events to prevent over-compaction of the soil. Construction will continue once CQA personnel determine the soil can be effectively disked. Structural Best Management Practices (BMP) and an effective vegetation plan will aid in erosion prevention. Surveying will be performed to verify that the vegetative cover layer has been installed to the minimum thickness of 12-inches.

D. Establishment of Vegetation

Permanent vegetation will be established using appropriate seasonal seeding mixtures. Seeding or sodding shall be performed immediately following application of the final cover.

2.3. Survey and Final Topography

Upon completion of the final cover construction, a topographic survey will be performed by a land surveyor licensed in the state of New Mexico. The final contour map should include all final contours, location of gas vents, gas monitoring wells, groundwater monitoring wells, drainage structures, fences, gages, access roads, and all other pertinent site features.

2.4. Sampling and Testing

As construction progresses, CQA monitors will conduct field and laboratory tests using standards set forth in the technical specifications. Standard operating procedures for soil testing will be prepared for site testing personnel that follow ASTM Test methods. These procedures will be for the following tests: Soil classification, moisture density relationship, field density and moisture, and thickness verification.

A. Soil Classification

Soil samples for analysis will be collected for the purpose of classifying the soil using the USCS. One (1) sample is required per soil type. The test procedure to follow in the laboratory will be ASTM D2487 and 2488 for soil classification. Extra testing must be performed whenever work or materials are suspect, marginal, or of poor quality. Extra testing may be conducted to provide additional data for engineering. Tests that do not meet minimum requirements will not contribute to the total number of tests performed in meeting the required test frequency.

B. Moisture Density Relationship of Soils

Soil samples will be collected for analysis to determine the Atterberg Limits, the percent passing the No. 200 sieve, and permeability. One (1) sample per soil type is required. The test procedure to follow in the laboratory will be ASTM D698. Extra testing must be performed whenever work or materials are suspect, marginal, or of poor quality. Extra testing may be conducted to provide additional data for engineering. Tests that do not meet minimum requirements will not contribute to the total number of tests performed in meeting the required test frequency.

C. Field Density and Moisture

Soil testing will be performed in situ or on undisturbed samples for the purpose of determining field density and moisture content. Three (3) tests are required per soil layer per acre. The test procedure to be followed for soil density will be ASTM D2922, performed in the field. The test procedure to follow for moisture content is either ASTM D2216 (laboratory) or ASTM D3017 (in situ). Extra testing must be performed whenever work or materials are suspect, marginal, or of poor quality. Extra testing may be conducted to provide additional data for engineering. Tests that do not meet minimum requirements will not contribute to the total number of tests performed in meeting the required test frequency.

D. Thickness Verification

Testing or surveying will be performed to ensure the constructed layer thicknesses meet minimum requirements. This verification will be performed at the top of the foundation layer, top of the vegetative support layer, and top of the vegetative cover layer. The work will be performed every 100-feet in each direction on a grid established by a land surveyor licensed in the State of New Mexico.

3.0 CONSTRUCTION QUALITY ASSURANCE FOR THE PRESCRIPTIVE COVER SYSTEM WITH GEOCOMPOSITE

3.1. Introduction

This section of the FCQCP Plan addresses the construction of the components in the prescriptive system and outlines the program to implement regarding materials selection and evaluation, laboratory test requirements, field test requirements, and treatment of problems. The scope of earthwork and related construction quality assurance includes the following elements (from bottom to top):

- 6-inch Daily Cover and 6-inch Intermediate Cover Layer
- 60-mil High Density Polyethylene (HDPE) Liner
- Geocomposite Liner
- 24-inch Infiltration Layer
- 12-inch Soil Erosion Layer

The Owner/Operator shall notify the division a minimum of 72-hours prior to construction and installation of any final cover system, to allow the division to witness installation.

3.2. Earthwork Construction

The following paragraphs describe soil properties, general construction procedures, and QA/QC methods to use in construction of the various layers of the final cover system.

A. Final and Intermediate Cover Layer

After the landfill reaches the maximum permitted grade of waste, final and intermediate cover soil will be placed according to the Site Operating Plan. The layer will consist of soil from the landfill site currently used as daily cover. A minimum of two (2) 6-inch layers of soil will be placed over the waste prior to commencing work on the Final Cover System. The contractor will rework the soil to provide a smooth surface, free of rocks and material larger than 2-inches in diameter, with soils compacted to a minimum 80% Standard Proctor Density. The soils will be graded to an elevation 36-inches below the proposed final contours. QA/QC for preparation of the layer will be performed under the supervision of the CQA POR. Upon completion of grading, the POR will determine the final and intermediate cover layer has been prepared to provide a uniform surface and will adequately serve as the foundation for the overlying base layer. Once soil is placed, graded, and approved, a survey will be performed to verify the final and intermediate cover is a minimum 12-inches thick. The layer will be probed every 100-feet in each direction to verify a thickness of 12-inches.

B. 60-mil High Density Polyethylene (HDPE) Liner

i. General

This Section covers the work necessary to construct and test the geomembrane lining (GML) system, which will consist of 60-mil high density polyethylene (HDPE) material. The objective is to provide an effective lining system at the completion of the work. The geomembrane liner shall generally conform to the testing requirements of GRI Standard GM13 – Test Properties, Testing Frequency and Recommended Warrant for High Density Polyethylene (HDPE) Smooth Textured Geomembranes, (Geosynthetic Research Institute; Folsom, PA; November 2014), except as modified herein.

ii. Submittals

a. Manufacturer's Certification of SLQCP Conformance

The Contractor shall submit written certification by the Manufacturer that the lining materials conform to the requirements of the SLQCP in Attachment C, are similar and of the same formulation as the certification submitted, and demonstrated by actual usage to be satisfactory for the intended application.

b. Contractor's and Manufacturer's QC Program

The Manufacturer and the Contractor shall each submit a complete description of the quality control program as applicable for manufacturing, handling, installing, testing, repairing, and providing a completed lining in accordance with requirements of the SLQCP in Attachment C. The description shall include but not be limited to polymer resin supplier, product identification, acceptance testing, fabrication and production testing, installation testing, documentation of changes, alterations and repairs, retests, and acceptance. Each shall present documented evidence of its ability and capacity to perform this Work.

c. Contractor's Installation Plan

The Contractor shall submit installation drawings, descriptions of installation procedures, and a schedule for performing/completing the Work. Installation drawings shall show a lining sheet layout with proposed size, number, position, and sequence of sheets placing and indicating the location of all field seams. Installation drawings shall also show complete details and/or methods for anchoring the lining at the perimeter, making field seams, and making anchors/seals to pipes and structures.

The Contractor shall submit a complete description of welding procedures for making field seams and repairs. The welding procedures shall conform to the latest procedures recommended by the lining Manufacturer and to the SLQCP.

The Contractor shall also submit for approval that the surface(s) on which the lining will be placed is acceptable by the Geotechnical Professional certification. Installation of the lining shall not commence until certification is furnished to the Geotechnical Professional.

d. Manufacturer's Warranty

The lining Manufacturer shall furnish a written lining material warranty as described in GRI GM13. The warranty shall be against manufacturing defects or workmanship and against deterioration due to ozone, ultraviolet, or other normal weather aging. The warranty shall be limited to replacement of material only and shall not cover installation of said material. It shall not cover damage due to vandalism, acts of animals, or supernatural acts of God. The warranty shall be for a period of 5 years from the date of GML installation.

e. Contractor's Warranty

The Contractor shall furnish a written guarantee that the entire lining work constructed by him to be free of defects in material and workmanship and installed pursuant to the SLQCP for a period of two (2) years following the date of acceptance of the work by the Geotechnical Professional. During the 23rd month, a pre-guarantee expiration inspection will be conducted to identify any necessary repair work covered by the guarantee. The Contractor shall agree to make any repairs or replacements made necessary by defects in materials or workmanship in the Work which become evident within said guarantee period. The Contractor shall make repairs and/or replacements promptly, the Owner may do so, and the Contractor shall be liable to the Owner for the cost of such repairs and/or replacements.

iii. Quality Assurance

Prior to start of work, the lining Manufacturer and the Contractor shall each submit for approval by the Geotechnical Professional documented evidence of the ability and capacity to perform this Work. Each shall have successfully manufactured and/or installed a minimum of 2-million sq.ft. of similar lining material in waste and/or liquid processing containment structures. The Contractor can meet these criteria by teaming with a subcontractor who is identified in the bid along with the firm's experience.

The Contractor shall submit the name and qualifications of the project superintendent assigned to the project whenever lining materials are handled/installed, as well as the names and qualifications of senior installation personnel on the project.

The Quality Control Plan(s) to implement for the Work by the lining Manufacturer and the Contractor shall be in accordance with applicable paragraphs of the SLQCP.

The Manufacturer shall provide onsite technical supervision and assistance at all times during installations of the lining system. The Manufacturer and Contractor, as applicable to each, shall submit for approval by the Geotechnical Professional written certification that the lining system was installed in accordance with the Manufacturer's recommendation, the SLQCP, project specification and drawings, and approved submittals.

The Geotechnical Professional will initiate a pre-installation meeting with the Manufacturer and Contractor before installing the lining system. Topics for review/discussion shall include, as a minimum, project plans and specifications, approved submittals, training and qualification procedures for Contractor personnel, and demonstration of making field-welded seam(s)-included peel and shear tests.

Prior to installation of the lining system, the Contractor shall instruct the workmen of the hazards of installation such as handling sheets of lining material in high winds, use of equipment, application of solvents, adhesives and caulks, and walking on lining surfaces. Work gloves, safety glasses, hard hats, and smooth-soled shoes are minimum safety wear requirements when working on the GML. Safety shoes must be worn when handling heavy objects.

The Geotechnical Professional shall have authority to order an immediate stoppage of work because of improper installation procedures, safety infractions, or for any reason resulting in a defective liner.

4.0 DELIVERY, STORAGE AND HANDLING

The Contractor shall submit for approval by the Geotechnical Professional method(s) for handling and storage of lining material(s) delivered to the project site. These materials shall be stored in accordance with the Manufacturer's recommendation.

Lining materials delivered to the site shall be inspected for damage, unloaded, and stored with a minimum of handling. Materials shall not be stored directly on the ground. The storage area shall be such that all materials are protected from mud, soil, dirt, and debris. The stacking of lining shall not be higher than two (2) rolls.

Under no circumstances shall the lining be subjected to materials, sandbags, equipment, or other items dragged across its surface. Nor shall workmen and others side down slopes atop the lining. All scuffed surfaces resulting from abuse of any kind caused by the Contractor in performance of the work shall be repaired at the Geotechnical Professional's direction.

The Contractor shall be completely responsible for shipping storage, handling, and installation of all lining materials in compliance with SLQCP.

5.0 PRODUCTS

The HDPE lining materials shall be new, first quality products designed and manufactured specifically for the purposes of the Work and shall have satisfactorily demonstrated by prior use to be suitable and durable for such purposes. The geomembrane shall be unmodified HDPE containing no plasticizers, fillers, chemical additives, reclaimed polymers, or extenders. For ultraviolet resistance, the GML material shall contain not less than 2.0% carbon black as determined by ASTM D1603. The only other compound ingredients to be added to the GML shall be antioxidants and heat stabilizers required for manufacturing. The GML shall be supplied as a single ply continuous sheet with no factory seams and in rolls with a minimum width of 15-feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest field seams.

The GML lining materials shall be as manufactured by GSE Lining Systems, Inc., Houston, Texas; Poly-America, Inc. Grand Prairie, Texas; National Seal Company, Galesburg, Illinois; or approved equal.

The standard tests described in Table D.1 will be performed on the GML material.

Table D.1 – STANDARD TESTS ON HDPE GML MATERIAL

Test	Type of Test	Standard Test Method	Frequency of Testing
Resin	Melt Flow Index	ASTM D1238	per 100,000 ft^2 and every resin lot
	Specific Gravity/Density	ASTM D1505	per 100,000 ft^2 and every resin lot
Manufacturer's Quality Control	Thickness	ASTM D5199 or ASTM D5994	per 100,000 ft^2 and every resin lot
	Specific Gravity/Density	ASTM D1505	per 100,000 ft^2 and every resin lot
	Carbon Black Content	ASTM D1603	per 100,000 ft^2 and every resin lot
	Carbon Black Dispersion	ASTM D5596	per 100,000 ft^2 and every resin lot
	Tensile Properties	ASTM D6693, Type IV	per 100,000 ft^2 and every resin lot
	Tear	ASTM D1004	per 100,000 ft^2 and every resin lot
	Puncture	ASTM D4833	per 100,000 ft^2 and every resin lot
Conformance Testing by 3rd Party Independent Laboratory	Thickness	ASTM D5199 or ASTM D5994	per 100,000 ft^2 and every resin lot
	Specific Gravity/Density	ASTM D1505	per 100,000 ft^2 and every resin lot
	Carbon Black Content	ASTM D1603	per 100,000 ft^2 and every resin lot
	Carbon Black Dispersion	ASTM D5596	per 100,000 ft^2 and every resin lot
	Tensile Properties	ASTM D6693, Type IV	per 100,000 ft^2 and every resin lot

Note: A-NSF 54 modified with 2-in Initial gauge length assumed for elongation at break.

Extrusion resin used for fusion welding with extrudate to make field seams between GML sheets and for repairs shall be HDPE produced from and the same as the HDPE sheet resin. Physical properties shall be same as HDPE lining sheets.

6.0 INSTALLATION PROCEDURES

Prior to installation of the GML, a site inspection will be conducted by the Geotechnical Professional and the Contractor to verify measurements, structures, and surface conditions to support the GML. The Contractor will provide written documentation to the Geotechnical Professional that surfaces to receive the GML have been inspected and are acceptable for installation of the lining.

Before the work begins, the Contractor will inspect all lining materials for damage from transit. Materials that cannot be repaired will be rejected and removed from the work area and site. During unwrapping of lining materials for use and placement, the Contractor will visually inspect all materials, particularly surfaces of lining sheets, for imperfections and faulty areas. All such defective places will be marked and repaired in accordance with approved methods.

The GML will be installed as shown on the project plans and approved installation drawings. Placement of the GML will be done such that good fit, without bridging, is a provided on all covers and grade changes. Excessive slack will be avoided to minimize rippling during the soil cover operation.

Sheets of GML materials will be of such lengths and widths and placed in such a manner as to keeping field seaming to a minimum. The lining will be anchored according to details shown on approved plans and drawings. The lining will be anchored and sealed to structures, pipes, and other types of penetrations, (if any), in accordance with details shown on approved plans and drawings. All changes in approved installation drawings and procedures must be approved by the Geotechnical Professional.

Extreme care will be taken during installation of the lining to be certain no damage is done to any part of the lining. Dragging of the GML material on the foundation layer will be avoided. Smoking by the installation personnel will be prohibited. All handling and installation procedures will be performed by workers wearing shoes with smooth soles. Shoes with patterned soles in relief shall be prohibited. No foot traffic will be allowed on the lining. All motor-driven equipment using fuel will have spark arrestors. No gasoline-driven generators or cans of gas or solvent will be placed directly on the lining material. Under no circumstances will the lining be used as a work area to prepare patches or to store tools and supplies. If needed, a tarpaulin of approved material will be spread out as a work area.

During installation, the Contractor will be responsible for protecting the lining against adverse effects of high winds such as uplift. Sand bags will be used, as required, to hold the lining material in position during installation. Sand bags will be sufficiently close-knit to preclude fines from working through the bottom, sides, or seams. Paper bags, whether or not lined with plastic, will not be permitted. Burlap bags, if used must be lined with plastic. Bags will contain not less than 40-pounds, nor more than 60-pounds of sand having 100% passing a number 8 screen and will be tied closed after filling, using only plastic ties. Bags that are split, torn, or otherwise losing the contents will immediately be removed from the work area and any spills immediately cleaned up. Metal or wire tires will not be used.

During installation, water shall not be allowed to pond on the GML material. The contractor shall have available appropriate pumps to immediately remove ponding water.

The GML material will not be installed under adverse climatic conditions unless the Contractor can demonstrate that his installation techniques adequately compensate for such adverse conditions and quality of workmanship is not compromised. Adverse climatic conditions occur when the air temperature measured 6-inches above the GML surface is less than 32°F and decreasing, or more than 90°F; when relative humidity is more than 80%; when raining; frost on the ground; or during conditions of excessive winds.

GML field seams will be lap seams as shown on approved plans and drawings. The lap seams will be formed by lapping the edges of GML sheets a minimum of 4-inches. The contact surfaces of the sheets will be wiped clean to remove dirt, dust, moisture, and other foreign materials. For fillet weld seams, bevel edge of GML and clean oxidation from surfaces to receive extrudate by disk grinding or equivalent not more than one (1) hour before seaming.

Lap seam intersections involving more than three (3) thicknesses of lining material will be avoided, and all seam intersections will be offset at least 2-feet. Non-horizontal field seams will be allowed on the slope and sheets of lining material on the slopes will extend down slope out onto bottom a minimum of 5-feet from the toe of slope.

Field seams between sheets of GML material will be made using approved fusion welding systems, equipment, and techniques. Approved fusion welding systems include fillet weld using extrudate, lap weld using extrudate, and lap weld using single or double wedge welder. If the wedge welder is used, excess free edge of the seam (wider than 3-inches) of the top sheet will be removed without affecting the integrity of the seam.

Any necessary repairs to the GML will be made with the lining material itself, using approved fusion welding systems, equipment, and techniques. The patch size will be 4-inches larger in all directions than the area to be patched. All corners of the patch will be rounded with a 1-inch minimum radius.

All seams and seals of the GML will be tightly bonded on completion of the work. Any lining surface showing injury because of scuffing or penetration by foreign objects or showing distress will be replaced or repaired as directed by the Geotechnical Professional.

Cleanup within the work area will be an ongoing responsibility of the Contractor. Particular care will be taken to ensure no trash, tools, or other unwanted materials are trapped beneath the lining. Care will be taken to ensure all scraps of lining materials are removed from the work area prior to completion of the installation.

7.0 FIELD QUALITY CONTROL

Inspection and testing will involve the fulltime observation of the installation of the GML, including the making and testing of lining seams, patches, and period measurement of the liner material thickness to ensure compliance. Field thickness measurements must be taken for each panel before it is seamed. The material thickness shall be checked using a micrometer at a minimum frequency of one (1) measurement per 5-feet along the leading edge of each panel with a minimum of five (5) measurements along the leading edge of the panel. No single measurement shall be less than 10% below the required nominal thickness in order for the panel to be accepted. In addition, the average of all measurements along the edge must be at least 60-mils.

Test seams will be made to verify that adequate conditions exist for field seaming to proceed. Each seamer will produce a test seam at the beginning of each shift to determine the peel and tensile strength of the seam. The Geotechnical Professional may require a sample field seam be made at any time during seaming production to verify equipment/operator performance and seam integrity. In addition, if a seaming operation has been suspended for more than half an hour or if a breakdown of the seaming equipment occurs, a test seam will be produced prior to resumption of seaming operations.

The trial weld sample must be a minimum of 3-feet long and 1-foot wide with the seam centered lengthwise. The Geotechnical Professional must observe all trial welding operations, quantitatively test each trial weld for peel and shear, and record the results. A minimum of two (2) peel and two (2) shear tests will be performed per trial seam. Double wedge weld trial seams shall have a minimum of four (4) peel tests performed. The trial weld shall be completed under the same conditions for which the panels will be welded. The trial weld must meet the requirements for peel and shear as stated in the following paragraph and the break must be ductile or a film tearing bond (FTB) for a wedge weld or extrusion weld.

During the field seaming operation, destructive samples will be removed from field seams by the Contractor at locations selected by the Geotechnical Professional. Repairs to the field seams will be made in accordance with repair procedures specified in the SLQCP. The samples will have a width of 12-inches plus the seam width and length of 42- to 48-inches. A minimum of one (1) stratified sample per 500-feet of field seam will be made. All field seams will have a fil tear bond in peel and shear and a minimum pound-per-inch width seam strength in shear when tested as specified in this SLQCP. At the very least, the peel adhesion and bonded shear strength must be 62% and 95% respectively of the strength of the parent material, but not less than 78-ppi and 120-ppi respectively. A sufficient amount of the seam must be removed in order to conduct field testing, independent laboratory testing, and archiving of enough material to retest the seam when necessary. The archived material will be kept at the independent laboratory. Field testing shall include at least two (2) peel tests per sample (four (4) when possible for testing both tracks on dual-track fusion welded seams). Destructive seam-testing locations shall be cap-stripped and the cap completely seamed by extrusion welding to the GML. Capped sections shall be non-destructively tested. Additional destructive test samples may be taken if deemed necessary by the Geotechnical Professional or his representative.

All field-tested samples from a destructive-test location must be passing in both shear and peel for the seam to be considered passing. The independent laboratory testing must confirm these field results. The passing criterion for independent laboratory testing includes four (4) of five (5) samples from each dual track fusion welded seam, when possible to test each seam, must be passing before the seam is considered as passing. Sample testing will be conducted by an independent testing agency who will save all test samples including specimens tested until notified by the Geotechnical Professional relative to their disposal. All specimens which have failed under test will be shipped immediately by express delivery to the Geotechnical Professional for determination or corrective measure to be taken, including retest or repair of failed section.

For destructive samples which have failed the passing criterion, the Contractor will reconstruct all the field seams between any two (2) previously passed seam locations which include the failed seam or will go on both sides of the failed seam location (10-feet minimum), take another sample each side, and test both. If both pass, the Contractor will repeat the process of taking samples for test. In all cases, acceptable field seams must be bound by two (2) passed test locations. The decision of the Geotechnical Professional will be final.

If field seam capping is required, the Contractor will use a cover strip of the same thickness as the lining (and from the same roll, if available) and of 8-inches minimum width. It will be positioned over the center of the field seam and welded to the lining using a fillet weld on each side.

All GML sheets, seams, anchors, seals, and repairs will be visually inspected by the Contractor for defects. In addition, all seams and repairs will be further checked by a metal probe. Depending on seam welding equipment sued, all seams and repairs will be tested by a vacuum testing device, a spark testing device, and/or air pressure. A visual inspection of the lining sheets, seams, anchors, and seals will be made by the Contractor as the installation progresses, and again on completion of the installation. Defective and questionable areas will be clearly marked and repaired. Final approval of repairs will be given by the Geotechnical Professional.

The Contractor will run a metal probe, such as a dull-pointed ice pick, along the length of all seams and repairs to ensure that the seam is a continuous and absent of leak paths. Defects will be clearly marked and repaired.

If the fillet weld, extrusion lap weld, or single hot-wedge fusion weld is used to weld seams, the Contractor will further test all seams and repairs in the GML by vacuum box. All vacuum box testing will be done in the presence of the Geotechnical Professional. The testing area will be cleaned of all dust, debris, dirt, and other foreign matter. A soap solution will be applied to the test area with a paint roller and the vacuum of 3-psi air pressure will be induced and held at least ten (10) seconds to mark for repair any suspicious areas as evidenced by bubbles in the soap solution.

If the fillet weld is used to weld seams, the Contractor will further test all seams and repairs in the GML by using a high voltage spark detector if vacuum box or air pressure methods cannot be performed. The setting of the detector will be 20,000-volts. To conduct this test, all seams to be tested will be provided with not less than gauge 24-30 copper wires properly embedded in the seams and grounded. All spark testing will be done in the presence of the Geotechnical Professional and defective areas marked for repair.

If the double hot-wedge is used, the Contractor will further test all seams in the GML by using the air pressure test consisting of inserting a needle with gauge in the air space between the welds. Air will be pumped into space to 35-psi and held for five (5) minutes. If pressure is not maintained, then the seam is unacceptable.

All costs of retesting of the GML including reruns of field weld tests and all repairs, will be at the Contractor's expense. The Contractor will retain responsibility for the integrity of the GML system until acceptance by the Geotechnical Professional. The GML will be accepted by the Geotechnical Professional when:

- Written certification letters including "as built" drawings are received by the Geotechnical Professional.
- Installation is complete.
- Documentation of completed installation, including all reports is complete.
- Verification of adequacy of field seams and repairs including associated testing is complete.

Acceptance of the competed work will include receipt of all submittals and all work completed to the satisfaction of the Geotechnical Professional.

A. Geocomposite

The geocomposite will be formed of two (2) non-woven geotextiles heat bounded to a geonet core. The geotextile on both sides of the geonet will be a minimum 8-ounce non-woven material meeting the standard test requirements in Table D.2. The geocomposite will be deployed directly on top of the geomembrane. The infiltration layer will be carefully spread on top of the geocomposite to avoid damage to the liner system.

Table D.2 – STANDARD TESTS FOR GEOCOMPOSITE MATERIALS

Test	Type of Test	Standard Test Method	Frequency of Testing
Manufacturer's Quality Control	Thickness	ASTM D5199	per manufacturer's quality control specifications
	Mass per Unit Area	ASTM D3776 (Option C)	per 100,000-ft^2 and every resin lot
	Ply Adhesion	ASTM D7005	per 100,000-ft^2 and every resin lot
	Transmissivity	ASTM D4716	per 100,000-ft^2 and every resin lot
Conformance Testing by 3rd Party Independent Laboratory	Thickness	ASTM D5199	per 100,000-ft^2 and every resin lot
	Mass per Unit Area	ASTM D3776 (Option C)	per 100,000-ft^2 and every resin lot
	Carbon Black Content	ASTM D4218	per 100,000-ft^2 and every resin lot
	Tensile Strength	ASTM D7179	per 100,000-ft^2 and every resin lot

Table D.3 – STANDARD TESTS ON GEOTEXTILE MATERIALS

Test	Type of Test	Standard Test Method	Frequency of Testing
Manufacturer's Quality Control	Mass per Unit Area	ASTM D5261	per 100,000-ft^2
	Grab Tensile Strength (%)(MD/CD)^1	ASTM D4632	per 100,000-ft^2
	Grab Elongation (%)(MD/CD)^1	ASTM D4632	per 100,000-ft^2
	Puncture Strength	ASTM D4833	per 100,000-ft^2
	Trapezoidal Tear Strength	ASTM D4533	per 100,000-ft^2
	Apparent Opening Size	ASTM D4751	per 100,000-ft^2
	Permittivity	ASTM D4491	per 100,000-ft^2
	UV Light Resistance	ASTM D4355	per 100,000-ft^2
	Burst Strength	ASTM D3786	per 100,000-ft^2
Conformance Testing by 3rd Party Independent Laboratory	Thickness	ASTM D5199	per 100,000-ft^2
	Mass per Unit Area	ASTM D5261	per 100,000-ft^2
	Grab Tensile Strength (%)(MD/CD)^1	ASTM D4632	per 100,000-ft^2
	Grab Elongation (%)(MD/CD)^1	ASTM D4632	per 100,000-ft^2
	Puncture Strength	ASTM D4833	per 100,000-ft^2
	Trapezoidal Tear Strength	ASTM D4533	per 100,000-ft^2
	Apparent Opening Size	ASTM D4751	per 100,000-ft^2
	Permittivity	ASTM D4491	per 100,000-ft^2
	Burst Strength	ASTM D3786	per 100,000-ft^2

1 - MD/CD = MD - Machine Direction/CD - Cross Direction

B. Infiltration Layer

The infiltration layer will consist of a 24-inch thick minimum soil layer (measured perpendicular to the foundation layer surface) placed on the top of and along the side slopes of the landfill. Material used for this layer will be obtained from the landfill site. It will be placed as a two (2) 12-inch lifts, and will be compacted to approximately 85% of standard proctor (ASTM D698) density (+5%), at a moisture content within +/-2% of optimum. The material may be classified as SM, SP, SW, or SC according to the Unified Soil Classification System (USCS). Testing will be completed, as needed, to classify the soil according to the USCS. Over-compacted soil in the infiltration layer will be disked or ripped (or any method approved by the POR) and recompacted to a density within the acceptable limits. If a density test fails, additional tests may be performed to define the over compacted area. The area to be reworked will be the area between passing density tests. The infiltration layer construction will be conducted in a systematic and timely fashion. Delays will be avoided in completing the infiltration layer. Placement of the infiltration layer will cease during rainfall events to prevent over-compaction. Before proceeding with construction after a rainfall event greater than 0.5-inches, the Contractor will complete, at a minimum, a 10-foot by 10-foot test pad to verify over-compaction will not occur as construction continues. A minimum of two (2) field density tests are required per test pad area. Test pad results will be reported in the Final Cover Evaluation Report.

C Soil Erosion Layer

The soil erosion layer will be placed on top of the infiltration layer over the entire surface of the final cover. The soil will have a minimum thickness of 12-inches and will be capable of sustaining vegetation. The soil will be placed in 6-inch lifts, at 85% standard proctor (ASTM D698) density and within +/-2% of optimum moisture content. The material may be classified as SM, SP, SW, or SC according to the Unified Soil Classification System (USCS). Testing will be completed, as needed, to classify the soil according to the USCS. Over-compacted soil in the soil erosion layer will be disked or ripped (or any method approved by the POR) and recompacted to a density within the acceptable limits. If a density test fails, additional tests may be performed to define the over-compacted area. The area to be reworked will be the area between passing density tests. The surface of the soil cover should be graded to the final grades as shown in Attachment B – Engineered Design Plans, and disked parallel to the proposed contours in preparation for seeding and to prevent excessive erosion after rainfall. The erosion control layer should be placed under the continuous QA/QC observation to ensure that a minimum thickness of 12-inches is applied and existing structures are protected. Placement of the erosion control layer will be stopped during rainfall events to prevent over-compaction of the soil. Construction will continue once CQA personnel determine the soil can be effectively disked. Structural BMP and an effective vegetation plan will aid in erosion prevention. Surveying will be performed to verify the vegetative cover layer has been installed to the minimum thickness of 12-inches.

D. Establishment of Vegetation

Permanent vegetation will be established using appropriate seasonal seeding mixtures. Seeding or sodding shall be performed immediately following application of the final cover.

7.1 Survey and Final Topography

Upon completion of construction of the final cover, a topographic survey will be performed by a qualified land surveyor. The final contour map should include all final contours, location of gas vents, gas monitoring wells, groundwater monitoring wells, drainage structures, fences, gages, access roads, and all other pertinent site features.

7.2 Sampling and Testing

As construction progresses, CQA monitors will conduct field and laboratory tests using standards set forth in the technical specifications. Standard operating procedures for soil testing will be prepared for site testing personnel that follow ASTM Test methods. These procedures will be for the following tests: Soil classification, moisture density relationship, field density and moisture, and thickness verification.

A. Soil Classification

Soil samples will be collected for analysis for the purpose of classifying the soil using the USCS. One (1) sample is required per soil type. The test procedure to follow in the laboratory will be ASTM D2487 and 2488 for soil classification. Extra testing must be performed whenever work or materials are suspect, marginal, or of poor quality. Extra testing may be conducted to provide additional data for engineering. Tests that do not meet minimum requirements will not contribute to the total number of tests performed in meeting the required test frequency.

B. Moisture Density Relationship of Soils

Soil samples will be collected for analysis to determine the Atterberg Limits, the percent passing the No. 200 sieve, and permeability. One (1) sample is required per soil type. The test procedure to be followed in the laboratory will be ASTM D698. Extra testing must be performed whenever work or materials are suspect, marginal, or of poor quality. Extra testing may be conducted to provide additional data for engineering. Tests that do not meet minimum requirements will not contribute to the total number of tests performed in meeting the required test frequency.

C. Field Density and Moisture

Soil testing will be performed in situ or on undisturbed samples for the purpose of determining field density and moisture content. Three (3) tests are required per soil layer per acre. The test procedure to be followed for soil density will be ASTM D2922 which will be performed in the field. The test procedure to be followed for moisture content will be either ASTM D2216 (laboratory) or ASTM D 017 (in situ). Extra testing must be performed whenever work or materials are suspect, marginal, or of poor quality. Extra testing may be conducted to provide additional data for engineering. Tests that do not meet minimum requirements will not contribute to the total number of tests performed in meeting the required test frequency.

D. Thickness Verification

Testing or surveying will be performed to ensure the constructed layer thicknesses meet minimum requirements. This verification will be performed at the top of the foundation layer, top of the vegetative support layer, and top of the vegetative cover layer. The work will be performed every 100-feet in each direction on a grid established by a surveyor registered in the State of New Mexico.

7.3 Vegetation Planting Plan

Planting of vegetation over the final cover system is important to ensure the cover system functions as intended. A recommended seed mixture is provided below in Table D.4.

7.4 Soil Preparation and Seeding

All seeds must conform to the requirements of the U.S. Department of Agriculture rules and regulations set forth in the Federal Seed Act. Cultivation area preparation will start as soon as practicable after completion of the erosion control layer to the lines and grades specified in Attachment B – Engineered Design Plans. The vegetation establishment contractor, with approval from the POR, may modify the seed mixture or the equipment used in the planting process. To prevent over-compaction of the constructed final cover, equipment used should not exert more than 16-psi ground pressure (except for harrowing equipment). The preferred planting period for the seed mix is between September 1 and November 7, taking advantage of the fall rains. If the time frame is unavailable, planting may occur between November 8 and February 14 or will be delayed until the following September. Table D.4 includes the recommended seed mix and application rates in pounds of pure live seed (PLS) per acre.

Table D.4 - SEED MIX AND RATE

Common Name	Pounds (lb) Pure Live Seed (PLS)/acre
Indiangrass	0.6
Green sprangletop	0.8
Sideoats grama	0.6
Little bluestem	1.35
Switchgrass	0.3
Hairy grama	0.2
Blue grama	0.6
Illinois bundleflower	0.75
Engelmann’s daisy	0.6
Texas wintergrass	0.75
Canada wildrye	0.6
Western wheatgrass	0.48

A. Broadcast Seeding

Distribute the seed or seed mixture uniformly over the areas shown on the plans using hand or mechanical distribution or hydroseeding on top of the soil. When seed and water are to be distributed as a slurry during hydroseeding, apply the mixture to the area to be seeded within thirty (30) minutes of placement of components in the equipment.

B. Straw or Hay Mulch Seeding

Plant seed using broadcast seeding. Immediately after planting the seed or seed mixture, apply straw or hay mulch uniformly over the seeded area. Apply straw or hay mulch at

0.5- to 2.5-tons/acre depending on the specific area. Use a tacking method over the mulched area.

C. Cellulose Fiber Mulch Seeding

Plant seed using broadcast seeding. Immediately after planting the seed or seed mixture, apply cellulose fiber mulch uniformly over the seeded area at the following rates:

- Sandy soils with slopes of 3:1 or less – 2500-pounds/acre.
- Sandy soils with slopes greater than 3:1 – 3000-pounds/acre.

Cellulose fiber mulch rates are based on dry weight of mulch per acre. Mix cellulose fiber mulch and water to make slurry and apply uniformly over the seeded area using suitable equipment.

D. Drill Seeding

Planting should be done at 3-mph to 5-mph, running the drill seeder in one (1) direction and making a second pass over the same area but perpendicular to the first pass. The optimum depth for seeding shall be from 1/16-inch to 1/8-inch. Grass, wildflower, and winter cover seed shall be applied by a method that achieves consistent distribution and proper seed-to-soil contact. Individual species or supplemental plantings may be planted using broadcast seeders.

E. Straw or Hay Mulching

Apply straw or hay mulch uniformly over the area as indicated on the plans. Apply straw mulch or hay mulch at 0.5- to 2.5-tons/acre depending on the specific area. Use a tacking method over the mulched area.

7.5 Fertilizer Recommendations

Apply the fertilizer uniformly at a rate equal to 50-pounds of nitrogen per acre. Seed and fertilizer may be distributed simultaneously during “Broadcast Seeding” operations, provided each component is applied at the rate specified by POR for the specific area. When temporary and permanent seeding are both specified for the same area, apply half of the required fertilizer during the temporary seeding operation and the other half during the permanent seeding operation. Use a commercial-grade fertilizer of neutral character, consisting of fast and slow release nitrogen, 50% derived from natural organic sources of area formaldehyde, phosphorus, and potassium. The fertilizer should have an N-P-K ration of 20-27-5.

7.6 Documentation

The quality assurance plan requires monitoring and documentation of construction activities; therefore, the POR and CQA monitor will document the means and methods which the quality assurance requirements have been addressed and satisfied. Documentation may consist of daily recordkeeping, testing and installation reports, nonconformance reports (if necessary), progress reports, photographic records, and design and specification revisions. The appropriate documentation will be included in the FCER. Standard report forms will be provided by the POR prior to construction.

7.7 Preparation of FCER

The POR, on behalf of the Owner, shall submit to the OCD an FCER for approval of the final cover system constructed. Final cover QA/QC testing will be performed in accordance with this FCQCP and should be part of the FCER which will be prepared in accordance with this FCQCP.

Permit Application

Lea County, New Mexico
C.K. Disposal E & P Landfill and Processing Facility
Permit No. TBD

Attachment E
HELP Model
NMAC 19.15.36.14(C)(9)

Robert R. Holder

ROBERT R. HOLDER
20239

05/12/2016

PARKHILL SMITH & COOPER

May 2016 REVISION 2

PSC Project # 01058015

ATTACHMENT E - HELP MODEL

APPENDICES

TABLES

1.0 Leachate Collection, Removal System – 19.15.36.14(C)(F)

C.K. Facility has been designed to comply with NMAC regulations for leachate collection and removal systems. NMAC requires leachate collection and removal system protective layer and soil component of the leak detection system shall consist of soil materials that shall be free of organic matter, have a portion of material passing the No. 200 sieve no greater than 5% by weight, and have a uniformity coefficient (Cu) less than 6, where Cu is defined as D60/D10. Geosynthetic materials or geocomposites including geonets and geotextiles, if used as components of the leachate collection and removal or leak detection system, shall have a hydraulic conductivity, transmissivity, chemical, and physical qualities that oilfield waste placement, equipment operation, or leachate generation will not adversely affect. These geosynthetics or geocomposites, if used in conjunction with the soil protective cover for liners, shall have a hydraulic conductivity designed to ensure that the liner's hydraulic head never exceeds 1-ft.

1.1 Hydrologic Evaluation of Landfill Performance (HELP) Model

USEPA developed the HELP model to evaluate water balance systems of landfills, cover systems, and other solid waste containment facilities. HELP model Version 3.07 was used to ensure the proposed alternate final cover system meets NMAC requirements and does not create a "bathtub effect." HELP model user guide is included in Appendix A.

1.2 Liner System Design

The design of the prescriptive liner system in accordance with NMAC is given below in Table E.1:

Table E.1 – PRESCRIPTIVE LINER SYSTEM DESIGN

Layer	Thickness	K_{sat} (cm/sec)
Protective soil layer	12-in	1×10^{-2}
Leachate Collection Layer	24-in	1×10^{-2}
Geo Membrane Liner	60-mil	2×10^{-13}
Leak Detection Layer	24-in	1×10^{-5}
Geomembrane	60-mil	1×10^{-13}
Clay Barrier Layer	24-in	1×10^{-7}

The design of the alternate liner system is given below in Table E.2:

Table E.2 – ALTERNATE LINER SYSTEM DESIGN

Layer	Thickness	K_{sat} (cm/sec)
Protective/Drainage Soil Layer	24-in	5.2×10^{-4}
Geocomposite	200-mil	10
Geo Membrane Liner	60-mil	2×10^{-13}
Geocomposite Leak Detection Layer	200-mil	10
Geo Membrane Liner	60-mil	2×10^{-13}
Geosynthetic Clay Liner		1×10^{-7}
Compacted Subgrade 90% Standard Proctor Dry Density	6-in	5.2×10^{-4}

1.3 Liner Simulation Results

The prescriptive liner demonstration results can be found in Appendix B. The alternate liner demonstration results are shown in Appendix C. The HELP model results show that the alternate liner does not create head on the liner system that exceeds NMAC's regulations of 12-in. The results from the simulations are shown below in Table E.3:

Table E.3 - HELP MODEL RESULTS

Simulation	Average Annual Percolation Rate through Bottom of Liner (in/year)	Average Annual Head on Primary HDPE Liner (inches)
Prescriptive	0	7.089
Alternate	0	0.032

2.0 Landfill Cap Design – 19.15.36.14(C)(9)

Final cover design consists of a prescriptive cover with geocomposite replacing the gravel layer along the crown of the landfill along with a performance based cover design that is to be used on the 4:1 sideslopes on the landfill cap. These covers are designed to prevent the "bathtub effect" which occurs when a more permeable cover is placed over a less permeable bottom liner. NMAC 19.15.36.14(C) allows the operator to propose a performance-based landfill design system using geosynthetics or geocomposites, including geogrids, geosynthetics clay liners, composite liner systems, etc., when supported by EPA's HELP model or other division-approved model to prevent the "bathtub effect."

2.1 Final Cover Design

The prescriptive final cover design is given below in Table E.4:

Table E.4 – PRESCRIPTIVE FINAL COVER DESIGN WITH GEOCOMPOSITE REPLACING THE GRAVEL LAYER

Layer	Thickness	K_{sat} (cm/sec)
Erosion layer	24-in	5.2×10^{-4}
Protection layer	12-in	5.2×10^{-4}
Geocomposite	200-mils	10
GeoMembrane liner	60-mil	2×10^{-13}
Foundation layer	12-in	1×10^{-2}

C.K. Facility proposes the following alternate final cover design on the 4:1 sideslopes as shown in Table E.5:

Table E.5 – ALTERNATE FINAL COVER DESIGN

Layer	Thickness	K_{sat} (cm/sec)
Erosion layer	12-in	5.2×10^{-4}
Infiltration layer	24-in	5.2×10^{-4}
Intermediate layer	12-in	5.2×10^{-4}

2.2 Alternate Final Cover Design with Geocomposite Replacing the Gravel Layer HELP Model Inputs

The vegetation for the final cover is modeled as a "poor stand of grass," therefore, the evaporative zone depth was set to 18-in, and the maximum leaf area index was set to 1.2. With the average sideslopes of 3% and where the alternative final cover is to be used and the regional high intensity, short duration storms that are experienced in eastern New Mexico, a runoff curve number of 80 was used.

2.3 Alternate Final Cover with Geocomposite Replacing the Gravel Layer System Simulation Results

The alternative final cover system HELP model demonstration is given in Appendix D. Through the analysis of the HELP model demonstrations, no percolation occurs through the third layer of the alternative final cover; therefore, no "bathtub effect" is created by the use of the alternative final cover system. Due to no percolation through the geomembrane layer of the alternative final cover the system meets the requirements of 19.15.36.14(C)(9).

2.4 Alternative Final Cover HELP Model Inputs

The vegetation for the final cover is modeled as a "poor stand of grass," therefore, the evaporative zone depth was set to 18-in, and the maximum leaf area index was set to 1.2. With the steep 4:1 sideslopes of where the alternative final cover is to be used and the regional high intensity, short duration storms that are experienced in eastern New Mexico, a runoff curve number of 92 was used.

2.5 Alternate Final Cover System Simulation Results

The alternative final cover system HELP model demonstration is given in Appendix E. Through the analysis of the HELP model demonstrations, no percolation occurs through the third layer of the alternative final cover; therefore, no "bathtub effect" is created by the use of the alternative final cover system. Due to no percolation through the geomembrane layer of the alternative final cover the system meets the requirements of 19.15.36.14(C)(9).

APPENDIX A

HELP MODEL USER GUIDE

THE HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL

USER'S GUIDE FOR VERSION 3

by

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DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Interagency Agreement No. DW21931425 to the U.S. Army Engineer Waterways Experiment Station. It has been subjected to the Agency’s peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today’s rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Risk Reduction Engineering Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments, and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report presents guidance on the use of the Hydrologic Evaluation of Landfill Performance (HELP) computer program. The HELP program is a quasi-two-dimensional hydrologic model for conducting water balance analysis of landfills, cover systems, and other solid waste containment facilities. The model accepts weather, soil and design data, and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives. The model is a tool for both designers and permit writers.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

The Hydrologic Evaluation of Landfill Performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The program was developed to conduct water balance analysis of landfills, cover systems, and solid waste disposal and containment facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers.

This report explains how to use Version 3 of the HELP model. Section 1 provides background and overview of the model, and lists software and hardware requirements. Section 2 describes basic landfill design and liquids management concepts. Section 3 presents definitions, options and limitations for input parameters as well as detailed guidance for selecting their input values. Section 4 provides detailed instructions on how to enter input, run the simulation and view or print output. Appendix A provides assistance for estimating material properties for moisture retention and saturated hydraulic conductivity.

The user interface or input facility is written in the Quick Basic environment of Microsoft Basic Professional Development System Version 7.1 and runs under DOS 2.1 or higher on IBM-PC and compatible computers. The HELP program uses an interactive and a user-friendly input facility designed to provide the user with as much assistance as possible in preparing data to run the model. The program provides weather and soil data file management, default data sources, interactive layer editing, on-line help, and data verification and accepts weather data from the most commonly used sources with several different formats.

HELP Version 3 represents a significant advancement over the input techniques of Version 2. Users of the HELP model should find HELP Version 3 easy to use and should be able to use it for many purposes, such as preparing and editing landfill profiles and weather data. Version 3 facilitates use of metric units, international applications, and designs with geosynthetic materials.

This report should be cited as follows:

> Schroeder, P. R., Aziz, N. M., Lloyd, C. M. and Zappi, P. A. (1994). "The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for Version 3," EPA/600/R-94/168a, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

This report was submitted in partial fulfillment of Interagency Agreement Number DW21931425 between the U.S. Environmental Protection Agency and the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. This report covers a period from November 1988 to June 1994 and work was completed as of June 1994.

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ACKNOWLEDGMENTS

The support of the project by the Waste Minimization, Destruction and Disposal Research Division, Risk Reduction Engineering Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH and the Headquarters, U.S. Army Corps of Engineers, Washington, DC, through Interagency Agreement No. DW21931425 is appreciated. In particular, the authors wish to thank the U.S. EPA Project Officer, Mr. Robert Landreth, for his long standing support.

The draft version of this document was prepared at Clemson University by Dr. Nadim M. Aziz, the author of the HELP Version 3 user interface, under contract with the USEPA Risk Reduction Engineering Laboratory and the USAE Waterways Experiment Station. The final version of this document was prepared at the USAE Waterways Experiment Station by Dr. Paul R. Schroeder and Ms. Cheryl M. Lloyd. Appendix A was written by Mr. Paul A. Zappi. The figures used in the report were prepared by Messrs. Jimmy Farrell and Christopher Chao.

The report and user interface were reviewed by Messrs. Elba A. Dardeau, Jr., and Daniel E. Averett. This report has not been subjected to the EPA review and, therefore, the contents do not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

SECTION 1

INTRODUCTION

The Hydrologic Evaluation of Landfill Performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data, and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The program was developed to conduct water balance analysis of landfills, cover systems and solid waste disposal and containment facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers.

1.1 BACKGROUND

The HELP program, Versions 1, 2 and 3, was developed by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for the U.S. Environmental Protection Agency (EPA), Risk Reduction Engineering Laboratory, Cincinnati, OH, in response to needs in the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, better known as Superfund) as identified by the EPA Office of Solid Waste, Washington, DC.

HELP Version 1 (Schroeder et al., 1984) represented a major advance beyond the Hydrologic Simulation on Solid Waste Disposal Sites (HSSWDS) program (Perrier and Gibson, 1980; Schroeder and Gibson, 1982), which was also developed at WES. The HSSWDS model simulated only the cover system, did not model lateral flow through drainage layers, and handled vertical drainage only in a rudimentary manner. The infiltration, percolation and evapotranspiration routines were almost identical to those used in the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model, which was developed by Knisel (1980) for the U.S. Department of Agriculture (USDA). The runoff and infiltration routines relied heavily on the Hydrology Section of the National Engineering Handbook (USDA, Soil Conservation Service, 1985). Version 1 of the HELP model incorporated a lateral subsurface drainage model and improved unsaturated drainage and liner leakage models into the HSSWDS model. In addition, the HELP model provided simulation of the entire landfill including leachate collection and liner systems.

Version 2 (Schroeder et al., 1988) represented a great enhancement of the capabilities of the HELP model. The WGEN synthetic weather generator developed by the USDA Agricultural Research Service (ARS) (Richardson and Wright, 1984) was added to the model to yield daily values of precipitation, temperature and solar radiation. This replaced the use of normal mean monthly temperature and solar radiation values and improved the modeling of snow and evapotranspiration. Also, a vegetative growth model from the Simulator for Water Resources in Rural Basins (SWRRB) model developed by the ARS (Arnold et al., 1989) was merged into the HELP model to calculate daily leaf area indices. Modeling of unsaturated hydraulic conductivity and flow and lateral drainage computations were improved. Accuracy was increased with the use of double precision. Default soil data were improved, and the model permitted use of more layers and initialization of soil moisture content. Input and editing were simplified. Output was clarified, and standard deviations were reported.

In Version 3, the HELP model has been greatly enhanced beyond Version 2. The number of layers that can be modeled has been increased. The default soil/material texture list has been expanded to contain additional waste materials, geomembranes, geosynthetic drainage nets and compacted soils. The model also permits the use of a user-built library of soil textures. Computation of leachate recirculation between soil layers and groundwater drainage into the landfill have been added. Moreover, HELP Version 3 accounts for leakage through geomembranes due to manufacturing defects (pinholes) and installation defects (punctures, tears and seaming flaws) and by vapor diffusion through the liner. The estimation of runoff from the surface of the landfill has been improved to account for large landfill surface slopes and slope lengths. The snowmelt model has been replaced with an energy-based model; the Priestly-Taylor potential evapotranspiration model has been replaced with a Penman method, incorporating wind and humidity effects as well as long wave radiation losses (heat loss at night). A frozen soil model has been added to improve infiltration and runoff predictions in cold regions. The unsaturated vertical drainage model has also been improved to aid in storage computations. Input and editing have been further simplified with interactive, full-screen, menu-driven input techniques.

In addition, the HELP Version 3 model provides a variety of methods for specifying precipitation, temperature and solar radiation data. Now, data from the most commonly available government and commercial sources can be imported easily. Moreover, data used in HELP Version 2 can still be used with minimum user effort. Specifying weather data manually and editing previously entered weather data can be easily done by using built-in spreadsheet facilities.

The use of data files in Version 3 is much simpler and more convenient than HELP Version 2 because data are saved permanently in user defined file names at a user-specified location. Similarly, the user has more flexibility to define units for every type of data needed to run the HELP model. Finally, Version 3 of the HELP model provides on-line help at every step of the data preparation process.

Although applicable to most landfill applications, the HELP model was developed specifically to perform hazardous and municipal waste disposal landfill evaluations as required by RCRA. Hazardous waste disposal landfills generally should have a liner to prevent migration of waste from the landfill, a final cover to minimize the production of leachate following closure, careful controls of runon and runoff, and limits on the buildup of leachate head over the liner to no more than 1 ft. The HELP model is useful for predicting the amounts of runoff, drainage, and leachate expected for reasonable designs as well as the buildup of leachate above the liner. However, the model should not be expected to produce credible results from input unrepresentative of landfills.

1.2 OVERVIEW

The principal purpose of this User's Guide is to provide the basic information needed to use the computer program. Thus, while some attention must be given to definitions, descriptions of variables and interpretation of results, only a minimal amount of such information is provided. Detailed documentation providing in-depth coverage of the theory and assumptions on which the model is based and the internal logic of the program is also available (Schroeder et al., 1994). Potential HELP users are strongly encouraged to study the documentation and this User's Guide before attempting to use the program to evaluate a landfill design. Additional documentation concerning the sensitivity of program inputs, application of the model and verification of model predictions are under development.

1.3 SYSTEM AND OPERATING DOCUMENTATION

1.3.1 Computer Equipment

The model entitled "The Hydrologic Evaluation of Landfill Performance" (HELP) was written to run on IBM-compatible personal computers (PC) under the DOS environment.

1.3.2 Required Hardware

The following IBM-compatible CPU (8088, 80286, 80386 or 80486) hardware is required:

1. Monitor, preferably color EGA or better

2. Floppy disk drive (5.25-inch double-sided, double- or high-density; or 3.5-inch

double-sided, double- or high-density)

3. Hard disk drive or a second floppy disk drive
4. 400k bytes or more of available RAM memory
5. 8087, 80287, 80387 or 80486 math co-processor
6. Printer, if a hard copy is desired

1.3.3 Software Requirements

The user must use Microsoft or compatible Disk Operating Systems (MS-DOS) Version 2.10 or a higher version. The user interface executable module was compiled and linked with Microsoft Basic Professional Development System 7.1. Other executable components were compiled with the Ryan-McFarland FORTRAN Version 2.42. The Microsoft Basic Professional Development System and Ryan-McFarland FORTRAN compiler are not needed to run the HELP Model.

SECTION 2

BASIC LANDFILL DESIGN CONCEPTS

2.1 BACKGROUND

Over the past 20 to 30 years, the sanitary landfill has come to be widely recognized as an economic and effective means for disposal of municipal and industrial solid wastes. Today, modern methods of landfill construction and management are sufficiently developed to ensure that even large volumes of such materials can be handled and disposed of in such a way as to protect public health and minimize adverse effects on the environment.

Recently, public attention has been focused on a special class of materials commonly referred to as hazardous wastes. The chemical and physical diversity, environmental persistence, and acute and chronic detrimental effects on human, plant and animal health of many of these substances are such that great care must be exercised in their disposal. Hazardous wastes are produced in such large quantities and are so diverse that universally acceptable disposal methods have yet to be devised. However, for the present, disposal or storage in secure landfills is usually a prudent approach. The current state of the art is an extension of sanitary landfill technology using very conservative design criteria. Some important basic principles and concepts of landfill design are summarized below. Specific emphasis is given to disposal of hazardous materials, but the discussion is also applicable to ordinary sanitary landfills.

2.2 LEACHATE PRODUCTION

Storage of any waste material in a landfill poses several potential problems. One problem is the possible contamination of soil, groundwater and surface water that may occur as leachate produced by water or liquid wastes moving into, through and out of the landfill migrates into adjacent areas. This problem is especially important when hazardous wastes are involved because many of these substances are quite resistant to biological or chemical degradation and, thus, are expected to persist in their original form for many years, perhaps even for centuries. Given this possibility hazardous waste landfills should be designed to prevent any waste or leachate from ever moving into adjacent areas. This objective is beyond the capability of current technology but does represent a goal in the design and operation of today’s landfills. The HELP model has been developed specifically as a tool to be used by designers and regulatory reviewers for selecting practical designs that minimize potential contamination problems.

In the context of a landfill, leachate is described as liquid that has percolated through the layers of waste material. Thus, leachate may be composed of liquids that originate from a number of sources, including precipitation, groundwater, consolidation, initial moisture storage, and reactions associated with decomposition of waste materials. The chemical quality of leachate varies as a function of a number of factors, including the quantity produced, the original nature of the buried waste materials, and the various chemical and biochemical reactions that may occur as the waste materials decompose. In the absence of evidence to the contrary, most regulatory agencies prefer to assume that any leachate produced will contaminate either ground or surface waters; in the light of the potential water quality impact of leachate contamination, this assumption appears reasonable.

The quantity of leachate produced is affected to some extent by decomposition reactions and initial moisture content; however, it is largely governed by the amount of external water entering the landfill. Thus, a key first step in controlling leachate migration is to limit production by preventing, to the extent feasible, the entry of external water into the waste layers. A second step is to collect any leachate that is produced for subsequent treatment and disposal. Techniques are currently available to limit the amount of leachate that migrates into adjoining areas to a virtually immeasurable volume, as long as the integrity of the landfill structure and leachate control system is maintained.

2.3 DESIGN FOR LEACHATE CONTROL

A schematic profile view of a somewhat typical hazardous waste landfill is shown in Figure 1. The bottom layer of soil may be naturally existing material or it may be hauled in, placed and compacted to specifications following excavation to a suitable subgrade. In either case, the base of the landfill should act as a liner with some minimum thickness and a very low hydraulic conductivity (or permeability). Treatments may be used on the barrier soil to reduce its permeability to an acceptable level. As an added factor of safety, an impermeable synthetic membrane may be placed on the top of the barrier soil layer to form a composite liner.

Immediately above the bottom composite liner is a leakage detection drainage layer to collect leakage from the primary liner, in this case, a geomembrane. Above the primary liner are a geosynthetic drainage net and a sand layer that serve as drainage layers for leachate collection. The drain layers composed of sand are typically at least 1-ft thick and have suitably spaced perforated or open joint drain pipe embedded below the surface of the liner. The leachate collection drainage layer serves to collect any leachate that may percolate through the waste layers. In this case where the liner is solely a geomembrane, a drainage net may be used to rapidly drain leachate from the liner, avoiding a significant buildup of head and limiting leakage. The liners are sloped to prevent ponding by encouraging leachate to flow toward the drains. The net effect is that very little leachate should percolate through the primary liner and virtually no migration of leachate through the bottom composite liner to the natural formations below. Taken as a whole, the drainage layers, geomembrane liners, and barrier soil liners may be referred to as the leachate collection and removal system (drain/liner system) and more specifically a double liner system.

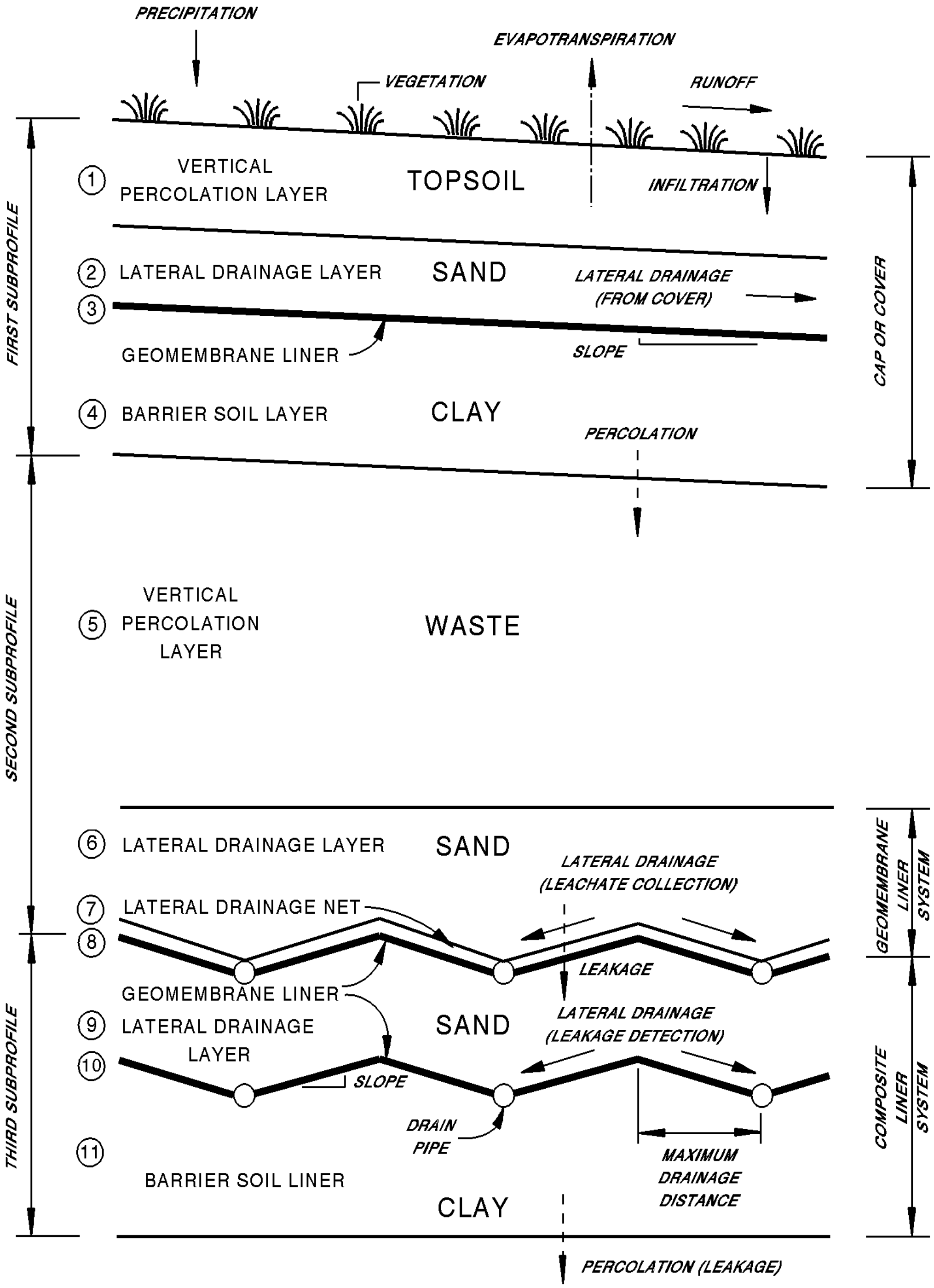

Figure 1. Schematic of Landfill Profile Illustrating Typical Landfill Features

After the landfill is closed, the leachate collection and removal system serves basically in a back-up capacity. However, while the landfill is open and waste is being added, these components constitute the principal defense against contamination of adjacent areas. Thus, care must be given to their design and construction.

Day-to-day operation of a modern sanitary landfill calls for wastes to be placed in relatively thin lifts, compacted, and covered with soil each day. Thus, wastes should not remain exposed for more than a few hours. Although the daily soil cover serves effectively to hide the wastes and limit the access of nuisance insects and potential disease vectors, it is of limited value for preventing the formation of leachate. Thus, even though a similar procedure can be used for hazardous wastes, the drainage/liner system must function well throughout and after the active life of the landfill.

When the capacity of the landfill is reached, the waste cells may be covered with a cap or final cover, typically composed of four distinct layers as shown in Figure 1. At the base of the cap is a drainage layer and a liner system layer similar to that used at the base of the landfill. Again, a geomembrane liner would normally be used in conjunction with the barrier soil liner for hazardous waste landfill but has been used less frequently in municipal waste landfills. The top of the barrier soil layer is graded so that water percolating into the drainage layer will tend to move horizontally toward some removal system (drain) located at the edge of the landfill or subunit thereof.

A layer of soil suitable for vegetative growth is placed at the top of final cover system to complete the landfill. A 2-ft-thick layer of soil having a loamy, silty nature serves this purpose well. The upper surface is graded so that runon is restricted and infiltration is controlled to provide moisture for vegetation while limiting percolation through the topsoil. Runoff is promoted but controlled to prevent excessive erosion of the cap. The vegetation used should be selected for ease of establishment in a given area, promotion of evapotranspiration and year-round protection from erosion. The root system should not penetrate, disrupt or desiccate the upper liner system (Layers # 3 and # 4). Grasses are usually best for this purpose; however, local experts should be consulted to aid in selection of appropriate species.

The combination of site selection, surface grading, transpiration from vegetation, soil evaporation, drainage through the sand, and the low hydraulic conductivity of the barrier soil liner serves effectively to minimize leachate production from external water. Added effectiveness is gained by the use of geomembrane liners in the cap in conjunction with the barrier soil liner. The cap should be no more permeable than the leachate collection and removal system so that the landfill will not gradually fill and overflow into adjacent areas following abandonment of the landfill. This phenomenon is sometimes referred to as the "bathtub" effect.

SECTION 3

PROGRAM DEFINITIONS, OPTIONS AND LIMITATIONS

3.1 INTRODUCTION

The HELP program was developed to provide landfill designers and regulators with a tool for rapid, economical screening of alternative designs. The program may be used to estimate the magnitudes of various components of the water budget, including the volume of leachate produced and the thickness of water-saturated soil (head) above liners. The results may be used to compare the leachate production potential of alternative designs, to select and size appropriate drainage and collection systems, and to size leachate treatment facilities.

The program uses weather (climatic), soil and design data to generate daily estimates of water movement across, into, through and out of landfills. To accomplish this objective and compute a water balance, daily precipitation is partitioned into surface storage (snow), snowmelt, interception, runoff, infiltration, surface evaporation, evapotranspiration from soil, subsurface moisture storage, liner leakage (percolation), and subsurface lateral drainage to collection, removal and recirculation systems.

This section discusses data requirements, nomenclature, important assumptions and limitations, and other fundamental information needed to run the program. The program documentation report (Schroeder et al., 1994) contains detailed explanations of the solution techniques employed and the computer programs.

The HELP program requires three general types of input data: weather data, soil data and design data. A summary of input options and data requirements is presented in this section. Section 4 provides step-by-step input instructions.

3.2 WEATHER DATA REQUIREMENTS

The weather data required in the HELP model are classified into four groups: evapotranspiration, precipitation, temperature, and solar radiation data. The HELP user may enter weather data using several options depending on the type of weather data being considered. The requirements for each weather data type are listed below. The units used are also listed next to each data type and/or variable. Customary units are based on the US Customary units, and Metric implies SI units.

3.2.1 Evapotranspiration Data

The evapotranspiration data can be entered in one of two ways:

1. ***Default Evapotranspiration Option with Location Specific Guidance*** *(Customary and Metric Units)*. This option uses the data provided by the HELP model for selected U.S. cities. The cities are listed in Table 1. The data needed for this option are:

    - **Location**

    - **Evaporative zone depth** (Guidance is available for the selected location based on a thick layer of loamy soil with a grassy form of vegetation. Clayey soils would generally have larger evaporative zone depths since it exerts greater capillary suction; analogously, sandy soils would have smaller evaporative depths. Shrubs and trees with tap roots would have larger evaporative zone depths than the values given in the guidance.) The user must specify an evaporative zone depth and can use the guidance along with specific design information to select a value. The program does not permit the evaporative depth to exceed the depth to the top of the topmost liner. Similarly, the evaporative zone depth would not be expected to extend very far into a sand drainage layer. The evaporative zone depth must be greater than zero. The evaporative zone depth is the maximum depth from which water may be removed by evapotranspiration. The value specified influences the storage of water near the surface and therefore directly affects the computations for evapotranspiration and runoff. Where surface vegetation is present, the evaporative depth should at least equal the expected average depth of root penetration. The influence of plant roots usually extends somewhat below the depth of root penetration because of capillary suction to the roots. The depth specified should be characteristic of the maximum depth to which the moisture changes near the surface due to drying over the course of a year, typically occurring during peak evaporative demand or when peak quantity of vegetation is present. Setting the evaporative depth equal to the expected average root depth would tend to yield a low estimate of evapotranspiration and a high estimate of drainage through the evaporative zone. An evaporative depth should be specified for bare ground to account for direct evaporation from the soil; this depth would be a function of the soil type and vapor and heat flux at the surface. The depth of capillary draw to the surface without vegetation or to the root zone may be only several inches in gravels; in sands the depth may be about 4 to 8 inches, in silts about 8 to 18 inches, and in clays about 12 to 60 inches.

    - **Maximum leaf area index** (Guidance is available for the selected location). The user must enter a maximum value of leaf area index for the vegetative cover. Leaf area index (LAI) is defined as the dimensionless ratio of the leaf area of actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing. The program provides the user with a maximum LAI value typical of the location selected if the value entered by the user cannot be supported without irrigation because of low rainfall or a short growing season. This statement should be considered only as a warning. The maximum LAI for bare ground is zero. For a poor stand of grass the LAI could approach 1.0; for a fair stand of grass, 2.0; for a good stand of grass, 3.5; and for an excellent

TABLE 1. CITIES FOR EVAPOTRANSPIRATION DATA AND SYNTHETIC TEMPERATURE AND SOLAR RADIATION DATA

ALABAMA
  Birmingham
  Mobile
  Montgomery
ALASKA
  Annette
  Bethel
  Fairbanks
ARIZONA
  Flagstaff
  Phoenix
  Tucson
  Yuma
ARKANSAS
  Fort Smith
  Little Rock
CALIFORNIA
  Bakersfield
  Blue Canyon
  Eureka
  Fresno
  Los Angeles
  Mt. Shasta
  Sacramento
  San Diego
  San Francisco
  Santa Maria
COLORADO
  Colorado Springs
  Denver
  Grand Junction
  Pueblo
CONNECTICUT
  Bridgeport
  Hartford
  New Haven
  Windsor Locks
DELAWARE
  Wilmington
DISTRICT OF COLUMBIA
  Washington
FLORIDA
  Jacksonville
  Miami
  Orlando
  Tallahassee
  Tampa
  West Palm Beach
GEORGIA
  Atlanta
  Augusta
  Macon
  Savannah
  Watkinsville
HAWAII
  Honolulu
IDAHO
  Boise
  Pocatello
ILLINOIS
  Chicago
  East St. Louis
INDIANA
  Evansville
  Fort Wayne
  Indianapolis
IOWA
  Des Moines
  Dubuque
KANSAS
  Dodge City
  Topeka
  Wichita
KENTUCKY
  Covington
  Lexington
  Louisville
LOUISIANA
  Baton Rouge
  Lake Charles
  New Orleans
  Shreveport
MAINE
  Augusta
  Bangor
  Caribou
  Portland
MARYLAND
  Baltimore
MASSACHUSETTS
  Boston
  Nantucket
  Plainfield
  Worchester
MICHIGAN
  Detroit
  East Lansing
  Grand Rapids
  Sault Sainte Marie
MINNESOTA
  Duluth
  Minneapolis
  St. Cloud
MISSISSIPPI
  Jackson
  Meridian
MISSOURI
  Columbia
  Kansas City
  St. Louis
MONTANA
  Billings
  Glasgow
  Great Falls
  Havre
  Helena
  Kalispell
  Miles City
NEBRASKA
  Grand Island
  North Platte
  Omaha
  Scottsbluff
NEVADA
  Elko
  Ely
  Las Vegas
  Reno
  Winnemucca
NEW HAMPSHIRE
  Concord
  Mt. Washington
  Nashua
NEW JERSEY
  Edison
  Newark
  Seabrook
NEW MEXICO
  Albuquerque
  Roswell
NEW YORK
  Albany
  Buffalo
  Central Park
  Ithaca
  New York
  Syracuse
NORTH CAROLINA
  Asheville
  Charlotte
  Greensboro
  Raleigh
NORTH DAKOTA
  Bismarck
  Williston
OHIO
  Cincinnati
  Cleveland
  Columbus
  Put-in-Bay
  Toledo
OKLAHOMA
  Olkahoma City
  Tulsa
OREGON
  Astoria
  Burns
  Meacham
  Medford
  Pendleton
  Portland
  Salem
  Sexton Summit
PENNSYLVANIA
  Philadelphia
  Pittsburgh
RHODE ISLAND
  Providence
SOUTH CAROLINA
  Charleston
  Columbia
SOUTH DAKOTA
  Huron
  Rapid City
TENNESSEE
  Chattanooga
  Knoxville
  Memphis
  Nashville

(Continued)

TABLE 1 (continued). CITIES FOR EVAPOTRANSPIRATION DATA AND SYNTHETIC TEMPERATURE AND SOLAR RADIATION DATA

- TEXAS
  - Abilene
  - Amarillo
  - Austin
  - Brownsville
  - Corpus Christi
  - Dallas
  - El Paso
  - Galveston
  - Houston
  - Midland
  - San Antonio
  - Temple
  - Waco
- UTAH
  - Cedar City
  - Milford
  - Salt Lake City
- VERMONT
  - Burlington
  - Montpelier
  - Rutland
- VIRGINIA
  - Lynchburg
  - Norfolk
  - Richmond
- WASHINGTON
  - Olympia
  - Pullman
  - Seattle
  - Spokane
  - Stampede Pass
  - Walla Walla
  - Yakima
- WEST VIRGINIA
  - Charleston
- WISCONSIN
  - Green Bay
  - Lacrosse
  - Madison
  - Milwaukee
- WYOMING
  - Cheyenne
  - Lander
- PUERTO RICO
  - San Juan

(Concluded)

stand of grass, 5.0. The LAI for dense stands of trees and shrubbery would also approach 5. The program is largely insensitive to values above 5. If the vegetative species limit plant transpiration (such as succulent plants), the maximum LAI value should be reduced to a value equivalent of the LAI for a stand of grass that would yield a similar quantity of plant transpiration. Most landfills would tend to have at best a fair stand of grass and often only a poor stand of grass because landfills are not designed as ideal support systems for vegetative growth. Surface soils are commonly shallow and provide little moisture storage for dry periods. Many covers may have drains to remove infiltrated water quickly, reducing moisture storage. Some covers have liners near the surface restricting root penetration and causing frequent saturation of the surface soil which limits oxygen availability to the roots. Some landfills produce large quantities of gas which, if uncontrolled, reduces the oxygen availability in the rooting zone and therefore limits plant growth.

The program produces values for the Julian dates starting and ending the growing season, the annual average wind speed, and the quarterly average relative humidity for the location. The values for the growing season should be checked carefully to agree with the germination and harvesting (end of seasonal growth) dates for your type of vegetation. For example, grasses in southern California would germinate in the fall when the rains occur and die off in late spring when the soil moisture is depleted. This contrasts with a typical growing season, which would start in the spring and end in the fall.

2. Manual Option *(Customary and Metric Units).* The data needed for this option are:

- **Location**

- **Evaporative zone depth**. The user must specify an evaporative zone depth and can use the guidance given under the default option along with specific design information to select a value. The program does not permit the evaporative depth to exceed the depth to the top of the topmost barrier soil layer. Similarly, the evaporative zone depth would not be expected to extend very far into a sand drainage layer. The evaporative zone depth must be greater than zero. The evaporative zone depth is the maximum depth from which water may be removed by evapotranspiration. The value specified influences the storage of water near the surface and, therefore, directly affects the computations for evapotranspiration and runoff. Where surface vegetation is present, the evaporative depth should at least equal the expected average depth of root penetration. The influence of plant roots usually extends somewhat below the depth of root penetration because of capillary suction to the roots. The depth specified should be characteristic of the maximum depth to which the moisture changes near the surface due to drying over the course of a year, typically occurring during peak evaporative demand or when peak quantity of vegetation is present. Setting the evaporative depth equal to the expected average root depth would tend to yield a low estimate of evapotranspiration and a high estimate of drainage through the evaporative zone. An evaporative depth should be specified for bare ground to account for direct evaporation from the soil; this depth would be a function of the soil type and vapor and heat flux at the surface. The depth of capillary draw to the surface without vegetation or to the root zone may be only several inches in gravels; in sands the depth may be about 4 to 8 inches, in silts about 8 to 18 inches, and in clays about 12 to 60 inches. Rooting depth is dependent on many factors -- species, moisture availability, maturation, soil type and plant density. In humid areas where moisture is readily available near the surface, grasses may have rooting depth of 6 to 24 inches. In drier areas, the rooting depth is very sensitive to plant species and to the depth to which moisture is stored and may range from 6 to 48 inches. The evaporative zone depth would be somewhat greater than the rooting depth. The local Agricultural Extension Service office can provide information on characteristic rooting depths for vegetation in specific areas.

- **Maximum leaf area index**. The user must enter a maximum value of leaf area index (LAI) for the vegetative cover. LAI is defined as the dimensionless ratio of the leaf area of actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing. The program provides the user with a maximum LAI value typical of the location selected if the value entered by the user cannot be supported without irrigation because of low rainfall or a short growing season. This statement should be considered only as a warning. The maximum LAI for bare ground is zero. For a poor stand of grass the LAI could approach 1.0; for a fair stand of grass, 2.0; for a good stand of grass, 3.5; and for an excellent stand of grass, 5.0. The LAI for dense stands of trees and shrubbery would also approach 5. The program is largely insensitive to values above 5. If the vegetative species limit plant transpiration (such as succulent plants), the maximum LAI value should be reduced to a value equivalent of the LAI for a stand of grass that would yield a similar quantity of plant transpiration. Most landfills would tend to have, at best, a fair stand of grass and often only a poor stand of grass because landfills are not designed as ideal support systems for vegetative growth. Surface soils are commonly shallow and provide little moisture storage for dry periods. Many covers may have drains to remove infiltrated water quickly, reducing moisture storage. Some covers have liners near the surface restricting root penetration and causing frequent saturation of the surface soil which limits oxygen availability to the roots. Some landfills produce large quantities of gas which, if uncontrolled, reduces the oxygen availability in the rooting zone and therefore limits plant growth.

- **Dates starting and ending the growing season**. The start of the growing season is based on mean daily temperature and plant species. Typically, the start of the growing season for grasses is the Julian date (day of the year) when the normal mean daily temperature rises above 50 to 55 degrees Fahrenheit. The growing season ends when the normal mean daily temperatures falls below 50 to 55 degrees Fahrenheit. In cooler climates the start and end would be at lower temperatures and in warmer climates at higher temperatures. Data on normal mean daily temperature is available from "Climates of the States" (Ruffner, 1985) and the "Climatic Atlas of the United States" (NOAA, 1974). In locations where the growing season extends year-round, the start of the growing season should be reported as day 0 and the end as day 367. The values for the growing season should be checked carefully to agree with the germination and harvesting (end of seasonal growth) dates for your type of vegetation. For example, grasses in southern California would germinate in the fall when the rains occur and die in late spring when the soil moisture is depleted. This contrasts with a typical growing season which would start in the spring and end in the fall.

- **Normal average annual wind speed**. This data is available from NOAA annual climatological data summary, "Climates of the States" (Ruffner, 1985) and the "Climatic Atlas of the United States" (NOAA, 1974).

- **Normal average quarterly relative humidity**. This data is available from NOAA annual climatological data summary, "Climates of the States" (Ruffner, 1985) and the "Climatic Atlas of the United States" (NOAA, 1974).

3.2.2 Precipitation Data

1. ***Default Precipitation Option*** *(Customary Units)*. The user may select 5 years of historical precipitation data for any of the 102 U.S. cities listed in Table 2. The input needed for this option is:

TABLE 2. CITIES FOR DEFAULT HISTORICAL PRECIPITATION DATA

- ALASKA
  - Annette
  - Bethel
  - Fairbanks
- ARIZONA
  - Flagstaff
  - Phoenix
  - Tucson
- ARKANSAS
  - Little Rock
- CALIFORNIA
  - Fresno
  - Los Angeles
  - Sacramento
  - San Diego
  - Santa Maria
- COLORADO
  - Denver
  - Grand Junction
- CONNECTICUT
  - Bridgeport
  - Hartford
  - New Haven
- FLORIDA
  - Jacksonville
  - Miami
  - Orlando
  - Tallahassee
  - Tampa
  - West Palm Beach
- GEORGIA
  - Atlanta
  - Watkinsville
- HAWAII
  - Honolulu
- IDAHO
  - Boise
  - Pocatello
- ILLINOIS
  - Chicago
  - East St. Louis
- INDIANA
  - Indianapolis
- IOWA
  - Des Moines
- KANSAS
  - Dodge City
  - Topeka
- KENTUCKY
  - Lexington
- LOUISIANA
  - Lake Charles
  - New Orleans
  - Shreveport
- MAINE
  - Augusta
  - Bangor
  - Caribou
  - Portland
- MASSACHUSETTS
  - Boston
  - Plainfield
  - Worcester
- MICHIGAN
  - East Lansing
  - Sault Sainte Marie
- MINNESOTA
  - St. Cloud
- MISSOURI
  - Columbia
- MONTANA
  - Glasgow
  - Great Falls
- NEBRASKA
  - Grand Island
  - North Omaha
- NEVADA
  - Ely
  - Las Vegas
- NEW HAMPSHIRE
  - Concord
  - Nashua
- NEW JERSEY
  - Edison
  - Seabrook
- NEW MEXICO
  - Albuquerque
- NEW YORK
  - Albany
  - Central Park
  - Ithaca
  - New York
  - Syracuse
- NORTH CAROLINA
  - Greensboro
- NORTH DAKOTA
  - Bismarck
- OHIO
  - Cincinnati
  - Cleveland
  - Columbus
  - Put-in-Bay
- OKLAHOMA
  - Oklahoma City
  - Tulsa
- OREGON
  - Astoria
  - Medford
  - Portland
- PENNSYLVANIA
  - Philadelphia
  - Pittsburgh
- RHODE ISLAND
  - Providence
- SOUTH CAROLINA
  - Charleston
- SOUTH DAKOTA
  - Rapid City
- TENNESSEE
  - Knoxville
  - Nashville
- TEXAS
  - Brownsville
  - Dallas
  - El Paso
  - Midland
  - San Antonio
- UTAH
  - Cedar City
  - Salt Lake City
- VERMONT
  - Burlington
  - Montpelier
  - Rutland
- VIRGINIA
  - Lynchburg
  - Norfolk
- WASHINGTON
  - Pullman
  - Seattle
  - Yakima
- WISCONSIN
  - Madison
- WYOMING
  - Cheyenne
  - Lander
- PUERTO RICO
  - San Juan

- Location

  NOTE: The user should be aware of the limitations of using the default historical precipitation data. None of the 102 locations for which data are available may be representative of the study site because rainfall is spatially very variable. In addition, the 5 years for which default data are available (1974-1978 in most cases) may not be typical, but were unusually wet or dry. The user should examine the rainfall and determine how representative it is of normal, wet and dry years at the study site. In addition, simulations should be run for more than five years to determine long-term performance of the landfill using, if necessary, another precipitation input option to examine the design under the range of possible weather conditions.

2. ***Synthetic Precipitation Option*** *(Customary or Metric Units)*. The program will generate from 1 to 100 years of daily precipitation data stochastically for the selected location using a synthetic weather generator. The precipitation data will have approximately the same statistical characteristics as the historic data at the selected location. If desired, the user can enter normal mean monthly precipitation values for the specific location to improve the statistical characteristics of the resulting daily values. The user is advised to enter normal mean monthly precipitation values if the project site is located more than a few miles from the city selected from Table 3 or if the land use or topography varies between the site and city. The daily values will vary from month to month and from year to year and will not equal the normal values entered. The same data is produced every time the option is used for a given location. The data required by the synthetic weather generator are:

   - Location (select from a list of 139 U.S. cities in Table 3)

   - Number of years of data to be generated

   - Normal mean monthly precipitation (Optional, default values are available.)

3. ***Create/Edit Precipitation Option*** *(Customary or Metric Units)*. Under the Create option, the user may enter from 1 to 100 years of daily precipitation data manually. The years, which need not be consecutive, can be entered in any order. The user may add or delete years of data or rearrange the order of the years of data. This same option can be used to edit the daily values of any year of data; commonly, this is used to add severe storm events, such as the 25-year, 24-hour precipitation event. The data required are:

   - Location

   - One or more years of daily precipitation data

TABLE 3. CITIES FOR SYNTHETIC PRECIPITATION DATA

- ALABAMA
  - Birmingham
  - Mobile
  - Montgomery
- ARIZONA
  - Flagstaff
  - Phoenix
  - Yuma
- ARKANSAS
  - Fort Smith
  - Little Rock
- CALIFORNIA
  - Bakersfield
  - Blue Canyon
  - Eureka
  - Fresno
  - Mt. Shasta
  - San Diego
  - San Francisco
- COLORADO
  - Colorado Springs
  - Denver
  - Grand Junction
  - Pueblo
- CONNECTICUT
  - Windsor Locks
- DELAWARE
  - Wilmington
- DISTRICT OF COLUMBIA
  - Washington
- FLORIDA
  - Jacksonville
  - Miami
  - Tallahassee
  - Tampa
- GEORGIA
  - Atlanta
  - Augusta
  - Macon
  - Savannah
- IDAHO
  - Boise
  - Pocatello
- ILLINOIS
  - Chicago
- INDIANA
  - Evansville
  - Fort Wayne
  - Indianapolis
- IOWA
  - Des Moines
  - Dubuque
- KANSAS
  - Dodge City
  - Topeka
  - Wichita
- KENTUCKY
  - Covington
  - Lexington
  - Louisville
- LOUISIANA
  - Baton Rouge
  - New Orleans
  - Shreveport
- MAINE
  - Caribou
  - Portland
- MARYLAND
  - Baltimore
- MASSACHUSETTS
  - Boston
  - Nantucket
- MICHIGAN
  - Detroit
  - Grand Rapids
- MINNESOTA
  - Duluth
  - Minneapolis
- MISSISSIPPI
  - Jackson
  - Meridian
- MISSOURI
  - Columbia
  - Kansas City
  - St. Louis
- MONTANA
  - Billings
  - Great Falls
  - Havre
  - Helena
  - Kalispell
  - Miles City
- NEBRASKA
  - Grand Island
  - North Platte
  - Scottsbluff
- NEVADA
  - Elko
  - Las Vegas
  - Reno
  - Winnemucca
- NEW HAMPSHIRE
  - Concord
  - Mt. Washington
- NEW JERSEY
  - Newark
- NEW MEXICO
  - Albuquerque
  - Roswell
- NEW YORK
  - Albany
  - Buffalo
  - New York
  - Syracuse
- NORTH CAROLINA
  - Asheville
  - Charlotte
  - Greensboro
  - Raleigh
- NORTH DAKOTA
  - Bismarck
  - Williston
- OHIO
  - Cleveland
  - Columbus
  - Toledo
- OKLAHOMA
  - Oklahoma City
  - Tulsa
- OREGON
  - Burns
  - Meachem
  - Medford
  - Pendleton
  - Portland
  - Salem
  - Sexton Summit
- PENNSYLVANIA
  - Philadelphia
  - Pittsburgh
- RHODE ISLAND
  - Providence
- SOUTH CAROLINA
  - Charleston
  - Columbia
- SOUTH DAKOTA
  - Huron
  - Rapid City
- TENNESSEE
  - Chattanooga
  - Knoxville
  - Memphis
  - Nashville
- TEXAS
  - Abilene
  - Amarillo
  - Austin
  - Brownsville
  - Corpus Christi
  - Dallas
  - El Paso
  - Galveston
  - Houston
  - San Antonio
  - Temple
  - Waco
- UTAH
  - Milford
  - Salt Lake City
- VIRGINIA
  - Norfolk
  - Richmond
- WASHINGTON
  - Olympia
  - Spokane
  - Stampede Pass
  - Walla Walla
  - Yakima
- WEST VIRGINIA
  - Charleston
- WISCONSIN
  - Green Bay
  - Lacrosse
  - Madison
  - Milwaukee
- WYOMING
  - Cheyenne

4. ***NOAA Tape Precipitation Option*** *(Customary Units)*. The option will convert the NOAA Summary of Day daily precipitation data written to diskette in ASCII print as-on-tape format into the format used by Version 3 of the HELP model. The following data are required for this option:

   - Location

   - NOAA ASCII print file of Summary of Day daily precipitation data in as-on-tape format

     NOTE: Daily precipitation data and normal mean monthly precipitation values for most locations are readily available in publications or on diskette from NOAA. Information on climatological data sources can be obtained from the National Climatic Data Center (NCDC), NOAA, Federal Building, Asheville, NC 28801, (704) 259-0682.

5. ***Climatedata™ Precipitation Option*** *(Customary Units)*. The program will convert daily precipitation data from an ASCII print file prepared by the Climatedata™ CD-ROM data base program into the format used by Version 3 of the HELP model. The Climatedata™ format is used by other CD-ROM, state and regional data bases and, therefore, those files can also be converted by this option. For example, the State of California and the Midwest Climatic Data Consortium used this same format. The following data are required for this option:

   - Location

   - Climatedata™ prepared file containing daily precipitation data

     NOTE: Hydrosphere Data Products, Inc. sells NOAA Summary of the Day precipitation data in a 4-disc CD-ROM data base called Climatedata™, one disc for each of four U.S. regions. Information on Climatedata™ is available from Hydrosphere, 1002 Walnut, Suite 200, Boulder, CO 80302, (800) 949-4937.

6. ***ASCII Precipitation Option*** *(Customary or Metric Units)*. The HELP model converts daily precipitation data in an ASCII file to the HELP format. Each year of ASCII precipitation data should be stored in a separate file. The first 365 or 366 values will be converted; excess data will be ignored. Inadequate data will yield an error. This option should also be used to convert data from spreadsheet format by first printing each year of precipitation to individual print files. The following data are required for this option:

   - Location

- Files containing ASCII data

- Years

7. ***HELP Version 2 Data Option*** *(Customary Units)*. Version 3 of the HELP model converts precipitation data prepared for use in Version 2 of the HELP model (Schroeder et al., 1988b) into the HELP Version 3 format. This option requires the following data:

   - Location

   - File containing HELP Version 2 data

8. ***Canadian Climatological Data Option*** *(Metric Units)*. The HELP model converts Canadian Climatological Data (Surface) in compressed or uncompressed diskette formats into the HELP Version 3 format. The following data are required by this option:

   - Location

   - Canadian Climatological Data file containing years of daily precipitation values

     NOTE: Canadian Climatological Data for most locations are readily available in publications of the Environment Canada, Atmospheric Environment Service, Canadian Climate Centre, Data Management Division, 4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4.

3.2.3 Temperature Data

1. ***Synthetic Temperature Option*** *(Customary or Metric Units)*. The program will generate from 1 to 100 years of temperature data stochastically for the selected location. The synthetic generation of daily temperature values is a weak function of precipitation and as such the user must first specify the precipitation. Generation of temperature data is limited to the number of years of precipitation data available. The synthetic temperature data will have approximately the same statistical characteristics as the historic data at the selected location. If desired, the user can enter normal mean monthly temperature values for the specific location to improve the statistical characteristics of the resulting daily values. The user is advised to enter normal mean monthly temperature values if the project site is located more than 100 miles from the city selected from Table 1 or if the difference in elevation between the site and the city is more than 500 feet. The data required by the synthetic weather generator are:

   - Location (select from a list of 183 U.S. cities in Table 1)

- Number of years of data to be generated
- Years of daily precipitation values
- Normal mean monthly temperature (Optional, default values are available.)

2. ***Create/Edit Temperature Option*** *(Customary or Metric Units)*. Under the create option, the user may enter up to 100 years of daily temperature data manually. The years, which need not be consecutive, can be entered in any order. The user may add or delete years of data or rearrange the order of the years of data. This same option can be used to edit the daily values of any year of data. The data required are:

   - Location
   - One or more years of daily temperature data

3. ***NOAA Tape Temperature Option*** *(Customary Units)*. This option will convert the NOAA Summary of Day daily temperature data written to diskette in ASCII print as-on-tape format into the format used by Version 3 of the HELP model. The program will accept either mean daily temperature or daily maximum and minimum temperature values. If maximum and minimum temperatures are used, the program averages the two to compute the daily mean temperature value. If mean temperature values are used, the same file is specified as the maximum and minimum temperature files. The following data are required for this option:

   - Location
   - NOAA ASCII print file of Summary of Day data file containing years of daily maximum temperature values or daily mean temperature values in as-on-tape format
   - NOAA ASCII print file of Summary of Day data file containing years of daily minimum temperature values or daily mean temperature values in as-on-tape format

     NOTE: Daily temperature (mean or maximum and minimum) data and normal mean monthly temperature values for most locations are readily available in publications or on diskette from NOAA. Information on climatological data sources can be obtained from the National Climatic Data Center, NOAA, Federal Building, Asheville, NC 28801, (704) 259-0682.

4. ***Climatedata™ Temperature Option*** *(Customary Units)*. The program will convert daily maximum and minimum temperature data from ASCII print files prepared by the Climatedata™ CD-ROM data base program into the daily mean

temperature data file format used by Version 3 of the HELP model. The Climatedata™ format is also used by other CD-ROM, state and regional data bases and therefore those files can also be converted by this option. For example, the State of California and the Midwest Climatic Data Consortium used this same format. The following data are required for this option:

- Location
- Climatedata™ prepared file containing daily maximum temperature data
- Climatedata™ prepared file containing daily minimum temperature data

  NOTE: Hydrosphere Data Products, Inc. sells NOAA Summary of the Day daily temperature data in a 4-disc CD-ROM data base called Climatedata™, one disc for each of four U.S. regions. Information on Climatedata™ is available from Hydrosphere, 1002 Walnut, Suite 200, Boulder, CO 80302, (800) 949-4937.

5. ***ASCII Temperature Option*** *(Customary or Metric Units)*. The HELP model converts daily mean temperature data in an ASCII file to the HELP format. Each year of ASCII temperature data should be stored in a separate file. The program will convert the first 365 or 366 values; excess data will be ignored. Inadequate data will yield an error. This option should also be used to convert data from spreadsheet format by first printing each year of temperature to individual print files. The following data are required for this option:

   - Location
   - Files containing ASCII data
   - Years

6. ***HELP Version 2 Data Option*** *(Customary Units)*. Version 3 of the HELP model converts temperature data prepared for use in Version 2 of the HELP model (Schroeder et al., 1988b) into the HELP Version 3 format. This option requires the following data:

   - Location
   - File containing HELP Version 2 data

7. ***Canadian Climatological Data Option*** *(Metric Units)*. The HELP model converts Canadian Climatological Data (Surface) in compressed or uncompressed diskette formats into the HELP Version 3 format. Conversion is available only for daily mean temperature values. The following data are required by this option:

- Location

- Canadian Climatological Data file containing years of daily mean temperature values

  NOTE: Canadian Climatological Data for most locations are readily available in publications of the Environment Canada, Atmospheric Environment Service, Canadian Climate Centre, Data Management Division, 4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4.

3.2.4 Solar Radiation Data

1. ***Synthetic Solar Radiation Option*** *(Customary or Metric Units)*. The program will generate from 1 to 100 years of daily solar radiation data stochastically for the selected location. The synthetic generation of daily solar radiation values is a strong function of precipitation and as such the user must first specify the precipitation. Generation of solar radiation data is limited to the number of years of precipitation data available. The synthetic solar radiation data will have approximately the same statistical characteristics as the historic data at the selected location. If desired, the user can enter the latitude for the specific location to improve the computation of potential solar radiation and the resulting daily values. The user is advised to enter the latitude if the project site is more than 50 miles north or south of the city selected from Table 1. The data required by the synthetic weather generator are:

   - Location (select from a list of 183 U.S. cities in Table 1)

   - Number of years of data to be generated

   - Years of daily precipitation values

   - Latitude (optional, default value is available.)

2. ***Create/Edit Solar Radiation Option*** *(Customary or Metric Units)*. Under the create option, the user may enter up to 100 years of daily solar radiation data manually. The years, which need not be consecutive, can be entered in any order. The user may add or delete years of data or rearrange the order of the years of data. This same option can be used to edit the daily values of any year of data. The input requirements are:

   - Location

   - One or more years of daily solar radiation data

3. ***NOAA Tape Solar Radiation Option*** *(Customary Units)*. This option will convert the NOAA Surface Airways Hourly solar radiation data written to diskette in ASCII print as-on-tape format into the format used by Version 3 of the HELP model. The following data are required for this option:

   - Location

   - NOAA ASCII print file of Surface Airways Hourly solar radiation data in as-on-tape format

     NOTE: Daily temperature (mean or maximum and minimum) data and normal mean monthly temperature values for most locations are readily available in publications or on diskette from the NOAA. Information on climatological data sources can be obtained from the National Climatic Data Center, NOAA, Federal Building, Asheville, NC 28801, (704) 259-0682.

4. ***Climatedata™ Solar Radiation Option*** *(Customary Units)*. The program will convert the Surface Airways ASCII print files of daily average solar radiation data into a daily solar radiation data file of the format used by HELP Version 3. It is anticipated that this option may also work with some other data sources as they become available. The following data are required for this option:

   - Location

   - Surface Airways prepared file containing years of daily solar radiation data

     NOTE: EarthInfo Inc. sells NOAA Surface Airways daily global solar radiation data in a 12-disc CD-ROM data base called Surface Airways as part of their NOAA data base, three discs for each of four U.S. regions. Information on Surface Airways is available from EarthInfo Inc., 5541 Central Avenue, Boulder, CO 80301-2846, (303) 938-1788. Hydrosphere Inc. is also developing a CD-ROM data base of NOAA Surface Airways data as part of their Climatedata™. Information on Climatedata™ is available from Hydrosphere, 1002 Walnut, Suite 200, Boulder, CO 80302, (800) 949-4937.

5. ***ASCII Solar Radiation Option*** *(Customary or Metric Units)*. The HELP model converts daily solar radiation data in an ASCII file to the HELP format. Each year of ASCII daily solar radiation data should be stored in a separate file. The program will convert the first 365 or 366 values; excess data will be ignored. Inadequate data will yield an error. This option should also be used to convert data from spreadsheet format by first printing each year of solar radiation to individual print files. The following data are required for this option:

   - Location

- Files containing ASCII data

- Years

6. ***HELP Version 2 Data Option*** *(Customary Units)*. Version 3 of the HELP model converts solar radiation data prepared for use in Version 2 of the HELP model (Schroeder et al., 1988b) into the HELP Version 3 format. This option requires the following data:

   - Location

   - File containing HELP Version 2 data

7. ***Canadian Climatological Data Option*** *(Metric Units)*. The HELP model converts Canadian Climatological Data (Surface) in compressed or uncompressed diskette formats into the HELP Version 3 format. Conversion is available only for hourly global solar radiation values. The input requirements are:

   - Location

   - Canadian Climatological Data file containing years of hourly global solar radiation values

     NOTE: Canadian Climatological Data for most locations are readily available in publications of the Environment Canada, Atmospheric Environment Service, Canadian Climate Centre, Data Management Division, 4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4.

3.3 SOIL AND DESIGN DATA REQUIREMENTS

The user may enter soil data by using the default soil/material textures option, the user-defined soil texture option, or a manual option. If the user selects a default soil texture, the program will display porosity, field capacity, wilting point, and hydraulic conductivity values of the soil that is stored as default. There are 42 default soil/material textures. If user-defined soil textures are selected, the program will display the porosity, field capacity, wilting point, and hydraulic conductivity of the selected soil from the user-defined soil texture data file. In the manual soil texture option, the user must specify values for the soil parameters. General data requirements for all options are listed below. Detailed explanations are given in Sections 3.4 through 3.9.

3.3.1 Landfill General Information

1. Project title

2. Landfill area *(Customary or Metric)*

3. Percentage of landfill area where runoff is possible

4. Method of initialization of moisture storage (user-specified or program initialized to near steady-state)

5. Initial snow water storage (optional, needed when moisture storage is user-specified)

3.3.2 Layer Data

1. Layer type (Four types of layers are permitted -- 1) vertical percolation, 2) lateral drainage, 3) barrier soil liner and 4) geomembrane liner.)

2. Layer thickness *(Customary or Metric)*

3. Soil texture

    - Select from 42 default soil/material textures to get the following data.
      Porosity, in vol/vol
      Field capacity, in vol/vol
      Wilting point, in vol/vol
      Saturated hydraulic conductivity (cm/sec)

    - Select from user-built soil texture library to get the following data.
      Porosity, in vol/vol
      Field capacity, in vol/vol
      Wilting point, in vol/vol
      Saturated hydraulic conductivity (cm/sec)

    - Enter the following data for manual soil texture descriptions.
      Porosity, in vol/vol
      Field capacity, in vol/vol
      Wilting point, in vol/vol
      Saturated hydraulic conductivity (cm/sec)

4. Initial volumetric soil water content (storage), in vol/vol (optional, needed when initial moisture storage is user-specified)

5. Rate of subsurface inflow to layer *(Customary or Metric)*

3.3.3 Lateral Drainage Layer Design Data

1. Maximum drainage length *(Customary or Metric)*
2. Drain slope, percent
3. Percentage of leachate collected from drainage layer that is recirculated
4. Layer to receive recirculated leachate from drainage layer

3.3.4 Geomembrane Liner Data

1. Pinhole density in geomembrane liner *(Customary or Metric)*
2. Geomembrane liner installation defects *(Customary or Metric)*
3. Geomembrane liner placement quality (six available options)
4. Geomembrane liner saturated hydraulic conductivity (vapor diffusivity), cm/sec
5. Geotextile transmissivity, cm^2/sec (optional, when placed with geomembrane)

3.3.5 Runoff Curve Number Information

Three methods are available to define a SCS AMC II runoff curve number.

1. User-specified curve number used without modification
2. User-specified curve number modified for surface slope and slope length
3. Curve number computed by HELP program based on surface slope, slope length, default soil texture, and quantity of vegetative cover

3.4 LANDFILL PROFILE AND LAYER DESCRIPTIONS

The HELP program may be used to model landfills with up to twenty layers of materials -- soils, geosynthetics, wastes or other materials. Figure 1 shows a typical landfill profile with eleven layers. The program recognizes four general types of layers.

1. Vertical percolation layers
2. Lateral drainage layers
3. Barrier soil liners

4. Geomembrane liners

It must be noted that correct classification of layers is very important because the program models the flow of water through the four types of layers in different ways.

Flow in a vertical percolation layer (e.g., Layers 1 and 5 in Figure 1) is by unsaturated vertical drainage downward due to gravity drainage; upward flux due to evapotranspiration is modeled as an extraction. The rate of gravity drainage (percolation) in a vertical percolation layer is a function of soil moisture and soil parameters. The saturated hydraulic conductivity specified for a vertical percolation layer should be in the vertical direction for anisotropic materials. The main role of a vertical percolation layer is to provide moisture storage. Waste layers and layers designed to support vegetation and provide evaporative storage are normally designated as vertical percolation layers.

Lateral drainage layers (e.g., Layers 2, 6, 7 and 9 in Figure 1) are layers directly above liners that are designed to promote drainage laterally to a collection and removal system. Vertical flow in a lateral drainage layer is modeled in the same manner as a vertical percolation layer, but saturated lateral drainage is allowed. The saturated hydraulic conductivity specified for a lateral drainage layer should be in the lateral direction (downslope) for anisotropic materials. A lateral drainage layer may be underlain by only another lateral drainage layer or a liner. The drainage slope specified for a lateral drainage should be the slope of the surface of the liner underlying the drainage layer in the direction of flow (the maximum gradient for a section of liner in a single plane) and may range from 0 to 50 percent. The drainage length specified for a lateral drainage layer is the length of the horizontal projection of a representative flow path from the crest to the collector rather than the distance along the slope. For slopes of less than 10 percent, the difference is negligible. The drainage length must be greater than zero but does not have a practical upper limit. Recirculation is permitted from lateral drainage layers directly above a liner where 0 to 100 percent of the drainage collected can be recirculated and redistributed in a user-specified vertical percolation or lateral drainage layer.

Barrier soil liners (e.g., Layers 4, and 11 in Figure 1) are intended to restrict vertical drainage (percolation/leakage). These layers should have saturated hydraulic conductivities substantially lower than those of the other types of layers. Liners are assumed to be saturated at all times but leak only when there is a positive head on the top surface of the liner. The percolation rate depends upon the depth of water-saturated soil (head) above the base of the liner, the thickness of the liner and the saturated hydraulic conductivity. The saturated hydraulic conductivity specified for a barrier soil liner should be its value for passing the expected permeant in the vertical direction for anisotropic materials. The program allows only downward saturated flow in barrier soil liners. Evapotranspiration and lateral drainage are not permitted from a liner. Thus, any water moving into a liner will eventually percolate through the liner. In Version 3 composite liners are modeled as two layers -- a geomembrane liner and a barrier soil liner as shown in Figure 1.

Geomembrane liners (e.g., Layers 3, 8 and 10 in Figure 1) are virtually impermeable synthetic membranes that reduce the area of vertical drainage/percolation/leakage to a very small fraction of the area located near manufacturing flaws and installation defects (punctures, tears and faulty seaming). A small quantity of vapor transport across the membrane also occurs and can be modeled by specifying the vapor diffusivity as the saturated hydraulic conductivity of the geomembrane. Geomembranes leak only when there is a positive head on the top surface of the liner. The leakage rate depends on the depth of saturated soil (head) above the liner, the saturated hydraulic conductivity of the drainage limiting soil layer adjacent to the membrane, the contact between the membrane and the adjacent drainage limiting soil layer, geomembrane properties and the size and number of holes in the geomembrane liner. Aging of geomembranes is not considered.

While the HELP program is quite flexible, there are some basic rules that must be followed regarding the arrangement of layers in the profile.

1. A vertical percolation layer may not be underlying a lateral drainage layer.

2. A barrier soil liner may not be underlying another barrier soil liner.

3. A geomembrane liner may not be placed directly between two barrier soil liners.

4. A geomembrane liner may not be underlying another geomembrane liner.

5. A barrier soil liner may not be placed directly between two geomembrane liners.

6. When a barrier soil liner or a geomembrane liner is not placed directly below the lowest drainage layer, all drainage layers below the lowest liner are treated as vertical percolation layers. Thus, no lateral drainage is computed for the bottom section of the landfill.

7. The top layer may not be a barrier soil liner.

8. The top layer may not be a geomembrane liner.

9. The profile can contain no more than a total of five barrier soil liners and geomembrane liners.

The HELP model does not permit two barrier soil liners to be adjacent to each other. If a design has two soil layers adjacent to each other that would be expected to act as a single liner and both soils will remain nearly saturated and contribute significantly to the head loss and restriction of vertical drainage, then the thickness of the two layers should be summed and an effective saturated hydraulic conductivity should be computed for the combined liner. The effective saturated hydraulic conductivity should be computed as follows:

$$K_e = \frac{T_e}{\sum_{i=1}^{n} \frac{T_i}{K_i}} = \frac{T_1 + T_2}{\frac{T_1}{K_1} + \frac{T_2}{K_2}} \qquad \textbf{(1)}$$

where

K_e = effective saturated hydraulic conductivity of combined liner
T_e = effective thickness of combined liner
T_i = thickness of liner soil i
K_i = saturated hydraulic conductivity of liner soil i
n = number of liner soils in the combined liner

For computational purposes, the soil profile is partitioned into subprofiles. Subprofiles are defined in relation to the location of the liners. The first (top) subprofile shown on Figure 1 extends from the landfill surface to the bottom of the highest liner system (bottom of the composite liner, Layer 4) upper barrier soil layer. The second subprofile extends from the top of the layer (Layer 5) below the bottom of the first liner system to the base of the second liner system (Layer 8). The third (bottom) subprofile extends from the top of the layer below the second liner system (the leakage detection drainage layer, Layer 9) to the base of the lowest liner (Layer 11). The program allows up to five liner systems and, therefore, five subprofiles plus an additional subprofile of vertical percolation layers below the bottom liner system. The program models the flow of water through one subprofile at a time from top to bottom, with the percolation or leakage from one subprofile serving as the inflow to the underlying subprofile.

3.5 SOIL CHARACTERISTICS

The user can assign soil characteristics to a layer using the default option, the user defined soil option, or the manual option. Table 4 shows the default characteristics for 42 soil/material types. The soil texture types are classified according to two standard systems, the U.S. Department of Agriculture textural classification system and the Unified Soil Classification System. The default characteristics of types 1 through 15 are typical of surficial and disturbed agricultural soils, which may be less consolidated and more aerated than soils typically placed in landfills (Breazeale and McGeorge, 1949; England, 1970; Lutton et al., 1979; Rawls et al., 1982). Clays and silts in landfills would generally be compacted except within the vegetative layer, which might be tilled to promote vegetative growth. Untilled vegetative layers may be more compacted than the loams listed in Table 4. Soil texture types 22 through 29 are compacted soils. Type 18 is representative of typical municipal solid waste that has been compacted; type 19 is the same waste but it accounts for 65 percent of the waste being in dead zones not contributing to drainage and storage. Soil types 16 and 17 denote very well compacted clay soils that might be used for barrier soil liners. The user assigns default soil characteristics to a layer by specifying the appropriate number for the material type. The

TABLE 4. DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	1.0x10^{-2}
2	S	SW	0.437	0.062	0.024	5.8x10^{-3}
3	FS	SW	0.457	0.083	0.033	3.1x10^{-3}
4	LS	SM	0.437	0.105	0.047	1.7x10^{-3}
5	LFS	SM	0.457	0.131	0.058	1.0x10^{-3}
6	SL	SM	0.453	0.190	0.085	7.2x10^{-4}
7	FSL	SM	0.473	0.222	0.104	5.2x10^{-4}
8	L	ML	0.463	0.232	0.116	3.7x10^{-4}
9	SiL	ML	0.501	0.284	0.135	1.9x10^{-4}
10	SCL	SC	0.398	0.244	0.136	1.2x10^{-4}
11	CL	CL	0.464	0.310	0.187	6.4x10^{-5}
12	SiCL	CL	0.471	0.342	0.210	4.2x10^{-5}
13	SC	SC	0.430	0.321	0.221	3.3x10^{-5}
14	SiC	CH	0.479	0.371	0.251	2.5x10^{-5}
15	C	CH	0.475	0.378	0.265	1.7x10^{-5}
16	Barrier Soil		0.427	0.418	0.367	1.0x10^{-7}
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	3.0x10^{-9}
18	Municipal Waste (900 lb/yd^3 or 312 kg/m^3)		0.671	0.292	0.077	1.0x10^{-3}
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	1.0x10^{-3}
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	1.0x10^{+1}
21	Gravel		0.397	0.032	0.013	3.0x10^{-1}
22	L*	ML	0.419	0.307	0.180	1.9x10^{-5}
23	SiL*	ML	0.461	0.360	0.203	9.0x10^{-6}
24	SCL*	SC	0.365	0.305	0.202	2.7x10^{-6}
25	CL*	CL	0.437	0.373	0.266	3.6x10^{-6}
26	SiCL*	CL	0.445	0.393	0.277	1.9x10^{-6}
27	SC*	SC	0.400	0.366	0.288	7.8x10^{-7}
28	SiC*	CH	0.452	0.411	0.311	1.2x10^{-6}
29	C*	CH	0.451	0.419	0.332	6.8x10^{-7}
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	5.0x10^{-5}
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	4.1x10^{-3}
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	1.0x10^{-2}
33	Fine Copper Slag*		0.375	0.055	0.020	4.1x10^{-2}
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	3.3x10^{+1}

* Moderately Compacted (Continued)

TABLE 4 (continued). DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification		Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	Geomembrane Material	vol/vol	vol/vol	vol/vol	cm/sec
35	High Density Polyethylene (HDPE)				$2.0x10^{-13}$
36	Low Density Polyethylene (LDPE)				$4.0x10^{-13}$
37	Polyvinyl Chloride (PVC)				$2.0x10^{-11}$
38	Butyl Rubber				$1.0x10^{-12}$
39	Chlorinated Polyethylene (CPE)				$4.0x10^{-12}$
40	Hypalon or Chlorosulfonated Polyethylene (CSPE)				$3.0x10^{-12}$
41	Ethylene-Propylene Diene Monomer (EPDM)				$2.0x10^{-12}$
42	Neoprene				$3.0x10^{-12}$

(concluded)

user-defined soil option accepts non-default soil characteristics for layers assigned soil type numbers greater than 42. This is especially convenient for specifying characteristics of waste layers. User-specified soil characteristics can be assigned any soil type number greater than 42.

When a default soil type is used to describe the top soil layer, the program adjusts the saturated hydraulic conductivities of the soils in the top half of the evaporative zone for the effects of root channels. The saturated hydraulic conductivity value is multiplied by an empirical factor that is computed as a function of the user-specified maximum leaf area index. Example values of this factor are 1.0 for a maximum LAI of 0 (bare ground), 1.8 for a maximum LAI of 1 (poor stand of grass), 3.0 for a maximum LAI of 2 (fair stand of grass), 4.2 for a maximum LAI of 3.3 (good stand of grass) and 5.0 for a maximum LAI of 5 (excellent stand of grass).

The manual option requires values for porosity, field capacity, wilting point, and saturated hydraulic conductivity. These and related soil properties are defined below.

Soil Water Storage (Volumetric Content): the ratio of the volume of water in a soil to the total volume occupied by the soil, water and voids.

Total Porosity: the soil water storage/volumetric content at saturation (fraction of total volume).

Field Capacity: the soil water storage/volumetric content after a prolonged period of gravity drainage from saturation corresponding to the soil water storage when a soil exerts a soil suction of 1/3 bar.

Wilting Point: the lowest soil water storage/volumetric content that can be achieved by plant transpiration or air-drying, that is the moisture content where a plant will be permanently wilted corresponding to the soil water storage when a soil exerts a soil suction of 15 bars.

Saturated Hydraulic Conductivity: the rate at which water drains through a saturated soil under a unit pressure gradient.

Porosity, field capacity and wilting point are all dimensionless numbers between 0 and 1. Porosity must be greater than field capacity, which in turn must be greater than the wilting point. The wilting point must be greater than zero. The values for porosity, field capacity and wilting point are not used for liners, except for initializing the soil water storage of liners to the porosity value.

The soil moisture retention properties of a layer should be adjusted downward if some volume of the layer does not participate in the drainage and storage of infiltrated water. This condition commonly exists in shallow layers of municipal solid waste because municipal solid waste is very heterogeneous and poorly compacted. The plastics in the waste also channels the drainage, limits the spreading of infiltration, and restricts the wetting of the waste and, therefore, the storage. Default soil texture number 19 provides adjusted retention values for a municipal solid waste with significant channeling; it assumes that only 25 percent of the volume is actively involved in drainage and storage of infiltration. As the values were computed by multiplying the values for municipal solid waste (default texture number 18) by 0.25; the initial soil water content would also be multiply by 0.25.

The HELP user has the option of specifying the initial volumetric water storage (content) of all layers except liners. Liners are assumed to remain saturated at all times. If the user chooses not to specify initial water contents, the program estimates values near steady-state and then runs one year of initialization to refine the estimates before starting the simulation. The soil water contents at the end of this year of initialization are taken as the initial values for the simulation period. The program then runs the complete simulation, starting again from the beginning of the first year of data. The results for the initialization period are not reported. To improve initialization to steady-state moisture storage, the user should replace thick vertical percolation and lateral drainage layers, that are below the evaporative zone and above the saturated zone above liners, with thin layers. Then, run the simulation for a number of years until steady-state is approximated. The final dimensionless water storage values after nearing steady-state should then be specified as the initial water contents in your actual simulation using the true dimensions of the layers.

The initial moisture content of municipal solid waste is a function of the composition of the waste; reported values for fresh wastes range from about 0.08 to 0.20 vol/vol. The average value is about 0.12 vol/vol for compacted municipal solid waste. If using default waste texture 19, where 75% of the volume is inactive, the initial moisture content should be that of only the active portion, 25% of the values reported above.

The soil water storage or content used in the HELP model is on a per volume basis (θ), volume of water (V_w) per total (bulk--soil, water and air) soil volume ($V_t = V_s + V_w + V_a$), which is characteristic of practice in agronomy and soil physics. Engineers more commonly express moisture content on a per mass basis (w), mass of water (M_w) per mass of soil (M_s). The two can be related to each other by knowing the dry bulk density (ρ_{db}), dry bulk specific gravity (Γ_{db}) of the soil (ratio of dry bulk density to water density (ρ_w)), wet bulk density (ρ_{wb}), wet bulk specific gravity (Γ_{wb}) of the soil (ratio of wet bulk density to water density.

$$\theta = w \frac{\rho_{db}}{\rho_w} = w \, \Gamma_{db} \tag{2}$$

$$\theta = \frac{w}{1 + w} \frac{\rho_{wb}}{\rho_w} = \frac{w}{1 + w} \Gamma_{wb} \tag{3}$$

3.6 GEOMEMBRANE CHARACTERISTICS

The user can assign geomembrane liner characteristics (vapor diffusivity/saturated hydraulic conductivity) to a layer using the default option, the user-defined soil option, or the manual option. Saturated hydraulic conductivity for geomembranes is defined in terms of its equivalence to the vapor diffusivity. The porosity, field capacity, wilting point and intial moisture content are not needed for geomembranes. Table 4 shows the default characteristics for 12 geomembrane liners. The user assigns default soil characteristics to a layer simply by specifying the appropriate geomembrane liner texture number. The user-defined option accepts user specified geomembrane liner characteristics for layers assigned textures greater than 42. Manual geomembrane liner characteristics can be assigned any texture greater than 42.

Regardless of the method of specifying the geomembrane "soil" characteristics, the program also requires values for geomembrane liner thickness, pinhole density, installation defect density, geomembrane placement quality, and the transmissivity of geotextiles separating geomembranes and drainage limiting soils. These parameters are defined below.

Pinhole Density: the number of defects (diameter of hole equal to or smaller than the geomembrane thickness; hole estimated as 1 mm in diameter) in a given area generally resulting from manufacturing flaws such as polymerization deficiencies.

Installation Defect Density: the number of defects (diameter of hole larger than the geomembrane thickness; hole estimated as 1 cm^2 in area) per acre resulting primarily from seaming faults and punctures during installation.

Geotextile Transmissivity: the product of the in-plane saturated hydraulic conductivity and thickness of the geotextile.

The density of pinholes and installation defects is a subject of speculation. Ideally, geomembranes would not have any defects. If any were known to exist during construction, the defects would be repaired. However, geomembranes are known to leak and therefore reasonably conservative estimates of the defect densities should be specified to determine the maximum probable leakage quantities.

The density of defects has been measured at a number of landfills and other facilities and reported in the literature. These findings provide guidance for estimating the defect densities. Typical geomembranes may have about 0.5 to 1 pinholes per acre (1 to 2 pinholes per hectare) from manufacturing defects. The density of installation defects is a function of the quality of installation, testing, materials, surface preparation, equipment, and QA/QC program. Representative installation defect densities as a function of the quality of installation are given below for landfills being built today with the state-of-the-art in materials, equipment and QA/QC. In the last column the frequency of achieving a particular installation quality is given. The estimates are based on limited data but are characteristic of the recommendations provided in the literature.

Installation Quality	Defect Density (number per acre)	Frequency (percent)
Excellent	Up to 1	10
Good	1 to 4	40
Fair	4 to 10	40
Poor	10 to 20*	10

* Higher defect densities have been reported for older landfills with poor installation operations and materials; however, these high densities are not characteristic of modern practice.

The user must also enter the placement quality of the geomembrane liner if pinholes or installation defects are reported. There are six different possible entries for the geomembrane liner placement quality. The program selects which equation will be used to compute the geomembrane based on the placement quality specified and the saturated hydraulic conductivity of the lower permeability soil (drainage limiting soil) adjacent to the geomembrane. The program has different equations for three ranges of saturated hydraulic conductivity: greater than or equal to 0.1 cm/sec; less than 0.1 and greater than or equal to 0.0001 cm/sec; and less than 0.0001 cm/sec.

1. *Perfect*: Assumes perfect contact between geomembrane and adjacent soil that limits drainage rate (no gap, "sprayed-on" seal between membrane and soil formed in place).

2. *Excellent*: Assumes exceptional contact between geomembrane and adjacent soil that limits drainage rate (typically achievable only in the lab or small field lysimeters).

3. *Good*: Assumes good field installation with well-prepared, smooth soil surface and geomembrane wrinkle control to insure good contact between geomembrane and adjacent soil that limits drainage rate.

4. *Poor*: Assumes poor field installation with a less well-prepared soil surface and/or geomembrane wrinkling providing poor contact between geomembrane and adjacent soil that limits drainage rate, resulting in a larger gap for spreading and greater leakage.

5. *Worst Case*: Assumes that contact between geomembrane and adjacent soil does not limit drainage rate, resulting in a leakage rate controlled only by the hole.

6. *Geotextile separating geomembrane liner and drainage limiting soil*: Assumes leakage spreading and rate is controlled by the in-plane transmissivity of the geotextile separating the geomembrane and the adjacent soil layer that would have otherwise limited the drainage. This quality would not normally be used with a geosynthetic clay liner (GCL) as the controlling soil layer. Upon wetting, the bentonite swells and extrudes into the geotextile, filling its voids and reducing its transmissivity below the point where it can contribute significantly to spreading of leakage. GCL's, when properly placed, tend to have intimate contact with the geomembrane (Harpur et al., 1993).

3.7 SITE CHARACTERISTICS

The user must also supply a value of the Soil Conservation Service (SCS) runoff curve number for Antecedent Moisture Condition II (AMC-II) or provide information so that a curve number can be computed. Unlike Version 2 of the HELP model, Version 3 accounts for surface slope effects on curve number and runoff. In Version 3 of the HELP model, there are three different options by which a curve number can be obtained.

1. A curve number defined by the user

2. A curve number defined by the user and modified according to the surface slope and slope length of the landfill

3. A curve number is computed by the HELP model based on landfill surface slope, slope length, soil texture of the top layer, and the vegetative cover. Some general guidance for selection of runoff curve numbers is provided in Figure 2 (USDA, Soil Conservation Service, 1985).

Two of the options account for surface slope. The correlation between surface slope conditions and curve number were developed for slopes ranging from 1 percent to as high as 50 percent and for slope lengths ranging from 50 feet to 2000 feet.

3.8 OVERVIEW OF MODELING PROCEDURE

The hydrologic processes modeled by the program can be divided into two categories: surface processes and subsurface processes. The surface processes modeled are snowmelt, interception of rainfall by vegetation, surface runoff, and surface evaporation. The subsurface processes modeled are evaporation from soil profile, plant transpiration, unsaturated vertical drainage, barrier soil liner percolation, geomembrane leakage and saturated lateral drainage.

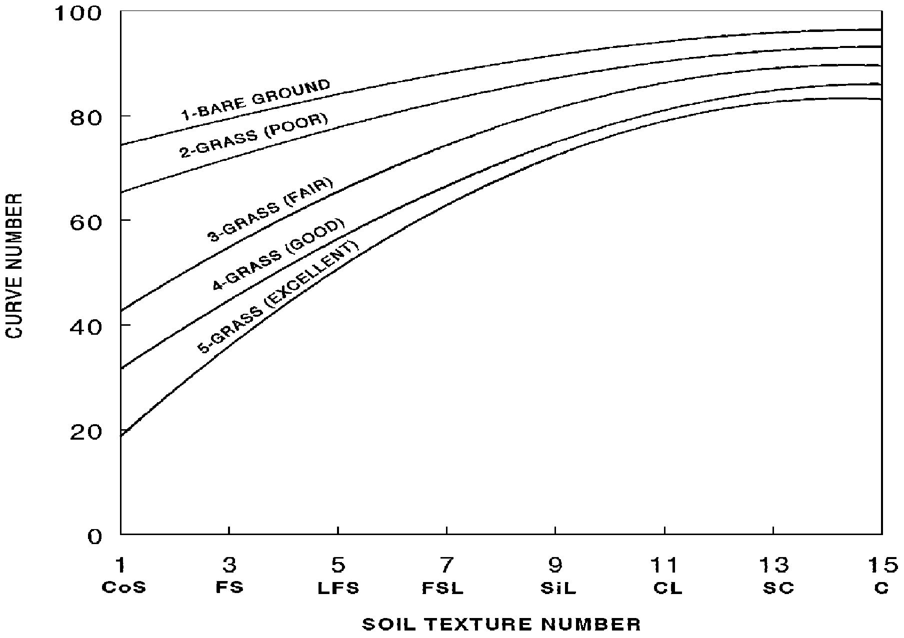

Figure 2. Relation between SCS Curve Number and Default Soil Texture Number for Various Levels of Vegetation

Daily infiltration into the landfill is determined indirectly from a surface water balance. Infiltration is assumed to equal the sum of rainfall, surface storage and snowmelt, minus the sum of runoff, additional storage in snowpack and evaporation of surface water. No liquid water is assumed to be held in surface storage from one day to the next except in the snowpack or when the top soil is saturated and runoff is not permitted. Each day, the free available water for infiltration, runoff, or evaporation from water on the surface is determined from the surface storage, discharge from the snowpack, and rainfall. Snowfall is added to the surface snow storage, which is depleted by either evaporation or melting. Snowmelt is added to the free available water and is treated as rainfall except that it is not intercepted by vegetation. The free available water is used to compute the runoff by the SCS rainfall-runoff relationship. The interception is the measure of water available to evaporate from the surface. Interception in excess of the potential evaporation is added to infiltration. Surface evaporation is then computed. Potential evaporation from the surface is first applied to the interception; any excess is applied to the snowmelt, then to the snowpack and finally to the groundmelt. Potential evaporation in excess of the evaporation from the surface is applied to the soil column and plant transpiration. The snowmelt and rainfall that does not run off or evaporate is assumed to infiltrate into the landfill along with any groundmelt that does not evaporate.

The first subsurface processes considered are soil evaporation and plant transpiration from the evaporative zone of the upper subprofile. A vegetative growth model accounts for the daily growth and decay of the surface vegetation. The other subsurface processes are modeled one subprofile at a time, from top to bottom, using a design-dependent time step ranging from 30 minutes to 6 hours. A storage-routing procedure is used to redistribute the soil water among the modeling segments that comprise the subprofile. This procedure accounts for infiltration or percolation into the subprofile and evapotranspiration from the evaporative zone. Then, if the subprofile contains a liner, the program computes the head on the liner. The head on the liner is then used to compute the leakage/percolation through the liner and, if lateral drainage is permitted above the top of the liner, the lateral drainage to the collection and removal system.

3.9 ASSUMPTIONS AND LIMITATIONS

3.9.1 Solution Methods

The modeling procedures documented in the previous section are necessarily based on many simplifying assumptions. Generally, these assumptions are reasonable and consistent with the objectives of the program when applied to standard landfill designs. However, some of these assumptions may not be reasonable for unusual designs. The major assumptions and limitations of the program are summarized below.

Runoff is computed using the SCS method based on daily amounts of rainfall and snowmelt. The program assumes that areas adjacent to the landfill do not drain onto the landfill. The time distribution of rainfall intensity is not considered. The program cannot be expected to give accurate estimates of runoff volumes for individual storm events on the basis of daily rainfall data. However, because the SCS rainfall-runoff relation is based on considerable daily field data, long-term estimates of runoff should be reasonable. The SCS method does not explicitly consider the length and slope of the surface over which overland flow occurs. This limitation has been removed by developing and implementing into the HELP input routine a procedure for computing curve numbers that take into consideration the effect of slope and slope length. The limitation, however, remains on the user specified curve number (the first method). This limitation is not a concern provided that the slope and slope length of the landfill do not differ dramatically from those of the test plots upon which the SCS method is based. Use of the SCS method probably underestimates runoff somewhat where the overland flow distance is very short or the slope is very steep or when the rainfall duration is very short and the intensity is very high.

The HELP model assumes Darcian flow by gravity influences through homogeneous soil and waste layers. It does not consider explicitly preferential flow through channels such as cracks, root holes, or animal burrows but allows for vertical drainage through the evaporative zone at moisture contents below field capacity. Similarly, the program allows vertical drainage from a layer at moisture contents below field capacity when the inflow would occupy a significant fraction of the available storage capacity below field capacity. The drainage rate out of a segment is assumed to equal the unsaturated hydraulic conductivity of the segment corresponding to its moisture content, provided that the underlying segment is not a liner and is not saturated. In addition to these special cases, the drainage rate out of a segment can be limited by the saturated hydraulic conductivity of the segment below it. When limited, the program computes an effective gradient for saturated flow through the lower segment. This permits vertical percolation or lateral drainage layers to be arranged without restrictions on their properties as long as they perform as their layer description implies and not as liners.

The model assumes that a. the soil moisture retention properties and unsaturated hydraulic conductivity can be calculated from the saturated hydraulic conductivity and limited soil moisture retention parameters (porosity, field capacity and wilting point) and b. the soil moisture retention properties fit a Brooks-Corey relation (Brooks et al., 1964) defined by the three soil moisture retention parameters. Upon obtaining the Brooks-Corey parameters, the model assumes that the unsaturated hydraulic conductivity relation with soil moisture is well described by the Campbell equation.

The model does not explicitly compute flow by differences in soil suction (soil suction gradient) and, as such, does not model the draw of water upward by capillary drying. This draw of water upward is modeled as an extraction rather than transport of water upward. Therefore, it is important that the evaporative zone depth be specified as the depth of capillary drying. Drainage downward by soil suction exerted by dry soils lower in the landfill profile is modeled as Darcian flow for any soil having a relative moisture content greater than the lower soils. The drainage rate is equal to the unsaturated hydraulic conductivity computed as a function of the soil moisture content. As such, the rate is assumed to be independent of the pressure gradient.

Leakage through barrier soil liners is modeled as saturated Darcian flow. Leakage is assumed to occur only as long as there is head on the surface of the liner. The model assumes that the head driving the percolation can be represented by the average head across the entire liner and can be estimated from the soil moisture storage. It is also assumed that the liner underlies the entire area of the landfill and, conservatively, that when leakage occurs, the entire area of the landfill leaks. The model does not consider aging or drying of the liner and, therefore, the saturated hydraulic conductivity of the liner does not vary as a function of time.

Geomembranes are assumed to leak primarily through holes. The leakage passes through the holes and spreads between the geomembrane and soil until the head is dissipated. The leakage then percolates through the soil at the rate dependent on the saturated hydraulic conductivity and the pressure gradient. Therefore, the net effect of a geomembrane is to reduce the area of percolation through the liner system. The program assumes the holes to be uniformly distributed and the head is distributed across the entire liner. The model does not consider aging of the liner and therefore the number and size of the holes do not vary as a function of time. In addition, it is conservatively assumed that the head on the holes can be represented by the average head across the entire liner and can be estimated from the soil moisture storage and that the liner underlies the entire area of the landfill.

The lateral drainage model is based on the assumption that the saturated depth profile is characteristic of the steady-state profile for the given average depth of saturation. As such, the model assumes that the lateral drainage rate for steady-state drainage at a given average depth of saturation is representative of unsteady lateral drainage rate for the same average saturated depth. In actuality the rate would be somewhat larger for periods when the depth is building and somewhat smaller for periods when the depth is falling. Steady drainage implies that saturated conditions exist above the entire surface of the liner, agreeing with the assumptions for leakage through liner systems.

The model assumes the vegetative growth and decay can be characterized by a vegetative growth model developed for crops and perennial grasses. In addition, it is assumed that the vegetation transpires water, shades the surface, intercepts rainfall and reduces runoff in similar quantities as grasses or as an adjusted equivalence of LAI.

3.9.2 Limits of Application

The model can handle water routing through or storage in up to twenty soil or waste layers; as many as five liner systems may be employed. The simulation period can range from 1 to 100 years. The model cannot simulate a capillary break or unsaturated lateral drainage.

The model has limits on the arrangement of layers in the landfill profile. Each layer must be described as being one of four types: vertical percolation layer, lateral drainage layer, barrier soil liner, or geomembrane liner. The model does not permit a vertical percolation layer to be placed directly below a lateral drainage layer. A barrier soil liner may not underlie another barrier soil liner. Geomembranes cannot envelop a barrier soil liner and barrier soil liners cannot envelop a geomembrane. The top layer may not be a liner. If a liner is not placed directly below the lowest lateral drainage layer, the lateral drainage layers in the lowest subprofile are treated by the model as vertical percolation layers. No other restrictions are placed on the order of the layers.

The lateral drainage equation was developed for the expected range of hazardous waste landfill design specifications. Permissible ranges for slope of the drainage layer are 0 to 50 percent. Due to dimensionless structure of the lateral drainage equation, there are no practical limits in the maximum drainage length.

Several interrelations must exist between the soil characteristics of a layer and of the soil subprofile. The porosity, field capacity and wilting point can theoretically range from 0 to 1 units of volume per volume; however, the porosity must be greater than the field capacity, and the field capacity must be greater than the wilting point.
Initial soil moisture storage must be greater than or equal to the wilting point and less than or equal to the porosity. The initial moisture content of liners must be equal to the porosity and the liners remain saturated. The field capacity and wilting point values are not used for barrier soil liners. Values for porosity, field capacity and wilting point are not needed for geomembranes.

Values for the leaf area index may range from 0 for bare ground to 5 for an excellent stand of grass. Detailed recommendations for leaf area indices and evaporative depths are given in the program.

The default values for the evaporation coefficient are based on experimental results. The basis for the calculation of these default values is described by Schroeder et al. (1994). The model imposes upper and lower limits of 5.1 and 3.3 so as not to exceed the range of experimental data.

Surface runoff from adjacent areas does not run onto the landfill, and the physical characteristics of the landfill specified by the user remain constant over the modeling period. No adjustments are made for the changes that occur in these characteristics as the landfill ages. Additionally, the program cannot model the filling process within a single simulation. Aging of materials and staging of the landfill operation must be modeled by successive simulations.

Default Soil Characteristics

The HELP model contains default values of soil characteristics based on soil texture class. The documentation for Version 3 describes the origin of these default values

(Schroeder et al., 1994). Recommended default values for LAI and evaporative depth based on thick loamy top soils are given in the program.

Manual Soil Characteristics

The HELP model computes values for the three Brooks-Corey parameters as described in the documentation for Version 3 (Schroeder et al., 1994) based on the values for porosity, field capacity and wilting point.

Soil Moisture Initialization

The soil moisture of the layers may be initialized by the user or the program. When initialized by the program, the process consists of three steps. The first step sets the soil moisture of all layers except barrier soil liners equal to field capacity and all barrier soil liners to porosity (saturation). In the second step, the program computes a soil moisture for each layer below the top barrier soil liner. These soil moisture contents are computed to yield an unsaturated hydraulic conductivity equal to 85 percent of the lowest effective saturated hydraulic conductivity of the all liner systems above the layer, including consideration for the presence of a synthetic geomembrane liner. If the unsaturated hydraulic conductivity is less than 1 x 10^{-6} cm/sec and if the computed soil moisture is greater than field capacity, the soil moisture is set to equal computed soil moisture instead of the field capacity. The third step in the initialization consists of running the model for one year of simulation using the first year of climate data and the initial soil moisture values selected in the second step. At the end of this year of initialization, the soil moisture values existing at that point are reported as the initial soil moisture values. The simulation is then restarted using the first year of climate data.

Synthetic Temperature and Solar Radiation Values

The synthetically generated temperature and solar radiation values are assumed to be representative of the climate at the site. Synthetic daily temperature is a function of normal mean monthly temperature and the occurrence of rainfall. Synthetic daily solar radiation is a function of latitude, occurrence of rainfall, average daily dry-day solar radiation and average daily wet-day solar radiation.

SECTION 4

PROGRAM INPUT

4.1 INTRODUCTION

This section describes the procedures and options available to input data, execute the model, and obtain results. The discussion includes general input information, some definitions and rules, the program structure, and detailed explanations of the options reached from the Main Menu. Guidance is given throughout the section for selecting the most appropriate values in certain situations, but the main purpose of this section is to describe the mechanics of using the user interface. Detailed guidance on the definitions of input parameters and selection of their values is presented in Section 3.

Version 3 of the HELP program is started by typing "HELP3" from the DOS prompt in the directory where the program resides. The program starts by displaying a title screen, a preface, a disclaimer and then the main menu. The user moves from the title screen to the main menu by striking any key such as the space bar. Upon reaching the main menu, the user can select any of seven options. The program automatically solicits input from the user based on the option selected. In general the HELP model requires the following data, some of which may be selected from the default values.

1. Units
2. Location
3. Weather data file names
4. Evapotranspiration information
5. Precipitation data
6. Temperature data
7. Solar radiation data
8. Soil and design data file name
9. General landfill and site information
10. Landfill profile and soil/waste/geomembrane data
11. SCS runoff curve number information

4.2 DEFINITIONS AND RULES

There are a few fundamental rules regarding the input facility that a user must keep in mind when using the model. These rules should be followed to move around the screens and to move within the same screen. Below are some definitions and rules.

1. ***Screens.*** A screen in the HELP user interface as used in this report is a single screen of information. These screens are divided into three categories:

- Input Screen: a screen on which the user can input data
- Selection Screen: a screen from which the user selects an entry from a list
- On-line Help Screen: a screen where assistance is provided. General assistance on the interface is displayed by pressing the ***F1*** key, technical assistance by pressing the ***F2*** key, and key operations by pressing the ***F3*** key.

This terminology is used throughout this section. Each module consists of two types of screens: "primary" and "secondary." Primary screens are main screens that form a loop for each option of HELP. Secondary screens are displayed from the primary screens as part of the input process. These screens can be input screens or selection screens.

2. Input Cells. When the program highlights a number of spaces (called an ”input cell” throughout this section), an input from the user is expected. At any input cell, the user has one of several options: enter the data requested, accept existing value, seek on-line help, or select one of the menu items listed at the bottom of the screen. Each cell is associated with a variable that is used directly or indirectly in the HELP model. Therefore, every effort must be made to assign a value to each cell when applicable. The user may input the value the first time around, or return to the cell at a later time during the program session. If an input cell is left blank, a value of zero will be assigned to the corresponding variable. If zero is not an appropriate answer to the question, it will produce erroneous results. The program will warn the user when a blank or zero is an inappropriate value.

Trailing decimal points are not required on input because the program automatically knows whether to treat a value as an integer or a floating point variable. For example, if a user wishes to enter the number nine, either 9, 9. or 9.00 is acceptable, provided the input cell is wide enough.

3. Selection Cells. These are cells that are used to select from a list of options. Selection cells highlight one item at a time. An item/option must be highlighted before it can be selected. Selection is made by pressing the ***Enter*** key.

4. Moving Between Cells. The user can move from one input screen to another, by pressing the ***Page Down*** key for the next screen or ***Page Up*** key for the previous screen in the loop of primary or secondary screens. Input screens are arranged in a loop format such that if the ***Page Down*** key is pressed from the last input screen the control will return to the first screen, and vice versa. The ***up and down arrows*** are used to move up and down through the cells of a screen. If the ***up arrow*** is pressed from the first cell on the screen, control will transfer to the last cell on the same screen, and vice versa. The ***Tab and Shift-Tab*** keys can be used to move to the right and to the left, respectively, among input and selection cells that are located on the same line. In addition, the ***left and right arrows*** may be used to move between selection cells that are located on the same line.

5. ***Moving Within an Input Cell.*** Each input cell is set to a given width depending on the type of information expected to be entered in that cell. The cursor will be initially located on the first character space of the cell. The ***left and right arrow*** keys may be used to move the cursor to different spaces within the cell. If a value is typed in the first space of the cell, the cell contents will be deleted. To delete a character, move the cursor to the character location and then press the ***Delete*** key, or move the cursor to the space that is to the right of the character and then press the ***Backspace*** key. A character can be inserted between characters in an input cell by moving the cursor to the desired position and then pressing the ***Insert*** key. The ***Insert*** key will shift all characters that are at and to the right of the cursor one position to the right.

6. ***Terminating.*** At any time during the session, the user may press the ***F9*** key to quit without saving changes, return to the main menu or exit the program. The ***Esc*** key and the ***Ctrl-Break*** keys will end some options and allow you to continue with other operations. The ***F10*** key is used to save the data or proceed. If necessary, the user can terminate input or execution by rebooting (***Ctrl-Alt-Del*** keys), resetting, or turning off the computer; however, the user is discouraged from terminating a run in these manners because some of the data may be lost.

7. ***On-Line Help.*** On-line help is available to the user from any cell location on the screen. By pressing ***F1***, information about the operations and purpose of the screen is displayed, and by pressing ***F2***, specific technical assistance for the highlighted cell is displayed. Note that the on-line help screens contain sections from this User's Guide and that the figures and tables mentioned on the screens are located in this document. The ***F3*** key displays various functions of keystrokes. Other specific information of the input screen is listed in menu line(s) at the bottom of screen.

8. ***System of Units.*** Throughout the HELP program the user is required to select a system of units. The HELP model allows the user to use either the customary system of units (a mixture of U.S. Customary and metric units traditionally used in landfill design and in Version 2 of the HELP model) or the Metric (SI) system of units. The user is not restricted to the same system for all data types; for example, the soil and design data can be in one system of units and the weather data can be in the other system. Moreover, it is not necessary for all types of weather data to have the same system of units (i.e., evapotranspiration data can be in the Metric system of units, while precipitation data is in customary units; the solar radiation data can be in customary units, while temperature data is in Metric units, and so on). Appropriate units are displayed in proper locations to keep the user aware of which units should be used for each data entry. Consistency in units is only required within each data type.

4.3 PROGRAM STRUCTURE

The flow or logic of the input facility of the HELP program may be viewed as a tree structure. The tree structure consists of nodes where new branches of the tree are started. The first node is called the trunk, root or parent node, and the terminal nodes of the tree are called leaves. All components (nodes) of the tree structure in the HELP model are screens that have different functions as defined previously, with the trunk node being the Main Menu. During an input session, the user should reach the leaf node if all the data for a given branch (module) are entered. Some of the nodes (screens) are common to more than one branch. The user must return to the node where the branch started in order to go to another branch. These movements can be accomplished with the special keys discussed above, such as ***Page Up, Page Down, F9, F10,*** etc.

4.4 MAIN MENU

At the beginning of each run, the Main Menu is displayed. A schematic of the main menu in Figure 3 shows the seven available modules (branches). Selection from the main menu is made by either moving the cursor to the desired module or by pressing the number of that option. Once a selection is made, program control transfers into an environment specific to that option and cannot transfer to another main menu option without exiting that environment to the main menu and then selecting another option. A brief description of each main menu option is presented below. More details are given in the following sections about specific data requirements for each option.

Option 1 on the main menu is ***"Enter/Edit Weather Data."*** This module permits the user to read evapotranspiration, precipitation, temperature, and solar radiation data files and then review, edit, and save the data or create new files. There are four primary screens in this module; they are a file selection screen, evapotranspiration data screen, a screen that controls the method used for specifying precipitation, temperature and solar radiation data, and a screen for saving weather data files. Several options are available for specifying precipitation, temperature and solar radiations data. These vary from using default data (for precipitation only) to synthetic and other user-defined data sources, such as NOAA Tape, Climatedata™, ASCII data, HELP Version 2 data, and Canadian Climatological data. Data may also be entered manually. Default and synthetic weather data generation is performed by selecting the city of interest from a list of cities and specifying (optional) additional data.

Option 2 on the main menu is ***"Enter/Edit Soil and Design Data."*** This module allows the user to read an already existing soil and design data file and then review, edit, and save the data or create a new data file. There are eight primary screens in the soil and design data module; they are a file selection screen, a landfill general information screen, three screens for entering design, soil and geomembrane liner data by layers, a screen for entering a runoff curve number, a data verification screen, and a screen for saving the soil and design data file. Input screens associated with this module provide

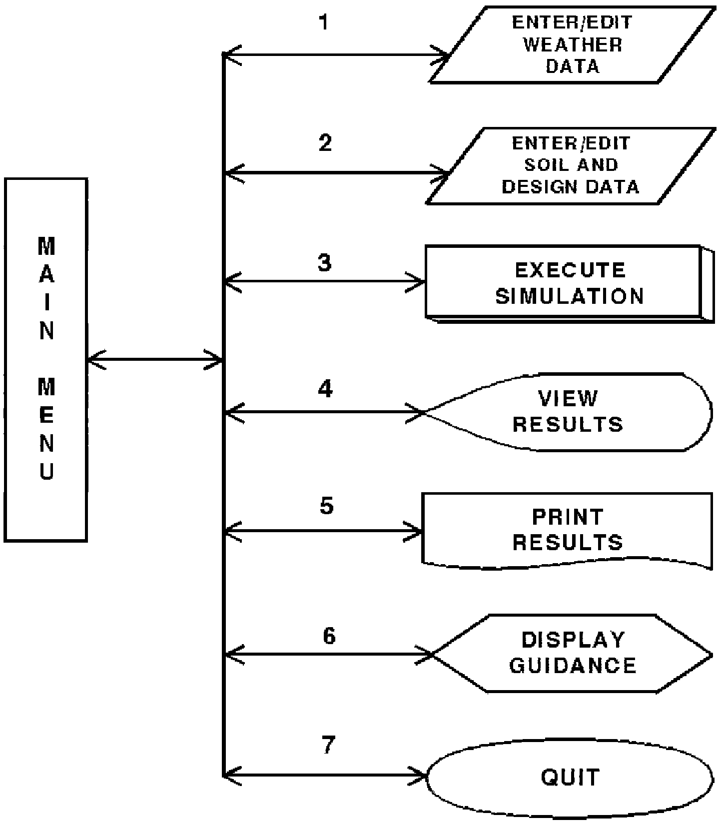

Figure 3. HELP3 Main Menu

cells for entering project title; system of units; initial soil conditions; landfill area; layer design information, such as layer type, thickness, soil texture, drainage characteristics; geomembrane liner information; and runoff curve number information including the ability to adjust the curve number a function of surface slope and length. At the end of this module, the user may request that the data be checked for possible violation of the design rules explained in Section 3. Under this module, the HELP model verifies the design data, soil and geomembrane liner properties and layer arrangement.

Option 3 on the main menu is ***"Execute Simulation."*** In this option the user defines the data files to be used in running the simulation component of the HELP model and selects the output frequency and simulation duration desired from execution. In this option the user can also view the list of files available and can make file selections from these lists.

Option 4 on the main menu is ***"View Results."*** This option allows the user to browse through the output file and examine the results of the run after executing the program. Option 5 is ***"Print Results,"*** and Option 6 is ***"Display Guidance"*** on general landfill design procedures and on the HELP model itself, containing much of the text of this user's guide. Finally, Option 7 is used to ***"Quit"*** running the model and return to DOS.

In the following sections, detailed explanations of the main menu options are presented, and methods of data entry to the program and various options are discussed.

4.5 WEATHER DATA

As mentioned above, this module is selected from the main menu by pressing 1, ***"Enter/Edit Weather Data."*** A schematic of this module is shown in Figure 4. In this module, the user can specify all of the weather data (evapotranspiration, precipitation, temperature and solar radiation) required to run the model. The four primary screens in this module are "Weather Data - File Editing", "Evapotranspiration Data", "Precipitation, Temperature, and Solar Radiation Data", and "Weather Data - File Saving". Several secondary screens may appear during the session depending upon the action taken by the user. On-line help screens are always available for display by pressing ***F1 or F2***. The individual primary screens and their secondary screens of this module are discussed below.

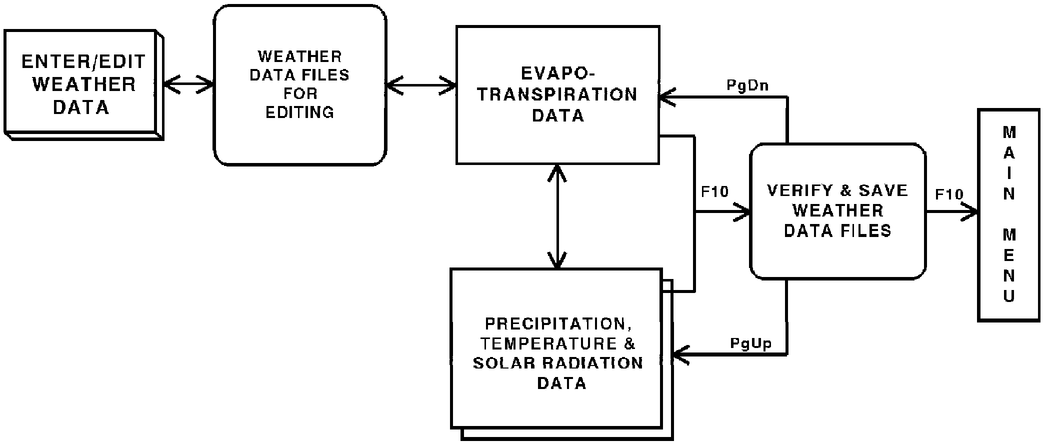

Figure 4. Schematic of Weather Data Module

4.5.1 Weather Data File Selection

The first screen in the weather data module is the "Weather Data - File Editing" screen. A schematic of this screen is shown in Figure 5. On this screen, the user may enter file names of existing files to select previously generated HELP Version 3 files for editing or leave the file names blank to create new data. One file name for each of the four types of weather data to be edited is needed. The DOS path may be specified if different from the active or default drive and subdirectory, such as C:\HELP3\DATA. The following gives file naming and extension information as displayed on the screen.

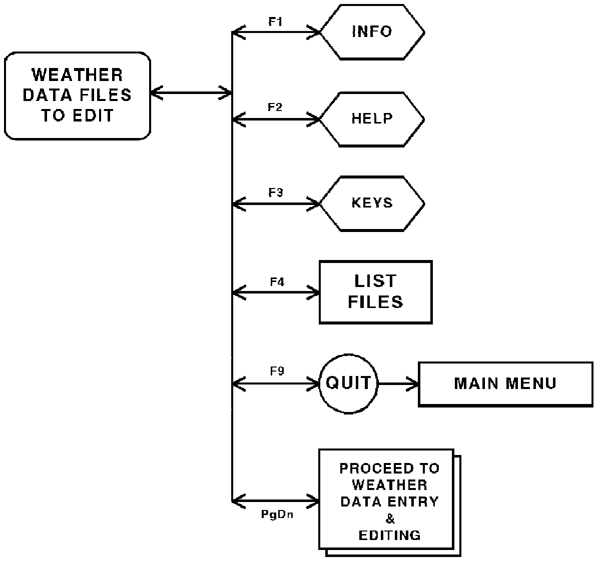

Figure 5. Schematic of "Weather Data - File Editing" Screen

Data Type	DOS Path (Drive and/or Subdirectory)	User Specified File Name
Precipitation		*.D4
Temperature		*.D7
Solar radiation		*.D13
Evapotranspiration		*.D11

* Any valid DOS name that the user desires (up to eight characters) is acceptable. The HELP program supplies the extension.

This convention must be always remembered when selecting file names for editing, saving, or converting data from other sources. However, when typing a file name on this screen, the user should not enter the extension because the program automatically assigns the proper extension to the file according to the weather types.

The current directory is displayed on the screen. The user may obtain a listing of all data files that reside on the current directory by pressing ***F4***. By pressing ***F4***, the program obtains a directory of all files that pertain to the weather data cell from which ***F4*** was pressed. For example, if ***F4*** was pressed from the temperature file cell, the program will display the list of files with an extension of D7 that reside on the currently specified directory. Up to 120 data files for any weather data type can be displayed on the screen. The name of the current directory where these files are located is also displayed. To obtain the data files pertaining to the weather information needed that reside in another directory, the user should type in the name of a valid drive and subdirectory in the Directory column and then press ***F4*** for the list of files in that subdirectory. To display a directory for another type of data, move the cursor to the row for that data type and repeat the process listed above.

To select a file from the list of displayed files, move the cursor to the desired file name and press ***Enter***. This action transfers control back to the previous screen, and the name of the file just selected will be displayed in the proper cell. The user can exit the "Data Files" screen without selecting a file by pressing the ***Esc*** key.

If the user wants to enter the file name in the file cell, the user must first enter the correct directory name. If an invalid directory is entered, the program will displayed the message, "Invalid Directory," and replace the entered directory name with the default directory name (where the program was started). The user then has another opportunity to enter the correct directory name. If the program cannot find the file name as entered, the message, "File Not Found," will be displayed. The previously entered file name is erased and the user has another opportunity to enter a correct file name. Pressing ***Page Down*** causes the program to read the valid data files selected and then proceeds to the first weather data entry screen.

4.5.2 Evapotranspiration (ET) Data

The evapotranspiration data requirements are listed in Section 3 and are entered to the program from the "Evapotranspiration Data" screen. This screen contains all information required by the HELP model to construct the evapotranspiration data file (*.D11). If the user specified an edit file name for the evapotranspiration data, the contents of the file will be displayed in the appropriate cells on this screen. The user can move the cursor to any cell to edit its contents. However, if no file was selected as an edit file, then data must be specified by the user. First, the user must select the system of units to be used for the evapotranspiration data, which may be entered in customary or metric units as explained in a previous section. A schematic of this screen is shown in Figure 6. The two methods for entering this data are the manual option and the default option.

Manual Option

This option requires the user to enter all evapotranspiration data manually. The user should first specify a location in the form of a city, state and latitude, followed by the evaporative zone depth, the maximum leaf area index, the Julian dates of the start (planting) and end (harvest) of the growing season, the annual average wind speed, and quarterly average relative humidities (in percentages) for the entered location.

Default Option

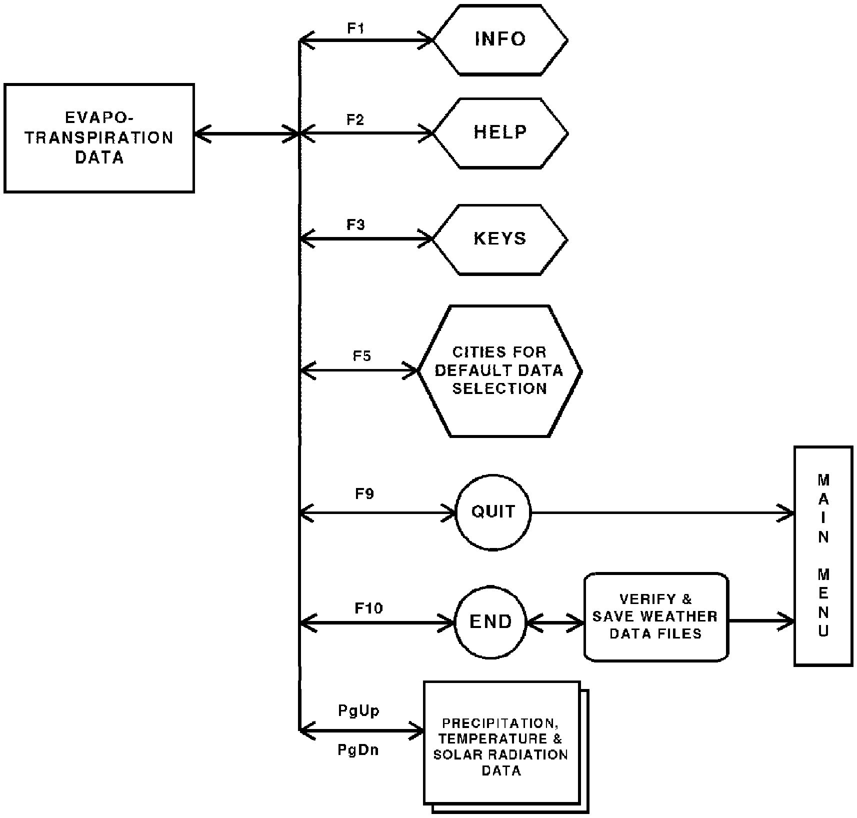

Figure 6. Schematic of "Evapotranspiration Data" Screen

This option takes advantage of an available list of cities for which default values are provided for most of the evapotranspiration data; guidance information is available for the rest of the data. This option is triggered from any input cell on the "Evapotranspiration Data" screen by pressing ***F5*** and selecting a location (state and city) from a displayed list of locations. This list of cities is the same as that in Table 3.

Once a city is selected, the program automatically displays values in the appropriate input cells for the city, state, latitude, growing season dates, wind speed, and the four quarterly humidity values for that location. The program, however, displays guidance information on the evaporative zone depth for that location depending on the vegetative cover. The user must enter a value of the evaporative zone depth that is appropriate for the landfill design, location, top soil, and vegetation. (See Section 3 for detailed guidance.)

The user must also enter a value for the maximum leaf area index for the site. If the value entered is greater than the default maximum allowable value based on the climate for the selected city, the program will display that value only as a guidance to the user. The user is not forced to change the entered value.

If the user decides to edit the name of the city or state, the program will erase the guidance information. Guidance is provided only for cities that are selected from the list obtained by pressing ***F5***.

The location of the landfill being evaluated is likely to be some distance from all of the listed cities. In this case, the user has the option to select a city that has an similar climate and edit the values to improve the data or to simply enter the information manually.

The bottom line of the "Evapotranspiration Data" screen provides additional help information. Once all data are entered, the user can move on to another screen by pressing ***Page Up*** or ***Page Down***, return to the main menu by pressing ***F9***, or proceed to save the evapotranspiration data by pressing ***F10***.

4.5.3 Precipitation, Temperature and Solar Radiation Data

The second screen in the weather data module is entitled "Precipitation, Temperature and Solar Radiation." From this screen, the user can select methods for creating the precipitation data file (*.D4), the temperature data file (*.D7), and the solar radiation data file (*.D13). A schematic of the main options available on this screen are shown in Figure 7. In Version 3 of the HELP model, all of the weather data need not be generated by the same method. For example, the user can enter the precipitation data using the synthetic weather generator, the temperature data using data from a NOAA data file, and solar radiation from an ASCII file. Seven options are available for entering temperature and solar radiation data. Under the precipitation data there are the same seven plus a default option. Figures 8, 9, and 10 show the possible options.

Default Precipitation

If the ***default precipitation option*** (*Customary Units Only*) is selected, the program will prompt the user with the list of states having default data. The HELP model provides default precipitation values for the list of cities in Table 1. To select a state, move the cursor to the desired state name and press ***Enter***. At this time the program prompts the user with the list of cities in the selected state for which default precipitation data is available. Similarly, the city can be selected by moving the cursor to the desired city and pressing ***Enter***. The user can return to the "Precipitation, Temperature and Solar Radiation" screen from either list by pressing ***Esc***. By doing so, neither a city nor a state is considered selected. However, once a city is selected, the program reads the five years of default precipitation data for the selected city. The usefulness of the default precipitation option is limited since it contains only five years of precipitation data. It is additionally limiting since these five years may be dry or wet years and may not be representative of the site in question.

The following options are available for entering "Precipitation, Temperature, and Solar Radiation" data.

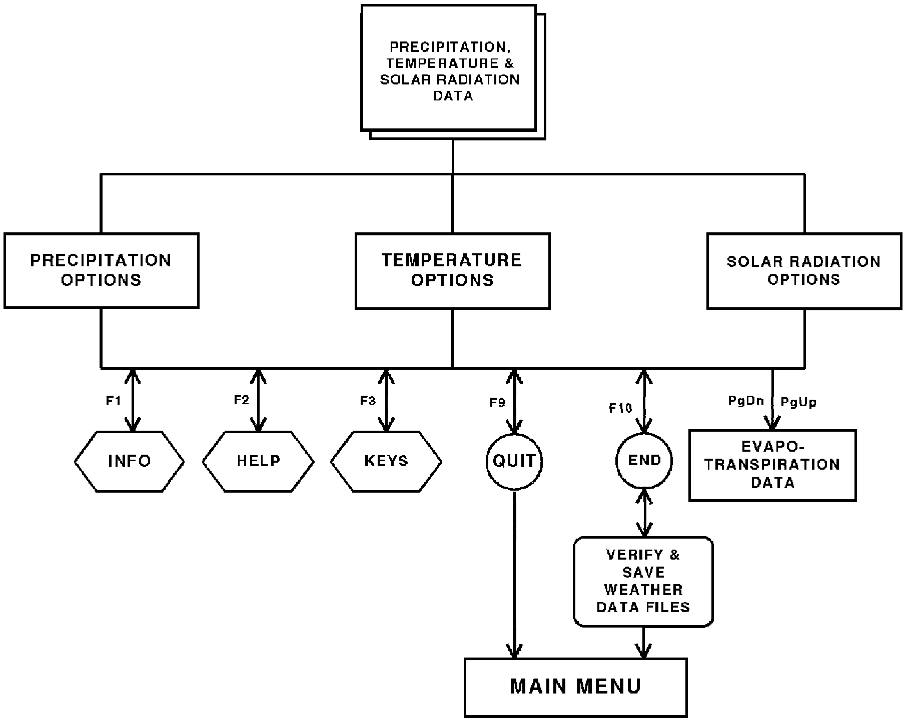

Figure 7. Schematic of "Precipitation, Temperature and Solar Radiation" Screen

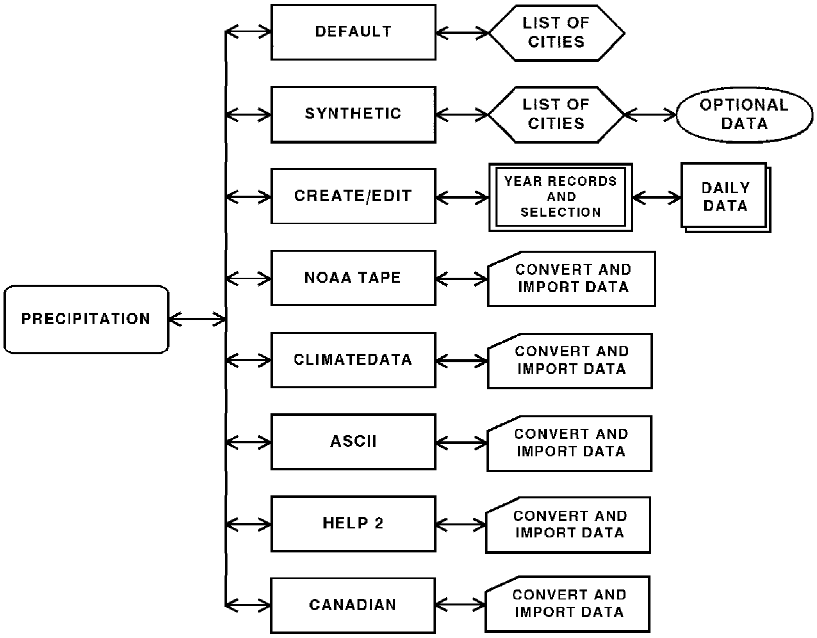

Figure 8. Precipitation Options

Synthetic

The second available method for entering precipitation data is to use the ***synthetic weather generator*** (*Customary or Metric Units*). (This is the first method on the screen for entering temperature and solar radiation data.) This option can be selected for temperature and solar radiation only if the user has previously entered precipitation data since the synthetic weather generator requires precipitation values for generating both temperature and solar radiation. By selecting the synthetic data option, the program prompts the user with a list of states for which it has synthetic weather data coefficients. Again the user can move the cursor to the appropriate state and press ***Enter*** to obtain the list of cities in that state for which synthetic data can be generated. From this list, the user can select the city where the project is located or a city with a climate similar to the project location. Selection is accomplished by moving the cursor to the selection cell highlighting the desired city and pressing ***Enter***. At any time, the user may abandon the input for the synthetic weather generator by pressing ***Esc***; the program will return to the "Precipitation, Temperature and Solar Radiation" screen without loss of previously entered data.

Once a city is selected, the program displays another screen called "Synthetic Precipitation Data", "Synthetic Temperature Data" or "Synthetic Solar Radiation Data." On this screen, the city and state are displayed, and the user is asked to provide additional

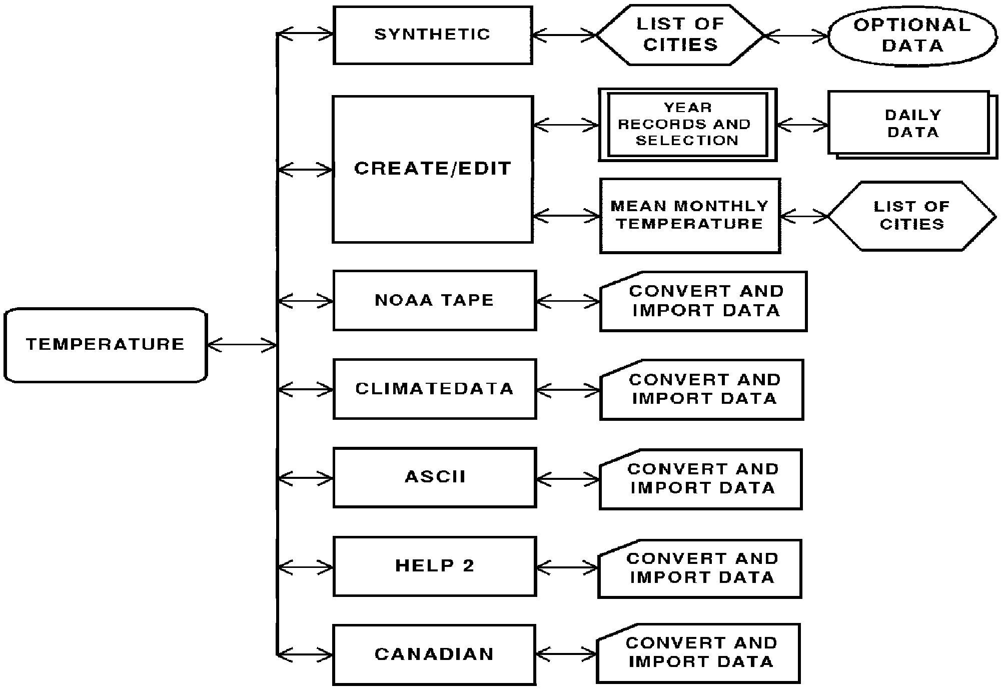

Figure 9. Temperature Options

information. The first value that must be entered is the number of years of synthetic data to be generated. The rest of the information on the screen is optional. For precipitation, the user can elect to use the default normal mean monthly precipitation values provided by the HELP program or to enter normal mean monthly precipitation values to be used in generating the synthetic precipitation for that location. For temperature, the user has the option to use the default normal mean monthly temperature values provided by the HELP program or to enter normal mean monthly temperature values to be used in generating the synthetic temperature for that location. Users are encouraged to enter their own normal mean monthly values especially if the landfill is not located at the selected city. The program uses the normal mean monthly data to adjust the data generated by the synthetic weather generator. If the user decides not to use the default values, the program will transfer control to the normal mean monthly data option under the "User" heading. At this time the user must input values for January through December. A blank cell for a given month will be recorded as zero, and the user must be careful not to leave a cell without an entry. A zero entry, however, is a valid entry. For solar radiation the optional value is the latitude for the location. The default latitude of the selected city will be displayed, but the user is encouraged to enter the latitude of the actual landfill location to obtain better solar radiation values.

Create/Edit

If the user selects the ***create/edit option*** (*Customary or Metric Units*) for manually

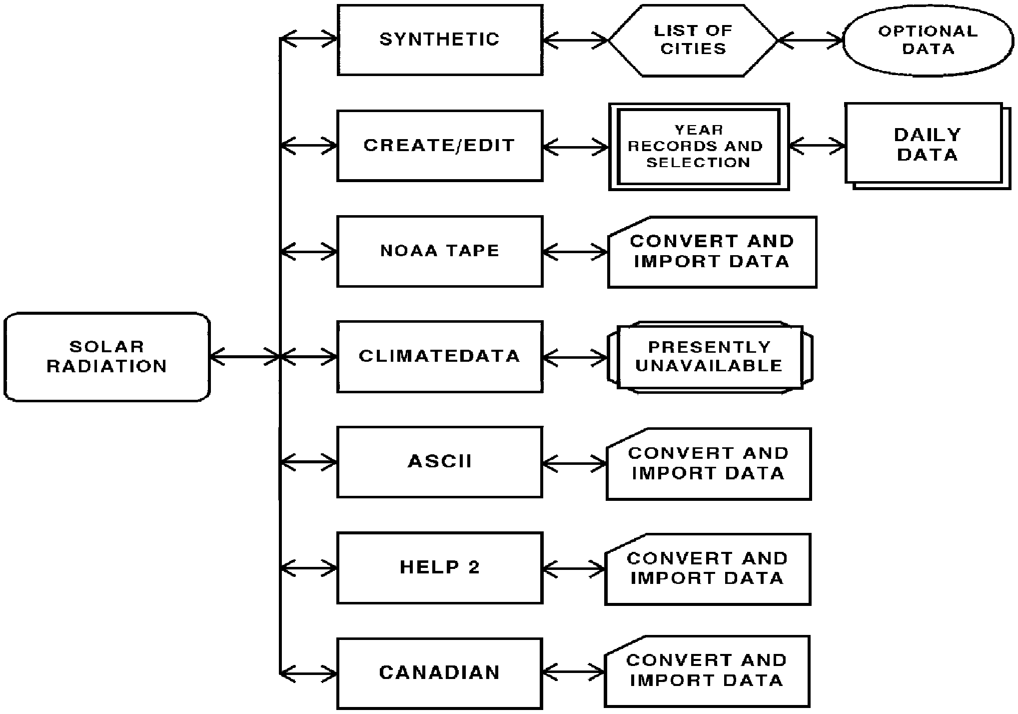

Figure 10. Solar Radiation Options

entering or editing precipitation, temperature and/or solar radiation data, the program prompts the user with a request to enter the city and state of the location and the units that will be used for entering the data manually. These requests appear on the same screen as "Precipitation, Temperature and Solar Radiation" screen and will be filled in with information when editing an existing data file. The user may press the ***Esc*** key to abandon the entry of this information and return to the selection of another weather data option. Once the location and units are specified, the program displays the yearly data screen.

Yearly Data Screen

This screen is like a spreadsheet that has four columns. Two of these columns are for the precipitation data, and one column each is for temperature and solar radiation. The first column is for the year for which the precipitation data is to be entered, and the second column is for total annual precipitation. The user cannot access the yearly total precipitation column since this total is computed by the program after the daily data for the year is entered. If the user reaches this screen from the precipitation option on the "Precipitation, Temperature, and Solar Radiation" screen, the user will only be able to move within the column under precipitation. Similarly, if the user reaches this screen from the temperature data option, then only movement in the temperature column is permitted, and analogously, for the solar radiation option.

To enter a new year of daily values, the user should move the cursor to a empty cell, type in the year and press ***Enter***. The program will display the daily data screen on which the daily values are entered. The user can return to the yearly data screen by pressing ***F10*** to retain the data (to a temporary file) or by pressing ***Esc*** to abandon the created data.

The user can enter up to 100 years of daily data. The yearly data screen can only display 20 rows at a time. The user, however, can move the cursor to the bottom of the screen and then cursor down to move to the next row until the hundredth row is displayed. Similarly, the user can move the cursor upward to display the rows in the spreadsheet that are not shown on the screen, if any. To move down 20 rows, press ***Page Down***, and to move up 20 rows, press ***Page Up***. To reach the last row, press ***End***, and to go to the first row press ***Home***.

To edit an existing year of daily values, the user must first create and/or read weather data. If the data were previously saved, the user should specify the existing data file "Weather Data - File Editing" screen immediately after selecting the "Enter/Edit Weather Data" option from the main menu. The HELP model reads the data from the edit file and stores it in a temporary file. Upon entering the ***create/edit*** option, the program displays the list of years for precipitation, the total annual precipitation for each year, and a list of years for the temperature and solar radiation data. To edit, move the cursor to the year that is to be edited and press ***Enter***. The program will display the daily data screen and the user may type over any values that need to be edited. The operation of the yearly data spreadsheet and the daily data spreadsheet is the same when editing existing data or when creating new data.

After entering or editing years of daily weather data, the user can return to the "Precipitation, Temperature and Solar Radiation" screen to exercise other weather data options. To retain the newly created or edited years of daily weather data, the user should press ***F10*** from the yearly data screen; the program will then replace the existing temporary data file containing all of the years of data for that type of weather data. To lose the newly entered or edited daily data, the user should press ***F9*** or ***Esc***; the program will retain the previously existing temporary data file containing the values of that type of weather data prior to entering the ***create/edit*** option.

Daily Data Screen

Upon selecting or specifying a year from the yearly data screen, the program displays the daily data screen, a spreadsheet for entering daily data. This spreadsheet consists of 10 columns and 37 rows. The spreadsheet contains information on the file name, the year, month, and day. This information is displayed at the top of the spreadsheet. The day and month are continuously updated as the user moves from one cell to another. The first day is considered January 1, and the last day is December 31. The spreadsheet is divided into two parts, the first part being rows 1 through 19, and the second part, rows 20 through 37. The user can move the cursor to the bottom of the screen and cursor down to move to the next row until the 37th row is displayed. Similarly, the user can move the cursor upward to display any rows in the spreadsheet that are not shown. To move from the upper to the lower portions of the spreadsheet and vice versa, press ***Page Down*** and ***Page Up***, respectively. To reach the last cell in the spreadsheet, press ***End***, and to return to the first cell, press ***Home***.

The user should input values one day at a time without leaving empty cells between months. For example, the first month (January) will extend to the first cell (or column) in the fourth row. The values for the first day in February should start in column 2 of row 4; no empty cells are left between months. An empty cell is considered by the program to indicate a value of zero for that day. A zero is a valid entry. The program keeps track of leap years and adjusts the month and day at the top of the spreadsheet accordingly. Since there are 37 lines with each line containing 10 days of data, there will be empty cells at the end of line 37 in the spreadsheet. These cells are ignored by the program.

If the user decides to quit entering data in the daily spreadsheet and return to the yearly spreadsheet, the user should press the ***Esc*** key. By doing so, whatever data were entered on the daily data sheet will be lost; the previously existing data will be retained. To exit the daily spreadsheet and retain the data entered on that sheet, the user should press ***F10***. Note that the ***F10*** key will retain the data in a temporary file only and not in any previously selected file. A separate temporary file is maintained for each year of daily data.

Once the user returns to the yearly weather sheet, more years can be entered or edited, and the daily values for these years can be input on the daily sheet in the same manner described above. After exiting the precipitation spreadsheet by pressing ***F10***, and upon returning to the yearly sheet, the annual total precipitation for that year is computed and displayed next to the year.

Editing Data on Yearly Data Screen

Besides selecting years for creating or editing daily data, the user has the options on the yearly data screen to select only a portion of a weather file for future use, to rearrange the years of data, to repeat the same year(s) of data for a longer simulation period or to insert years of data into an existing file. These options are performed using the functions to add (insert) a year above or below an existing year in the list of years, delete a year, move a year to a position above or below an existing year in the list of years, or copy a year to a position above or below an existing year in the list of years. The options are performed only on the type of data (precipitation, temperature or solar radiation) highlighted when the ***create/edit*** option was selected. This is done by using the following key combinations of functions:

Alt A	adds/inserts a year (either new, being moved or being copied) above the highlighted year (where the cursor is positioned)
Alt B	adds/inserts a year (either new, being moved or being copied) below the highlighted year (where the cursor is positioned)
Alt D	deletes the highlighted year (where the cursor is positioned)
Alt M	tags the highlighted year (where the cursor is positioned) to be moved to another location to be designated using the cursor and ***Alt A*** or ***Alt B***
Alt C	tags the highlighted year (where the cursor is positioned) to be copied to another location to be designated using the cursor and ***Alt A*** or ***Alt B***

To add a new year directly above a certain year, for example above the year on line 29 (Line numbering is shown on the left edge of the screen.), the user should move the cursor to line 29, hold the ***Alt*** key down, and press ***A***. The result of this action is that a blank cell is inserted above line 29, and the program shifts the year on line 29 and all the years below it one line downward (i.e. year on line 29 moves to line 30, year on line 30 moves to line 31, etc.), and line 29 will be a blank line for the user to enter the value for the new year.

To add a year directly below a certain year, for example below the year on line 5, the user should move the cursor to line 5, hold the ***Alt*** key down, and press ***B***. The result of this action is that a blank cell is inserted below line 5, and the program shifts the year on line 6 and all the years below it one line downward (i.e. year on line 6 moves to line 7, year on line 7 moves to line 8, etc.), and line 6 will be a blank cell for the user to enter the value of the new year.

The ***Alt D*** combination causes the program to delete a year from the list of years. For example, to delete the year on line 15, the user should move the cursor to line 15, hold the ***Alt*** key down, and press ***D***. The program will delete information on line 15 and will shift the years on lines 16 to 100 upward one line (i.e., year on line 16 moves to line 15, year on line 17 moves to line 16, etc.), and cell on line 100 becomes an empty cell. The user is cautioned that the deleted year cannot be recovered without quitting and losing all changes (***F9*** or ***Esc***). The original temporary file is replaced only when the changes are finally retained by pressing ***F10*** from the yearly data screen.

The copy command allows the user to place a year that is identical to another year on another line. For example, to copy the year on line 70 to line 5, move the cursor to line 70 and press the ***Alt C*** combination, then move the cursor to line 5 and press the ***Alt A*** combination. At this point, the user must specify a value for the new year; the value must be different from the value of any other year in the data set for that type of weather data. This action will cause the new value for the year to appear on line 5 but the daily values will be the same as those found for the year copied and previously found in line 70. (The user may obtain the same result after the ***Alt C*** combination by moving to line 4 and pressing the combination ***Alt B***).

The move command allows the user to move one year from one location on the yearly data screen to another. For example, to move the year on line 32 above the year on line 56, move the cursor to line 32, press the ***Alt M*** combination, and move the cursor to line 56 and press the ***Alt A*** combination. This action will cause the year on line 32 to be deleted and be placed directly above the year on line 56. (The user may obtain the same result after the ***Alt M*** combination by moving to line 55 and pressing the combination ***Alt B***).

The ***Esc*** key can be used to quit the move and copy functions (after pressing ***Alt M*** or ***Alt C*** and before pressing ***Alt A*** or ***Alt B***. By editing the data as discussed above, the user is actually arranging the order of the precipitation data of the years. Actual rearranging of data in the data file, however, takes place only after the user presses ***F10***.

NOAA Tape Data

This option allows the user to enter data to the HELP model from a NOAA data set

(*Customary Units Only*). If this option is selected, the user must enter the city and state for the site and the NOAA file name. For the precipitation and temperature options, the NOAA data file should contain daily Summary of Day data written in as-on-tape format. Note that for temperature data two file names are requested, one for the maximum temperature and the other for the minimum temperature. If the user has only a mean temperature data file, the mean temperature data file name should be entered for both maximum and minimum temperature data file names. For the solar radiation option the NOAA data file should contain hourly Surface Airways data written in as-on-tape format. Example NOAA data files are included with the HELP program -- PC49215A.PRN for precipitation, MX49215A.PRN for maximum temperature and MN49215A.PRN for minimum temperature. When entering the NOAA file name, the user should include the DOS path (if the file location is different than the default directory), file name and extension. The user can abandon the entry of this data by pressing ***Esc***. Once valid information is entered, the program reads the data from the specified file and converts it to the HELP Version 3 format.

Climatedata™

This option allows the user to enter daily precipitation or temperature data to the HELP model from Climatedata™ (*Customary Units Only*). If this option is selected, the user must enter the city and state for the site and the Climatedata™ file name. Note that for temperature data, two file names are requested, one for the maximum temperature file and the other for the minimum temperature file. The Climatedata™ file should have been created by exporting or printing the CD-ROM data to an ASCII print file. This same format is used by data bases other than Climatedata™ and therefore these data bases can be converted using this same option. Example Climatedata™ files are included with the HELP program -- BIRM.PRC for precipitation, BIRM.MAX for maximum temperature and BIRM.MIN for minimum temperature. When entering the Climatedata™ file name, the user should include the DOS path (if the file location is different than the default directory), file name and extension. The user can abandon the entry of this data by pressing ***Esc***. Once valid information is entered, the program reads the data from the specified file and converts it to the HELP Version 3 format.

ASCII Data

This option allows the user to enter daily weather data to the HELP model from ASCII data files (*Customary or Metric Units*). The ASCII data set is composed of lines of data whose values are separated by a blank(s), a comma or other non-numeric symbol. If this option is selected, the user must enter the city and state for the site, the units of the data in the ASCII files. The user can abandon the entry of this data by pressing ***Esc***. Once valid information is entered, the program then asks for the file name and year of the ASCII data set, one year at a time. Each file should contain only one year of daily values for a particular type of data, either precipitation, mean temperature or solar radiation. Example ASCII data files are included with the HELP program -- RAIN.1 and RAIN.2 for precipitation, TEMP.1 and TEMP.2 for temperature and SOLAR.1 and

SOLAR.2 for solar radiation. When entering the ASCII data file name, the user should include the DOS path (if the file location is different than the default directory), file name and extension. In order to return from this option to the "Precipitation, Temperature, and Solar Radiation" screen, press ***Esc***.

HELP 2

This option allows the user to enter weather data to the HELP model Version 3 from a data file used in the HELP model Version 2 (*Customary Units Only*). If this option is selected, the user must enter the city and state for the site and the HELP Version 2 data file name. Example HELP 2 data files are included with the HELP program -- ALA4 for precipitation, ALA7 for temperature and ALA13 for solar radiation. When entering the HELP 2 data file name, the user should include the DOS path (if the file location is different than the default directory), file name and extension. The user can abandon the entry of this data by pressing ***Esc***. Once valid information is entered, the program reads the data from the specified file and converts it to the HELP Version 3 format.

Canadian

This option allows the user to enter weather data to the HELP model from a Canadian Climatological Data (Surface) file (*Metric Units Only*). If this option is selected, the user must enter the city and state for the site and the Canadian Climatological Data file name. The precipitation and mean temperature data files should contain daily values written in either compressed or uncompressed diskette format. The solar radiation data file should contain hourly global solar radiation values also written in either compressed or uncompressed diskette format. Example Canadian data files are included with the HELP program -- CAN4.DAT and CCAN4.DAT for precipitation, CAN7.DAT and CCAN7.DAT for temperature and CAN13.DAT and CCAN13.DAT for solar radiation. When entering the Canadian data file name, the user should include the DOS path (if the file location is different than the default directory), file name and extension. The user can abandon the entry of this data by pressing ***Esc***. Once valid information is entered, the program reads the data from the specified file and converts it to the HELP Version 3 format.

4.5.4 Saving Weather Data

During the creation of the weather data explained above, the data are saved in temporary files. To save the data to permanent files, the user must press ***F10*** from the primary screens. Once the ***F10*** key is pressed, the program verifies that all the data have been entered. If any of the data is incomplete, the program displays a list of the problem areas. The user can return to the primary screens to complete the data or continue to save the incomplete data. After displaying the deficiencies, the program displays the "Weather Data - File Saving" screen. Here the user may save all or only some of the four weather types, or completely abandon the save option. The user should tag each type of data to be saved by entering a "Y" in the "SAVE" column and those not to be saved by entering a "N" in the "SAVE" column. Default file names are displayed in appropriate locations on this screen; these are the same names as used in Version 2. At this time, the user may enter new file names for any or all of the four types of weather data. (See Section 4.5.1 for file naming convention used in HELP.) If the file already exists, the program will display "File Already Exists" after entering the name. After replacing all file names of interest, the user should press ***F10*** or ***Page Down*** to complete the saving to the requested file names. If files already exists for any of the file names as they would for the default names, the program will ask the user about overwriting each existing file. If the user answers "Y" for all of the files, the program will overwrite the files, complete the saving process and return to the main menu. If the user answers "N" for any file, the program will interrupt the saving, return to the "SAVE" column and change the tag to "N". The user can then change the tag back to "Y", rename the file, and restart the saving by pressing ***F10*** or ***Page Down***. The program provides other options listed on the "File Saving" screen to enable the user to return the weather data entry screens (***Page Up***) or to return to the main menu without saving the data (***F9***). The user must be cautioned that the ***F9*** option will cause all the data created (if any) to be lost. Figure 11 shows the available options.

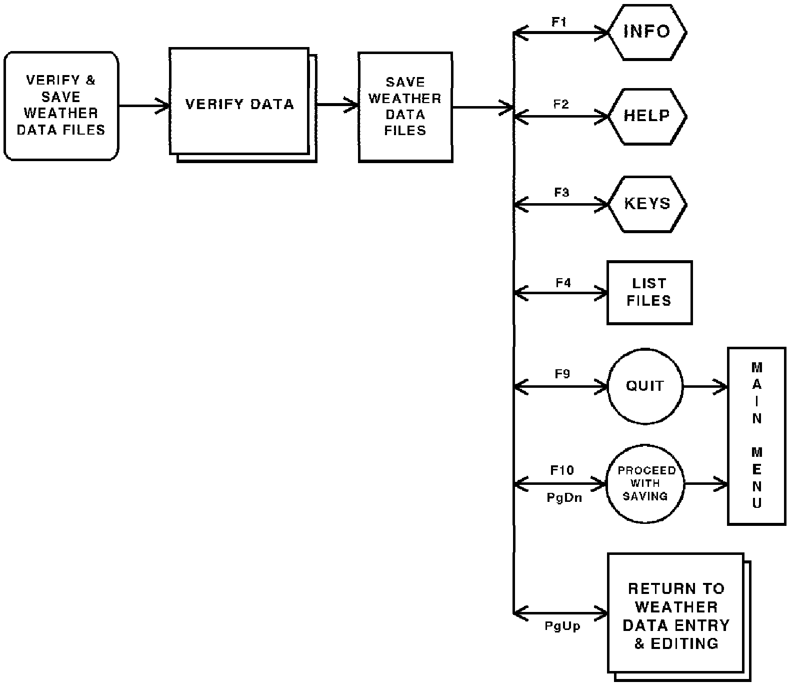

Figure 11. "Weather Data - File Saving" Screen Options

4.6 SOIL AND DESIGN DATA

This module is selected from the main menu by pressing 2, ***"Enter/Edit Soil and Design."*** While in this module, the user will be able to enter site information, a landfill profile, layer design data, characteristics of soils, geomembranes and other materials, and SCS runoff curve number information. The primary screens in this module are the "Soil and Design Data - File Editing" screen, "Landfill General Information" screen, three Landfill Profile Design and Layer Data screens, "Runoff Curve Number Information" screen, "Verification and Saving" screen and "Soil and Design Data - File Saving" screen. Several secondary screens may appear during the session depending on the action taken by the user. On-line help screens are always available for display by pressing ***F1*** or ***F2***. The individual primary screens and their secondary screens of this module are discussed below. Figure 12 shows a schematic of the soil and design data module.

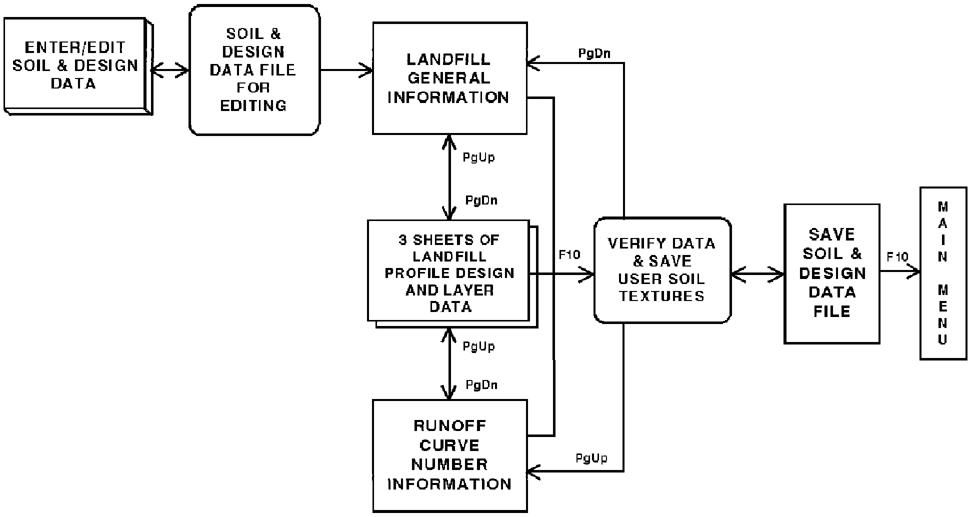

Figure 12. Schematic of Soil and Design Data Module

4.6.1 Soil and Design Data File Selection

The first screen in the soil and design module is the "Soil and Design Data - File Editing" screen. A schematic of this screen is shown in Figure 13. On this screen the user may enter the file name of an existing file to select a previously generated HELP Version 3 file for editing or leave the file name blank to create new data. When selecting a file to be edited, the user may specify the DOS path if different from the default drive and subdirectory, such as C:\HELP3\DATA. The default directory is initially displayed in the directory cell on the screen. If the user specifies a drive or a directory that does not exist, the program will display respectively "Invalid Drive" or "Invalid Directory" and replaces the content with the default directory. The soil and design data file may have any valid DOS name of up to 8 characters. If the user enters an illegal file name, the program displays "Bad File Name" and clears the file name. If the user specifies a file name that does not exist, the program displays "File Not Found" and clears the file name.

The program adds an extension of .D10 to the file name. As such, the user should not specify the extension in HELP Version 3 whenever entering a file name for editing or saving.

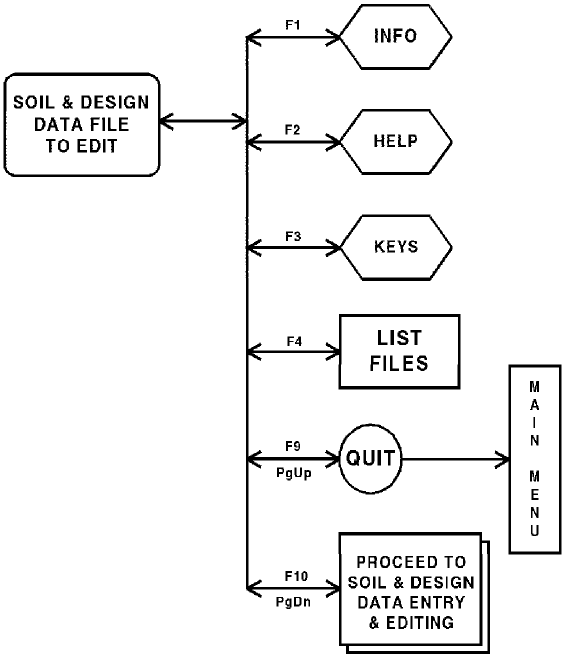

Figure 13. "Soil and Design Data - File Editing" Screen Options

As shown in Figure 13, the user may obtain a listing of all soil and design data files that reside on the directory currently specified in the directory cell by pressing ***F4***. Up to 120 data files can be displayed on the screen. The name of the current directory where these files are located is also displayed. To change to another directory, the user should enter the name of that directory in the column labeled DIRECTORY. To select a file from the list of displayed files, move the cursor to the file and select it by pressing ***Enter***. This transfers control back to the previous screen and the name of the file just selected will be displayed in the proper cell. The user can exit the list-of-files screen without selecting a file by pressing ***F4*** again or ***Esc***.

When ready to proceed to enter new data or edit existing data, the user should press ***Page Down*** or ***F10***. The program then reads the data file to be edited, if a file is specified, and proceeds to the "Landfill General Information" screen. If a new data set is to be created (file name left blank), the program initializes the soil and design data and then asks for the system of units to be used throughout the module (*Customary or Metric*). Proper units are displayed throughout the module for entries that require units.

4.6.2 Landfill General Information

The second input screen in the soil and design data module is the "Landfill General Information" screen. Figure 14 shows the screen and its branches as a schematic. By moving the cursor to the appropriate cell, the user can enter new information or edit the information that was read from the edit file. The first entry is the ***project title*** which is only used for identification of the simulation.

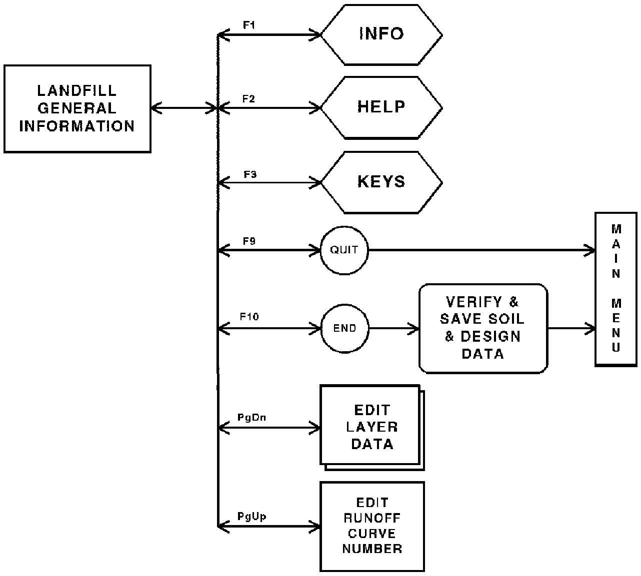

Figure 14. Schematic of "Landfill General Information" Screen

The second entry on this screen is the ***landfill area***. The units of the area are displayed next to the input cell according to the system of units selected. The user should enter the area in acres for Customary units or in hectares for Metric units. The third entry is for the ***percent of area where runoff is possible***. This variable specifies the portion of the area that is sloped in a manner that would permit drainage off the surface. The runoff estimates predicted by the model are equal to the computed runoff by the curve number method times this percent. The difference between the computed runoff and the actual runoff is added to the infiltration.

Next, the user must select the method of ***moisture content initialization***; that is whether or not the user wishes to specify the initial moisture storage. If the user answers "N" (no) to this question, the program assumes near steady-state values and then runs the first year of the simulation to improve the initialization to steady-state. The soil water contents at the end of this year of initialization are taken as the initial values for the simulation period. The program then runs the complete simulation, starting again at the beginning of the first year of weather data. The results for the initialization period are not reported. However, if the user answers "Y" (yes), the user is requested to enter the ***amount of water or snow water on the surface*** in the units selected. Later, the user should enter the initial moisture content of each layer as explained in the next section.

4.6.3 Landfill Layer Data

The next step in the soil and design data module is to input the design specifications of the landfill profile, one layer at a time. Layer data are entered in three screens. These screens have a spreadsheet layout where each row represents a layer. Figure 15 shows the three spreadsheets and their associated screens. The first row of cells on the screens is the uppermost layer in the landfill. Each column of cells on the screens represents a variable or a property of the layer or its material. Variable names are listed in the first two rows of the screen, and the third row contains the units of that variable, if any. Every highlighted cell is associated with a highlighted property (heading of a column) and a highlighted layer number (row label). The user should enter the value of the specified property for the corresponding layer. All entries must obey certain rules which are discussed below.

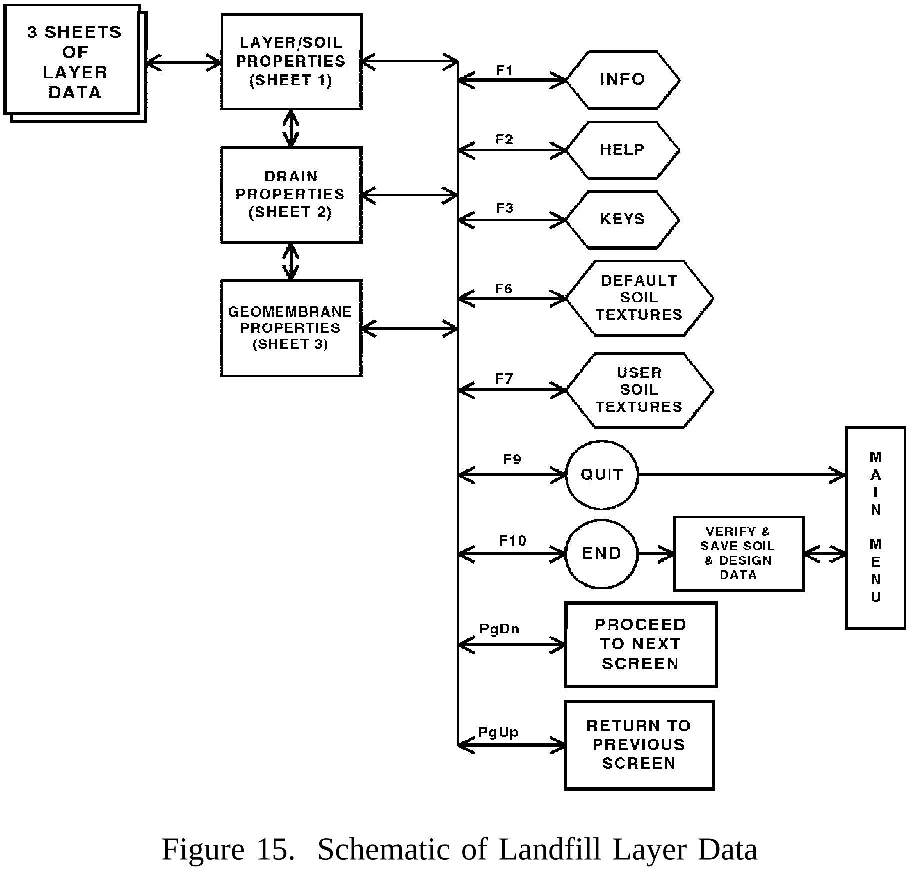

Figure 15. Schematic of Landfill Layer Data

Layer Type

The user should input ***layer type*** in the first column of the spreadsheet. The four layer types and their associated code numbers that the program recognizes are vertical percolation (1), lateral drainage (2), barrier soil liner (3), and geomembrane liner (4). These are defined as follows:

1. A layer of moderate to high permeability material that drains vertically primarily as unsaturated flow is classified as a ***vertical percolation layer*** as long as it is not underlain by a liner with a lateral drainage collection and removal system. The primary purpose of a vertical percolation layer is to provide moisture storage; as such, top soil layers and waste layers are often vertical percolation layers.

2. A layer of moderate to high permeability material that is underlain by a liner with a lateral drainage collection and removal system is classified as a ***lateral drainage layer***. The layer drains vertically primarily as unsaturated flow and laterally as a saturated flow.

3. A layer of low permeability soil designed to limit percolation/leakage is classified as a ***barrier soil liner***. The layer drains only vertically as a saturated flow.

4. A geomembrane (synthetic flexible membrane liner) designed to restrict vertical drainage and limit leakage is classified as a ***geomembrane liner***. Leakage is modeled as vapor diffusion and leakage through small manufacturing defects and installation flaws.

While the HELP program is quite flexible, there are some basic rules regarding the arrangement of layers in the profile that must be followed.

1. A vertical percolation layer may not be underlying a lateral drainage layer.

2. A barrier soil liner may not be underlying another barrier soil liner.

3. A geomembrane liner may not be placed directly between two barrier soil liners.

4. A geomembrane liner may not be underlying another geomembrane liner.

5. A barrier soil liner may not be placed directly between two geomembrane liners.

6. When a barrier soil liner or a geomembrane liner is not placed directly below the lowest drainage layer, all drainage layers below the lowest liner are treated as vertical percolation layers. Thus, no lateral drainage is computed for the bottom section of the landfill.

7. The top layer may not be a barrier soil liner.

8. The top layer may not be a geomembrane liner.

9. The profile can contain no more than a total of five barrier soil liners and geomembrane liners.

The program checks for rule violations only at the time the user saves the data. Therefore, to reduce the time involved in evaluating a landfill, the user is encouraged to design a proper layer sequence before saving the data.

In the second column, which has the heading "***Layer Thickness***," the user should enter the thickness of each layer in the landfill profile even for the geomembrane liner, in inches or cm. The values must be greater than zero; a blank cell is taken as a value of zero. Again, during data verification the program checks for layer thickness of zero and issues a violation statement when the user tries to save the data.

In the third column, the user should enter the ***soil texture number*** of the soil that forms the layer. The 4 possible options for the user to enter soil texture numbers are:

1. Select from a list of default textures for 42 soils, wastes, geomembranes, geosynthetics and other materials.

2. Select from a library of user-defined textures that were previously saved and numbered by the user (up to 100 such textures are allowed).

3. Enter a new soil texture number that can be used again in this design and that can later be saved in the library of user defined textures (material properties must also be entered manually for this texture).

4. Leave the texture number blank and enter the material properties manually.

Default Soil/Material Textures

Default soil/material textures have numbers from 1 to 42 and are listed in Table 4. The user can either type the soil texture number or press ***F6*** to select a texture from the list of default textures. If the user enters a default soil/material texture number manually, the program automatically assigns the default values for ***porosity, field capacity, wilting point, and hydraulic conductivity*** to the layer. On the other hand, the user may press ***F6*** to obtain the list of soil textures on a separate screen. On the soil texture screen, the user can move the cursor to the desired texture or press ***Page Down*** to display the rest of the default soil textures. After cursoring to the desired texture, press ***Enter*** to select it. At this time, program control returns to layer spreadsheet screen and displays the selected soil texture number, along with the porosity, field capacity, wilting point, and hydraulic conductivity in appropriate cells. Notice that the only information available for the default geomembrane liners is the hydraulic conductivity (liner vapor diffusivity). If the user changes any of the four soil properties obtained for a default soil/material texture, the program automatically resets the soil texture number to 0. The user can then assign the values a new soil texture number that is not used in either the list of default or previously saved user defined textures if the user wishes to save the material characteristics for future use.

As mentioned above, default soil/material textures are obtained by pressing ***F6*** and are available on all three screens. To move from one screen of default soil/material textures to another the user should press ***Page Up*** or ***Page Down***. To return to the layer spreadsheet without making a selection, press ***Esc***. A selection is made only by moving the cursor to the desired soil texture and pressing ***Enter***.

User-Defined Soil Texture

In Version 3 of the HELP model, the user has three options to specify material characteristics, in addition to selecting soil textures from the default list. One method is to enter all of the material characteristics manually without specifying a soil texture number. This method is used when the user does not wish to save these characteristics for use again in this simulation or future simulations. The second method, which allows the user to assign a new soil texture number to the manually entered values for the soil properties, is used when the same characteristics are to be used in future simulations and the characteristics are to be permanently saved in a library of user-defined textures. A library of up to 100 soil textures may be saved in a "user-defined soil texture" data file. The creation and addition of textures to this file are explained in Section 4.6.5 of this User’s Guide. The third method is to select a user-defined texture that was previously saved in the library. If this library of user-defined soil textures exists, the user can display the list of available textures for selection by pressing ***F7***. Selecting a user-defined soil texture for a given layer is identical to that of selecting a default soil/material textures; the user should move the cursor to the desired soil texture and press ***Enter***. At this point, program control returns to the layer spreadsheet and displays soil texture values, porosity, field capacity, wilting point, and hydraulic conductivity of the selected soil in the layer (row) where ***F7*** was pressed. Also, in the same manner as in default soil/material textures, the user can simply type the number of the user-defined soil texture in "Soil Texture No." column of the first screen of the layer spreadsheets, and the program will automatically obtain the soil characteristics for that soil texture and place them in the proper location on the layer spreadsheet.

Whenever ***F7*** is pressed, control transfers to the user-defined soil textures. To move among pages of soil textures press ***Page Up*** and ***Page Down***. To make a selection, press ***Enter***, and to return to the layer spreadsheet without making a selection, press ***Esc***.

The values entered for the moisture storage parameters in columns 4 through 7 of the first screen of layer spreadsheets are interrelated. In column 4 the ***porosity*** must be greater than zero but less than 1. In column 5 the ***field capacity*** must be between zero and 1 but must be smaller than the porosity. In column 6 the ***wilting point*** must be greater than zero but less than the field capacity. In column 7 the ***initial moisture content*** must be greater than or equal to the wilting point and less than or equal to the porosity. If the user had indicated on the "Landfill General Information" screen that the program should specify initial moisture content for the soil layers, the program will ignore all input in column 7. As such, the user does not need to enter data in this column. On the other hand, if the user had indicated that the user wishes to specify the initial moisture content, these values must be entered manually. An empty cell is interpreted as zero for initial moisture, violating the rules. If the layer is a liner, the program during execution automatically sets the initial water content equal to the porosity of the layer. The program will detect violations of these values and will report them to the user during verifications when the data is to be saved to a file.

The second screen of layer spreadsheets can be obtained by pressing ***Page Down***. On this sheet the user will notice that the layer type is already appearing. In the first column of cells the ***saturated hydraulic conductivity*** must be specified in the appropriate units (cm/sec). If the soil texture selected was a default soil/material texture or a user-defined soil texture, the saturated hydraulic conductivity will be displayed in this column. Remember that changing the saturated hydraulic conductivity causes the soil texture number on the previous screen to revert to zero in the same manner as changing any of the other material characteristics (porosity, field capacity or wilting point).

Drainage Layer Design

Information on lateral drainage layer design must be entered manually for each lateral drainage layer directly above the liner regardless of the method used to enter soil textures. The required information is the drainage length, drainage layer slope, recirculation percentage and recirculation destination. These parameters are found in the second through fifth column of cells on the second spreadsheet screen of layer data. These columns are used only for the lateral drainage layers directly above the liner; data placed in rows for other layers will be ignored during execution. The second column of cells on this second screen of layer data is for entering the ***maximum drainage length*** of lateral drainage layers, which is the length of the horizontal projection of the flow path down the slope of a liner to the water/leachate collection system. This length must be greater than zero. In third column of cells the user should enter the ***drain slope*** in percent. This slope is the maximum gradient of the surface of the liner at the base of the lateral drainage layer; this is the slope along the flow path.

In Version 3, the HELP program allows ***leachate/drainage recirculation*** to be simulated. The amount of leachate/lateral drainage to be recirculated from a given layer should be entered as a percent of the layer’s drainage in the fourth column of cells. The layer to which this leachate drainage should be recirculated should be entered on the same row in the fifth column of cells. The value entered is the number of the layer receiving recirculation. Layer numbers are those numbers displayed on the left side of the screen. These numbers are 1 through 20 and refer to the order of the layers in the profile. The

HELP model does not allow leachate recirculation to a liner.

Version 3 of the HELP model also allows the user to specify ***subsurface inflow*** into the landfill from a groundwater source. The amount of subsurface inflow into each layer should be entered in the last column of the second spreadsheet of layer data and is considered to be a steady flow rate into the landfill at the layer where the inflow value is entered. If subsurface inflow is specified for the bottom layer, the program will assume no leakage through the bottom of the landfill. For most landfills, the inflows will be zero and this column can be left blank.

After entering the necessary values in the second spreadsheet screen of layer data, the user should press ***Page Down*** to go to the third and last screen of layer data. Pressing ***Page Up*** will return to the first spreadsheet of layer data, allowing the user to edit the previously entered values. Again, on the third spreadsheet screen, the layer type of all layers in the profile are displayed to aid in positioning data on the screen.

Geomembrane Liner Design

All of the entries on third screen of layer data pertain to geomembrane liner properties such as ***geomembrane liner pinhole density***, ***geomembrane liner installation defect density***, ***geomembrane liner placement quality***, and associated ***geotextile transmissivity*** (if present). Values must be entered for each geomembrane liner (layer type 4) in the profile. Guidance on estimating the pinhole and installation defect density as well as definitions for these parameters is provided in Section 3. The placement quality options are also described in Section 3 and are presented below. The geotextile transmissivity should be specified only when a placement quality of 6 is used.

In the third column of cells the user should input the geomembrane liner placement quality. The HELP program recognizes the following six types of placement quality.

1. Perfect contact

2. Excellent contact

3. Good field placement

4. Poor field placement

5. Bad contact -- worst case

6. Geotextile separating geomembrane liner and controlling soil layer

Typically, placement quality 6 would not be used with a geosynthetic clay liner (GCL) despite the presence of a geotextile since, upon wetting, the clay extrudes through the geotextile and provides intimate contact with the geomembrane.

After completing input for one layer, the user can go back to the first spreadsheet and enter information for other layers. ***Page Up*** and ***Page Down*** are used to move backward and forward between spreadsheets. The user may also input values on one spreadsheet completely filling it, and move on to the next spreadsheet filling in the information for the layers entered in the first spreadsheet and so on. No blank rows be left in the spreadsheet between layers; however, if the user does leave some blank lines, the program will not save these as layers.

Layer Editing

While entering or editing the properties of the layers in the landfill defined in the three spreadsheets of layer data, the user has the option to add a layer to the profile, delete a layer, move a layer to another location in the profile, or copy a layer to another location. When using these layer editing functions, the program operates simultaneously on all three screens of layer data. This is done by using the following key combinations:

Alt A adds/inserts a layer (either new, being moved or being copied) above the highlighted layer (where the cursor is positioned)

Alt B adds/inserts a layer (either new, being moved or being copied) below the highlighted layer (where the cursor is positioned)

Alt D deletes the highlighted layer (where the cursor is positioned)

Alt M tags the highlighted layer (where the cursor is positioned) to be moved to another location to be designated using the cursor and ***Alt A*** or ***Alt B***

Alt C tags the highlighted layer (where the cursor is positioned) to be copied to another location to be designated using the cursor and ***Alt A*** or ***Alt B***

To add a new layer directly above a certain layer, for example above the layer on line 6 (shown on the left edge of the screen), the user should move the cursor to line 6, hold the ***Alt*** key down, and press ***A***. The result of this action is that a blank line is inserted above the layer that was at line 6, and the program shifts the layer on line 6 and all the layers below it one line downward (i.e. layer on line 6 moves to line 7, layer on line 7 moves to line 8, etc.), and line 6 will be a blank line for the user to enter the values for the new layer.

To add a layer right below a certain layer, for example below the layer on line 5, the user should move the cursor to line 5, hold the ***Alt*** key down, and press ***B***. The result of this action is that a blank line is inserted below line 5, and the program shifts the layer on line 6 and all the layers below it one line downward (i.e. layer on line 6 moves to line 7, layer on line 7 moves to line 8, etc.), and line 6 will be a blank cell for the user to enter the value of the new layer.

The ***Alt D*** combination causes the program to delete a layer from the list of layers. For example, to delete the layer on line 3, the user should move the cursor to line 3, hold the ***Alt*** key down and press ***D***. The program will delete all information on line 3 and will shift the layers on lines 4 to 20 upward one line (i.e., layer on line 4 moves to line 3, layer on line 5 moves to line 4, etc.), and line 20 becomes a blank line. The user is cautioned that the deleted layer cannot be recovered without quitting and losing all changes (***F9*** or ***Esc***).

The copy command allows the user to place a layer that is identical to another layer on another line. For example, to copy the layer on line 7 to line 2, move the cursor to line 7 and press the ***Alt C*** combination, then move the cursor to line 2 and press the ***Alt A*** combination. This action will cause the program to insert a layer with values the same as those formerly found at line 7 above the layer formerly found at line 2. The layers formerly at and below line 2 will be moved downward one line. (The user may obtain the same result after the ***Alt C*** combination by moving to line 1 and pressing the combination ***Alt B***).

The move command allows the user to move a layer from one row on the screens of layer data to another row. For example, to move the layer on line 3 above the layer on line 6, move the cursor to line 3, press the ***Alt M*** combination, and move the cursor to line 6 and press the ***Alt A*** combination. This action will cause the layer on line 3 to be deleted and be placed directly above the layer on line 6. This will cause line 4 to move up one line to line 3, line 5 to move to line 4 and line 3 to move to line 5; the other lines will be unchanged. (The user may obtain the same result after the ***Alt M*** combination by moving to line 5 and pressing the combination ***Alt B***).

The ***Esc*** key can be used to quit the move and copy functions (after pressing ***Alt M*** or ***Alt C*** and before pressing ***Alt A*** or ***Alt B***). By editing the data as discussed above, the user may arrange the order of the layers and run the model to test several possible configurations.

If the user has 20 lines completely filled with layers and then decides to add or copy a layer, the layer that is already in line 20 will disappear and cannot be recovered. Therefore, care must be taken not to add layers that will cause the loss of the layers at the bottom of the spreadsheet.

When all the layers of the profile are entered, press ***Page Down*** from the third layer spreadsheet to proceed with the rest of the soil and design data entry. Pressing ***Page Up*** from the first layer spreadsheet passes control to the "Landfill General Information" screen.

4.6.4 Runoff Curve Number

The "Runoff Curve Number Information" screen may be reached from the third layer spreadsheet by pressing ***Page Down***, or from the "Landfill General Information" Screen by pressing ***Page Up***. A schematic of the options associated with the "Runoff Curve Number Information" screen is shown in Figure 16. This screen is composed of three options that can be used to specify the runoff curve number. The first option is to use an ***user-specified curve number*** that the HELP model will use without modification. The second option is to request the HELP model to ***modify a user-specified curve number*** according to the surface slope and surface slope length. In the third option the user requests a ***HELP model computed runoff curve number*** based on surface slope, slope length, soil texture of the top layer in the landfill profile, and vegetation. To select one of these three options, the user should move the cursor to the desired option and press ***Enter***. This action will cause the program to transfer control down to the box for the option selected. For each option, the user must input all required information. Although the user can move from one box to the other (use ***Tab*** and ***Shift Tab*** keys), care should be taken to insure that the desired method is the one that will be used by HELP. The HELP model uses that option in which data was last entered; this option is marked by a small arrow in front of the option.

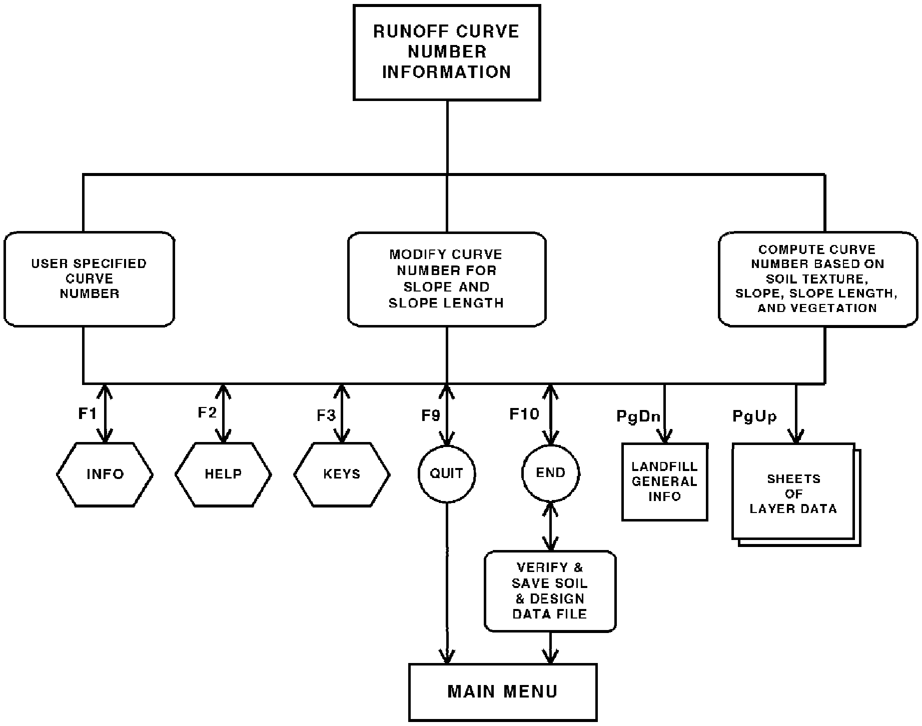

Figure 16. Schematic of "Runoff Curve Number Information" Screen Options

The user should refer to the HELP model documentation for Version 3 for the techniques used in the computation of the curve number based on slope and slope length. The value of the slope must be input in percent, and slope length must be input in the units indicated. If the top layer in the landfill is obtained from the default soil/material textures, the soil texture number for that layer will be displayed in the appropriate cell on the screen. The user can solicit help on the ***vegetation cover*** by pressing the ***F2*** key. The only valid entries for the vegetation are 1 through 5, according to the following:

1. Bare ground

2. Poor stand of grass

3. Fair stand of grass

4. Good stand of grass

5. Excellent stand of grass

If the user selects the option that requires the HELP model to compute the curve number, the program first calculates the SCS runoff curve number for landfills with mild surface slopes (2 to 5 percent) based on the vegetation type and the soil texture on the top layer if one of the default soil/material textures is selected (soil texture types 1 through 18, 20 and 22 through 29) in the same manner as Version 2 (Schroeder et al., 1988b). HELP Version 3 then adjusts the SCS runoff curve number based on the surface slope and the length of the slope.

4.6.5 Verifying and Saving Soil and Design Data

Pressing ***F10*** anywhere in the soil and design option transfers control to the "Verification and Saving" screen. This screen provides the user with several options: verify landfill general design data, verify soil layer/geomembrane properties, verify layer arrangement, review/save user-defined soil textures, and save soil and design data. The user can select any of these options by moving the cursor to the option and pressing ***Enter***. Figure 17 shows the verify and save soil and design data options.

The user can verify the data before attempting to save the data by exercising the first three options on the "Verification and Saving" screen. These options are available mainly for the convenience of the new user since experienced users will be familiar with data requirements and the data will always be verified before saving. To check the data entered on the general landfill and runoff information screens, the user should select the first option, "Verify Landfill General Information Design Data." If there are no violations or warnings, the program will write "OK" to the right of the option; otherwise the program will list the problems and then write "BAD" to the right of the option.

The user can check the layer descriptions (the values on a row of the third screens

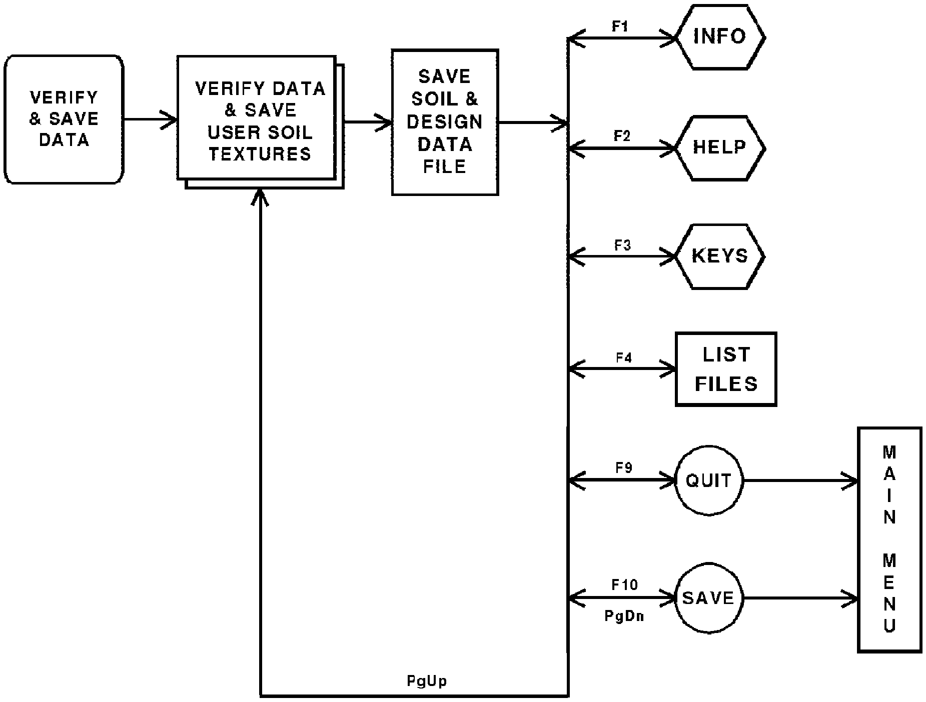

Figure 17. Verify and Save Soil and Design Data Options

of layer data) by selecting the "Verify Soil Layer/Geomembrane Properties" option. The program will examine each row for completeness for the type of layer described; for example, the program will insure that a placement quality was entered for all geomembrane liners (layer type 4). It will also check for the appropriateness of the values; for example, it will insure that the porosity is greater than the field capacity. If there are no violations or warnings, the program will write "OK" to the right of the option; otherwise the program will list the problems and then write "BAD" to the right of the option. Similarly, the user can check for violations in the ordering of the layers from top to bottom based on the layer types specified by selecting the "Verify Layer Arrangement" option. This option will check the nine rules for ordering of layers; for example, the program will insure that the top layer is not a liner. This option operates in the same manner as the verification options.

Another available option on this screen is to review the user defined soil textures that were used in the landfill profile for inclusion in or deletion from the library of user defined soil textures. Upon selecting this option, the program lists all of the non-zero user-defined soil textures used in the profile and allows the user to enter or edit a name to describe the material in the user soil library. Then after entering the names or labels, the user should tag all of the soil textures to be included in the library with a "Y" in the column of cells under the "SAVE" heading. Similarly, the user should tag all of the soil textures to be deleted from or not included in the library with a "N" in the column of cells under the "SAVE" heading. To complete the additions and deletions to the library, the user should press ***F10***; to cancel the additions and deletions and return to the

"Verification and Saving" screen, the user should press ***Esc*** or ***F9***.

If the user selects the "Save Soil and Design Data" option, the program automatically checks for possible violation of rules or errors in the soil and design data. This checking encompasses verification of presence, arrangement and values entered for the general landfill information, the landfill profile and layer data, and the runoff curve number information. The program scans through the three landfill profile spreadsheets of layer data one layer at a time and reports the errors as they are encountered. If any violations or inconsistencies are found, the program displays them on multiple screens. The user should press ***Enter*** or ***Page Down*** to proceed through the screens and reach the "File Saving" screen where the data can be saved in a file. If the user wishes to return to "Verification and Saving" screen, press ***Esc***.

Upon reaching the "File Saving" screen, the user can return to the verification and input screens to correct violations by editing the data. To return, press ***Page Up*** successively until the desired screen is reached. On the other hand, the user can still save the data now and make corrections at a later time if there were violations. However, it should not be expected that the HELP model will provide meaningful answers for such data.

Soil and design data are saved in a file specified on the "Soil and Design Data - File Saving" screen. The program displays the default file name, DATA10, for saving in the default directory. DATA10 is the same name for the soil and design data as used in Version 2 except that Version 3 adds an extension of .D10 to the specified soil and design data file name. To save the data, the user should enter "Y" in the "Save" column. Then, the user should specify the directory in which to save the file. If the directory cannot be found, the program responds "Invalid Directory" and replaces it with the default directory. After the directory, the user should enter the file name (no extension or period). If the file already exists, the program will display "File Already Exists." After entering the file name, the user should press ***F10*** or ***Page Down*** to complete the saving to the requested file name. If the file already exists as the default file would, the program will ask whether the user wishes to have the existing file overwritten. If the user answers "Y", the program will overwrite the file, complete the saving process and return to the main menu. If the user answers "N", the program will interrupt the saving, return to the "SAVE" column and change the tag to "N". The user can then change the tag back to "Y", rename the file, and restart the saving by pressing ***F10*** or ***Page Down***. The program provides other options listed on the "File Saving" screen to provide the means for the user to display a directory of existing soil and design data files (***F4***), to return to the data entry screens (***Page Up***) or to return to the main menu without saving the data (***F9***). The user must be cautioned that the ***F9*** option will cause all the data created (if any) to be lost. Figure 17 shows the available options.

4.7 EXECUTING THE SIMULATION

Option 3 on the main menu is "Execute Simulation". This option is composed of two primary screens: "Execution Files - File Management" screen and "Output Selection" screen and is shown schematically in Figure 18.

Execution Files

This screen is used to define the weather and soil and design data files that contain the data to be used in the HELP model simulation. Six files must be specified to run HELP model. The input data files required are a precipitation data file, a temperature data file, a solar radiation data file, an evapotranspiration data file, and a soil and design data file; and for output, the HELP model requires one file on which the results are to be written.

The user must enter the file names without extension since the HELP model recognizes the following extensions for the various types of files:

.D4 for precipitation data

.D7 for temperature data

.D11 for evapotranspiration data

.D13 for solar radiation data

.D10 for soil and design data

.OUT for the output

When the program initially displays the "Execution Files - File Management" screen, the program lists the default directory name in each cell in the directory column and the file names of each type of data that were used in the last simulation. The user should enter the directory, if different than the default directory, for each type of file. If an invalid directory is entered, the program displays the message "Invalid Directory" and replaces the directory with the default directory. If user enters a file name that could not be found on the specified directory, then the program displays the message "File Not Found" and erases the file name.

As shown in Figure 18, the user may obtain a list of all files that reside on the current directory by pressing ***F4***. When the user presses ***F4***, the program obtains a directory of all files that pertain to the type of file at the cell where ***F4*** was pressed. For example, if ***F4*** was pressed from the temperature file cell, the program will display the list of files with extension D7 that reside on the current directory displayed in temperature file row. Up to 120 data files for any file type can be displayed on a separate screen. The name of the current directory where these files are located is also displayed. The user can obtain the list of data files with the same extension that are available in another valid

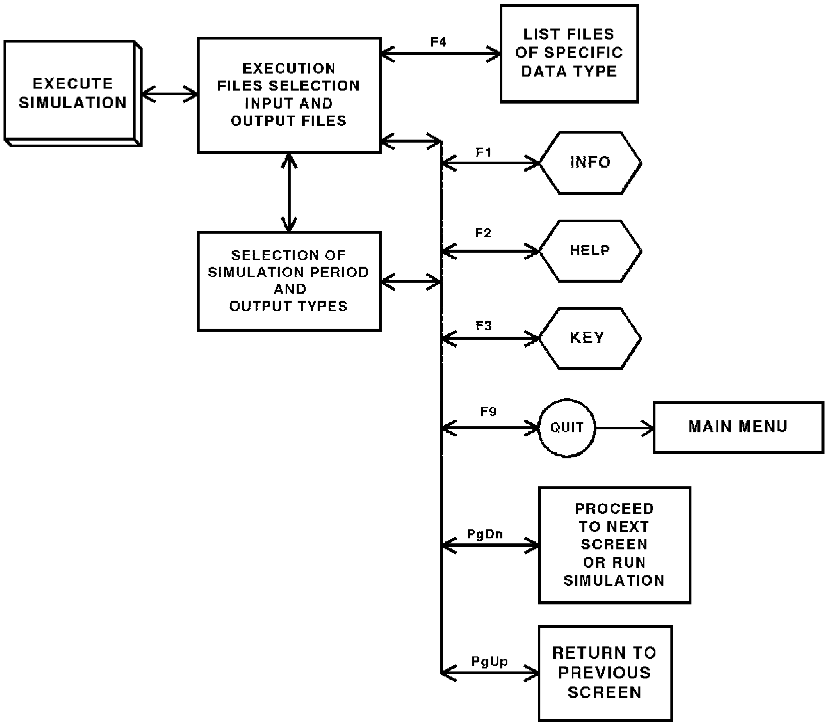

Figure 18. Schematic of "Execute Simulation" Option

directory by entering the name of that directory in the column labeled DIRECTORY and on the same row as the file type of interest.

To select a file from the list of displayed files, move the cursor to the file and select it by pressing ***Enter***. This transfers control back to the previous screen and the name of the file just selected will be displayed in the proper cell. The user can exit the list-of-files screen without selecting a file by pressing the ***Esc*** key.

Once file names have been selected, the user can proceed to the next screen of the execution module by pressing ***Page Down*** or ***F10***. If the output file already exists, the user is prompted with a warning indicating that this file already exists. The program then asks whether the file should be overwritten. If the user answers "N", the program moves the cursor to the output file name cell so that the user can enter a new file name. If the user answers "Y", the program proceeds to the "Output Selection" screen. Before displaying the next screen, the program reads the weather data files to determine the maximum allowable simulation period.

Output Selection

On this screen, the user selects the units of the HELP model output, the number of years to simulate, and the output frequency. The user may use a maximum of 100 years of simulation provided that weather data are available for that many years. If the weather data in the selected files have a different number of years, the HELP model allows the simulation period to be no larger than the minimum number of years available in any of the daily weather data files. If the simulation period selected is smaller than the maximum allowable period, the program will use the years of weather data starting at the top of the files.

The rest of the information available on this screen is for selecting the type of optional output desired (daily, monthly or annual). The user may select any, all or none of the available options. The program will always write the summary output to the output file as well as a description of the input data. In order to select additional or different output frequencies, move the cursor to the desired output frequency and type "Y". Once all execution files and output frequency data are selected, the user should press ***Page Down*** or ***F10*** to start the simulation. To move back to the "Execution Files" screen, press ***Page Up***.

4.8 VIEWING RESULTS

Option 4 on the main menu is to view the results of execution. This option is used to browse through the output file before printing. Figure 19 is a schematic of this option. The program displays the "View Results" screen. The user should enter the desired directory and file name. The file name can be selected from a list of files by pressing ***F4***. After selecting the file, press ***Page Down*** or ***F10*** to display the selected file. The viewing function uses the LIST program written by Vernon D. Buerg and instructions on its use are available on screen by typing ***?*** or ***F1***. To display other types of files, first enter the extension of the file of interest, then the directory and the file name. To return to the main menu, press ***Page Down*** or ***F10***.

4.9 PRINTING RESULTS

Option 5 on the main menu is used to print the output file. Figure 20 is a schematic of this option. The program displays the "Print Results" screen. The user should enter the desired directory and file name. The file name can be selected from a list of files by pressing ***F4***. After selecting the file, press ***Page Down*** or ***F10*** to print the selected file. The print function uses the DOS PRINT command and instructions on its use are available in a DOS manual. The output file is 80 characters wide for all output options except daily output, which can be up to 132 characters wide. When printing output with daily results, it may be necessary to select a compressed font on your printer before printing to avoid wrapping or loss of output.

To print other types of files, first enter the extension of the file of interest, then the directory and the file name. To return to the main menu, press ***Page Down*** or ***F10***. Alternatively, the output file or any data file, which are ASCII text files, could be imported into other software such as word processors and printed in the format desired.

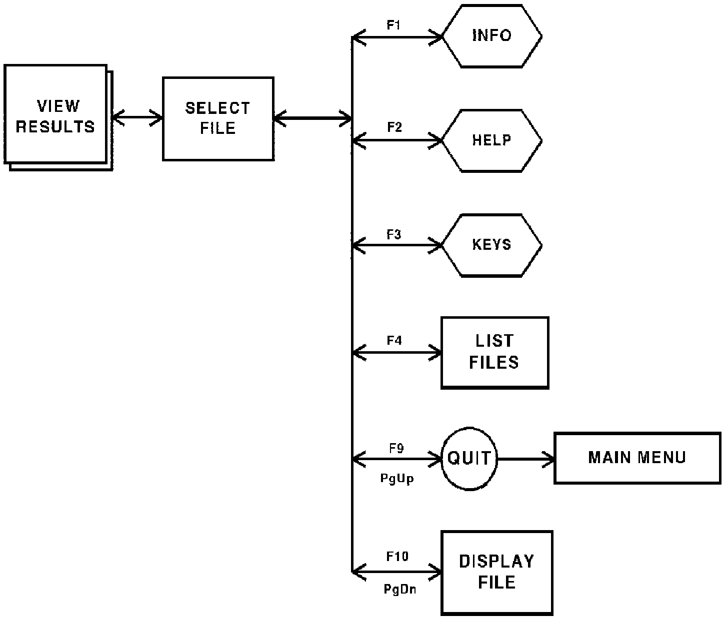

Figure 19. Schematic of "View Results" Option

Similarly, the output, in total or part, can be printed within the Viewing Option using the LIST program and blocking sections to be printed.

4.10 DISPLAYING GUIDANCE

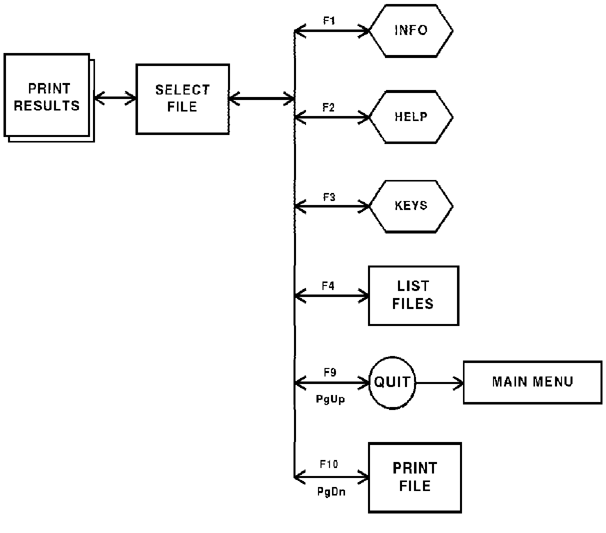

Figure 20. Schematic of "Print Results" Option

On-line help is provided throughout the program. However, option 6 on the main menu gives an overview of the HELP program, as well as, general criteria for landfill design and guidance on using the model. Most of this user guide is displayed in this option and the guidance refers to figures and tables in this guide. In addition, the on-line guidance uses the same section numbering as this guide.

4.11 QUITTING HELP

Option 7 on the main menu is to quit the HELP program and return to DOS.

REFERENCES

Arnold, J. G., Williams, J. R., Nicks, A. D., and Sammons, N. B. (1989). "SWRRB, A basin scale simulation model for soil and water resources management," Texas A&M University Press, College Station, TX. 142 pp.

Breazeale, E., and McGeorge, W. T. (1949). "A new technic for determining wilting percentage of soil," *Soil Science* 68, 371-374.

Brooks, R. H., and Corey, A. T. (1964). "Hydraulic properties of porous media," *Hydrology Papers* (3), Colorado State University, Fort Collins, CO. 27 pp.

England, C. B. (1970). "Land capability: A hydrologic response unit in agricultural watersheds," ARS 41-172, USDA Agricultural Research Service. 12 pp.

Harpur, W. A., Wilson-Fahmy, R. F., and Koerner, R. M. (1993). "Evaluation of the contact between geosynthetic clay liners and geomembranes in terms of transmissivity," *Proceeedings of GRI Seminar on Geosynthetic Liner Systems,* Geosynthetic Research Institute, Drexel University, Philadelphia, PA. 143-154.

Knisel, W. J., Jr., Editor. (1980). "CREAMS, A field scale model for chemicals, runoff, and erosion from agricultural management systems, volumes I, II and III." USDA-SEA, Conservation Research Report 26. 643 pp.

Lutton, R. J., Regan, G. L., and Jones, L. W. (1979). "Design and construction of covers for soil waste landfills," EPA-600/2-79-165, US Environmental Protection Agency, Cincinnati, OH. 249 pp.

National Oceanic and Atmospheric Administration. (1974). *Climatic atlas of the United States.* US Department of Commerce, Environmental Science Services Administration, Nation Climatic Center, Ashville, NC. 80 pp.

Perrier, E. R., and Gibson, A. C. (1980). "Hydrologic simulation on solid waste disposal sites," EPA-SW-868, US Environmental Protection Agency, Cincinnati, OH. 111 pp.

Rawls, W. J., Brakensiek, D. L., and Saxton, K. E. (1982). "Estimation of soil water properties," *Transactions of the American Society of Agricultural Engineers* 25(5), 1316-1320.

Richardson, C. W., and Wright, D. A. (1984). "WGEN: A model for generating daily weather variables," ARS-8, USDA Agricultural Research Service. 83 pp.

Ruffner, J. A. (1985). *Climates of the states, National Oceanic and Atmospheric*

Administration narrative summaries, tables, and maps for each state, volume 1 Alabama - New Mexico and volume 2 New York - Wyoming and territories. Gale Research Company, Detroit, MI. 758 pp. and 1572 pp.

Schroeder, P. R., and Gibson, A. C. (1982). "Supporting documentation for the hydrologic simulation model for estimating percolation at solid waste disposal sites (HSSWDS)," Draft Report, US Environmental Protection Agency, Cincinnati, OH. 153 pp.

Schroeder, P. R., Gibson, A. C., and Smolen, M. D. (1984). "The hydrologic evaluation of landfill performance (HELP) model, volume II, documentation for version 1," EPA/530-SW-84-010, US Environmental Protection Agency, Cincinnati, OH. 256 pp.

Schroeder, P. R., Peyton, R. L., McEnroe, B. M., and Sjostrom, J. W. (1988). "The hydrologic evaluation of landfill performance (HELP) model: Volume III. User's guide for version 2," Internal Working Document EL-92-1, Report 1, US Army Engineer Waterways Experiment Station, Vicksburg, MS. 87 pp.

Schroeder, P. R., McEnroe, B. M., Peyton, R. L., and Sjostrom, J. W. (1988). "The hydrologic evaluation of landfill performance (HELP) model: Volume IV. Documentation for version 2," Internal Working Document EL-92-1, Report 2, US Army Engineer Waterways Experiment Station, Vicksburg, MS. 72 pp.

Schroeder, P. R., Dozier, T. S., Zappi, P. A., McEnroe, B. M., Sjostrom, J.W., and Peyton, R.L. (1994). "The hydrologic evaluation of landfill performance (HELP) model: Engineering documentation for version 3," EPA/600/8-94/xxx, US Environmental Protection Agency, Cincinnati, OH. 105 pp.

USDA, Soil Conservation Service. (1985). "Chapter 9, hydrologic soil-cover complexes." *National engineering handbook, section 4, hydrology*. US Government Printing Office, Washington, D.C. 11 pp.

BIBLIOGRAPHY

Darilek, G. T., Laine, D. L., and Parra, J. O. (1989). "The electrical leak location method geomembrane liners: Development and applications." *Geosynthetics '89 Conference Proceedings*. San Diego, CA, 456-466.

Giroud, J. P., and Bonaparte, R. (1989). "Leakage through liners constructed with geomembranes -- part I. Geomembrane liners," *Geotextiles and Geomembranes* 8(1), 27-67.

Giroud, J. P., and Bonaparte, R. (1989). "Leakage through liners constructed with geomembranes -- part II. Composite liners," *Geotextiles and Geomembranes* 8(2), 71-111.

Giroud, J. P., Khatami, A., and Badu-Tweneboah, K. (1989). "Evaluation of the rate of leakage through composite liners," *Geotextiles and Geomembranes* 8(4), 337-340.

McEnroe, B. M., and Schroeder, P. R. (1988). "Leachate collection in landfills: Steady case," *Journal of the Environmental Engineering Division* 114(5), 1052-1062.

Oweis, I. S., Smith, D. A., Ellwood, R. B., and Greene, D. S. (1990). "Hydraulic characteristics of municipal refuse," *Journal of Geotechnical Engineering* 116(4), 539-553.

US Environmental Protection Agency. (1985). "Covers for uncontrolled hazardous waste sites," EPA/540/2-85/002, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH. 529 pp.

US Environmental Protection Agency. (1988). "Guide to technical resources for the design of land disposal facilities," EPA/625/6-88/018, Risk Reduction Engineering Laboratory, Cincinnati, OH. 63 pp.

US Environmental Protection Agency. (1989). "Technical guidance document: Final covers for hazardous waste landfills and surface impoundments," EPA/530-SW-89-047, Office of Solid Waste and Emergency Response, Washington, D.C. 39 pp.

APPENDIX A

CALCULATING SOIL, WASTE AND MATERIAL PROPERTIES

A.1 BACKGROUND

The HELP program requires values for the total porosity, field capacity, wilting point, and saturated hydraulic conductivity of each layer of soil, waste, or other material in a landfill profile. These values can be selected from a list of default materials provided by the HELP program (Table 4) or specified by the user. User-specified values can be measured, estimated, or calculated using empirical or semi-empirical methods presented in this appendix. Selecting the HELP values from default materials or calculating them based on empirical or semi-empirical techniques are not intended to replace laboratory or field generated data. Default and calculated values are suitable for planning purposes, parametric studies, and design comparisons, but are not recommended for accurate water balance predictions. The default and calculated values are for water retention and flow; therefore, leachate is assumed to behave the same as water. The effects of macropores resulting from poor construction practices, burrowing animals, desiccation cracks, etc. are not taken into account in the calculation of the properties or in the default values, but the saturated hydraulic conductivity of the surface soil described by the default values is modified for grassy vegetation.

A.2 EMPIRICAL METHOD

The empirical method for calculating HELP program user-defined values employs empirical equations reported by Brakensiek et al. (1984) and Springer and Lane (1987) to determine soil water retention parameters (field capacity and wilting point) and an empirical equation developed by Kozeny-Carman to determine saturated hydraulic conductivity. The total porosity and percent sand, silt, and clay of each layer is the minimum data required to calculate user-defined values using this method.

A.2.1 Total Porosity

Total porosity is a measure of the volume of void (water and air) space in the bulk volume of porous media. At 100 percent saturation, total porosity is equivalent to the volumetric water content of the media (volume of water per total volume of media) or

$$Total\ Porosity = \frac{Water\ Volume}{Total\ Volume} \tag{A-1}$$

Total porosity can be calculated by developing a solid, liquid, and air phase relationship of each layer. This relationship can be calculated using the water content (on a weight basis) and density (wet or dry) of a sample. Introductory geotechnical engineering textbooks such as Holtz and Kovacs (1981) and Perloff and Baron (1976) provide detail guidance for determining phase relationships. Total porosity is also related to void ratio (ratio of void volume to solid volume) by the following equation:

$$Total\ Porosity = \frac{Void\ Ratio}{1 + Void\ Ratio} \qquad \text{(A-2)}$$

A.2.2 Soil-Water Retention

Field capacity is the volumetric water content of a soil or waste layer at a capillary pressure of 0.33 bars. Field capacity is also referred to as the volumetric water content of a soil remaining following a prolonged period of gravity drainage. Wilting point is the volumetric water content of a soil or waste layer at a capillary pressure of 15 bars. Wilting point is also referred to as the lowest volumetric water content that can be achieved by plant transpiration. The general relation among soil moisture retention parameters and soil texture class is shown below.

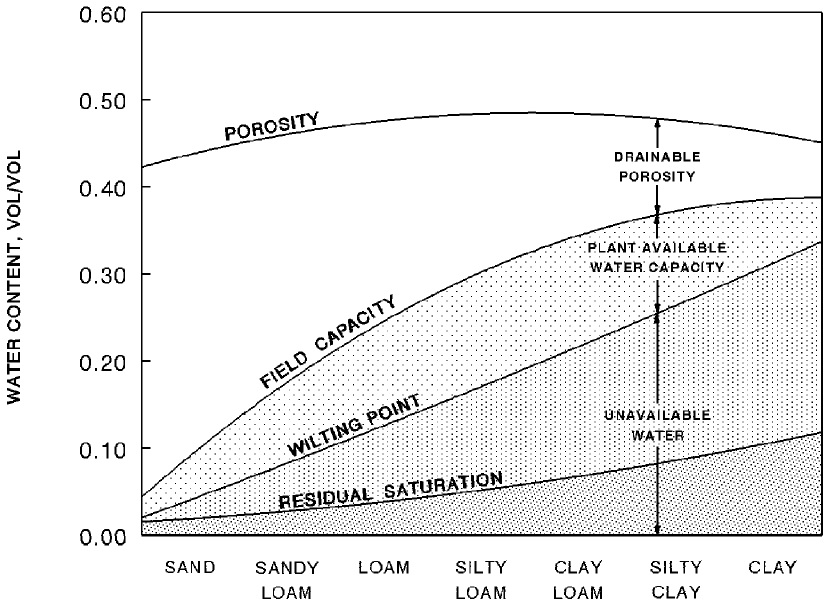

Figure A-21. General Relation Among Soil Moisture Retention Properties and Soil Texture Class

Brakensiek et al. (1984) and Springer and Lane (1987) reported the following empirical equations, which were developed using data from natural soils with a wide range of sand (5-70 percent) and clay (5-60 percent) content:

$$\textit{Field Capacity} = 0.1535 - (0.0018)(\%\ \textit{Sand}) + (0.0039)(\%\ \textit{Clay}) + (0.1943)(\textit{Total Porosity}) \tag{A-3}$$

$$\textit{Wilting Point} = 0.0370 - (0.0004)(\%\ \textit{Sand}) + (0.0044)(\%\ \textit{Clay}) + (0.0482)(\textit{Total Porosity}) \tag{A-4}$$

Sand and clay percentages should be determined using a grain size distribution chart and particle sizes defined by the U.S. Department of Agriculture textural soil classification system. According to this system, sand particles range in size from 0.05 mm to 2.0 mm, silt particles from 0.002 mm to 0.05 mm, and clay particles are less than 0.002 mm.

Numerous other equations relating field capacity and wilting point to soil textural properties have been developed. Most of these equation were developed using site-specific data. However, Gupta and Larson (1979) developed empirical equations for field capacity and wilting point using data from separate and mixed samples of dredged sediment and soil from 10 geographic locations in eastern and central United States. Rawls and Brakensiek (1982) and Rawls et al. (1982) also developed empirical equations by fitting the Brooks and Corey's (1964) soil water retention equation to soil water retention and matrix potential data from 500 natural soils in 18 states. Rawls' (1982) equations are not applicable to soils subjected to compactive efforts.

Williams et al. (1992) concluded that equations used to predict water contents based on texture and bulk density alone provided poorer estimates of water content, with large errors at some capillary pressures, in comparison with models that incorporate even one known value of water content. HELP users generally do not have adequate information to use models that require unsaturated water content information; therefore, Equations A-3 and A-4 are used to calculate the water retention of soil and waste layers.

A.2.3 Saturated Hydraulic Conductivity

Saturated hydraulic conductivity (sometimes referred to as the coefficient of permeability) is used as a constant in Darcy's law governing flow through porous media. Hydraulic conductivity is a function of media properties, such as the particle size, void ratio, composition, fabric and degree of saturation, and the kinematic viscosity of the fluid moving through the media. Saturated hydraulic conductivity is used to describe flow through porous media where the void spaces are filled with a wetting fluid (e.g. water). Permeability, unlike saturated hydraulic conductivity, is solely a function of media properties. Henri Darcy's experiments resulted in the following equation for hydraulic conductivity (Freeze and Cherry, 1979):

$$K = \left(\frac{g}{\nu}\right) C\ d^2 \tag{A-5}$$

where

K = hydraulic conductivity, cm/sec

g = acceleration due to gravity, 981 cm/sec^2

υ = kinematic viscosity of water, 1.14 x 10^{-2} cm^2/sec at 15°C

C = proportionality constant, replaced in Equation A-6 by a function of the porosity

d = particle diameter, cm, approximated for nonuniform particles by Equation A-7

Darcy's proportionality constant is dependent on the shape and packing of the soil grains (Freeze and Cherry, 1979). Since porosity represents an integrated measure of the packing arrangement in a porous media, the following semi-empirical, uniform pore-size equation relating Darcy's proportionality constant and porosity was developed by Kozeny-Carman (Freeze and Cherry, 1979):

$$K_s = \left(\frac{g}{\nu}\right)\left[\frac{n^3}{(1-n)^2}\right]\left(\frac{d_g^2}{1.80\times 10^4}\right) \tag{A-6}$$

where

K_s = saturated hydraulic conductivity, cm/sec

g = acceleration due to gravity = 981 cm/sec^2

υ = kinematic viscosity of water, 1.14 x 10^{-2} cm^2/sec at 15°C

n = total porosity

d_g = geometric mean soil particle diameter, mm, computed by Equation A-7

The original Kozeny equation was obtained from a theoretical derivation of Darcy's Law where the porous media was treated as a bundle of capillary tubes (Bear 1972). Carman introduced an empirical coefficient to Kozeny's equation to produce the semi-empirical Kozeny-Carman equation (Brutsaert 1967). The Kozeny-Carman's equation reported in Freeze and Cherry (1979) was altered to allow the mean particle size to be entered in millimeters.

Freeze and Cherry (1979) indicated that the particle diameter of a non-uniform soil can be described using a mean particle size diameter. Shirazi and Boersma (1984) indicated that geometric rather than arithmetic statistical properties are advocated for describing soil samples. The reason, in part, is that there is a wide range of particle sizes in a natural soil sample making the geometric scale much more suitable than the arithmetic scale. Therefore, the mean particle diameter in Kozeny-Carman's equation reported in Freeze and Cherry (1979) was identified as the geometric mean soil particle diameter.

Shirazi et al. (1988) and Shiozawa and Campbell (1991) indicated that bimodal models describe particle grain size curves more accurately than unimodal models. However, analysis performed by Shiozawa and Campbell (1991) on six Washington state soils exhibiting varying sand, silt, and clay fractions indicated that the unimodal model accurately predicted the geometric mean soil particle diameter in all soils tested. Therefore, Shiozawa and Campbell (1991) developed an equation for geometric mean soil particle diameter by using the unimodal model developed by Shirazi and Boersma (1984); using geometric mean particles sizes based on the USDA classification system, as recommended by Shirazi, et al. (1988); and assuming that the soil was composed entirely of clay, silt, and sand. Shiozawa and Campbell's (1991) equation was altered to relate percent silt and clay to the particle diameter; resulting in the following equation:

$$d_g = \exp\left[-1.151 - 0.07713\ (\%\ Clay) - 0.03454\ (\%\ Silt)\right] \qquad \text{(A-7)}$$

where

d_g = geometric mean soil particle diameter, mm

Percent silt and clay should be determined using a grain size distribution chart and grain sizes defined by the U.S. Department of Agriculture (USDA) textural soil classification system (see para A.2.2).

Kozeny-Carman's equation coupled with Shiozuwa and Campbell's equation for mean diameter was applied to soils data provided by Lane and Washburn (1946). These data included void ratio and grain size distribution curves for three soils composed of differing degrees of silt and sand. The saturated hydraulic conductivity predicted by Kozeny-Carman's equation was compared with laboratory data provided by Lane and Washburn (1946). This comparison indicated that Kozeny-Carman's saturated hydraulic conductivity equation coupled with Shiozuwa and Campbell's mean diameter equation can overpredict measured values by one to two orders of magnitude. Although conservative, these results reemphasize the fact that semi-empirical equations are not meant to replace laboratory or field measured data.

Numerous other empirical equations, with limited application, have been developed to estimate saturated hydraulic conductivity from the physical properties of soils. For example, Freeze and Cherry (1979), Holtz and Kovacs (1981), and Lambe and Whitman (1969) presented various forms of Allen Hazen's equation for determining the saturated hydraulic conductivity of silt, sand, and gravel soils. Rawls and Brakensiek (1985) also presented an equation for determining the saturated hydraulic conductivity of soils with varying degrees of sand (5-70 percent) and clay (5-60 percent).

A.3 SEMI-EMPIRICAL METHOD

The semi-empirical method for determining the HELP program user-defined values employs a theoretical equation developed by Brooks and Corey (1964) to determine soil-water retention parameters (field capacity and wilting point) and a semi-empirical equation developed by Brutsaert (1967) and Rawls et al. (1982) to calculate saturated hydraulic conductivity. The total porosity, residual volumetric water content, pore-size distribution index, and bubbling pressure of each layer are the minimum data required to calculate the user-defined values for this method. As previously mentioned, total porosity can be calculated using Equation A-1 or A-2.

A.3.1 Soil-Water Retention

The HELP program does not allow the user to define the Brooks-Corey parameters (residual volumetric water content, pore-size distribution index, and bubbling pressure) of the soil, waste, or barrier layers; therefore, if these data are available, the user must first calculate field capacity and wilting point using Brooks and Corey's (1964) water retention equation:

$$\frac{\theta - \theta_r}{\phi - \theta_r} = \left(\frac{\psi_b}{\psi} \right)^{\lambda} \qquad \text{(A-8)}$$

where

θ = volumetric water content (field capacity or wilting point), unitless

θ_r = residual saturation volumetric water content, unitless

ϕ = total porosity, unitless

λ = pore-size distribution index, unitless

ψ = capillary pressure, bars (at field capacity, 0.33, or wilting point, 15.0)

ψ_b = bubbling pressure, bars

The volumetric water content in Equation A-8 is, by definition, equivalent to field capacity at a capillary pressure of 0.33 bar and is equivalent to wilting point at a capillary pressure of 15 bars. The HELP program will use the calculated field capacity and wilting point values to recalculate the Brooks-Corey parameters; however, because the program estimates the residual saturation water content from the wilting point before using Equation A-8 to calculate the other Brooks-Corey parameters, the program values will differ slightly from the laboratory data.

A.3.2 Saturated Hydraulic Conductivity

Brutsaert (1967) derived a saturated hydraulic conductivity relation by substituting Brooks-Corey's water retention equation into the Childs and Collis-George (1950) series-parallel coefficient of permeability integral. Rawls et al. (1982 and 1983) presented the following form of Brutsaert's (1967) equation:

$$K_s = a \frac{(\phi - \theta_r)^2}{(\psi_b)^2} \frac{\lambda^2}{(\lambda + 1)(\lambda + 2)} \tag{A-9}$$

where

K_s = saturated hydraulic conductivity, cm/sec

a = constant representing the effects of various fluid constants and gravity, 21 cm^3/sec

ϕ = total porosity, unitless

θ_r = residual volumetric water content, unitless

ψ_b = bubbling pressure, cm

λ = pore-size distribution index, unitless

Childs and Collis-George's (1950) series-parallel coefficient of permeability model assumes that the porous media is equivalent to a number of parallel portions each with a different hydraulic conductivity and each with uniform pore size. The hydraulic conductivity of each portion is obtained from the assumption of a bundle of capillary tubes parallel to the direction of flow. The media is fractured at a normal plane with two resulting faces, which are then rejoined after some random displacement (Brutsaert, 1967).

Rawls et al. (1982) fit Equation A-9 (using geometric mean values for Brooks-Corey parameters) to saturated hydraulic conductivity values from their data base and obtained a good correlation between these and predicted values. Rawls et al. (1982) and Rawls et al. (1983) subsequently recommended using an "a" constant of 21 cm/sec. However, Rawls et al. (1982) fit Equation A-9 to data presented by other researchers and obtained saturated hydraulic conductivities that overpredicted the data by three to four times. Although conservative, these results re-emphasize the fact that empirical equations are not meant to replace laboratory or field measured data.

A.4 VEGETATED, SATURATED HYDRAULIC CONDUCTIVITY

If the saturated hydraulic conductivity of a soil or waste layer is not selected from the HELP default data base, the program will not adjust the saturated hydraulic conductivity to account for root penetration by surface vegetation. Therefore, the user must adjust the saturated hydraulic conductivity in the top half of the evaporative zone. The program adjusts the default values using the following equation developed by regressing changes in infiltration resulting from vegetation.

$$(K_s)_v = [1.0 + 0.5966\ (LAI) + 0.132659\ (LAI)^2 + 0.1123454\ (LAI)^3 - 0.04777627\ (LAI)^4 + 0.004325035\ (LAI)^5]\ (K_s) \tag{A-10}$$

where

$(K_s)_v$ = vegetated saturated hydraulic conductivity in top half of evaporative zone, cm/sec

LAI = leaf area index, unitless

K_s = unvegetated saturated hydraulic conductivity in top half of evaporative zone, cm/sec

A.5 CONCLUSIONS

The HELP program user-defined values for total porosity, field capacity, wilting point, and saturated hydraulic conductivity can be conservatively calculated using empirical or semi-empirical methods presented in this appendix. Total porosity, percent sand, silt and clay, and particle diameter are the minimum data required to calculate user-defined values using the empirical method. Total porosity and Brooks-Corey parameters are the minimum data required for the semi-empirical method. Where available, comparisons with measured values re-emphasized the fact that neither of these methods is intended to replace laboratory or field generated data.

A.6 REFERENCES

Bear, J. (1972). *Dynamics of fluids in porous media*. American Elsevier Publishing Company, New York. 764 pp.

Brakensiek, D. L., Rawls, W. J., and Stephenson, G. R. (1984). "Modifying SCS hydrologic soil groups and curve numbers for rangeland soils." *Annual meeting of the American society of agricultural engineers, Pacific northwest region*. Kennewick, WA, USDA-ARS, Paper Number PNR-84-203. 13 pp.

Brooks, R. H., and Corey, A. T. (1964). "Hydraulic properties of porous media," *Hydrology Papers* (3), Colorado State University, Fort Collins, CO. 27 pp.

Brutsaert, W. (1967). "Some methods of calculating unsaturated permeability," *Transactions of the American Society of Agricultural Engineers* 10(3), 400-404.

Childs, E. C., and Collis-George, N. (1950). "The permeability of porous material," *Proceeding of the Royal Society* 201, Section A.

Freeze, R. A., and Cherry, J. A. (1979). *Groundwater*. Prentice-Hall, Englewood Cliffs, NJ. 604 pp.

Gupta, S. C., and Larson, W. E. (1979). "Estimating soil water retention characteristics from particle size distribution, organic matter percent, and bulk density," *Water Resources Research* 15(6), 1633-1635.

Holtz, R. D., and Kovacs, W. D. (1981). *An introduction to geotechnical engineering*. Prentice-Hall, Englewood Cliffs, NJ. 733 pp.

Lambe, T. W., and Whitman, R. V. (1969). *Soil mechanics*. John Wiley and Sons, New York. 553 pp.

Lane, K. S., and Washburn, D. E. (1946). "Capillary tests by capillarimeter and by soil filled tubes." *Proceedings of the twenty-sixth annual meeting of the Highway Research Board,* Washington, D.C., 460-473.

Perloff, W. H., and Baron, W. (1976). *Soil mechanics - principles and applications*. John Wiley and Sons, New York. 745 pp.

Rawls, W. J., and Brakensiek, D. L. (1982). "Estimating soil water retention from soil properties," *Journal of the Irrigation and Drainage Division* 108(IR2), 166-171.

Rawls, W. J., and Brakensiek, D. L. (1985). "Prediction of soil water properties for hydrologic modelling." *Proceedings of watershed management in the eighties*. B. Jones and T. J. Ward, ed., American Society of Civil Engineers, New York, 293-299.

Rawls, W. J., Brakensiek, D. L., and Saxton, K. E. (1982). "Estimation of soil water properties," *Transactions of the American Society of Agricultural Engineers* 25(5), 1316-1320.

Rawls, W. J., Brakensiek, D. L., and Soni, B. (1983). "Agricultural management effects on soil water processes - part I: Soil water retention and green and ampt infiltration parameters," *Transactions of the American Society of Agricultural Engineers* 26(6), 1747-1757.

Shiozawa, S., and Campbell, G. S. (1991). "On the calculation of mean particle diameter and standard deviation from sand, silt, and clay fractions," *Soil Science* 152(6), 427-431.

Shirazi, M. A., and Boersma, L. (1984). "A unifying quantitative analysis of soil texture," *Soil Science Society of America Journal* 48(1), 142-147.

Shirazi, M. A., Boersma, L., and Hart, J. W. (1988). "A unifying quantitative analysis of soil texture: Improvement of precision and extension of scale," *Soil Science Society of America Journal* 52(1), 181-190.

Springer, E. P., and Lane, L. J. (1987). "Hydrology-component parameter estimation." *Chapter 6, simulation of production and utilization of rangelands (SPUR) - documentation and user guide*. J. R. Wight and J. W. Skiles, eds, ARS-63, US Department of Agriculture, Agricultural Research Service. 372 pp.

Williams, R. D., Ahujam, L. R., and Naney, J. W. (1992). "Comparison of methods to estimate soil water characteristics from soil texture, bulk density, and limited data," *Soil Science* 153(3), 172-184.

APPENDIX B

PRESCRIPTIVE LINER HELP MODEL DEMONSTRATION

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*****************************************************************
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 **
**
 **
**
 **             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**
 **               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)
**
 **                 DEVELOPED BY ENVIRONMENTAL LABORATORY
**
 **                   USAE WATERWAYS EXPERIMENT STATION
**
 **            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
**
 **
**
 **
**

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 PRECIPITATION DATA FILE:    Q:\DATA4.D4
 TEMPERATURE DATA FILE:      Q:\DATA7.D7
 SOLAR RADIATION DATA FILE:  Q:\DATA13.D13
 EVAPOTRANSPIRATION DATA:    Q:\DATA11.D11
 SOIL AND DESIGN DATA FILE:  Q:\DATA10.D10
 OUTPUT DATA FILE:           Q:\RCRA.OUT


 TIME:  20:18     DATE:  11/ 2/2015



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```
      TITLE:  CK DISPOSAL PRESCRIPTIVE LINER

*****************************************************************
*************


      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   1
            THICKNESS                  =    12.00   INCHES
            POROSITY                   =     0.4170 VOL/VOL
            FIELD CAPACITY             =     0.0450 VOL/VOL
            WILTING POINT              =     0.0180 VOL/VOL
            INITIAL SOIL WATER CONTENT =     0.0181 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.999999978000E-02
CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED
BY  2.01
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE
ZONE.


                                    LAYER  2
                                    --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER   1
            THICKNESS                  =    24.00   INCHES
            POROSITY                   =     0.4170 VOL/VOL
            FIELD CAPACITY             =     0.0450 VOL/VOL
            WILTING POINT              =     0.0180 VOL/VOL
            INITIAL SOIL WATER CONTENT =     0.0656 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.999999978000E-02
CM/SEC
            SLOPE                      =     2.00   PERCENT
            DRAINAGE LENGTH            =   1160.0    FEET
```

```
                                    LAYER  3
                                    --------

                        TYPE 4 - FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
            THICKNESS                   =     0.06   INCHES
            POROSITY                    =     0.0000 VOL/VOL
            FIELD CAPACITY              =     0.0000 VOL/VOL
            WILTING POINT               =     0.0000 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12
CM/SEC
            FML PINHOLE DENSITY         =     0.00   HOLES/ACRE
            FML INSTALLATION DEFECTS    =     1.00   HOLES/ACRE
            FML PLACEMENT QUALITY       =  1 - PERFECT



                                    LAYER  4
                                    --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER   0
            THICKNESS                   =    24.00   INCHES
            POROSITY                    =     0.4530 VOL/VOL
            FIELD CAPACITY              =     0.1900 VOL/VOL
            WILTING POINT               =     0.0850 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.1900 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-05
CM/SEC
            SLOPE                       =     2.00   PERCENT
            DRAINAGE LENGTH             =   1160.0    FEET



                                    LAYER  5
                                    --------

                        TYPE 4 - FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
            THICKNESS                   =     0.06   INCHES
            POROSITY                    =     0.0000 VOL/VOL
            FIELD CAPACITY              =     0.0000 VOL/VOL
            WILTING POINT               =     0.0000 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12
CM/SEC
            FML PINHOLE DENSITY         =     0.00   HOLES/ACRE
            FML INSTALLATION DEFECTS    =     0.00   HOLES/ACRE
```

```
            FML PLACEMENT QUALITY       =  4 - POOR


                                    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. COND.   =  0.100000001000E-06
CM/SEC


                    GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                    ----------------------------------------

          NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

         SCS RUNOFF CURVE NUMBER            =     80.00
         FRACTION OF AREA ALLOWING RUNOFF   =      0.0
PERCENT
         AREA PROJECTED ON HORIZONTAL PLANE =    142.000  ACRES
         EVAPORATIVE ZONE DEPTH             =     18.0    INCHES
         INITIAL WATER IN EVAPORATIVE ZONE  =      0.325  INCHES
         UPPER LIMIT OF EVAPORATIVE STORAGE =      7.506  INCHES
         LOWER LIMIT OF EVAPORATIVE STORAGE =      0.324  INCHES
         INITIAL SNOW WATER                 =      0.000  INCHES
         INITIAL WATER IN LAYER MATERIALS   =     16.599  INCHES
         TOTAL INITIAL WATER                =     16.599  INCHES
         TOTAL SUBSURFACE INFLOW            =      0.00
INCHES/YEAR


                     EVAPOTRANSPIRATION AND WEATHER DATA
                     -----------------------------------

          NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                   Eunice                 New Mexico

              STATION LATITUDE                        =  32.42
DEGREES
```

```
              MAXIMUM LEAF AREA INDEX                =   1.20
              START OF GROWING SEASON (JULIAN DATE)  =     65
              END OF GROWING SEASON (JULIAN DATE)    =    321
              EVAPORATIVE ZONE DEPTH                 =  18.0
INCHES
              AVERAGE ANNUAL WIND SPEED              =  12.20 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  58.00 %
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  59.00 %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  57.00 %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  60.00 %


          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
        0.24        0.28        0.27        0.37        0.77
0.91
        1.38        2.17        1.72        0.99        0.33
0.27


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES
FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
       43.70       47.70       55.00       64.10       72.10
79.80
       81.70       80.60       74.20       64.40       52.30
46.00


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED
USING
```

```
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO
                     AND STATION LATITUDE  =  33.24 DEGREES




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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    1
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---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.00    0.19    0.02    0.56
0.02    0.00
                                  1.03    2.57    2.89    0.42
0.89    0.11

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.001   0.117   0.025   0.134
0.344   0.000
                                  0.627   2.775   2.573   0.062
0.700   0.450

 LATERAL DRAINAGE COLLECTED       0.0514  0.0444  0.0490  0.0453
0.0448  0.0448
   FROM LAYER  2                  0.0453  0.0502  0.0604  0.0709
0.0666  0.0692

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  4                  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
```

```
 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
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---------------


 AVERAGE DAILY HEAD ON            1.696   1.622   1.617   1.546
1.479   1.529
   TOP OF LAYER  3                1.494   1.657   2.061   2.339
2.272   2.286

 STD. DEVIATION OF DAILY          0.040   0.012   0.031   0.018
0.044   0.035
   HEAD ON TOP OF LAYER  3        0.042   0.079   0.329   0.056
0.022   0.066

 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  5                0.000   0.000   0.000   0.001
0.001   0.001

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    1
 -----------------------------------------------------------------
---------------
                                          INCHES         CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                           8.70
4484502.500    100.00
```

```
   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       7.808
4024478.500     89.74

   DRAINAGE COLLECTED FROM LAYER  2         0.6422
331017.844      7.38

   PERC./LEAKAGE THROUGH LAYER  3           0.000124
64.095      0.00

   AVG. HEAD ON TOP OF LAYER  3             1.7998

   DRAINAGE COLLECTED FROM LAYER  4         0.0000
0.072      0.00

   PERC./LEAKAGE THROUGH LAYER  6           0.000002
1.280      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0004

   CHANGE IN WATER STORAGE                  0.250
129003.625      2.88

   SOIL WATER AT START OF YEAR             18.879
9731514.000

   SOIL WATER AT END OF YEAR               19.130
9860517.000

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
1.106      0.00


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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    2
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---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.44    0.18    0.42    0.33
1.51    1.84
                                  1.33    1.69    1.42    0.00
0.34    0.85

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.160   0.186   0.214   0.172
1.427   1.963
                                  1.265   1.613   0.605   0.647
0.183   0.435

 LATERAL DRAINAGE COLLECTED       0.0745  0.0687  0.0767  0.0757
0.0768  0.0796
   FROM LAYER  2                  0.0839  0.0834  0.0785  0.0824
0.0800  0.0808

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  4                  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
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---------------
```

```
 AVERAGE DAILY HEAD ON            2.461   2.510   2.531   2.583
2.534   2.716
   TOP OF LAYER  3                2.770   2.755   2.679   2.722
2.730   2.668

 STD. DEVIATION OF DAILY          0.049   0.010   0.046   0.018
0.026   0.084
   HEAD ON TOP OF LAYER  3        0.028   0.023   0.041   0.114
0.019   0.032

 AVERAGE DAILY HEAD ON            0.001   0.001   0.001   0.001
0.001   0.001
   TOP OF LAYER  5                0.001   0.001   0.001   0.001
0.001   0.001

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000


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                          ANNUAL TOTALS FOR YEAR    2
 ----------------------------------------------------------------
---------------
                                          INCHES         CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                           10.35
5335011.500    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       8.870
4572279.500     85.70

   DRAINAGE COLLECTED FROM LAYER  2         0.9411
485098.969      9.09

   PERC./LEAKAGE THROUGH LAYER  3           0.000182
```

```
93.929      0.00

   AVG. HEAD ON TOP OF LAYER  3             2.6383

   DRAINAGE COLLECTED FROM LAYER  4         0.0000
0.179      0.00

   PERC./LEAKAGE THROUGH LAYER  6           0.000002
1.280      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0010

   CHANGE IN WATER STORAGE                  0.539
277632.156      5.20

   SOIL WATER AT START OF YEAR             19.130
9860517.000

   SOIL WATER AT END OF YEAR               19.668
10138149.000

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000           -
0.476      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    3
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---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------
```

```
 PRECIPITATION                    0.31    0.14    0.64    0.13
0.70    0.36
                                  2.84    0.96    1.48    0.03
2.58    0.16

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.222   0.160   0.301   0.296
0.839   0.253
                                  2.776   0.899   1.203   0.175
1.310   0.804

 LATERAL DRAINAGE COLLECTED       0.0788  0.0705  0.0818  0.0850
0.0908  0.0867
   FROM LAYER  2                  0.0907  0.0902  0.0867  0.0895
0.0836  0.1034

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  4                  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            2.601   2.578   2.700   2.899
2.996   2.957
   TOP OF LAYER  3                2.994   2.979   2.958   2.955
2.851   3.415

 STD. DEVIATION OF DAILY          0.010   0.029   0.083   0.015
0.058   0.046
   HEAD ON TOP OF LAYER  3        0.055   0.040   0.020   0.064
0.057   0.215
```

```
 AVERAGE DAILY HEAD ON            0.001   0.001   0.001   0.002
0.002   0.002
   TOP OF LAYER  5                0.002   0.002   0.002   0.002
0.002   0.002

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    3
 ----------------------------------------------------------------
---------------
                                          INCHES         CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                           10.33
5324701.500    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       9.239
4762178.500     89.44

   DRAINAGE COLLECTED FROM LAYER  2         1.0376
534847.312     10.04

   PERC./LEAKAGE THROUGH LAYER  3           0.000201
103.562      0.00

   AVG. HEAD ON TOP OF LAYER  3             2.9069

   DRAINAGE COLLECTED FROM LAYER  4         0.0000
0.310      0.00

   PERC./LEAKAGE THROUGH LAYER  6           0.000002
1.280      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0017
```

```
   CHANGE IN WATER STORAGE                  0.054
27674.041      0.52

   SOIL WATER AT START OF YEAR             19.668
10138149.000

   SOIL WATER AT END OF YEAR               19.722
10165824.000

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
0.008      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    4
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.00    0.11    0.06    0.30
0.11    0.03
                                  2.06    3.82    0.13    2.00
0.05    0.58

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.082   0.074   0.022   0.067
```

```
0.251   0.077
                                  1.732   3.990   0.105   1.053
0.344   0.182

 LATERAL DRAINAGE COLLECTED       0.1104  0.0965  0.0973  0.0880
0.0854  0.0797
   FROM LAYER  2                  0.0774  0.0798  0.0748  0.0793
0.1084  0.1082

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  4                  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            3.644   3.407   3.213   3.002
2.821   2.718
   TOP OF LAYER  3                2.554   2.636   2.553   2.618
3.698   3.572

 STD. DEVIATION OF DAILY          0.066   0.052   0.076   0.056
0.033   0.051
   HEAD ON TOP OF LAYER  3        0.040   0.022   0.035   0.301
0.114   0.064

 AVERAGE DAILY HEAD ON            0.002   0.002   0.002   0.002
0.002   0.002
   TOP OF LAYER  5                0.003   0.003   0.003   0.003
0.003   0.003

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000
```

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                           ANNUAL TOTALS FOR YEAR    4
 -----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                           9.25
4768006.500    100.00

   RUNOFF                                  0.000
0.000      0.00

   EVAPOTRANSPIRATION                      7.979
4113023.500     86.26

   DRAINAGE COLLECTED FROM LAYER  2        1.0852
559383.375     11.73

   PERC./LEAKAGE THROUGH LAYER  3          0.000210
108.313      0.00

   AVG. HEAD ON TOP OF LAYER  3            3.0362

   DRAINAGE COLLECTED FROM LAYER  4        0.0000
0.456      0.00

   PERC./LEAKAGE THROUGH LAYER  6          0.000002
1.283      0.00

   AVG. HEAD ON TOP OF LAYER  5            0.0025

   CHANGE IN WATER STORAGE                 0.185
95597.750      2.00

   SOIL WATER AT START OF YEAR            19.722
10165824.000

   SOIL WATER AT END OF YEAR              19.907
10261421.000

   SNOW WATER AT START OF YEAR             0.000
```

```
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
0.104      0.00


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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    5
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---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.14    0.22    0.33    0.00
1.58    0.94
                                  1.04    0.52    2.30    1.52
0.33    0.76

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.179   0.156   0.194   0.185
1.461   0.849
                                  0.600   0.922   1.812   1.326
0.689   0.297

 LATERAL DRAINAGE COLLECTED       0.1084  0.0949  0.0992  0.0955
0.0974  0.0902
   FROM LAYER  2                  0.0897  0.0897  0.0864  0.0924
0.0914  0.0911

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
```

```
   LAYER  3                        0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED        0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  4                   0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                        0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 -----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON             3.579   3.470   3.276   3.259
3.215   3.076
   TOP OF LAYER  3                 2.962   2.962   2.949   3.050
3.118   3.007

 STD. DEVIATION OF DAILY           0.049   0.058   0.040   0.022
0.041   0.069
   HEAD ON TOP OF LAYER  3         0.047   0.038   0.034   0.034
0.041   0.022

 AVERAGE DAILY HEAD ON             0.003   0.003   0.003   0.003
0.003   0.003
   TOP OF LAYER  5                 0.003   0.003   0.003   0.004
0.004   0.004

 STD. DEVIATION OF DAILY           0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5         0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    5
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 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                            9.68
4989653.000    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       8.669
4468587.500     89.56

   DRAINAGE COLLECTED FROM LAYER  2         1.1264
580596.500     11.64

   PERC./LEAKAGE THROUGH LAYER  3           0.000218
112.420      0.00

   AVG. HEAD ON TOP OF LAYER  3             3.1603

   DRAINAGE COLLECTED FROM LAYER  4         0.0000
0.603      0.00

   PERC./LEAKAGE THROUGH LAYER  6           0.000002
1.280      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0033

   CHANGE IN WATER STORAGE                 -0.115        -
59535.371     -1.19

   SOIL WATER AT START OF YEAR             19.907
10261421.000

   SOIL WATER AT END OF YEAR               19.792
10201886.000

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
2.480      0.00

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          AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH
5
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---------------

                          JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT
MAY/NOV  JUN/DEC
                          -------  -------  -------  -------
-------  -------
   PRECIPITATION
   -------------
     TOTALS                 0.18     0.17     0.29     0.26
0.78     0.63
                            1.66     1.91     1.64     0.79
0.84     0.49

     STD. DEVIATIONS        0.19     0.04     0.26     0.21
0.74     0.77
                            0.78     1.32     1.04     0.91
1.02     0.34

   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

   EVAPOTRANSPIRATION
   ------------------
     TOTALS                 0.129    0.139    0.151    0.171
0.864    0.628
                            1.400    2.040    1.260    0.652
0.645    0.433

     STD. DEVIATIONS        0.088    0.044    0.123    0.084
0.574    0.817
```

```
                            0.903    1.330    0.974    0.546
0.433    0.234

   LATERAL DRAINAGE COLLECTED FROM LAYER  2
   ----------------------------------------
     TOTALS                 0.0847   0.0750   0.0808   0.0779
0.0790   0.0762
                            0.0774   0.0787   0.0774   0.0829
0.0860   0.0906

     STD. DEVIATIONS        0.0249   0.0216   0.0203   0.0196
0.0206   0.0181
                            0.0187   0.0165   0.0108   0.0085
0.0154   0.0160

   PERCOLATION/LEAKAGE THROUGH LAYER  3
   ------------------------------------
     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

   LATERAL DRAINAGE COLLECTED FROM LAYER  4
   ----------------------------------------
     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

   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  3
   -------------------------------------
     AVERAGES                2.7960   2.7174   2.6674   2.6578
2.6091   2.5993
                             2.5550   2.5976   2.6398   2.7368
2.9338   2.9896

     STD. DEVIATIONS         0.8205   0.7588   0.6693   0.6671
0.6790   0.6182
                             0.6186   0.5454   0.3676   0.2819
0.5253   0.5287

   DAILY AVERAGE HEAD ON TOP OF LAYER  5
   -------------------------------------
     AVERAGES                0.0014   0.0015   0.0016   0.0016
0.0017   0.0017
                             0.0018   0.0018   0.0019   0.0020
0.0020   0.0021

     STD. DEVIATIONS         0.0011   0.0011   0.0011   0.0011
0.0011   0.0012
                             0.0012   0.0012   0.0012   0.0012
0.0012   0.0012


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      AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1
THROUGH    5
 ------------------------------------------------------------------
---------------
                                      INCHES            CU. FEET
PERCENT
                                -------------------

-------------   ---------
  PRECIPITATION                 9.66    (   0.710)    4980375.0
100.00
```

```
  RUNOFF                              0.000   (  0.0000)
0.00      0.000

  EVAPOTRANSPIRATION                  8.513   (  0.6044)
4388109.50     88.108

  LATERAL DRAINAGE COLLECTED          0.96649 (  0.19399)
498188.781   10.00304
    FROM LAYER  2

  PERCOLATION/LEAKAGE THROUGH         0.00019 (  0.00004)
96.464     0.00194
    LAYER  3

  AVERAGE HEAD ON TOP                 2.708 (    0.543)
    OF LAYER  3

  LATERAL DRAINAGE COLLECTED          0.00000 (  0.00000)
0.324    0.00001
    FROM LAYER  4

  PERCOLATION/LEAKAGE THROUGH         0.00000 (  0.00000)
1.281     0.00003
    LAYER  6

  AVERAGE HEAD ON TOP                 0.002 (    0.001)
    OF LAYER  5

  CHANGE IN WATER STORAGE             0.183   (  0.2433)
94074.44      1.889


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```

```
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                 PEAK DAILY VALUES FOR YEARS    1 THROUGH    5
    -------------------------------------------------------------
-----------
                                                  (INCHES)
(CU. FT.)
                                                 ----------
-------------
       PRECIPITATION                               1.17
603088.187

       RUNOFF                                      0.000
0.0000

       DRAINAGE COLLECTED FROM LAYER  2            0.00374
1928.69055

       PERCOLATION/LEAKAGE THROUGH LAYER  3        0.000001
0.37345

       AVERAGE HEAD ON TOP OF LAYER  3             3.830

       MAXIMUM HEAD ON TOP OF LAYER  3             7.089

       LOCATION OF MAXIMUM HEAD IN LAYER  2
             (DISTANCE FROM DRAIN)                85.9 FEET

       DRAINAGE COLLECTED FROM LAYER  4            0.00000
0.00185

       PERCOLATION/LEAKAGE THROUGH LAYER  6        0.000000
0.00351

       AVERAGE HEAD ON TOP OF LAYER  5             0.004

       MAXIMUM HEAD ON TOP OF LAYER  5             0.013

       LOCATION OF MAXIMUM HEAD IN LAYER  4
             (DISTANCE FROM DRAIN)                 0.0 FEET

       SNOW WATER                                  0.61
311956.6560


       MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.1200

       MINIMUM VEG. SOIL WATER (VOL/VOL)                   0.0180
```

```
        ***  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.


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```

```
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                    FINAL WATER STORAGE AT END OF YEAR    5
     ------------------------------------------------------------
----------
                     LAYER        (INCHES)       (VOL/VOL)
                     -----        --------       ---------
                       1            0.6865         0.0572

                       2            2.0164         0.0840

                       3            0.0000         0.0000

                       4            4.5610         0.1900

                       5            0.0000         0.0000

                       6           10.2480         0.4270

                   SNOW WATER       0.000

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```

APPENDIX C

ALTERNATE LINER HELP MODEL DEMONSTRATION

```
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 **
**
 **
**
 **             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**
 **               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)
**
 **                 DEVELOPED BY ENVIRONMENTAL LABORATORY
**
 **                   USAE WATERWAYS EXPERIMENT STATION
**
 **            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
**
 **
**
 **
**

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 PRECIPITATION DATA FILE:    Q:\DATA4.D4
 TEMPERATURE DATA FILE:      Q:\DATA7.D7
 SOLAR RADIATION DATA FILE:  Q:\DATA13.D13
 EVAPOTRANSPIRATION DATA:    Q:\DATA11.D11
 SOIL AND DESIGN DATA FILE:  Q:\DATA10.D10
 OUTPUT DATA FILE:           Q:\RCRA.OUT


 TIME:  11:23     DATE:  11/ 4/2015



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```

```
      TITLE:  LEACHATE GENERATION FOR PRESCRIPTIVE LINER

*****************************************************************
*************



      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   7
            THICKNESS                  =    24.00   INCHES
            POROSITY                   =     0.4730 VOL/VOL
            FIELD CAPACITY             =     0.2220 VOL/VOL
            WILTING POINT              =     0.1040 VOL/VOL
            INITIAL SOIL WATER CONTENT =     0.1604 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.520000001000E-03
CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED
BY  2.01
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE
ZONE.



                                    LAYER  2
                                    --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  20
            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 =     0.0100 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   10.0000000000
CM/SEC
            SLOPE                      =     2.00   PERCENT
            DRAINAGE LENGTH            =   1160.0    FEET
```

```
                                    LAYER  3
                                    --------

                        TYPE 4 - FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
            THICKNESS                   =      0.06   INCHES
            POROSITY                    =      0.0000 VOL/VOL
            FIELD CAPACITY              =      0.0000 VOL/VOL
            WILTING POINT               =      0.0000 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12
CM/SEC
            FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
            FML PLACEMENT QUALITY       =  1 - PERFECT


                                    LAYER  4
                                    --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  20
            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  =      0.0100 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =   10.0000000000
CM/SEC
            SLOPE                       =      2.00   PERCENT
            DRAINAGE LENGTH             =   1160.0    FEET


                                    LAYER  5
                                    --------

                        TYPE 4 - FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
            THICKNESS                   =      0.06   INCHES
            POROSITY                    =      0.0000 VOL/VOL
            FIELD CAPACITY              =      0.0000 VOL/VOL
            WILTING POINT               =      0.0000 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12
CM/SEC
            FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
```

```
            FML PLACEMENT QUALITY       =  1 - PERFECT



                                    LAYER  6
                                    --------

                          TYPE 3 - BARRIER SOIL LINER
                          MATERIAL TEXTURE NUMBER  17
            THICKNESS                   =      0.24   INCHES
            POROSITY                    =      0.7500 VOL/VOL
            FIELD CAPACITY              =      0.7470 VOL/VOL
            WILTING POINT               =      0.4000 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08
CM/SEC



                    GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                    ----------------------------------------

          NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

         SCS RUNOFF CURVE NUMBER             =     80.00
         FRACTION OF AREA ALLOWING RUNOFF    =      0.0
PERCENT
         AREA PROJECTED ON HORIZONTAL PLANE  =    142.000  ACRES
         EVAPORATIVE ZONE DEPTH              =     18.0    INCHES
         INITIAL WATER IN EVAPORATIVE ZONE   =      2.517  INCHES
         UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.514  INCHES
         LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.872  INCHES
         INITIAL SNOW WATER                  =      0.000  INCHES
         INITIAL WATER IN LAYER MATERIALS    =      4.033  INCHES
         TOTAL INITIAL WATER                 =      4.033  INCHES
         TOTAL SUBSURFACE INFLOW             =      0.00
INCHES/YEAR



                     EVAPOTRANSPIRATION AND WEATHER DATA
                     -----------------------------------

          NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                   Eunice                 New Mexico

              STATION LATITUDE                       =  32.42
DEGREES
```

```
              MAXIMUM LEAF AREA INDEX               =   1.20
              START OF GROWING SEASON (JULIAN DATE)  =     65
              END OF GROWING SEASON (JULIAN DATE)    =    321
              EVAPORATIVE ZONE DEPTH                 =  18.0
INCHES
              AVERAGE ANNUAL WIND SPEED              =  12.20 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  58.00 %
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  59.00 %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  57.00 %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  60.00 %


          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
        0.24        0.28        0.27        0.37        0.77
0.91
        1.38        2.17        1.72        0.99        0.33
0.27


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES
FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
       41.40       45.90       52.80       61.90       70.30
79.00
       81.40       79.20       72.30       61.70       49.10
42.50


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED
USING
```

```
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO
                     AND STATION LATITUDE  =  33.24 DEGREES





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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    1
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.00    0.19    0.02    0.56
0.02    0.00
                                  1.03    2.57    2.89    0.42
0.89    0.11

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.260   0.260   0.242   0.297
0.375   0.000
                                  0.725   2.873   2.892   0.085
0.433   0.332

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  2                  0.0000  0.0002  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0001  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0003  0.0000  0.0000
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0001  0.0000
0.0000  0.0000
   FROM LAYER  4                  0.0000  0.0003  0.0000  0.0000
0.0000  0.0000
```

```
 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


 ------------------------------------------------------------------
---------------
                   MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ------------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  3                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  3        0.000   0.000   0.000   0.000
0.000   0.000

 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  5                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    1
 ------------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                            8.70
4484502.500    100.00
```

```
   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       8.774
4522800.000    100.85

   DRAINAGE COLLECTED FROM LAYER  2         0.0002
89.524      0.00

   PERC./LEAKAGE THROUGH LAYER  3           0.000379
195.191      0.00

   AVG. HEAD ON TOP OF LAYER  3             0.0000

   DRAINAGE COLLECTED FROM LAYER  4         0.0004
195.076      0.00

   PERC./LEAKAGE THROUGH LAYER  6           0.000000
0.115      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0000

   CHANGE IN WATER STORAGE                 -0.075        -
38580.012     -0.86

   SOIL WATER AT START OF YEAR              4.035
2079778.000

   SOIL WATER AT END OF YEAR                3.960
2041198.000

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000           -
2.302      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    2
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.44    0.18    0.42    0.33
1.51    1.84
                                  1.33    1.69    1.42    0.00
0.34    0.85

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.278   0.276   0.325   0.411
1.977   2.019
                                  1.331   1.689   0.498   0.453
0.434   0.483

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0005  0.0000
   FROM LAYER  2                  0.0001  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0010  0.0000
   LAYER  3                       0.0003  0.0000  0.0000  0.0001
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0009  0.0000
   FROM LAYER  4                  0.0002  0.0001  0.0000  0.0001
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


 ----------------------------------------------------------------
---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------
```

```
 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  3                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  3        0.000   0.000   0.000   0.000
0.000   0.000

 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  5                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    2
 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                           10.35
5335011.500    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                      10.174
5244386.000     98.30

   DRAINAGE COLLECTED FROM LAYER  2         0.0006
317.828      0.01

   PERC./LEAKAGE THROUGH LAYER  3           0.001287
```

```
663.594      0.01

   AVG. HEAD ON TOP OF LAYER  3             0.0000

   DRAINAGE COLLECTED FROM LAYER  4         0.0013
663.392      0.01

   PERC./LEAKAGE THROUGH LAYER  6           0.000000
0.202      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0000

   CHANGE IN WATER STORAGE                  0.174
89642.734      1.68

   SOIL WATER AT START OF YEAR              3.960
2041198.000

   SOIL WATER AT END OF YEAR                4.134
2130840.750

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
1.740      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    3
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------
```

```
 PRECIPITATION                    0.31    0.14    0.64    0.13
0.70    0.36
                                  2.84    0.96    1.48    0.03
2.58    0.16

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.308   0.227   0.404   0.368
1.331   0.322
                                  2.903   0.960   1.246   0.264
0.873   0.476

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  2                  0.0001  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0001  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0002  0.0000  0.0000  0.0000
0.0000  0.0001

 LATERAL DRAINAGE COLLECTED       0.0000  0.0001  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  4                  0.0002  0.0000  0.0000  0.0000
0.0000  0.0001

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


 ----------------------------------------------------------------
---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  3                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  3        0.000   0.000   0.000   0.000
0.000   0.000
```

```
 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  5                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    3
 ----------------------------------------------------------------
---------------
                                             INCHES          CU.
FEET     PERCENT
                                            --------
----------    -------
   PRECIPITATION                              10.33
5324701.500    100.00

   RUNOFF                                      0.000
0.000      0.00

   EVAPOTRANSPIRATION                          9.682
4990909.000     93.73

   DRAINAGE COLLECTED FROM LAYER  2            0.0001
46.137      0.00

   PERC./LEAKAGE THROUGH LAYER  3              0.000343
176.920      0.00

   AVG. HEAD ON TOP OF LAYER  3                0.0000

   DRAINAGE COLLECTED FROM LAYER  4            0.0003
176.659      0.00

   PERC./LEAKAGE THROUGH LAYER  6              0.000000
0.177      0.00

   AVG. HEAD ON TOP OF LAYER  5                0.0000
```

```
   CHANGE IN WATER STORAGE                  0.647
333568.906      6.26

   SOIL WATER AT START OF YEAR              4.134
2130840.750

   SOIL WATER AT END OF YEAR                4.781
2464409.750

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
0.450      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    4
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------

------- -------

 PRECIPITATION                    0.00    0.11    0.06    0.30
0.11    0.03
                                  2.06    3.82    0.13    2.00

0.05    0.58

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000

0.000   0.000

 EVAPOTRANSPIRATION               0.696   0.662   0.169   0.103
```

```
0.316   0.050
                                  0.928   4.808   0.274   0.788
0.813   0.654

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0020  0.0000
0.0000  0.0000
   FROM LAYER  2                  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0019  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0019  0.0000
0.0000  0.0000
   FROM LAYER  4                  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


 ----------------------------------------------------------------
---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  3                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  3        0.000   0.000   0.000   0.000
0.000   0.000

 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  5                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5        0.000   0.000   0.000   0.000
0.000   0.000
```

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                           ANNUAL TOTALS FOR YEAR    4
 -----------------------------------------------------------------
---------------
                                          INCHES         CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                            9.25
4768006.500    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                      10.263
5290159.500    110.95

   DRAINAGE COLLECTED FROM LAYER  2         0.0020
1034.288      0.02

   PERC./LEAKAGE THROUGH LAYER  3           0.001894
976.410      0.02

   AVG. HEAD ON TOP OF LAYER  3             0.0000

   DRAINAGE COLLECTED FROM LAYER  4         0.0019
976.339      0.02

   PERC./LEAKAGE THROUGH LAYER  6           0.000000
0.154      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0000

   CHANGE IN WATER STORAGE                 -1.017       -
524166.375    -10.99

   SOIL WATER AT START OF YEAR              4.781
2464409.750

   SOIL WATER AT END OF YEAR                3.764
1940243.250

   SNOW WATER AT START OF YEAR              0.000
```

```
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
2.735      0.00


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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    5
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.14    0.22    0.33    0.00
1.58    0.94
                                  1.04    0.52    2.30    1.52
0.33    0.76

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.355   0.270   0.278   0.161
0.494   1.735
                                  0.851   0.896   1.989   1.449
0.467   0.429

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0017
   FROM LAYER  2                  0.0000  0.0000  0.0000  0.0001
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0017
```

```
   LAYER  3                      0.0000  0.0000  0.0000  0.0002
0.0000  0.0000

 LATERAL DRAINAGE COLLECTED      0.0000  0.0000  0.0000  0.0000
0.0000  0.0017
   FROM LAYER  4                 0.0000  0.0000  0.0000  0.0002
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH     0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  6                      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


 -----------------------------------------------------------------
---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 -----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON           0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  3               0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY         0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  3       0.000   0.000   0.000   0.000
0.000   0.000

 AVERAGE DAILY HEAD ON           0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  5               0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY         0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  5       0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    5
```

```
 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                            9.68
4989653.000    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       9.374
4832135.500     96.84

   DRAINAGE COLLECTED FROM LAYER  2         0.0018
929.118      0.02

   PERC./LEAKAGE THROUGH LAYER  3           0.001863
960.420      0.02

   AVG. HEAD ON TOP OF LAYER  3             0.0000

   DRAINAGE COLLECTED FROM LAYER  4         0.0019
960.231      0.02

   PERC./LEAKAGE THROUGH LAYER  6           0.000000
0.190      0.00

   AVG. HEAD ON TOP OF LAYER  5             0.0000

   CHANGE IN WATER STORAGE                  0.302
155628.641      3.12

   SOIL WATER AT START OF YEAR              3.764
1940243.250

   SOIL WATER AT END OF YEAR                4.066
2095871.870

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000           -
0.884      0.00

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          AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH
5
 ----------------------------------------------------------------
---------------

                          JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT
MAY/NOV  JUN/DEC
                          -------  -------  -------  -------
-------  -------
   PRECIPITATION
   -------------
     TOTALS                 0.18     0.17     0.29     0.26
0.78     0.63
                            1.66     1.91     1.64     0.79
0.84     0.49

     STD. DEVIATIONS        0.19     0.04     0.26     0.21
0.74     0.77
                            0.78     1.32     1.04     0.91
1.02     0.34

   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

   EVAPOTRANSPIRATION
   ------------------
     TOTALS                 0.379    0.339    0.284    0.268
0.899    0.825
                            1.348    2.245    1.380    0.608
0.604    0.475

     STD. DEVIATIONS        0.181    0.182    0.088    0.132
0.729    0.973
```

```
                            0.899    1.639    1.081    0.537
0.220    0.117

   LATERAL DRAINAGE COLLECTED FROM LAYER  2
   ----------------------------------------
     TOTALS                 0.0000   0.0000   0.0004   0.0000
0.0001   0.0003
                            0.0000   0.0000   0.0000   0.0000
0.0000   0.0000

     STD. DEVIATIONS        0.0000   0.0000   0.0009   0.0000
0.0002   0.0008
                            0.0000   0.0001   0.0000   0.0000
0.0000   0.0000

   PERCOLATION/LEAKAGE THROUGH LAYER  3
   ------------------------------------
     TOTALS                 0.0000   0.0000   0.0004   0.0000
0.0002   0.0003
                            0.0001   0.0001   0.0000   0.0000
0.0000   0.0000

     STD. DEVIATIONS        0.0000   0.0000   0.0008   0.0000
0.0004   0.0007
                            0.0001   0.0001   0.0000   0.0001
0.0000   0.0000

   LATERAL DRAINAGE COLLECTED FROM LAYER  4
   ----------------------------------------
     TOTALS                 0.0000   0.0000   0.0004   0.0000
0.0002   0.0003
                            0.0001   0.0001   0.0000   0.0000
0.0000   0.0000

     STD. DEVIATIONS        0.0000   0.0000   0.0008   0.0000
0.0004   0.0007
                            0.0001   0.0001   0.0000   0.0001
0.0000   0.0000

   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  3
   -------------------------------------
     AVERAGES               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

   DAILY AVERAGE HEAD ON TOP OF LAYER  5
   -------------------------------------
     AVERAGES               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


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      AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1
THROUGH    5
 ----------------------------------------------------------------
---------------
                                      INCHES           CU. FEET
PERCENT
                                ------------------
-------------   ---------
  PRECIPITATION                  9.66    (   0.710)    4980375.0
100.00
```

```
  RUNOFF                          0.000   (  0.0000)
0.00      0.000

  EVAPOTRANSPIRATION              9.654   (  0.6112)
4976077.50     99.914

  LATERAL DRAINAGE COLLECTED      0.00094 (  0.00091)
483.379    0.00971
    FROM LAYER  2

  PERCOLATION/LEAKAGE THROUGH     0.00115 (  0.00076)
594.507     0.01194
    LAYER  3

  AVERAGE HEAD ON TOP             0.000 (    0.000)
    OF LAYER  3

  LATERAL DRAINAGE COLLECTED      0.00115 (  0.00076)
594.339    0.01193
    FROM LAYER  4

  PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)
0.168     0.00000
    LAYER  6

  AVERAGE HEAD ON TOP             0.000 (    0.000)
    OF LAYER  5

  CHANGE IN WATER STORAGE         0.006   (  0.6284)
3218.77      0.065


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```

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                 PEAK DAILY VALUES FOR YEARS    1 THROUGH    5
    -------------------------------------------------------------
-----------
                                                 (INCHES)
(CU. FT.)
                                                ----------
-------------
       PRECIPITATION                              1.17
603088.187

       RUNOFF                                     0.000
0.0000

       DRAINAGE COLLECTED FROM LAYER  2           0.00113
579.91150

       PERCOLATION/LEAKAGE THROUGH LAYER  3       0.001099
566.47491

       AVERAGE HEAD ON TOP OF LAYER  3            0.001

       MAXIMUM HEAD ON TOP OF LAYER  3            0.032

       LOCATION OF MAXIMUM HEAD IN LAYER  2
             (DISTANCE FROM DRAIN)                0.0 FEET

       DRAINAGE COLLECTED FROM LAYER  4           0.00075
388.73694

       PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000000
0.00351

       AVERAGE HEAD ON TOP OF LAYER  5            0.001

       MAXIMUM HEAD ON TOP OF LAYER  5            0.002

       LOCATION OF MAXIMUM HEAD IN LAYER  4
             (DISTANCE FROM DRAIN)                0.0 FEET

       SNOW WATER                                 0.61
314229.4060


       MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.2071

       MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.1040
```

```
        ***  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.


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                    FINAL WATER STORAGE AT END OF YEAR    5
     ------------------------------------------------------------
----------
                     LAYER        (INCHES)       (VOL/VOL)
                     -----        --------       ---------
                       1           3.8800          0.1617

                       2           0.0020          0.0100

                       3           0.0000          0.0000

                       4           0.0020          0.0100

                       5           0.0000          0.0000

                       6           0.1800          0.7500

                   SNOW WATER      0.000

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APPENDIX D

ALTERNATE GEOCOMPOSITE FINAL COVER HELP MODEL DEMONSTRATION

```
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 **
**
 **
**
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**
 **                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)
**
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY
**
 **                    USAE WATERWAYS EXPERIMENT STATION
**
 **             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
**
 **
**
 **
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 PRECIPITATION DATA FILE:    Q:\DATA4.D4
 TEMPERATURE DATA FILE:      Q:\DATA7.D7
 SOLAR RADIATION DATA FILE:  Q:\DATA13.D13
 EVAPOTRANSPIRATION DATA:    Q:\DATA11.D11
 SOIL AND DESIGN DATA FILE:  Q:\DATA10.D10
 OUTPUT DATA FILE:           Q:\RCRA.OUT


 TIME:   8:13     DATE:   5/11/2016




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```
      TITLE:  C.K. Disposal Prescriptive Final Cover with
Geocompsite


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      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   7
            THICKNESS                    =    12.00   INCHES
            POROSITY                     =     0.4730 VOL/VOL
            FIELD CAPACITY               =     0.2220 VOL/VOL
            WILTING POINT                =     0.1040 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.1577 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.520000001000E-03
CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED
BY  2.01
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE
ZONE.



                                    LAYER  2
                                    --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
            THICKNESS                    =    24.00   INCHES
            POROSITY                     =     0.4730 VOL/VOL
            FIELD CAPACITY               =     0.2220 VOL/VOL
            WILTING POINT                =     0.1040 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.1925 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.520000001000E-03
CM/SEC
```

```
                                    LAYER  3
                                    --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  20
            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  =      0.0100 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =   10.0000000000
CM/SEC
            SLOPE                       =      3.00   PERCENT
            DRAINAGE LENGTH             =   1345.0    FEET



                                    LAYER  4
                                    --------

                        TYPE 4 - FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
            THICKNESS                   =      0.06   INCHES
            POROSITY                    =      0.0000 VOL/VOL
            FIELD CAPACITY              =      0.0000 VOL/VOL
            WILTING POINT               =      0.0000 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12
CM/SEC
            FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
            FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
            FML PLACEMENT QUALITY       =  1 - PERFECT



                                    LAYER  5
                                    --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
            THICKNESS                   =     12.00   INCHES
            POROSITY                    =      0.4730 VOL/VOL
            FIELD CAPACITY              =      0.2220 VOL/VOL
            WILTING POINT               =      0.1040 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.2093 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.520000001000E-03
CM/SEC
```

```
                    GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                    ----------------------------------------

          NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

         SCS RUNOFF CURVE NUMBER            =    80.00
         FRACTION OF AREA ALLOWING RUNOFF   =   100.0
PERCENT
         AREA PROJECTED ON HORIZONTAL PLANE  =    80.000  ACRES
         EVAPORATIVE ZONE DEPTH             =    18.0    INCHES
         INITIAL WATER IN EVAPORATIVE ZONE  =     2.517  INCHES
         UPPER LIMIT OF EVAPORATIVE STORAGE =     8.514  INCHES
         LOWER LIMIT OF EVAPORATIVE STORAGE =     1.872  INCHES
         INITIAL SNOW WATER                 =     0.000  INCHES
         INITIAL WATER IN LAYER MATERIALS   =     9.026  INCHES
         TOTAL INITIAL WATER                =     9.026  INCHES
         TOTAL SUBSURFACE INFLOW            =     0.00
INCHES/YEAR



                     EVAPOTRANSPIRATION AND WEATHER DATA
                     -----------------------------------

          NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                   Eunice                 New Mexico

              STATION LATITUDE                        =  32.42
DEGREES
              MAXIMUM LEAF AREA INDEX                 =   1.20
              START OF GROWING SEASON (JULIAN DATE)   =     65
              END OF GROWING SEASON (JULIAN DATE)     =    321
              EVAPORATIVE ZONE DEPTH                  =  18.0
INCHES
              AVERAGE ANNUAL WIND SPEED               =  12.20 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  58.00 %
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  59.00 %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  57.00 %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  60.00 %



          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```

```
      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
        0.24        0.28        0.27        0.37        0.77
0.91
        1.38        2.17        1.72        0.99        0.33
0.27


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES
FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
       41.40       45.90       52.80       61.90       70.30
79.00
       81.40       79.20       72.30       61.70       49.10
42.50


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO
                     AND STATION LATITUDE  =  33.24 DEGREES




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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    1
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC

                                 ------- ------- ------- -------
```

```
------- -------

 PRECIPITATION                    0.00    0.19    0.02    0.56
0.02    0.00
                                  1.03    2.57    2.89    0.42
0.89    0.11

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.260   0.260   0.242   0.297
0.375   0.000
                                  0.725   2.873   2.892   0.085
0.433   0.332

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0001  0.0000
0.0000  0.0000
   FROM LAYER  3                  0.0000  0.0005  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  4                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0023  0.0193  0.0000
0.0000  0.0000
   LAYER  5                       0.0176  0.0126  0.0085  0.0000
0.0000  0.0000


 ----------------------------------------------------------------
---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  4                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  4        0.000   0.000   0.000   0.000
0.000   0.000


*****************************************************************
```

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                           ANNUAL TOTALS FOR YEAR    1
 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                            8.70
2526480.250    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       8.774
2548056.250    100.85

   DRAINAGE COLLECTED FROM LAYER  3         0.0006
160.353      0.01

   PERC./LEAKAGE THROUGH LAYER  4           0.000000
0.050      0.00

   AVG. HEAD ON TOP OF LAYER  4             0.0000

   PERC./LEAKAGE THROUGH LAYER  5           0.060328
17519.127      0.69

   CHANGE IN WATER STORAGE                 -0.135        -
39254.195     -1.55

   SOIL WATER AT START OF YEAR             11.690
3394799.250

   SOIL WATER AT END OF YEAR               11.555
3355545.000

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000           -
1.399      0.00
```

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    2
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.44    0.18    0.42    0.33
1.51    1.84
                                  1.33    1.69    1.42    0.00
0.34    0.85

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.278   0.276   0.325   0.411
1.977   2.019
                                  1.331   1.689   0.498   0.453
0.434   0.483

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0014  0.0000
   FROM LAYER  3                  0.0004  0.0000  0.0000  0.0001
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  4                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0050  0.0126  0.0030  0.0044
0.0155  0.0079
   LAYER  5                       0.0051  0.0098  0.0000  0.0070
0.0057  0.0000
```

```
 -----------------------------------------------------------------
---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 -----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  4                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  4        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    2
 -----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                          10.35
3005640.500    100.00

   RUNOFF                                  0.000
0.000      0.00

   EVAPOTRANSPIRATION                     10.174
2954583.500     98.30

   DRAINAGE COLLECTED FROM LAYER  3        0.0019
552.829      0.02

   PERC./LEAKAGE THROUGH LAYER  4          0.000000
0.084      0.00

   AVG. HEAD ON TOP OF LAYER  4            0.0000
```

```
   PERC./LEAKAGE THROUGH LAYER  5           0.076052
22085.373      0.73

   CHANGE IN WATER STORAGE                  0.098
28417.533      0.95

   SOIL WATER AT START OF YEAR             11.555
3355545.000

   SOIL WATER AT END OF YEAR               11.653
3383962.500

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
1.108      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    3
 ----------------------------------------------------------------
---------------

                                  JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                  ------- ------- ------- -------
------- -------

 PRECIPITATION                     0.31    0.14    0.64    0.13
0.70    0.36
                                   2.84    0.96    1.48    0.03
2.58    0.16

 RUNOFF                            0.000   0.000   0.000   0.000
0.000   0.000
                                   0.000   0.000   0.000   0.000
```

```
0.000   0.000

 EVAPOTRANSPIRATION              0.308   0.227   0.404   0.368
1.331   0.322
                                 2.903   0.960   1.246   0.264
0.873   0.476

 LATERAL DRAINAGE COLLECTED      0.0000  0.0001  0.0000  0.0000
0.0000  0.0000
   FROM LAYER  3                 0.0002  0.0000  0.0000  0.0000
0.0000  0.0001

 PERCOLATION/LEAKAGE THROUGH     0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  4                      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH     0.0011  0.0065  0.0084  0.0010
0.0000  0.0050
   LAYER  5                      0.0106  0.0028  0.0063  0.0018
0.0017  0.0043


 ----------------------------------------------------------------
---------------
                   MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON           0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  4               0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY         0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  4       0.000   0.000   0.000   0.000
0.000   0.000


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                          ANNUAL TOTALS FOR YEAR    3
 ----------------------------------------------------------------
```

```
---------------
                                          INCHES         CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                           10.33
2999831.750    100.00

   RUNOFF                                   0.000
0.000      0.00

   EVAPOTRANSPIRATION                       9.682
2811779.750     93.73

   DRAINAGE COLLECTED FROM LAYER  3         0.0004
125.590      0.00

   PERC./LEAKAGE THROUGH LAYER  4           0.000000
0.074      0.00

   AVG. HEAD ON TOP OF LAYER  4             0.0000

   PERC./LEAKAGE THROUGH LAYER  5           0.049517
14379.692      0.48

   CHANGE IN WATER STORAGE                  0.598
173546.641      5.79

   SOIL WATER AT START OF YEAR             11.653
3383962.500

   SOIL WATER AT END OF YEAR               12.250
3557509.000

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
0.095      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    4
 ------------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.00    0.11    0.06    0.30
0.11    0.03
                                  2.06    3.82    0.13    2.00
0.05    0.58

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.696   0.662   0.169   0.103
0.316   0.050
                                  0.928   4.808   0.274   0.788
0.813   0.654

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0038  0.0000
0.0000  0.0000
   FROM LAYER  3                  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  4                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0058  0.0049  0.0071  0.0097
0.0000  0.0029
   LAYER  5                       0.0007  0.0007  0.0014  0.0000
0.0000  0.0000


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--------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ------------------------------------------------------------------
--------------


 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
```

```
0.000   0.000
   TOP OF LAYER  4                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  4        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    4
 -----------------------------------------------------------------
---------------
                                               INCHES          CU.
FEET     PERCENT
                                              --------
----------    -------
   PRECIPITATION                                 9.25
2686200.750    100.00

   RUNOFF                                        0.000
0.000      0.00

   EVAPOTRANSPIRATION                           10.263
2980371.500    110.95

   DRAINAGE COLLECTED FROM LAYER  3              0.0039
1132.726      0.04

   PERC./LEAKAGE THROUGH LAYER  4                0.000000
0.064      0.00

   AVG. HEAD ON TOP OF LAYER  4                  0.0000

   PERC./LEAKAGE THROUGH LAYER  5                0.033227
9649.194      0.36

   CHANGE IN WATER STORAGE                      -1.050       -
304954.406    -11.35

   SOIL WATER AT START OF YEAR                  12.250
3557509.000
```

```
   SOIL WATER AT END OF YEAR               11.200
3252554.750

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
1.842      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    5
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.14    0.22    0.33    0.00
1.58    0.94
                                  1.04    0.52    2.30    1.52
0.33    0.76

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.000   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.355   0.270   0.278   0.161
0.494   1.735
                                  0.851   0.896   1.989   1.449
0.467   0.429

 LATERAL DRAINAGE COLLECTED       0.0000  0.0000  0.0000  0.0000
0.0000  0.0034
   FROM LAYER  3                  0.0000  0.0000  0.0000  0.0002
```

```
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  4                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

 PERCOLATION/LEAKAGE THROUGH      0.0014  0.0089  0.0033  0.0032
0.0000  0.0050
   LAYER  5                       0.0031  0.0006  0.0006  0.0077
0.0023  0.0000


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---------------
                    MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


 AVERAGE DAILY HEAD ON            0.000   0.000   0.000   0.000
0.000   0.000
   TOP OF LAYER  4                0.000   0.000   0.000   0.000
0.000   0.000

 STD. DEVIATION OF DAILY          0.000   0.000   0.000   0.000
0.000   0.000
   HEAD ON TOP OF LAYER  4        0.000   0.000   0.000   0.000
0.000   0.000


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                           ANNUAL TOTALS FOR YEAR    5
 ----------------------------------------------------------------
---------------
                                          INCHES         CU.
FEET     PERCENT
                                         --------

----------    -------
   PRECIPITATION                            9.68
2811072.000    100.00

   RUNOFF                                   0.000
0.000      0.00
```

```
   EVAPOTRANSPIRATION                      9.374
2722330.000     96.84

   DRAINAGE COLLECTED FROM LAYER  3        0.0037
1064.447      0.04

   PERC./LEAKAGE THROUGH LAYER  4          0.000000
0.082      0.00

   AVG. HEAD ON TOP OF LAYER  4            0.0000

   PERC./LEAKAGE THROUGH LAYER  5          0.036156
10499.788      0.37

   CHANGE IN WATER STORAGE                 0.266
77178.484      2.75

   SOIL WATER AT START OF YEAR            11.200
3252554.750

   SOIL WATER AT END OF YEAR              11.466
3329733.250

   SNOW WATER AT START OF YEAR             0.000
0.000      0.00

   SNOW WATER AT END OF YEAR               0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE             0.0000           -
0.590      0.00

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          AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH
5
 ----------------------------------------------------------------
---------------

                          JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT
```

```
MAY/NOV  JUN/DEC
                          -------  -------  -------  -------
-------  -------
   PRECIPITATION
   -------------
     TOTALS                 0.18     0.17     0.29     0.26
0.78     0.63
                            1.66     1.91     1.64     0.79
0.84     0.49

     STD. DEVIATIONS        0.19     0.04     0.26     0.21
0.74     0.77
                            0.78     1.32     1.04     0.91
1.02     0.34

   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

   EVAPOTRANSPIRATION
   ------------------
     TOTALS                 0.379    0.339    0.284    0.268
0.899    0.825
                            1.348    2.245    1.380    0.608
0.604    0.475

     STD. DEVIATIONS        0.181    0.182    0.088    0.132
0.729    0.973
                            0.899    1.639    1.081    0.537
0.220    0.117

   LATERAL DRAINAGE COLLECTED FROM LAYER  3
   ----------------------------------------
     TOTALS                 0.0000   0.0000   0.0008   0.0000
0.0003   0.0007
                            0.0001   0.0001   0.0000   0.0001
0.0000   0.0000

     STD. DEVIATIONS        0.0000   0.0000   0.0017   0.0000
0.0006   0.0015
                            0.0002   0.0002   0.0000   0.0001
0.0000   0.0000

   PERCOLATION/LEAKAGE THROUGH LAYER  4
```

```
   ------------------------------------
     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

   PERCOLATION/LEAKAGE THROUGH LAYER  5
   ------------------------------------
     TOTALS                 0.0027   0.0070   0.0082   0.0037
0.0031   0.0042
                            0.0074   0.0053   0.0034   0.0033
0.0019   0.0009

     STD. DEVIATIONS        0.0026   0.0039   0.0066   0.0038
0.0069   0.0029
                            0.0067   0.0056   0.0038   0.0038
0.0023   0.0019


 ----------------------------------------------------------------
---------------
                AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
 ----------------------------------------------------------------
---------------


   DAILY AVERAGE HEAD ON TOP OF LAYER  4
   -------------------------------------
     AVERAGES               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


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```
      AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1
THROUGH    5
 ----------------------------------------------------------------
---------------
                                     INCHES           CU. FEET
PERCENT
                               -------------------

-------------   ---------
  PRECIPITATION                  9.66    (   0.710)    2805845.0
100.00

  RUNOFF                         0.000   (  0.0000)
0.00      0.000

  EVAPOTRANSPIRATION             9.654   (  0.6112)
2803424.00     99.914

  LATERAL DRAINAGE COLLECTED     0.00209 (  0.00165)
607.189    0.02164
    FROM LAYER  3

  PERCOLATION/LEAKAGE THROUGH    0.00000 (  0.00000)
0.071     0.00000
    LAYER  4

  AVERAGE HEAD ON TOP            0.000 (    0.000)
    OF LAYER  4

  PERCOLATION/LEAKAGE THROUGH    0.05106 (  0.01770)
14826.636     0.52842
    LAYER  5

  CHANGE IN WATER STORAGE       -0.045   (  0.6222)     -
13013.19     -0.464


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                 PEAK DAILY VALUES FOR YEARS    1 THROUGH    5
    -------------------------------------------------------------
-----------
                                                 (INCHES)
(CU. FT.)
                                                ----------
-------------
       PRECIPITATION                              1.17
339768.000

       RUNOFF                                     0.000
0.0000

       DRAINAGE COLLECTED FROM LAYER  3           0.00223
648.03772

       PERCOLATION/LEAKAGE THROUGH LAYER  4       0.000000
0.00198

       AVERAGE HEAD ON TOP OF LAYER  4            0.002

       MAXIMUM HEAD ON TOP OF LAYER  4            0.036

       LOCATION OF MAXIMUM HEAD IN LAYER  3
             (DISTANCE FROM DRAIN)                0.0 FEET

       PERCOLATION/LEAKAGE THROUGH LAYER  5       0.002267
658.27747

       SNOW WATER                                 0.61
177030.6410


       MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.2071

       MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.1040


        ***  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.

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                   FINAL WATER STORAGE AT END OF YEAR    5
     ------------------------------------------------------------
----------
                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1           1.9241          0.1603

                      2           4.6200          0.1925

                      3           0.0020          0.0100

                      4           0.0000          0.0000

                      5           2.2560          0.1880

                  SNOW WATER      0.000

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APPENDIX E

ALTERNATE SOIL FINAL COVER HELP MODEL DEMONSTRATION

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 **
**
 **
**
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**
 **                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)
**
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY
**
 **                    USAE WATERWAYS EXPERIMENT STATION
**
 **             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
**
 **
**
 **
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 PRECIPITATION DATA FILE:    Q:\DATA4.D4
 TEMPERATURE DATA FILE:      Q:\DATA7.D7
 SOLAR RADIATION DATA FILE:  Q:\DATA13.D13
 EVAPOTRANSPIRATION DATA:    Q:\DATA11.D11
 SOIL AND DESIGN DATA FILE:  Q:\DATA10.D10
 OUTPUT DATA FILE:           Q:\RCRA.OUT


 TIME:   8:37     DATE:   5/11/2016



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```
      TITLE:  C.K. Disposal Alternate Final Cover

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      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW
WATER
               WERE SPECIFIED BY THE USER.



                                    LAYER  1
                                    --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
            THICKNESS                  =    12.00   INCHES
            POROSITY                   =     0.4730 VOL/VOL
            FIELD CAPACITY             =     0.2220 VOL/VOL
            WILTING POINT              =     0.1040 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.1040 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.520000001000E-03
CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED
BY  2.01
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE
ZONE.



                                    LAYER  2
                                    --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
            THICKNESS                  =    24.00   INCHES
            POROSITY                   =     0.4730 VOL/VOL
            FIELD CAPACITY             =     0.2220 VOL/VOL
            WILTING POINT              =     0.1040 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.1040 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.520000001000E-03
CM/SEC



                                    LAYER  3
                                    --------
```

```
                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
            THICKNESS                   =     12.00   INCHES
            POROSITY                    =      0.4730 VOL/VOL
            FIELD CAPACITY              =      0.2220 VOL/VOL
            WILTING POINT               =      0.1040 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.1040 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.520000001000E-03
CM/SEC




                    GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                    ----------------------------------------

          NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

         SCS RUNOFF CURVE NUMBER            =     92.00
         FRACTION OF AREA ALLOWING RUNOFF   =    100.0
PERCENT
         AREA PROJECTED ON HORIZONTAL PLANE  =     62.000  ACRES
         EVAPORATIVE ZONE DEPTH             =     18.0    INCHES
         INITIAL WATER IN EVAPORATIVE ZONE   =      1.872  INCHES
         UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.514  INCHES
         LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.872  INCHES
         INITIAL SNOW WATER                 =      0.104  INCHES
         INITIAL WATER IN LAYER MATERIALS   =      4.992  INCHES
         TOTAL INITIAL WATER                =      5.096  INCHES
         TOTAL SUBSURFACE INFLOW            =      0.00
INCHES/YEAR




                     EVAPOTRANSPIRATION AND WEATHER DATA
                     -----------------------------------

          NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                   Eunice                 New Mexico

              STATION LATITUDE                       =  32.42
DEGREES
              MAXIMUM LEAF AREA INDEX                =   1.20
              START OF GROWING SEASON (JULIAN DATE)  =     65
              END OF GROWING SEASON (JULIAN DATE)    =    321
              EVAPORATIVE ZONE DEPTH                 =  18.0
INCHES
              AVERAGE ANNUAL WIND SPEED              =  12.20 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  58.00 %
```

```
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  59.00 %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  57.00 %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  60.00 %


          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
        0.24        0.28        0.27        0.37        0.77
0.91
        1.38        2.17        1.72        0.99        0.33
0.27


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES
FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV
JUN/DEC
      -------     -------     -------     -------     -------
-------
       41.40       45.90       52.80       61.90       70.30
79.00
       81.40       79.20       72.30       61.70       49.10
42.50


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED
USING
                   COEFFICIENTS FOR    ROSWELL             NEW
MEXICO
                     AND STATION LATITUDE  =  33.24 DEGREES
```

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    1
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.00    0.19    0.02    0.56
0.02    0.00
                                  1.03    2.57    2.89    0.42
0.89    0.11

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.000   0.078   0.153   0.000
0.006   0.000

 EVAPOTRANSPIRATION               0.104   0.172   0.038   0.150
0.316   0.114
                                  0.723   2.795   2.730   0.086
0.433   0.332

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

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                           ANNUAL TOTALS FOR YEAR    1
 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
```

```
   PRECIPITATION                              8.70
1958022.120    100.00

   RUNOFF                                     0.237
53371.152      2.73

   EVAPOTRANSPIRATION                         7.992
1798707.000     91.86

   PERC./LEAKAGE THROUGH LAYER  3             0.000000
0.097      0.00

   CHANGE IN WATER STORAGE                    0.471
105943.867      5.41

   SOIL WATER AT START OF YEAR                4.992
1123494.870

   SOIL WATER AT END OF YEAR                  5.567
1252845.000

   SNOW WATER AT START OF YEAR                0.104
23406.240      1.20

   SNOW WATER AT END OF YEAR                  0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE                0.0000
0.038      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    2
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------
```

```
 PRECIPITATION                    0.44    0.18    0.42    0.33
1.51    1.84
                                  1.33    1.69    1.42    0.00
0.34    0.85

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.080
                                  0.018   0.134   0.000   0.000
0.000   0.000

 EVAPOTRANSPIRATION               0.277   0.277   0.327   0.401
1.977   1.938
                                  1.311   1.560   0.500   0.450
0.436   0.483

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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                           ANNUAL TOTALS FOR YEAR    2
 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                           10.35
2329371.250    100.00

   RUNOFF                                   0.232
52166.973      2.24

   EVAPOTRANSPIRATION                       9.938
2236746.250     96.02

   PERC./LEAKAGE THROUGH LAYER  3           0.000000
0.008      0.00

   CHANGE IN WATER STORAGE                  0.180
40456.672      1.74
```

```
   SOIL WATER AT START OF YEAR              5.567
1252845.000

   SOIL WATER AT END OF YEAR                5.746
1293301.750

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
1.407      0.00

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    3
 ----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.31    0.14    0.64    0.13
0.70    0.36
                                  2.84    0.96    1.48    0.03
2.58    0.16

 RUNOFF                           0.000   0.000   0.000   0.000
0.001   0.000
                                  0.081   0.000   0.003   0.000
0.010   0.000

 EVAPOTRANSPIRATION               0.311   0.228   0.407   0.368
1.319   0.314
                                  2.831   0.960   1.240   0.266
0.871   0.473
```

```
 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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                           ANNUAL TOTALS FOR YEAR    3
 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------

----------    -------
   PRECIPITATION                           10.33
2324869.500    100.00

   RUNOFF                                   0.095
21365.184      0.92

   EVAPOTRANSPIRATION                       9.587
2157655.000     92.81

   PERC./LEAKAGE THROUGH LAYER  3           0.000000
0.011      0.00

   CHANGE IN WATER STORAGE                  0.648
145849.016      6.27

   SOIL WATER AT START OF YEAR              5.746
1293301.750

   SOIL WATER AT END OF YEAR                6.395
1439150.750

   SNOW WATER AT START OF YEAR              0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000
0.433      0.00
```

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                   MONTHLY TOTALS (IN INCHES) FOR YEAR    4
 -----------------------------------------------------------------
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.00    0.11    0.06    0.30
0.11    0.03
                                  2.06    3.82    0.13    2.00
0.05    0.58

 RUNOFF                           0.000   0.000   0.000   0.000
0.000   0.000
                                  0.105   0.103   0.000   0.219
0.000   0.000

 EVAPOTRANSPIRATION               0.657   0.691   0.126   0.104
0.313   0.051
                                  0.898   4.616   0.285   0.720
0.728   0.644

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000


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                              ANNUAL TOTALS FOR YEAR    4
 ----------------------------------------------------------------
---------------
                                              INCHES          CU.
FEET     PERCENT
                                             --------
----------    -------
   PRECIPITATION                                9.25
2081805.620    100.00

   RUNOFF                                       0.428
96321.555      4.63

   EVAPOTRANSPIRATION                           9.832
2212849.500    106.29

   PERC./LEAKAGE THROUGH LAYER  3               0.000000
0.017      0.00

   CHANGE IN WATER STORAGE                     -1.010       -
227365.391    -10.92

   SOIL WATER AT START OF YEAR                  6.395
1439150.750

   SOIL WATER AT END OF YEAR                    5.384
1211785.370

   SNOW WATER AT START OF YEAR                  0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                    0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE                  0.0000           -
0.084      0.00


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                      MONTHLY TOTALS (IN INCHES) FOR YEAR    5
 ----------------------------------------------------------------
```

```
---------------

                                 JAN/JUL FEB/AUG MAR/SEP APR/OCT
MAY/NOV JUN/DEC
                                 ------- ------- ------- -------
------- -------

 PRECIPITATION                    0.14    0.22    0.33    0.00
1.58    0.94
                                  1.04    0.52    2.30    1.52
0.33    0.76

 RUNOFF                           0.000   0.000   0.000   0.000
0.062   0.008
                                  0.031   0.000   0.002   0.004
0.000   0.000

 EVAPOTRANSPIRATION               0.299   0.277   0.294   0.128
0.480   1.514
                                  1.327   0.572   1.912   1.436
0.586   0.471

 PERCOLATION/LEAKAGE THROUGH      0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
   LAYER  3                       0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

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                           ANNUAL TOTALS FOR YEAR    5
 ----------------------------------------------------------------
---------------
                                          INCHES          CU.
FEET     PERCENT
                                         --------
----------    -------
   PRECIPITATION                            9.68
2178580.750    100.00

   RUNOFF                                   0.107
24006.961      1.10

   EVAPOTRANSPIRATION                       9.297
2092354.250     96.04
```

```
   PERC./LEAKAGE THROUGH LAYER  3            0.000000
0.017      0.00

   CHANGE IN WATER STORAGE                   0.276
62219.055      2.86

   SOIL WATER AT START OF YEAR               5.384
1211785.370

   SOIL WATER AT END OF YEAR                 5.661
1274004.370

   SNOW WATER AT START OF YEAR               0.000
0.000      0.00

   SNOW WATER AT END OF YEAR                 0.000
0.000      0.00

   ANNUAL WATER BUDGET BALANCE               0.0000
0.580      0.00

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          AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH
5
 ----------------------------------------------------------------
---------------

                          JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT
MAY/NOV  JUN/DEC
                          -------  -------  -------  -------
-------  -------
   PRECIPITATION
   -------------
     TOTALS                 0.18     0.17     0.29     0.26
0.78     0.63
                            1.66     1.91     1.64     0.79
0.84     0.49

     STD. DEVIATIONS        0.19     0.04     0.26     0.21
```

```
0.74     0.77
                            0.78     1.32     1.04     0.91
1.02     0.34

   RUNOFF
   ------
     TOTALS                 0.000    0.000    0.000    0.000
0.013    0.018
                            0.047    0.063    0.032    0.045
0.003    0.000

     STD. DEVIATIONS        0.000    0.000    0.000    0.000
0.027    0.035
                            0.044    0.061    0.068    0.098
0.004    0.000

   EVAPOTRANSPIRATION
   ------------------
     TOTALS                 0.330    0.329    0.238    0.230
0.881    0.786
                            1.418    2.101    1.333    0.592
0.611    0.481

     STD. DEVIATIONS        0.201    0.207    0.152    0.142
0.741    0.877
                            0.832    1.639    1.011    0.527
0.190    0.111

   PERCOLATION/LEAKAGE THROUGH LAYER  3
   ------------------------------------
     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


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      AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1
THROUGH    5
```

```
 ----------------------------------------------------------------
---------------
                                      INCHES           CU. FEET
PERCENT
                                --------------------
-------------   ---------
  PRECIPITATION                   9.66    (   0.710)    2174529.7
100.00

  RUNOFF                          0.220   (  0.1343)
49446.36      2.274

  EVAPOTRANSPIRATION              9.329   (  0.7873)
2099662.50     96.557

  PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)
0.030     0.00000
    LAYER  3

  CHANGE IN WATER STORAGE         0.113   (  0.6533)
25420.65      1.169

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                 PEAK DAILY VALUES FOR YEARS    1 THROUGH    5
    -------------------------------------------------------------
-----------
                                                  (INCHES)
(CU. FT.)
                                                 ----------
-------------
       PRECIPITATION                               1.17
263320.187

       RUNOFF                                      0.188
42384.7461

       PERCOLATION/LEAKAGE THROUGH LAYER  3        0.000000
0.01419

       SNOW WATER                                  0.61
137198.7500


       MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.2067

       MINIMUM VEG. SOIL WATER (VOL/VOL)                   0.1040

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                    FINAL WATER STORAGE AT END OF YEAR    5
     ------------------------------------------------------------
----------
                     LAYER        (INCHES)       (VOL/VOL)
                     -----        --------       ---------
                       1            1.8329         0.1527

                       2            2.5796         0.1075

                       3            1.2482         0.1040

                   SNOW WATER       0.000

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Permit Application

Lea County, New Mexico
C.K. Disposal E & P Landfill and Processing Facility
Permit No. TBD

Attachment F
Geosynthetic and Pipe Document

November 2015

PSC Project # 01058015

PARKHILL SMITH & COOPER

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

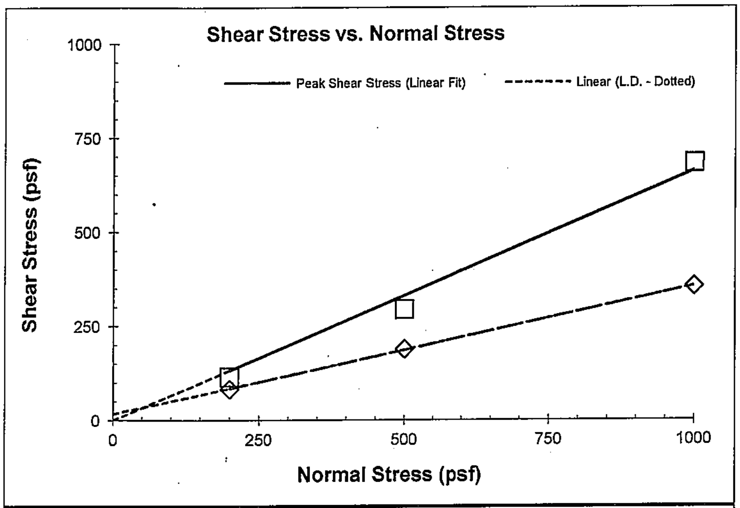
Interface Friction Test Report

Client: **PSI**
Project: **City of El Paso, Clint Landfill**
Test Date: 10/11/11-10/11/11

TRI Log#: E2357-60-01
Test Method: ASTM D 5321

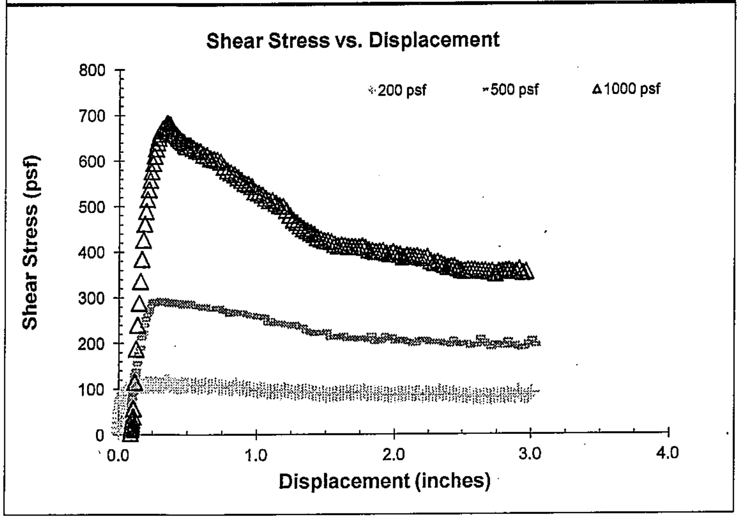
John M. Allen, P.E., 10/11/2011
Quality Review/Date

Tested Interface: GSE FS2-200E-08-08 Double-sided Geocomposite (131381527) vs. GSE 60 mil HDPE Textured Geomembrane (102162724)



Test Results	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	33.5	18.7
Y-intercept or Adhesion (psf):	0	17

Shearing occurred at the interface. The peak friction angle regression analysis was adjusted to fit a zero y-intercept.



Test Conditions

Upper Box & GSE FS2-200E-08-08 double-sided geocomposite

Lower Box GSE 60 mil HDPE textured geomembrane

Box Dimensions: 12"x12"x4"

Interface Conditioning: Interface soaked and loading applied for a minimum of 1 hour prior to shear.

Test Condition: Wet

Shearing Rate: 0.04 inches/minute

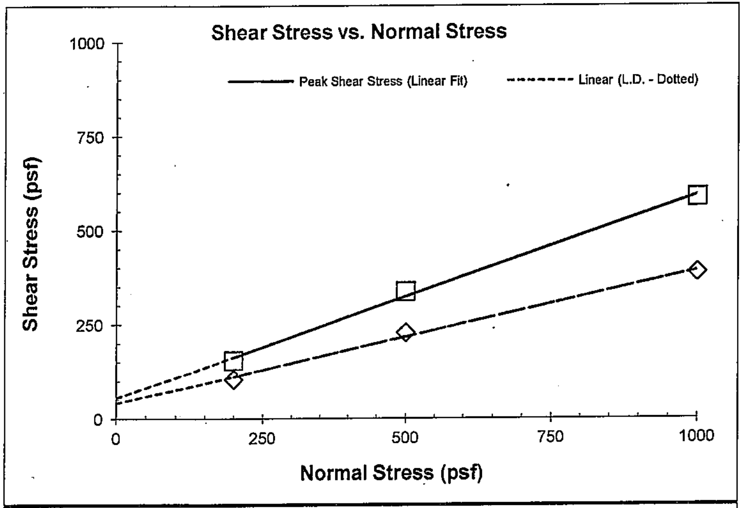
Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	10	13	18
Normal Stress (psf)	200	500	1000
Corrected Peak Shear Stress (psf)	116	295	683
Corrected Large Displacement Shear Stress (psf)	83	189	355
Peak Secant Angle (degrees)	30.1	30.5	34.3
Large Displacement Secant Angle (degrees)	22.5	20.7	19.5
Asperity (mils)	21.0	20.8	28.6

Interface Friction Test Report

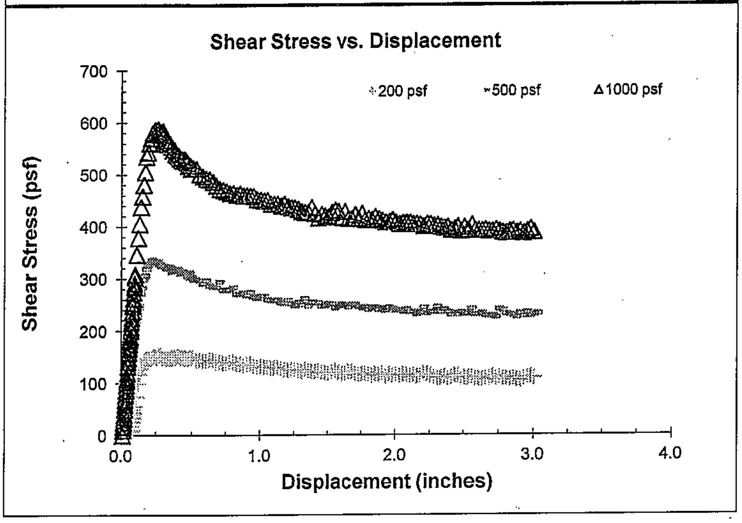
Client:	**PSI**	TRI Log#: E2357-60-01	John M. Allen, P.E., 10/17/2011
Project:	**City of El Paso, Clint Landfill**	Test Method: ASTM D 6243	Quality Review/Date
Test Date:	10/14/11-10/17/11		

Tested Interface: BentoLiner NSL GCL (502193561) vs. GSE 60 mil HDPE Textured Geomembrane (102162724)



Test Results		
	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	**28.2**	**19.3**
Y-intercept or Adhesion (psf):	**56**	**42**

Shearing occurred at the interface.



Test Conditions

Upper Box &	BentoLiner NSL GCL (non-woven side)
Lower Box	GSE 60 mil HDPE textured geomembrane
Box Dimensions: 12"x12"x4"	
Interface Conditioning:	Interface soaked and loading applied for a minimum of 72 hours prior to shear.
Test Condition: Wet	
Shearing Rate: 0.04 inches/minute	

Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	10	13	18
Normal Stress (psf)	200	500	1000
Corrected Peak Shear Stress (psf)	155	338	588
Corrected Large Displacement Shear Stress (psf)	105	228	388
Peak Secant Angle (degrees)	37.7	34.0	30.4
Large Displacement Secant Angle (degrees)	27.7	24.5	21.2
Asperity (mils)	23.0	21.2	21.8

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

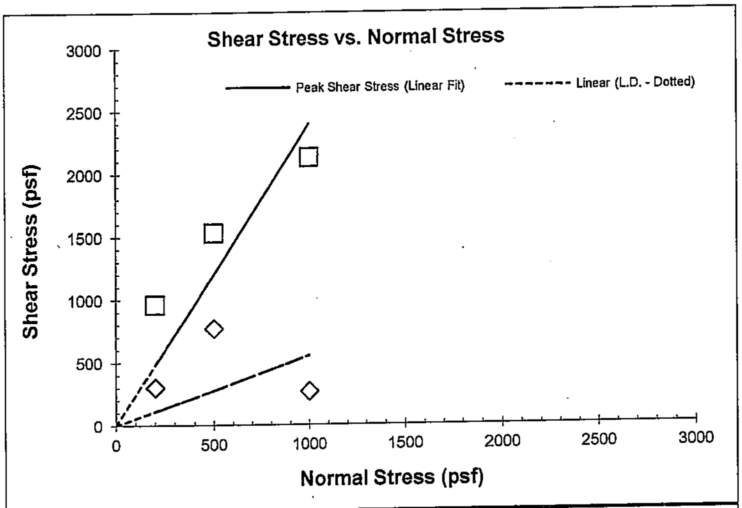
Interface Friction Test Report

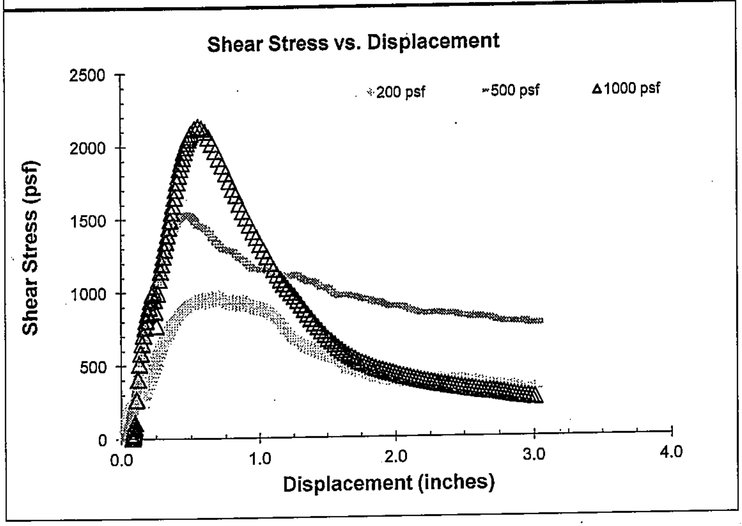
Client: **PSI**
Project: **City of El Paso, Clint Landfill**
Test Date: 10/14/11-10/17/11

TRI Log#: E2357-60-01
Test Method: ASTM D 6243

John M. Allen, P.E., 10/17/2011
Quality Review/Date

Tested Interface: Internal Shear of BentoLiner NSL GCL (502193561)





Test Results

	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	55.2	29.0
Y-intercept or Adhesion (psf):	730	0

The GCL sheared internally under all loads. The large displacement friction angle regression analysis was adjusted to fit a zero y-intercept.

Test Conditions

Upper Box & BentoLiner NSL GCL

Lower Box BentoLiner NSL GCL

Box Dimensions: 12"x12"x4"

Interface Conditioning: Interface soaked and loading applied for a minimum of 72 hours prior to shear.

Test Condition: Wet

Shearing Rate: 0.04 inches/minute

Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	10	13	18
Normal Stress (psf)	200	500	1000
Corrected Peak Shear Stress (psf)	963	1535	2134
Corrected Large Displacement Shear Stress (psf)	302	771	268
Peak Secant Angle (degrees)	78.3	72.0	64.9
Large Displacement Secant Angle (degrees)	56.5	57.0	15.0

TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

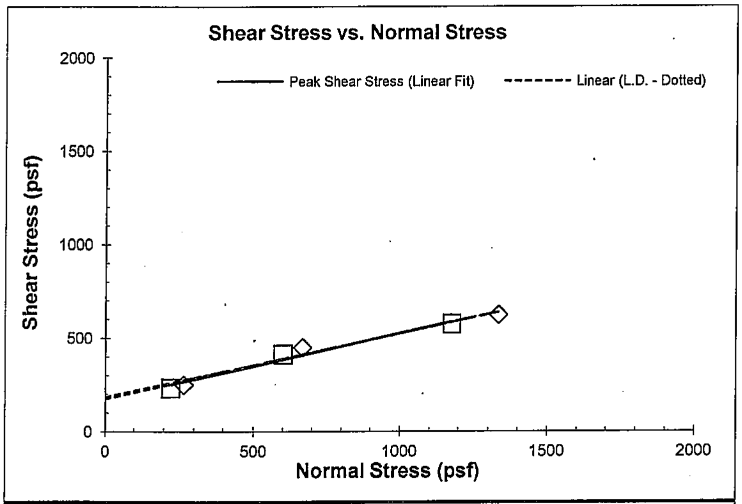
Interface Friction Test Report

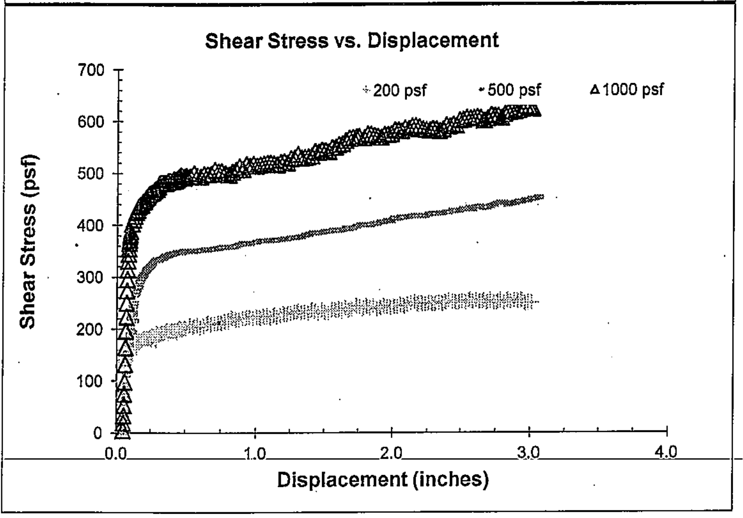
Client: **PSI**
Project: **City of El Paso, Clint Landfill**
Test Date: 11/03/11-11/07/11

TRI Log#: E2357-60-01
Test Method: ASTM D 6243

John M. Allen, P.E., 11/07/2011
Quality Review/Date

Tested Interface: Soil mixed with Ash vs. BentoLiner NSL GCL (502193561)


Shear Stress vs. Normal Stress


Shear Stress vs. Displacement

Test Results

	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	**19.4**	**18.8**
Y-intercept or Adhesion (psf):	**174**	**184**

Note: Regression angles include an area correction. Shearing occurred at the Soil/GCL interface under all loads.

Test Conditions

Upper Box &	BentoLiner NSL GCL (scrim side down)
Lower Box	Soil Ash Blend (5% ash) remolded to 112.0 pcf at 14.5% moisture content
Box Dimensions: 12"x12"x4"	
Interface Conditioning:	Interface soaked and loading applied for a minimum of 72 hours prior to shear.
Test Condition: Wet	
Shearing Rate: 0.04 inches/minute	

Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	10	13	18
Area Corrected Normal Stress (psf)	224	602	1178
Area Corrected Peak Shear Stress (psf)	235	415	576
Area Corrected Large Displacement Normal Stress (psf)	267	667	1335
Area Corrected Large Displacement Shear Stress (psf)	251	450	624
Peak Secant Angle (degrees)	46.3	34.6	26.1
Large Displacement Secant Angle (degrees)	43.2	34.0	25.1

PRODUCT DATA SHEET

GSE BentoLiner EC Geosynthetic Clay Liner

GSE BentoLiner "EC" is a lightly needle-punched reinforced composite geosynthetic clay liner (GCL) comprised of a uniform layer of granular sodium bentonite encapsulated between a woven and a nonwoven geotextile. The product is intended for use on relatively flat slope surfaces and low load applications where minimal internal shear strength is required.

[*]

AT THE CORE:
This composite clay liner is intended for use on relatively flat slope surfaces and low load applications where minimal internal shear strength is required.

Product Specifications

Tested Property	Test Method	Frequency	Value
Geotextile Property			
Cap Nonwoven, Mass/Unit Area	ASTM D 5261	1/200,000 ft²	3.0 oz/yd² MARV⁽¹⁾
Carrier Woven, Mass/Unit Area	ASTM D 5261	1/200,000 ft²	3.1 oz/yd² MARV
Bentonite Property			
Swell Index	ASTM D 5890	1/100,000 lb	24 ml/2 g min
Moisture Content	ASTM D 4643	1/100,000 lb	12% max
Fluid Loss	ASTM D 5891	1/100,000 lb	18 ml max
Finished GCL Property			
Bentonite, Mass/Unit Area(2)	ASTM D 5993	1/40,000 ft²	0.75 lb/ft² MARV
Tensile Strength(3)	ASTM D 6768	1/40,000 ft²	30 lb/in MARV
Peel Strength	ASTM D 6496 ASTM D 4632(4)	1/40,000 ft²	1 lb/in MARV 6 lb MARV
Hydraulic Conductivity(5)	ASTM D 5887	1/Week	5×10^{-9} cm/sec max
Index Flux(5)	ASTM D 5887	1/Week	1×10^{-8} m³/m²/sec max
Internal Shear Strength(6)	ASTM D 6243	Periodically	150 psf Typical
TYPICAL ROLL DIMENSIONS			
Width x Length(7)	Typical	Every Roll	15.5 ft x 150 ft
Area per Roll	Typical	Every Roll	2,325 ft²
Packaged Weight	Typical	Every Roll	2,600 lb

NOTES:
- (1)Minimum Average Roll Value.
- (2)At 0% moisture content.
- (3)Tested in machine direction.
- (4)Modified ASTM D 4632 to use a 4 in wide grip. The maximum peak of five specimens averaged in machine direction.
- (5)Deaired, deionized water @ 5 psi maximum effective confining stress and 2 psi head pressure.
- (6)Typical peak value for specimen hydrated for 24 hours and sheared under a 200 psf normal stress.
- (7)Roll widths and lengths have a tolerance of ±1%.

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PRODUCT DATA SHEET

GSE FabriNet 200 mil Geocomposite

GSE FabriNet geocomposite consists of a 200 mil thick GSE HyperNet geonet heat-laminated on one or both sides with a GSE nonwoven needle-punched geotextile. The geotextile is available in mass per unit area range of 6 oz/yd^2 to 16 oz/yd^2. The geocomposite is designed and formulated to perform drainage function under a range of anticipated site loads, gradients and boundary conditions.

[*]

AT THE CORE:
A 200 mil thick HyperNet geonet heat-laminated on one or both sides with a nonwoven needlepunched geotextile.

Product Specifications

Tested Property	Test Method	Frequency	Minimum Average Roll Value(1)		
Geocomposite			6 oz/yd^2	8 oz/yd^2	10 oz/yd^2
Transmissivity(2), gal/min/ft, (m^2/sec) Double-Sided Composite Single-Sided Composite	ASTM D 4716	1/540,000 ft^2	0.5 (1x10^{-4}) 4.8 (1x10^{-3})	0.5 (1x10^{-4}) 4.8 (1x10^{-3})	0.4 (9x10^{-5}) 4.3 (9x10^{-4})
Ply Adhesion, lb/in	ASTM D 7005	1/50,000 ft^2	1.0	1.0	1.0
Geonet Core(1,3) – GSE HyperNet					
Geonet Core Thickness, mil	ASTM D 5199	1/50,000 ft^2	200	200	200
Transmissivity(2), gal/min/ft (m^2/sec)	ASTM D 4716		9.6 (2 x 10^{-3})	9.6 (2 x 10^{-3})	9.6 (2 x 10^{-3})
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94
Tensile Strength (MD), lb/in	ASTM D 7179	1/50,000 ft^2	45	45	45
Carbon Black Content, %	ASTM D 4218	1/50,000 ft^2	2.0	2.0	2.0
Geotextile(1,3)					
Mass per Unit Area, oz/yd^2	ASTM D 5261	1/90,000 ft^2	6	8	10
Grab Tensile Strength, lb	ASTM D 4632	1/90,000 ft^2	160	220	260
Grab Elongation	ASTM D 4632	1/90,000 ft^2	50%	50%	50%
CBR Puncture Strength, lb	ASTM D 6241	1/540,000 ft^2	435	575	725
Trapezoidal Tear Strength, lb	ASTM D 4533	1/90,000 ft^2	65	90	100
AOS, US sieve(1), (mm)	ASTM D 4751	1/540,000 ft^2	70 (0.212)	80 (0.180)	100 (0.150)
Permittivity, sec^{-1}	ASTM D 4491	1/540,000 ft^2	1.5	1.3	1.0
Water Flow Rate, gpm/ft^2	ASTM D 4491	1/540,000 ft^2	110	95	75
UV Resistance, % retained	ASTM D 4355 (after 500 hours)	per formulation	70	70	70
NOMINAL ROLL DIMENSIONS(4)					
Roll Width, ft			14.75	14.75	14.75
Roll Length, ft	Double-Sided Composite Single-Sided Composite		270 300	260 300	230 290
Roll Area, ft^2	Double-Sided Composite Single-Sided Composite		3,982 4,425	3,835 4,425	3,392 4,277

NOTES:
- (1) All geotextile properties are minimum average roll values except AOS which is maximum average roll value and UV resistance is typical value. Geonet core thickness is nominal value.
- (2) Gradient of 0.1, normal load of 10,000 psf, water at 70˚F between steel plates for 15 minutes. Contact GSE for performance transmissivity value for use in design.
- (3) Component properties prior to lamination.
- (4) Roll widths and lengths have a tolerance of ±1%.

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PRODUCT DATA SHEET

GSE HyperNet Geonet 175 - 225 mil

GSE HyperNet geonet is a synthetic drainage material manufactured from a premium grade high density polyethylene (HDPE) resin. The structure of the GSE HyperNet geonet is formed specifically to transmit fluids uniformly under a variety of field conditions. The geonet is formulated to be resistant to ultraviolet light for a period of time necessary to complete the installation.

AT THE CORE:

A synthetic geonet engineered specifically to transmit fluids consistently under a variety of field conditions.

Product Specifications

Tested Property	Test Method	Frequency	Minimum Average Roll Value		
			175 mil	200 mil	225 mil
Geonet Thickness, mil(1)	ASTM D 5199	1/50,000 ft^2	175	200	225
Transmissivity(2), gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	4.8 (1.0 x 10^{-3})	9.6 (2 x 10^{-3})	12 (2.5x10^{-3})
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94
Tensile Strength (MD), lb/in	ASTM D 7179	1/50,000 ft^2	40	45	50
Carbon Black Content, %	ASTM D 4218	1/50,000 ft^2	2.0	2.0	2.0
NOMINAL ROLL DIMENSIONS(3)					
Roll Width, ft			15	15	15
Roll Length, ft			350	330	330
Roll Area, ft^2			5,250	4,950	4,950

NOTES:

- (1)Geonet thickness is nominal value.
- (2)Gradient of 0.1, normal load of 10,000 psf, water at 70° F, between steel plates for 15 minutes. Contact GSE for performance transmissivity value for use in design.
- (3)Roll widths and lengths have a tolerance of ±1%

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PRODUCT DATA SHEET

GSE HD Smooth Geomembrane

GSE HD is a smooth high density polyethylene (HDPE) geomembrane manufactured with the highest quality resin specifically formulated for flexible geomembranes. This product is used in applications that require excellent chemical resistance and endurance properties.

[*]

AT THE CORE:
An HDPE geomembrane used in applications that require excellent chemical resistance and endurance properties.

Product Specifications

These product specifications meet GRI GM 13

Tested Property	Test Method	Frequency	Minimum Average Value				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, mil Lowest individual reading	ASTM D 5199	every roll	30 27	40 36	60 54	80 72	100 90
Density, g/cm^3	ASTM D 1505	200,000 lb	0.940	0.940	0.940	0.940	0.94
Tensile Properties (each direction) Strength at Break, lb/in-width Strength at Yield, lb/in-width Elongation at Break, % Elongation at Yield, %	ASTM D 6693, Type IV Dumbbell, 2 ipm G.L. 2.0 in G.L. 1.3 in	20,000 lb	 114 63 700 12	 152 84 700 12	 228 126 700 12	 304 168 700 12	 380 210 700 12
Tear Resistance, lb	ASTM D 1004	45,000 lb	21	28	42	56	70
Puncture Resistance, lb	ASTM D 4833	45,000 lb	54	72	108	144	180
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note(1)	Note(1)	Note(1)	Note(1)	Note(1)
Notched Constant Tensile Load, hr	ASTM D 5397, Appendix	200,000 lb	500	500	500	500	500
Oxidative Induction Time, mins	ASTM D 3895, 200°C; O_2, 1 atm	200,000 lb	>100	>100	>100	>100	>100
TYPICAL ROLL DIMENSIONS							
Roll Length(2), ft			1,120	870	560	430	340
Roll Width(2), ft			22.5	22.5	22.5	22.5	22.5
Roll Area, ft^2			25,200	19,575	12,600	9,675	7,650

NOTES:
- (1)Dispersion only applies to mear spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- (2)Roll lengths and widths have a tolerance of ±l%.
- GSE HD is available in rolls weighing approximately 3,900 lb.
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77°C when tested according to ASTM D 746.
- *Modified.

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PRODUCT DATA SHEET

GSE HD Textured Geomembrane

GSE HD Textured is a co-extruded textured high density polyethylene (HDPE) geomembrane available on one or both sides. It is manufactured from the highest quality resin specifically formulated for flexible geomembranes. This product is used in applications that require increased frictional resistance, excellent chemical resistance and endurance properties.

[*]

AT THE CORE:
An HDPE geomembrane used in applications that require increased frictional resistance, excellent chemical resistance and endurance properties.

Product Specifications

These product specifications meet GRI GM13

Tested Property	Test Method	Frequency	Minimum Average Value				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, mil Lowest individual reading	ASTM D 5994	every roll	30 27	40 36	60 54	80 72	100 90
Density, g/cm^3	ASTM D 1505	200,000 lb	0.940	0.940	0.940	0.940	0.940
Tensile Properties (each direction Strength at Break, lb/in-width Strength at Yield, lb/in-width Elongation at Break, % Elongation at Yield, %	ASTM D 6693, Type IV Dumbell, 2 ipm G.L. 2.0 in G.L. 1.3 in	20,000 lb	 45 63 100 12	 60 84 100 12	 90 126 100 12	 120 168 100 12	 150 210 100 12
Tear Resistance, lb	ASTM D 1004	45,000 lb	21	28	42	56	70
Puncture Resistance, lb	ASTM D 4833	45,000 lb	45	60	90	120	150
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note(1)	Note(1)	Note(1)	Note(1)	Note(1)
Asperity Height, mil	ASTM D 7466	second roll	16	18	18	18	18
Notched Constant Tensile Load(2), hr	ASTM D 5397, Appendix	200,000 lb	500	500	500	500	500
Oxidative Induction Time, mins	ASTM D 3895, 200°C; O$_2$, 1 atm	200,000 lb	>100	>100	>100	>100	>100
TYPICAL ROLL DIMENSIONS							
Roll Length(3), ft	Double-Sided Textured Single-Sided Textured		830 1,010	700 780	520 540	400 410	330 330
Roll Width(3), ft			22.5	22.5	22.5	22.5	22.5
Roll Area, ft^2	Double-Sided Textured Single-Sided Textured		18,675 22,725	15,750 17,550	11,700 12,150	9,000 9,225	7,425 7,425

NOTES:

- (1)Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- (2)NCTL for GSE HD Textured is conducted on representative smooth membrane samples.
- (3)Roll lengths and widths have a tolerance of ±1%.
- GSE HD Textured is available in rolls weighing approximately 4,000 lb.
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77°C when tested according to ASTM D 746.
- *Modified.

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Chemical Resistance Chart

GSE is the world's leading supplier of high quality, polyethylene geomembranes and geonets. GSE polyethylene geomembranes and geonets are resistant to a great number and combinations of chemicals. Note that the effect of chemicals on any material is influenced by a number of variable factors such as temperature, concentration, exposed area and duration. Many tests have been performed that use geomembranes and geonets and certain specific chemical mixtures. Naturally, however, every mixture of chemicals cannot be tested for, and various criteria may be used to judge performance. Reported performance ratings may not apply to all applications of a given material in the same chemical. Therefore, these ratings are offered as a guide only.

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
A			
Acetic acid	100%	S	L
Acetic acid	10%	S	S
Acetic acid anhydride	100%	S	L
Acetone	100%	L	L
Adipic acid	sat. sol.	S	S
Allyl alcohol	96%	S	S
Aluminum chloride	sat. sol.	S	S
Aluminum fluoride	sat. sol.	S	S
Aluminum sulfate	sat. sol.	S	S
Alum	sol.	S	S
Ammonia, aqueous	dil. sol.	S	S
Ammonia, gaseous dry	100%	S	S
Ammonia, liquid	100%	S	S
Ammonium chloride	sat. sol.	S	S
Ammonium fluoride	sol.	S	S
Ammonium nitratesat. sol.	S	S	
Ammonium sulfate	sat. sol.	S	S
Ammonium sulfide	sol.	S	S
Amyl acetate	100%	S	L
Amyl alcohol	100%	S	L
B			
Barium carbonate	sat. sol.	S	S
Barium chloride	sat. sol.	S	S
Barium hydroxide	sat. sol.	S	S
Barium sulfate	sat. sol.	S	S
Barium sulfide	sol.	S	S
Benzaldehyde	100%	S	L
Benzene	—	L	L
Benzoic acid	sat. sol.	S	S
Beer	—	S	S
Borax (sodium tetraborate)	sat. sol.	S	S
Boric acid	sat. sol.	S	S
Bromine, gaseous dry	100%	U	U
Bromine, liquid	100%	U	U
Butane, gaseous	100%	S	S
1-Butanol	100%	S	S
Butyric acid	100%	S	L
C			
Calcium carbonate	sat. sol.	S	S
Calcium chlorate	sat. sol.	S	S
Calcium chloride	sat. sol.	S	S
Calcium nitrate	sat. sol.	S	S
Calcium sulfate	sat. sol.	S	S
Calcium sulfide	dil. sol.	L	L
Carbon dioxide, gaseous dry	100%	S	S
Carbon disulfide	100%	L	U
Carbon monoxide	100%	S	S
Chloracetic acid	sol.	S	S
Carbon tetrachloride	100%	L	U
Chlorine, aqueous solution	sat. sol.	L	U
Chlorine, gaseous dry	100%	L	U
Chloroform	100%	U	U
Chromic acid	20%	S	L
Chromic acid	50%	S	L
Citric acid	sat. sol.	S	S
Copper chloride	sat. sol.	S	S
Copper nitrate	sat. sol.	S	S
Copper sulfate	sat. sol.	S	S
Cresylic acid	sat. sol.	L	—
Cyclohexanol	100%	S	S
Cyclohexanone	100%	S	L
D			
Decahydronaphthalene	100%	S	L
Dextrine	sol.	S	S
Diethyl ether	100%	L	—
Dioctylphthalate	100%	S	L
Dioxane	100%	S	S
E			
Ethanediol	100%	S	S
Ethanol	40%	S	L
Ethyl acetate	100%	S	U
Ethylene trichloride	100%	U	U
F			
Ferric chloride	sat. sol.	S	S
Ferric nitrate	sol.	S	S
Ferric sulfate	sat. sol.	S	S
Ferrous chloride	sat. sol.	S	S
Ferrous sulfate	sat. sol.	S	S
Fluorine, gaseous	100%	U	U
Fluorosilicic acid	40%	S	S
Formaldehyde	40%	S	S
Formic acid	50%	S	S
Formic acid	98-100%	S	S
Furfuryl alcohol	100%	S	L
G			
Gasoline	—	S	L
Glacial acetic acid	96%	S	L
Glucose	sat. sol.	S	S
Glycerine	100%	S	S
Glycol	sol	S	S
H			
Heptane	100%	S	U
Hydrobromic acid	50%	S	S
Hydrobromic acid	100%	S	S
Hydrochloric acid	10%	S	S
Hydrochloric acid	35%	S	S
Hydrocyanic acid	10%	S	S
Hydrofluoric acid	4%	S	S
Hydrofluoric acid	60%	S	L
Hydrogen	100%	S	S
Hydrogen peroxide	30%	S	L
Hydrogen peroxide	90%	S	U
Hydrogen sulfide, gaseous	100%	S	S
Lactic acid	100%	S	S
Lead acetate	sat. sol.	S	—
Magnesium carbonate	sat. sol.	S	S
Magnesium chloride	sat. sol.	S	S
Magnesium hydroxide	sat. sol.	S	S
Magnesium nitrate	sat. sol.	S	S
Maleic acid	sat. sol.	S	S
Mercuric chloride	sat. sol.	S	S
Mercuric cyanide	sat. sol.	S	S
Mercuric nitrate	sol.	S	S

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
Mercury	100%	S	S
Methanol	100%	S	S
Methylene chloride	100%	L	—
Milk	—	S	S
Molasses	—	S	S
N			
Nickel chloride	sat. sol.	S	S
Nickel nitrate	sat. sol.	S	S
Nickel sulfate	sat. sol.	S	S
Nicotinic acid	dil. sol.	S	—
Nitric acid	25%	S	S
Nitric acid	50%	S	U
Nitric acid	75%	U	U
Nitric acid	100%	U	U
O			
Oils and Grease	—	S	L
Oleic acid	100%	S	L
Orthophosphoric acid	50%	S	S
Orthophosphoric acid	95%	S	L
Oxalic acid	sat. sol.	S	S
Oxygen	100%	S	L
Ozone	100%	L	U
P			
Petroleum (kerosene)	—	S	L
Phenol	sol	S	S
Phosphorus trichloride	100%	S	L
Photographic developer	cust. conc.	S	S
Picric acid	sat. sol.	S	—
Potassium bicarbonate	sat. sol.	S	S
Potassium bisulfide	sol.	S	S
Potassium bromate	sat. sol.	S	S
Potassium bromide	sat. sol.	S	S
Potassium carbonate	sat. sol.	S	S
Potassium chlorate	sat. sol.	S	S
Potassium chloride	sat. sol.	S	S
Potassium chromate	sat. sol.	S	S
Potassium cyanide	sol.	S	S
Potassium dichromate	sat. sol.	S	S
Potassium ferricyanide	sat. sol.	S	S
Potassium ferrocyanide	sat. sol.	S	S
Potassium fluorid	sat. sol.	S	S
Potassium hydroxide	10%	S	S
Potassium hydroxide	sol.	S	S
Potassium hypochlorite	sol.	S	L
Potassium nitrate	sat. sol.	S	S
Potassium orthophosphate	sat. sol.	S	S
Potassium perchlorate	sat. sol.	S	S
Potassium permanganate	20%	S	S
Potassium persulfate	sat. sol.	S	S
Potassium sulfate	sat. sol.	S	S
Potassium sulfite	sol.	S	S
Propionic acid	50%	S	S
Propionic acid	100%	S	L
Pyridine	100%	S	L
Q			
Quinol (Hydroquinone)	sat. sol.	S	S
S			
Salicylic acid	sat. sol.	S	S

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
Silver acetate	sat. sol.	S	S
Silver cyanide	sat. sol.	S	S
Silver nitrate	sat. sol.	S	S
Sodium benzoate	sat. sol.	S	S
Sodium bicarbonate	sat. sol.	S	S
Sodium biphosphate	sat. sol.	S	S
Sodium bisulfite	sol.	S	S
Sodium bromide	sat. sol.	S	S
Sodium carbonate	sat. sol.	S	S
Sodium chlorate	sat. sol.	S	S
Sodium chloride	sat. sol.	S	S
Sodium cyanide	sat. sol.	S	S
Sodium ferricyanide	sat. sol.	S	S
Sodium ferrocyanide	sat. sol.	S	S
Sodium fluoride	sat. sol.	S	S
Sodium hydroxide	40%	S	S
Sodium hydroxide	sat. sol.	S	S
Sodium hypochlorite	15% active chlorine	S	S
Sodium nitrate	sat. sol.	S	S
Sodium nitrite	sat. sol.	S	S
Sodium orthophosphate	sat. sol.	S	S
Sodium sulfate	sat. sol.	S	S
Sodium sulfide	sat. sol.	S	S
Sulfur dioxide, dry	100%	S	S
Sulfur trioxide	100%	U	U
Sulfuric acid	10%	S	S
Sulfuric acid	50%	S	S
Sulfuric acid	98%	S	U
Sulfuric acid	fuming	U	U
Sulfurous acid	30%	S	S
T			
Tannic acid	sol.	S	S
Tartaric acid	sol.	S	S
Thionyl chloride	100%	L	U
Toluene	100%	L	U
Triethylamine	sol.	S	L
U			
Urea	sol.	S	S
Urine	—	S	S
W			
Water	—	S	S
Wine vinegar	—	S	S
Wines and liquors	—	S	S
X			
Xylenes	100%	L	U
Y			
Yeast	sol.	S	S
Z			
Zinc chloride	sat. sol.	S	S
Zinc (II) chloride	sat. sol.	S	S
Zinc (IV) chloride	sat. sol.	S	S
Zinc oxide	sat. sol.	S	S
Zinc sulfate	sat. sol.	S	S

Specific immersion testing should be undertaken to ascertain the suitability
of chemicals not listed above with reference to special requirements.

Notes:
(S) Satisfactory: Liner material is resistant to the given reagent at the given concentration and temperature. No mechanical or chemical degradation is observed.
(L) Limited Application Possible: Liner material may reflect some attack. Factors such as concentration, pressure and temperature directly affect liner performance against the given media. Application, however, is possible under less severe conditions, e.g. lower concentration, secondary containment, additional liner protections, etc.
(U) Unsatisfactory: Liner material is not resistant to the given reagent at the given concentration and temperature. Mechanical and/or chemical degradation is observed.
(–) Not tested
sat. sol. = Saturated aqueous solution, prepared at 20°C (68°F)
sol. = aqueous solution with concentration above 10% but below saturation level
dil. sol. = diluted aqueous solution with concentration below 10%
cust. conc. = customary service concentration

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TR-19/2007

Chemical Resistance of Thermoplastics Piping Materials

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CHEMICAL RESISTANCE OF THERMOPLASTICS PIPING MATERIALS

Foreword

This report was developed and published with the technical help and financial support of the members of the PPI (Plastics Pipe Institute, Inc.). The members have shown their interest in quality products by assisting independent standards-making and user organizations in the development of standards, and also by developing reports on an industry-wide basis to help engineers, code officials, specifying groups, and users.

The purpose of this technical report is to provide information on the transport of various chemicals using thermoplastic piping materials.

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PPI intends to revise this report from time to time, in response to comments and suggestions from users of the report. Please send suggestions of improvements to the address below. Information on other publications can be obtained by contacting PPI directly or visiting the web site.

The Plastics Pipe Institute
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September 2007

This report has been developed as an informative guide on resistance of thermoplastic piping materials to chemical attack. It is divided into two main sections: (1) a discussion of chemical resistance and general considerations for end use applications and (2) a listing of chemical resistance data (table) for several thermoplastic piping materials applicable to *non-pressure* applications. Determination of suitability for specific applications under stress (pressurized service) is beyond the scope of this report.

SECTION I: CHEMICAL RESISTANCE IN GENERAL

Thermoplastic materials generally are resistant to attack from many chemicals which makes them suitable for use in many process applications. The suitability for use in a particular process piping application is a function of:

I. Material

   A. The specific plastic material: ABS, CPVC, PP, PVC, PE, PB, PVDF, PEX[1], PA11, PK
   B. The specific plastic material physical properties as identified by its cell classification according to the appropriate ASTM material specification.

II. Product and Joint System

   A. Piping product dimensions, construction, and composition (layers, fillers, etc.).
   B. Joining system. Heat fusion and solvent cementing do not introduce different materials into the system. Mechanical joints can introduce gaskets such as elastomers, or other thermoplastic or non-thermoplastic materials used as mechanical fitting components.
   C. Other components and appurtenances in the piping system.

III. Use Conditions - Internal and External

   A. Chemical or mixtures of chemicals, and their concentrations.
   B. Operating temperature — maximum, minimum, and cyclical variations.
   C. Operating pressure or applied stress — maximum, minimum and cyclical variations.
   D. Life-cycle information — such as material cost, installation cost, desired service life, maintenance, repair and replacement costs, etc.

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[1] Once cross-linked, PEX is no longer considered a thermoplastic material; however, it is included in this report as convenience for the reader.

Types of Chemical Attack on Plastics

In general, chemicals that affect plastics do so in one of two ways. One effect is chemical solvation or permeation; the other is direct chemical attack.

Chemical Solvation or Permeation

In the case of solvation or permeation, physical properties may be affected, but the polymer molecule structure itself is not chemically changed, degraded or destroyed. In solvation or permeation, gas, vapor or liquid molecules pass through the polymer, typically without damaging the plastic material itself. If the solvating chemical can be removed completely, the plastic is generally restored to its original condition. However, removal of the chemical is not always possible, and, in such cases, these chemical solvation effects may be permanent.

Sometimes the polymer itself may not be soluble, but it may contain a soluble compounding ingredient that may be extracted from the polymer compound. This is rare because such extractable ingredients are either not used in pipe compounds, or they are chemically bonded to the molecular polymer matrix and in such small amounts that they cannot be leached out to any significant extent.

Permeation may do little if any harm to the material, but it may have application-related effects. The permeating chemical may transfer into a fluid on the other side of the pipe. In general, thermoplastic pipes should not be used where a permeating chemical in the environment surrounding the pipe could compromise the purity of a fluid, such as potable water inside the pipe (See also PPI *Statement N* on Pipe Permeation). In gas or vapor transmission service, there may be a very slight loss of contents through the pipe wall. Lastly, a permeating chemical entrained in the material may be released when heat fusion or solvent cement joining is performed. Thus, heat fusion or solvent cement joining may be unreliable if performed on permeated pipes.

Direct Chemical Attack

Direct chemical attack occurs when exposure to a chemical causes a chemical alteration of the polymer molecules by chain scission, crosslinking, oxidation or substitution reactions. Direct chemical attack may cause profound, irreversible changes that cannot be restored by removal of the chemical. Examples of this type of attack are 50% chromic acid at 140 °F on PVC, aqua regia on PVC at 73 °F, 95% sulfuric acid at 73 °F on PE and wet chlorine gas on PVC and PE. Direct chemical attack frequently causes a severe reduction of mechanical physical properties such as tensile strength, ductility, and impact resistance, and susceptibility to cracking from applied stress (stress cracking).

Chemical resistance may vary greatly from one plastic material to another (i.e., PVC, ABS, PE, etc.), and also among different cell classifications of the same plastic type (e.g. PVC 1120 to PVC 2110, PE 3608 to PE 4710, etc.). There may also be slight variations among commercial products having the same cell classification.

The chemical resistance of plastic piping is basically a function of the chemical resistance of the thermoplastic material, in addition to additives and other ingredients in the final compound. In general, the less inert compounding ingredients used the better the chemical resistance. Thermoplastic pipes with significant filler percentages may be susceptible to chemical attack where an unfilled material may be affected to a lesser degree or not at all.

Other Considerations

Chemical Families

While the effect of each individual chemical is specific, some chemicals can be grouped into general categories based on similarities in chemical characteristics (acids, bases, alcohols, etc.). For example, water-based (aqueous) solutions of neutral inorganic salts generally have the same effect on thermoplastic piping materials as water alone; thus, sodium chloride, potassium alum, calcium chloride, copper sulfate, potassium sulfate and zinc chloride solutions have the same effect as water. However, at elevated temperatures and/or high concentrations, some oxidizing salt solutions may attack some plastic materials.

Further, with organic chemicals in a specific series such as alcohols, ketones, or acids, etc., as the molecular weight of the organic chemical series increases, the chemical resistance of a particular plastic material to members of the specific organic chemical series frequently also increases. Thus, while one type of polyvinyl chloride at 73 °F is not suitable for use with ethyl acetate, it is suitable for the higher molecular weight butyl acetate.

Accelerating factors (concentration, temperature, stress)

Generally, the resistance of a particular plastic to a specific chemical decreases with an increase in concentration. For example, at 73°F polyethylene pipe can be used to carry 70% sulfuric acid but is not satisfactory for 95% sulfuric acid.

Also, the resistance of a particular plastic to a specific chemical generally decreases as temperature increases, generally decreases with increasing applied stress, and generally decreases where temperature or applied stress are varied or cycled. These effects can be greater overall in combination.

Combinations of Chemicals

In some cases, combinations of chemicals may have a synergistic effect on a thermoplastic material where the individual chemicals do not. It cannot be assumed that an individual chemical's lack of effect would apply for combinations that include several chemicals. When the possible combined effect of several chemicals is unknown, the material should be tested in the complete chemical mixture(s) in question.

Multi-Layered (Composite) Piping

Some piping products utilize a multi-layered (*composite*) construction, in which the pipe wall is constructed of layers of different materials. The layers may consist of both thermoplastic and non-thermoplastic – for example, PE/AL/PE and PEX/AL/PEX pipes, which contain a mid-wall aluminum layer. An all-thermoplastic composite pipe may contain PVC, ABS, and PVC layers. Layered composite material pipes may have chemical resistance that differs from the chemical resistance of the individual materials.

Rate of Chemical Attack

Chemicals that attack plastics do so at a certain rate, some slowly and some more quickly. But usually, any chemical attack is increased when temperature or stress are increased, or when temperature or stress are varied. The particular rate must be taken into consideration in the life-cycle evaluation for a particular application. It has been observed in some chemical plants that while a particular application may have a relatively short service life, the overall life-cycle cost may be economically feasible and justifiable. Each combination of material cost, installation cost and service life must be evaluated and judged on its own merits.

In some cases involving a slow rate of chemical attack, particularly when the application will be pressurized, simple immersion data, like that represented in the following resistance tables, may not adequately characterize performance throughout the intended design life. Longer-term testing to replicate service conditions is advisable to fully measure the effects of these chemicals.

SECTION 2: CHEMICAL RESISTANCE DATA FOR THERMOPLASTIC PIPING IN ***<u>NON-PRESSURE</u>*** APPLICATIONS AND DATA TABLE

When thermoplastic pipes come into contact with chemical agents, it is important to know how the pipe may be affected. For gravity flow or non-pressure applications, where the pipe is not subject to continuous internal pressure or thermal stress, chemical immersion test data may provide suitable information. The pipe manufacturer may have additional data from similar tests, or information on previous installations under similar field conditions.

The following table provides resistance data, with the following cautions:

I. *Data Sources.* The following chemical resistance information has been obtained from numerous sources. The data are based primarily on plastic material test specimens that have been immersed in the chemical, and to a lesser degree, on field-experience. In most cases, detailed information on the test conditions (such as exposure time), and on test results (such as change in weight, change in volume, and change in strength) was not available. Therefore, this information is best used only for comparison of different thermoplastic materials.

II. *Combinations of Chemicals.* . Chemicals that individually do not have an effect may affect the pipe if combined with certain other chemicals. The listings that follow do not address chemical combinations.

III. *Composite Piping.* Layered composite piping may have chemical resistance that differs from that of the individual materials in the layers. The listings that follow are not applicable to layered composite piping products.

IV. *Applicability to fiberglass, filled materials.* The listings that follow are not applicable to composite piping products such as reinforced epoxy resin (fiberglass) pipes, or to thermoplastic pipes containing significant percentages of filler materials.

V. *Concentrations.* Where no concentrations are given, the relatively pure material is indicated, except in the case of solids where saturated aqueous solutions are indicated.

NOTE: *Even though indicated as acceptable with certain temperature limitations, the use of PVC piping with liquid hydrocarbons such as gasoline and jet fuels should be limited to short-term exposure such as secondary containment systems. This piping is not recommended for long-term exposure to liquid hydrocarbons.*

Resistance Codes

The following code is used in the data table:

Code	Meaning	Typical Result
140	Plastic type is generally resistant to temperature (°F) indicated by code.	Swelling < 3% or weight loss < 0.5% and elongation at break not significantly changed.
R to 73	Plastic type is generally resistant to temperature (°F) indicated by code and may have limited resistance at higher temperatures.	Swelling < 3% or weight loss < 0.5% and elongation at break not significantly changed.
C to 73	Plastic type has limited resistance to temperature (°F) indicated by code and may be suitable for some conditions.	Swelling 3-8% or weight loss 0.5-5% and/or elongation at break decreased by < 50%.
N	Plastic type is not resistant.	Swelling > 8% or weight loss > 5% and/or elongation at break decreased by > 50%.
—	Data not available.	

Plastic Materials Identification

ABS	acrylonitrile-butadiene-styrene
CPVC	chlorinated polyvinyl chloride
PP	polypropylene
PVC	polyvinyl chloride
PE	polyethylene
PB	polybutylene
PVDF	poly vinylidene fluoride
PEX	crosslinked polyethylene
PA11	polyamide 11
PK	polyketone

CHEMICALS THAT DO NOT NORMALLY AFFECT THE PROPERTIES OF AN UNSTRESSED THERMOPLASTIC MAY CAUSE COMPLETELY DIFFERENT BEHAVIOR (SUCH AS STRESS CRACKING) WHEN UNDER THERMAL OR MECHANICAL STRESS (SUCH AS CONSTANT INTERNAL PRESSURE OR FREQUENT THERMAL OR MECHANICAL STRESS CYCLES). UNSTRESSED IMMERSION TEST CHEMICAL RESISTANCE INFORMATION IS APPLICABLE ONLY WHEN THE THERMOPLASTIC PIPE WILL NOT BE SUBJECT TO MECHANICAL OR THERMAL STRESS THAT IS CONSTANT OR CYCLES FREQUENTLY.

WHEN THE PIPE WILL BE SUBJECT TO A CONTINUOUS APPLIED MECHANICAL OR THERMAL STRESS OR TO COMBINATIONS OF CHEMICALS, TESTING THAT DUPLICATES THE EXPECTED FIELD CONDITIONS AS CLOSELY AS POSSIBLE SHOULD BE PERFORMED ON REPRESENTATIVE SAMPLES OF THE PIPE PRODUCT TO PROPERLY EVALUATE PLASTIC PIPE FOR USE IN THIS APPLICATION.

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Acetaldehyde CH_3 CHO	--	---	N	140	N	C to 73	C to 73	---	C to 140	C to 176	R to 73
	Aq. Of 40%	---	N	---	C to 73	R to 73	---	N	R to 73	---	---
Acetamide CH_3 $CONH_2$	5%	120	---	140	---	140	---	---	140	---	---
Acetic Acid CH_3 COOH	vapor	120	180	180	140	140	140	---	140	---	---
	5%	---	---	---	---	---	---	---	---	---	R to 176
	10%	---	---	---	---	---	---	R to 248	140	R to 176	---
	25%	N	180	180	140	140	140	---	140	---	---
	40%	---	---	---	---	---	---	R to 140	R to 176	---	---
	50%	---	---	---	---	---	---	R to 140	R to 176	C to 68	---
	60%	N	N	180	73	73	73	R to 104	73	---	---
	80%	---	---	---	---	---	---	R to 104	---	---	---
	85%	N	N	120	73	73	73	---	73	---	---
	glacial	N	N	120	73	73	73	R to 104	R to 68	---	---
Acetic Anhydride $(CH_3\ CO)_2$ O	---	N	N	73	N	73	140	N	73	C to 68	---
Acetone CH_3 $COCH_3$	5%	N	N	73	N	C to 73	140	R to 212	C to 73	C to 140	---
	10%	---	---	---	---	---	---	R to 122	---	---	---
	100%	---	---	---	---	---	---	---	---	---	R to 73 C to 122
Acetophenone C_6 H_5 $COCH_3$	---	N	---	120	--	73	---	R to 68	73	---	---
Acetyl Chloride CH_3 COCl	---	N	N	---	N	---	---	N	---	---	---
Acetylene HC≡CH	gas 100%	73	N	73	N	73	C to 73	---	73	140	---
Acetylnitrile	---	---	N	---	N	---	---	---	---	---	---
Acrylic Acid H_2 C=CHCOOH	97%	---	N	---	N	140	---	---	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Acrylonitrile $H_2 C{=}CHC{\equiv}N$	---	---	N	---	N	140	---	---	140	---	---
Adipic Acid $COOH(CH_2)_4 COOH$	sat'd	---	180	140	140	140	73	R to 176	140	---	---
Allyl Alcohol $CH_2 = CHCH_2 OH$	96%	---	C to 73	140	R to 73	140	140	---	N	---	---
Allyl Chloride $CH_2{=}CHCH_2 Cl$	--	---	N	---	N	C to 73	---	140	C to 73	---	---
	Liquid	---	---	---	---	---	---	R to 68	---	---	---
Aluminum Ammonium Sulfate (Alum) $AlNH_4 (SO_4)_2 \cdot 12H_2O$	sat'd	---	180	140	140	140	---	---	140	---	---
Aluminum Chloride Aqueous $AlCl_2$	sat'd	160	180	180	140	140	140	R to 212	140	---	---
Aluminum Fluoride Anhydrous AlF_3	sat'd	160	180	180	73	140	140	R to 212	140	---	---
Aluminum Hydroxide $Al(OH)_3$	sat'd	160	180	180	140	140	140	R to 212	140	---	N
Aluminum Nitrate $Al(NO_3)_3 \cdot 9H_2 O$	sat'd	---	180	180	140	140	140	R to 212	140	---	---
Aluminum Oxychloride	--	---	180	180	140	---	140	---	---	---	---
Aluminum Potassium Sulfate (Alum) $AlK(SO_4)_2 \cdot 12H_2 O$	sat'd	160	180	140	140	140	---	R to 212	140	---	---
Aluminum Sulfate (Alum) $Al_2 (SO_4)_3$	sat'd	160	180	140	140	140	C to 73	R to 212	140	194	---
	20%	---	---	---	---	---	---	---	---	---	R to 73
Ammonia Gas NH_3	100%	N	N	140	140	140	140	---	140	140	---
Ammonia Liquid NH_3	100%	160	N	140	N	140	73	---	140	140	---
Ammonium Acetate CH_3COONH_4	sat'd	120	180	73	140	140	---	R to 212	140	---	---
Ammonium Bifluoride $NH_4 HF_2$	sat'd	---	180	180	140	---	140	---	140	---	---
Ammonium Bisulfide $(NH_4)HS$	---	---	---	---	140	---	---	---	---	---	---
Ammonium Carbonate $(NH_4)_2CO_3$	sat'd	---	180	212	140	140	140	R to 248	140	---	---
Ammonium Chloride NH_4Cl	sat'd	120	180	212	140	140	140	R to 212	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Ammonium Dichromate $(NH_4)_2Cr_2O_7$	--	---	73	---	73	---	---	---	---	---	---
Ammonium Fluoride NH_4F	10%	120	180	212	140	140	---	R to 212	140	---	---
	25%	120	180	212	C to 140	140	73	---	140	---	---
Ammonium Hydroxide NH_4OH	10%	120	N	212	140	140	140	---	140	---	N
	30%	---	---	---	---	R to 140	---	---	R to 140	---	---
	Conc.	---	---	---	---	---	---	---	194	---	---
Ammonium Metaphosphate	Sat’d	--	--	R to 212	R to 140	R to 140	R to 140	R to 248	R to 140	---	---
Ammonium Nitrate NH_4NO_3	sat’d	120	180	212	140	140	140	R to 212	140	---	---
Ammonium Persulfate $(NH_4)_2S_2O_8$	---	---	180	140	140	140	140	R to 212	140	---	---
Ammonium Phosphate (Monobasic) $NH_4H_2PO_4$	all	120	180	212	140	140	140	R to 248	140	---	---
Ammonium Sulfate $(NH_4)_2SO_4$	Sat’d.	120	180	212	140	140	140	R to 212	140	---	---
	20%	---	---	---	---	---	---	---	---	---	R to 73
Ammonium Sulfide $(NH_4)_2S$	dilute	120	180	212	140	140	140	---	140	---	---
	Sat’d.	---	---	---	---	140	---	---	---	---	---
Ammonium Thiocyanate NH_4SCN	50-60%	120	180	212	140	140	140	R to 212	73	---	---
Amyl Acetate $CH_3COOC_5H_{11}$	--	N	N	N	N	73	---	R to 122	73	C to 194	---
Amyl Alcohol $C_5H_{11}OH$	--	---	N	---	N	140	140	R to 212	R to 140	---	---
	100%	---	---	---	---	---	C to 140	---	---	---	---
n-Amyl Chloride $CH_3(CH_2)_3CH_2Cl$	--	N	N	N	N	C to 73	---	---	C to 73	---	---
Anisole C_7H_8O	--	---	---	---	---	---	---	---	---	---	C to 73
Aniline $C_6H_5NH_2$	--	N	N	---	N	73	C to 140	R to 68	C to 140	---	N
Aniline Chlorohydrate	--	---	N	---	N	C to 73	N	---	C to 73	---	---

May not be fully applicable to pressurized applications

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Aniline Hydrochloride $C_6 H_5 NH_2 \bullet HCl$	sat'd	---	N	---	N	140	N	---	140	---	---
Anthraquinone $C_{14}H_8O_2$	--	---	180	---	140	C to 73	C to 73	---	C to 73	---	---
Anthraquinone Sulfonic Acid $C_{14} H_7 O_2 \bullet SO_3 \bullet H_2O$	--	---	180	73	140	140	C to 73	---	C to 73	---	---
Antifreeze	--	---	---	---	---	---	---	---	---	---	R to 73 C to 176
Antimony Trichloride $SbCl_3$	sat'd	---	180	140	140	140	140	R to 140	140	---	---
Aqua Regia (Nitrohydrochloric Acid)	--	N	R to 73	N	C to 73	N	N	C to 194	N	---	---
Arsenic Acid $H_3 AsO_4$	80%	---	180	140	140	140	140	R to 248	140	---	---
Aryl Sulfonic Acid $C_6 H_5 SO_3 H$	--	---	180	---	140	73	---	---	73	---	---
Asphalt	--	---	N	73	N	73	140	---	73	---	---
Barium Carbonate $BaCO_3$	sat'd	120	180	140	140	140	140	R to 248	140	---	---
Barium Chloride BaCl2 •2H2O	sat'd	120	180	140	140	140	140	R to 212	140	194	---
Barium Hydroxide $Ba(OH)_2$	sat'd	73	180	140	140	140	140	---	R to 212	---	---
	10%	---	---	---	---	---	---	---	---	---	R to 73
	30%	---	---	---	---	R to 140	---	---	R to 140	---	---
Barium Nitrate $Ba(NO_3)_2$	sat'd	73	180	140	73	140	---	---	140	---	---
Barium Sulfate $BaSO_4$	sat'd	73	180	140	140	140	140	R to 212	140	---	---
Barium Sulfide BaS	sat'd	73	180	140	140	140	140	---	R to 248	---	---
Beer	--	120	180	180	140	R to 140	140	R to 248	R to 140	68	R to 73
Beet Sugar Liquors	--	---	180	180	140	73	140	---	73	---	---
Benzaldehyde $C_6 H_5 CHO$	10%	N	R to 73	73	R to 73	73	C to 73	---	73	R to 104	---
	99%	---	---	---	---	---	---	---	---	---	C to 73
Benzene $C_6 H_6$	--	N	N	N	N	C to 120	N	C to 122	R to 68	---	---

May not be fully applicable to pressurized applications

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Benzene Sulfonic Acid $C_6 H_5 SO_3 H$	10%	---	180	180	140	R to 73	---	---	R to 73	---	---
	10%+	---	N	---	N	---	---	---	---	---	---
Benzoic Acid $C_6 H_5 COOH$	all	160	180	73	140	140	140	---	R to 248	---	---
Benzoyl Chloride C_6H_5COCl	Sat. Sol.	---	---	---	---	---	---	C to 68	---	---	---
Benzyl Alcohol $C_6 H_5 CH_2 OH$	--	---	N	120	N	140	---	R to 122	140	R to 68	---
Benzyl Chloride C_7H_7Cl	--	---	---	---	---	---	---	---	R to 140	---	---
Bismuth Carbonate $(BiO)_2 CO_3$	Sat'd.	---	180	180	140	140	140	---	140	---	---
Black Liquor	sat'd	---	180	140	140	120	140	---	120	---	---
Bleach	5% Active Cl_2	---	180	120	140	C to 140	---	---	C to 140	---	R to 73
	12% Active Cl_2	73	185	120	140	73	140	---	73	---	---
Borax $Na_3 B_4 O_7 \cdot 10H_2O$	sat'd	160	180	212	140	140	140	---	140	---	---
Boric Acid $H_3 BO_3$	Sat'd	160	180	212	140	140	140	R to 212	140	---	---
Brake Fluid	--	---	---	140	---	140	---	---	140	---	---
Brine	sat'd	---	180	140	140	140	140	---	140	---	---
Bromic Acid $HBrO_3$	Sat'd	---	180	N	140	N	140	R to 212	N	---	---
	10%	---	---	---	---	140	---	---	---	---	---
Bromine Br_2	Liquid	73	N	N	N	N	N	R to 248	N	N	---
	vapor 25%	---	180	N	140	N	---	---	N	---	---
Bromine Water	cold sat'd	---	180	N	140	N	C to 73	R to 176	N	---	---
Bromobenzene $C_6 H_5 Br$	--	---	---	---	N	---	---	---	---	---	---
Bromotoluene (Benzyl bromide) $C_6 H_5 CH_2 Br$	--	---	---	C	N	---	---	---	---	---	---
Butadiene $H_2 C{=}CHCH{=}CH_2$	50%	---	180	N	140	73	---	---	73	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
	Gas	---	---	---	---	---	---	R to 212	---	---	---
Butane $C_4 H_{10}$	50%	---	180	140	140	140	N	---	140	---	---
	Gas	---	---	---	---	---	---	R to 68	---	---	---
n-Butanol $C_4 H_9OH$	Liquid	---	---	---	---	---	---	R to 140	---	---	R to 73
Butyl Acetate $CH_3COOCH_2CH_2CH_2CH_3$	100%	N	N	C to 73	N	C to 73	C to 73	C to 104	C to 73	R to 194	---
Butyl Alcohol $CH_3 (CH_2)_2 CH {}_2OH$	--	---	C to 73	180	140	140	140	---	140	C to 104	---
Butyl Cellosolve $HOCH_2 CH_2 O(CH_2)_3CH_3$	--	---	N	---	73	---	---	---	---	---	---
n-Butyl Chloride $C_4 H_9 Cl$	--	N	N	---	---	---	---	---	---	---	---
Butyl Glycol $HOCH_2 CH_2 O(CH_2)_3CH_3$	Liquid	---	---	---	---	---	---	R to 212	---	---	---
Butylene © $CH_3 CH{=}CHCH_3$	Liquid	---	---	N	140	120	---	---	120	---	---
Butyl Phenol $C_4 H_9 C_6 H_4 OH$	--	---	---	N	C to 73	73	73	---	R to 176	---	---
Butyl Phthalate $C_{16}H_{22}O_4$	--	---	N	180	---	---	---	R to 140	---	---	---
Butyl Stearate $CH_3(CH2)_{16}COO(CH_2)_3CH_3$	--	---	---	---	73	---	---	---	---	---	---
Butynediol $HOCH_2 C{\equiv}CCH {}_2OH$	--	---	---	---	73	---	---	----	---	---	---
Butyric Acid $CH_3 CH_2 CH_2 COOH$	--	N	N	180	73	73	73	---	73	---	---
	20%	---	---	---	---	---	---	R to 212	---	---	---
	Liquid	---	---	---	---	---	---	R to 176	73	---	---
Cadmium Cyanide $Cd(CN)_2$	--	---	180	---	140	---	---	---	---	---	---
Calcium Bisulfide $Ca(HS)_2$ o6H $_2O$	--	---	73	---	N	140	---	---	140	---	---
Calcium Bisulfite $Ca(HSO_3)_2$	--	---	180	180	140	N	140	---	N	---	---
	Sat'd	---	---	---	---	---	---	R to 248	---	---	---
Calcium Carbonate $CaCO_3$	Sat'd	---	180	180	140	140	140	R to 248	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Calcium Chlorate $Ca(ClO_3)_2 \cdot 2H_2O$	--	---	180	180	140	140	140	R to 248	140	---	---
Calcium Chloride $CaCl_2$	5%	---	---	---	---	---	---	---	---	---	R to 176
	Sat'd	120	180	180	140	140	140	R to 248	R to 176	R to 194	---
Calcium Hydroxide $Ca(OH)_2$	--	160	180	180	140	140	140	---	140	---	---
	2%	---	---	---	---	---	---	---	---	---	R to 73
	30%	---	---	---	---	R to 140	---	---	R to 140	---	---
Calcium Hypochlorite $Ca(OCl)_2$	30%	160	180	140	140	140	140	---	140	---	---
	Sat'd	---	---	---	---	---	---	C to 212	---	---	---
Calcium Nitrate $Ca(NO_3)_2$	--	---	180	180	140	140	140	---	140	---	---
	50%	---	---	---	---	140	---	R to 212	140	---	---
	Sat'd	---	---	---	---	---	---	R to 176	---	---	---
Calcium Oxide CaO	--	---	180	---	140	140	---	---	140	---	---
Calcium Sulfate $CaSO_4$	--	100	180	180	140	140	140	R to 212	140	---	---
Calcium Hydrogen Sulfide $Ca(HS)_2$	>10%	---	---	---	---	---	---	R to 248	---	---	---
Camphor $C_{10}H_{16}O$	--	N	---	73	73	73	---	---	73	---	---
Cane Sugar Liquors $C_{12}H_{22}O_{11}$	--	---	180	180	140	140	150	---	140	---	---
Carbitol $CH_3CH_2O(CH_2)_2O(CH_2)_2OH$	--	---	N	---	73	---	---	---	---	---	---
Carbon Dioxide CO_2	Dry 100%	160	180	140	140	140	---	R to 212	140	---	---
	Wet	160	180	140	140	140	140	---	140	---	---
Carbon Disulfide CS_2	--	N	N	N	N	C to 140	---	---	R to 68	R to 104	---
Carbon Monoxide CO	Gas	---	180	180	140	140	140	R to 140	140	---	---
Carbon Tetrachloride CCl_4	--	N	N	N	73	C to 73	N	C to 212	C to 68	N	R to 73

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Carbonic Acid $H_2 CO_3$	Sat'd	185	180	140	140	140	---	---	140	---	---
Castor Oil	--	---	C to 180	140	140	73	140	---	73	---	---
Caustic Potash KOH	50%	160	180	180	140	140	73	---	140	---	---
Caustic Soda (Sodium Hydroxide) NaOH	40%	160	180	180	140	140	73	---	140	---	---
Cellosolve	--	---	N	73	73	C to 120	140	---	C to 120	---	---
Cellosolve Acetate $CH_3 COOCH_2 CH_2 OC_2 H_5$	--	---	N	73	73	---	---	---	---	---	---
Chloral Hydrate $CCl_3 CH (OH)_2$	All	---	180	C to 73	140	120	140	---	120	---	---
Chloramine $NH_2 Cl$	Dilute	---	N	73	73	73	---	---	73	---	---
Chloric acid $HClO_3 \cdot 7H_2 O$	10%	---	180	73	140	73	---	---	73	---	---
	20%	---	185	73	140	73	---	---	73	---	---
Chlorine Gas Cl_2	0-20 PPM moisture content	N	C to 73	N	C to 73	C to 73	---	R to 212	C to 73	---	---
	20-50 PPM moisture content	N	N	N	N	C to 73	---	---	C to 73	---	---
	50+ PPM moisture content	N	N	N	N	C to 73	---	N	C to 73	---	---
Chlorine	Liquid	N	N	N	N	N	---	---	N	---	N
Chlorinated Water											
	Sat'd	---	180	180	140	C to 120	140	R to 212	C to 120	---	---
Chloroacetic Acid $CH_2 ClCOOH$	50%	N	180	C to 73	140	120	N	---	120	---	---
	>10%	---	---	---	---	---	---	R to 140	---	---	---
Chloroacetyl Chloride $ClCH_2 COCl$	--	---	---	---	73	---	---	---	---	---	---
Chlorobenzene $C_6 H_5 Cl$	Dry	N	N	73	N	C to 75	N	---	C to 75	---	---
	Liquid	---	---	---	---	---	---	R to 140	R to 68	C to 176	---
Chlorobenzyl Chloride $ClC_6 H_4 CH_2 Cl$	--	---	N	---	N	C to 120	---	---	C to 120	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Chloroethanol $ClCH_2CH_2OH$	Liquid	---	---	---	---	---	N	R to 122	---	---	---
Chloroform $CHCl_3$	Dry	N	N	N	N	C to 75	C to 73	---	C to 75	---	---
	Liquid	---	---	---	---	---	---	R to 212	N	---	C to 73
Chloromethane CH_3Cl	Gas	---	---	---	---	---	---	R to 212	---	---	---
Chloropicrin $CCl_3\ NO_2$	--	---	---	---	N	73	---	---	73	---	---
Chlorosulfonic Acid $ClSO_2\ OH$	--	---	73	N	73	C to 120	N	---	C to 120	---	---
	50%	---	---	---	---	---	---	R to 68	---	---	---
	100%	---	---	---	---	N	---	---	N	---	---
Chromic Acid $H_2\ CrO_4$	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
	10%	73	180	140	140	73	140	R to 212	73	N	---
	20%	---	---	---	---	---	---	R to 212	---	---	---
	25%	---	---	---	---	---	---	R to 212	---	---	---
	30%	N	180	73	140	73	140	R to 212	73	---	---
	40%	N	180	73	140	73	73	R to 212	73	---	---
	50%	N	C to 140	73	N	73	N	R to 212	73	---	---
Chromium Potassium Sulfate $CrK(SO_4)_2 \bullet 12H_2\ O$	>10%	---	---	---	---	---	---	R to 212	---	---	---
	--	-	--	73	---	73	---	---	73	---	---
	Sat'd	---	---	---	---	---	R to 212	---	---	---	---
Citric Acid $C_6\ H_8\ O_7$	Sat'd	160	180	140	140	140	140	R to 248	140	C to 140	---
Coconut Oil	--	---	C to 180	73	140	73	140	R to 248	73	---	---
Cod Liver Oil	Work Sol.	---	---	---	---	---	---	R to 248	---	---	---
Coffee	--	---	180	140	140	140	---	---	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Coke Oven Gas	--	---	---	73	140	140	---	---	140	---	---
Copper Acetate $Cu(C_2 H_3 O_2)_2 \bullet H_2 O$	Sat'd	---	73	73	73	---	---	---	---	---	---
Copper Carbonate $CuCO_3$	Sat'd	---	180	---	140	140	---	---	140	---	---
Copper Chloride $CuCl_2$	Sat'd	73	180	140	140	140	140	---	140	---	---
Copper Cyanide $CuCN$	Sat'd	---	180	---	140	140	140	R to 212	140	---	---
Copper Fluoride $CuF_2 \bullet 2H_2 O$	2%	---	180	73	140	140	140	---	140	---	---
Copper Nitrate $Cu(NO_3)_2 \bullet 3H_2 O$	30%	---	180	140	140	140	140	---	---	---	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
Copper Sulfate $CuSO_4 \bullet 5H_2 O$	Sat'd	120	180	120	140	140	140	R to 212	140	R to 194	---
Corn Oil	--	---	C to 180	73	140	120	---	---	120	---	---
Corn Syrup	--	---	185	140	140	140	---	---	140	---	---
Cottonseed Oil	--	120	C to 180	140	140	R to 140	140	---	R to 140	---	---
Creosote	--	---	N	73	N	140	---	---	140	---	---
Cresol $CH_3 C_6 H_4 OH$	90%	N	N	R to 73	N	73	N	R to 68	73	---	---
Cresylic Acid	50%	---	180	---	140	C to 73	N	---	C to 73	---	---
Crotonaldehyde $CH_3 CH{=}CHCHO$	--	---	N	C to 73	N	---	---	---	---	---	---
	Liquid	---	---	---	---	---	---	R to 104	--	---	---
Crude Oil	--	---	C to 180	140	140	C to 120	C to 73	R to 212	C to 120	R to 140	---
Cupric Chloride $CuCl_2 \bullet 2H_2O$	20%	---	---	---	---	---	---	---	---	---	R to 73
Cupric Fluoride CuF_2	--	---	180	---	140	140	---	---	140	---	---
Cupric Sulfate $CuSO_4 \bullet 5H_2 O$	Sat'd	100	180	73	140	140	---	---	---	---	---
Cuprous Chloride $CuCl$	Sat'd	70	180	---	140	140	---	---	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Cyclohexane $C_6 H_{12}$	--	73	N	N	N	N	---	R to 248	N	C to 140	---
Cyclohexanol $C_6 H_{11} OH$	--	C to 120	N	140	N	73	C to 73	R to 104	73	---	---
Cyclohexanone $C_6 H_{10} O$	Liquid	N	N	73	N	120	N	N	C to 176	C to 140	---
Detergents (Heavy Duty)	--	---	C to 180	180	140	R to 140	---	---	R to 140	---	R to 73
Dextrin (Starch Gum)	Sat'd	---	180	140	140	140	140	---	140	---	---
Dextrose $C_6H_{12}O_6$	Sat'd	---	180	140	140	140	140	---	140	---	---
Diacetone Alcohol $CH_3 COCH_2 C(CH_3)_2 OH$	--	---	N	120	N	---	---	---	---	C to 140	---
Dibutoxyethyl Phthalate $C_{20}H_{30}O_6$	--	---	N	---	N	---	---	---	---	---	---
n-Dibutyl Ether $C_4 H_9 OC_4 H_9$	--	---	---	---	---	73	---	---	73	---	---
Dibutyl Phthalate $C_6 H_4 (COOC_4 H_9)_2$	--	N	N	73	N	73	---	---	73	---	---
Dibutyl Sebacate $C_4 H_9 OCO(CH_2)_8OCOC_4 H_9$	--	---	---	73	73	73	---	---	73	---	---
Dichloroacetic Acid $CHCl_2COOH$	50%	---	---	---	---	---	---	R to 176	---	---	---
Dichlorobenzene $C_6 H_4 Cl_2$	--	N	N	C to 73	N	C to 120	---	---	C to 120	---	R to 73
	Liquid	---	---	---	---	---	---	R to 140	---	---	---
Dichloroethylene $C_2 H_2Cl_2$	--	---	N	C to 73	N	C to 120	---	---	C to 120	---	---
	Liquid	---	---	---	---	---	---	R to 248	---	---	---
Diesel Fuels	--	---	C to 180	140	140	73	C to 73	R to 212	73	---	---
Diethanolamine $(CH_2CH_2OH)_2NH$	Solid	---	---	---	---	---	---	N	---	---	---
	20%	---	---	---	---	---	---	---	R to 194	---	---
Diethylamine $C_4 H_{10} NH$	--	N	N	---	N	C to 120	N	N	C to 120	---	---
Diethyl Ether $C_4 H_{10} O$	--	N	N	73	73	C to 140	---	---	C to 140	140	---
Diglycolic Acid $O(CH_2 COOH)_2$	Sat'd	---	180	140	140	140	140	---	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
	10%	---	---	---	---	---	---	R to 140	---	---	---
Dimethylamine $(CH_3)_2 NH$	--	---	---	73	140	73	N	N	73	---	---
Dimethylformamide $HCON(CH_3)_2$	--	N	N	180	N	120	---	---	120	---	C to 73
	Liquid	---	---	---	---	---	---	---	N	---	---
Dimethylhydrazine $(CH_3)_2 NNH_2$	--	---	---	---	N	---	---	---	---	---	---
Dimethyl Phthalate $C_6 H_4 (COOCH_3)_2$	--	---	N	---	---	C to 73	---	---	C to 73	---	---
Dioctyl Phthalate $C_6 H_4 (COOC_8 H_{17})_2$	--	N	N	C to 73	N	73	C to 73	---	73	140	---
Dioxane $C_4H_8O_2$	--	--	N	C to 140	N	140	---	---	140	---	---
	Liquid	---	---	---	---	---	---	C to 68	---	---	---
Diphenyl Oxide $(C_6 H_5)_2 O$	Sat'd	---	---	---	---	73	---	---	73	---	---
Disodium Phosphate $Na_2 HPO_4$	--	---	180	140	140	140	140	---	140	---	---
Dishwashing Liquid (Cascade®)	--	---	---	---	---	---	---	---	---	---	R to 73
DOWTHERM A	--	---	---	---	N	---	---	---	---	---	---
Ethanol $C_2 H_5 OH$	40%	---	---	---	---	---	---	R to 68	---	---	---
	95%	---	---	---	---	---	---	R to 122	R to 140	---	---
	Liquid	---	---	---	---	---	---	R to 122	R to 140	---	R to 176
Ether ROR	--	N	N	C to 73	N	73	N	---	73	---	---
Ethyl Acetate $CH_3 COOCH_2CH_3$	--	N	N	C to 140	N	73	C to 73	---	73	140	R to 73 C to 176
	Liquid	---	---	---	---	---	---	C to 68	---	---	---
Ethyl Acetoacetate $CH_3 COCH_2 COOC_2 H_5$	--	N	N	---	N	---	---	---	---	---	---
Ethyl Acrylate $CH_2{=}CHCOOC_2 H_5$	--	---	N	---	N	---	---	---	---	---	---
Ethyl Alcohol (Ethanol) $C_2 H_5 OH$	--	---	C to 140	140	140	140	140	---	140	C to 104	R to 176

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Ethyl Benzene $C_6 H_5 C_2 H_5$	--	---	---	C to 73	N	C to 73	---	---	---	---	---
Ethyl Chloride $C_2 H_5 Cl$	Dry	---	N	C to 73	N	C to 73	---	---	C to 73	---	---
	Gas	---	---	---	---	---	---	R to 212	---	---	---
Ethyl Chloroacetate $ClCH_2COOC_2H_5$	--	---	---	---	N	---	---	---	---	---	---
Ethyl Ether $(C_2 H_5)_2 O$	Liquid	---	N	N	N	N	N	R to 122	R to 68	---	---
Ethylene Bromide $BrCH_2 CH_2 Br$	Dry	---	N	---	N	---	N	---	---	---	---
Ethylene Chloride (Vinyl Chloride) $CH_2 CH Cl$	Dry	N	N	C to 73	N	C to 140	---	---	C to 140	---	---
Ethylene Chlorohydrin $ClCH_2 CH_2 OH$	--	---	N	73	N	---	N	---	---	---	---
	Liquid	---	---	---	---	---	---	C to 68	---	---	---
Ethylene Diamine $NH_2 CH_2 CH_2 NH_2$	--	N	---	73	N	140	---	---	140	---	---
Ethylene Dichloride $C_2 H_4 Cl_2$	Dry	N	N	C to 140	N	C to 73	140	---	C to 73	---	---
Ethylene Glycol $OHCH_2CH_2 OH$	Liquid	73	C to 180	212	140	140	140	R to 212	R to 212	---	C to 176
Ethylene Oxide $CH_2 CH_2 O$	--	---	N	C to 73	N	73	---	---	73	C to 140	---
2-Ethylhexanol $CH_3 (CH_2)_3 CHC_2 H_5 CH_2OH$	--	---	---	---	---	73	---	---	73	---	---
Fatty Acids R-COOH	--	160	73	120	140	120	150	---	120	194	---
Ferric Chloride (Aqueous) $FeCl_3$	Sat'd	120	180	140	140	140	150	R to 212	140	---	---
Ferric Hydroxide $Fe(OH)_3$	Sat'd	160	180	140	140	140	---	---	140	---	---
Ferric Nitrate $Fe(NO_3)_3 \bullet 9H_2 O$	Sat'd	160	180	140	140	140	140	R to 212	140	---	---
Ferric Sulfate $Fe_2 (SO_4)_3$	--	160	180	140	140	140	140	---	140	---	---
	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Ferrous Chloride $FeCl_2$	Sat'd	160	180	140	140	140	140	R to 212	140	---	---
Ferrous Hydroxide $Fe(OH)_2$	Sat'd	160	180	140	140	140	---	---	140	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Ferrous Nitrate $Fe(NO_3)_2$	--	160	180	140	140	140	---	---	140	---	---
Ferrous Sulfate $FeSO_4$	--	160	180	140	140	140	140	---	140	---	---
	20%	---	---	---	---	---	---	---	---	---	R to 73
	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Ferrous Chloride $FeCl_2$	Sat'd	160	180	140	140	140	140	R to 212	140	---	---
Fish Oil	---	---	180	180	140	140	140	---	140	---	---
Fluoroboric Acid HBF_4	---	73	73	140	140	140	---	---	140	---	---
	Solid	---	---	---	---	---	---	R to 104	---	---	---
Fluorine Gas (Dry) F_2	100%	---	73	N	73	C to 73	C to 73	---	C to 73	N	---
Fluorine Gas (Wet) F_2	--	N	73	N	73	N	N	---	N	N	---
Fluorosilicic Acid H_2SiF_6	25%	---	---	---	---	---	---	R to 212	---	---	---
	30%	---	R to 140	140	140	140	---	R to 212	---	---	---
	40%	---	---	---	---	---	---	R to 140	---	---	---
	50%	---	73	73	140	140	140	R to 212	--	---	---
	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Formaldehyde HCHO	Dilute	160	73	140	140	140	140	R to 176	---	C to 104	---
	35%	160	C to 73	140	140	140	140	---	140	---	---
	37%	160	C to 73	140	140	140	140	R to 212	140	---	---
	50%	---	C to 73	---	140	140	140	---	140	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Formic Acid HCOOH	--	N	C to 73	140	73	140	150	---	140	---	---
	10%	---	---	---	---	---	---	R to 212	R to 140	N	N
	40%	---	---	---	---	---	---	R to 212	R to 140	---	---
	50%	---	---	---	---	---	---	R to 176	R to 140	---	---
	85%	---	---	---	---	---	---	R to 212	---	---	---
	100%	---	---	---	---	140	---	---	140	---	---
Freon 11 CCl_3F	100%	N	73	N	140	73	---	---	73	---	---
Freon 12 CCl_2F_2	100%	---	73	73	140	73	---	---	73	68	---
	Work. Sol.	---	---	---	---	---	---	R to 212	R to 68	---	---
Freon 21 $CHCl_2F$	100%	---	---	N	N	C to 120	---	---	C to 120	---	---
Freon 22 $CHClF_2$	100%	---	73	73	N	C to 120	---	---	C to 120	68	---
Freon 113 $C_2Cl_2F_3$	100%	---	---	N	140	73	---	---	73	---	---
Freon 114 $C_2Cl_2F_4$	100%	---	---	N	140	73	---	---	73	---	---
Fructose $C_6 H_{12} O_6$	Sat’d	73	180	180	140	140	140	---	140	---	---
Fruit Juice	Work. Sol.	---	---	---	---	---	---	R to 212	---	104	---
Furfural $C_4 H_3 OCHO$	100%	N	N	N	N	C to 140	---	---	C to 140	C to 140	---
Gallic Acid $C_6 H_2 (OH)_3 CO_2 H \bullet H_2 O$	--	---	73	---	140	73	---	---	73	---	---
Gasoline, Leaded*	--	N	N	N	140	73	N	---	73	---	---
Gasoline, Unleaded*	--	N	N	N	140	73	N	---	73	---	R to 176
Gasoline (Fuel)	--	---	---	---	---	---	---	R to 212	---	R to 160	---
Gasohol*	--	N	N	N	140	73	N	---	73	---	---
Gasoline, Sour*	--	N	N	N	140	C to 73	N	---	C to 73	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Gelatin	--	---	180	180	140	140	140	---	140	---	---
Glucose $C_6 H_{12} O_6 \cdot H_2 O$	--	120	180	212	140	140	140	---	140	---	---
	10%	---	---	---	---	---	---	R to 248	---	---	---
Glue	--	---	---	140	140	140	---	---	140	---	---
Glycerine $C_3 H_5 (OH)_3$	--	140	180	212	140	140	140	---	140	---	---
	Liquid	---	---	---	---	---	---	R to 248	---	---	---
Glycol $OHCH_2 CH_2 OH$	--	---	C to 180	212	140	140	---	---	140	C to 140	---
Glycolic Acid $OHCH_2 COOH$	Sat’d	---	180	73	140	140	---	---	140	---	---
	10%	---	---	---	---	---	---	R to 212	---	---	---
	30%	---	---	---	---	---	---	R to 140	---	---	---
	65%	---	---	---	---	---	---	R to 212	---	---	---
Glyoxal OCHCHO	--	---	---	---	---	140	---	---	140	---	---
Grape Sugar	--	---	180	---	140	---	---	---	---	---	---
Grapefruit Juice	Work. Sol.	---	---	---	---	---	---	R to 122	---	---	---
Grease	--	---	---	---	---	---	---	---	---	194	---
Green Liquor	--	160	180	---	140	---	140	---	---	---	---
Heptane (Type 1) $C_7 H_{16}$	--	73	180	N	140	73	N	---	73	---	---
	Liquid	---	---	---	---	---	---	R to 212	C to 176	---	---
n-Hexane $C_6 H_{14}$	--	C	73	73	73	---	---	---	---	---	---
	Liquid	---	---	---	---	---	---	R to 176	---	---	R to 73
Hexanol, Tertiary Type I $CH_3 (CH_2)_4 CH_2 OH$	--	---	180	---	140	140	140	---	140	---	---
Hydraulic Oil (Petroleum)	--	---	---	---	73	73	---	---	73	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Hydrazine $H_2 NNH_2$	--	---	N	73	N	---	---	---	---	---	---
Hydrobromic Acid HBr	20%	73	73	140	140	140	140	R to 212	140	---	---
	50%	N	---	120	---	140	---	R to 140	140	---	---
	66%	---	---	---	---	---	---	R to 212	---	---	---
Hydrochloric Acid HCl	1%	---	---	---	---	---	---	---	---	---	R to 176
	10%	C to 120	180	140	140	140	140	R to 212	R to 212	C to 104	N
	20%	---	---	---	---	---	---	R to 212	R to 212	---	---
	30%	C to 73	180	140	140	140	140	R to 212	R to 140	---	---
	Conc.	---	---	---	---	---	---	---	R to 140	---	---
Hydrocyanic Acid HCN	--	160	180	73	140	140	140	---	140	---	---
	Sat'd	---	---	---	---	---	---	R to 248	---	---	---
	10%	---	---	---	---	---	---	R to 248	---	---	---
Hydrofluoric Acid HF	Dilute	73	73	180	73	140	140	R to 212	140	---	---
	30%	N	73	140	73	140	140	---	140	---	---
	40%	---	---	---	---	---	---	R to 212	---	---	---
	50%	N	N	73	73	120	140	R to 212	120	---	---
	60%	---	---	---	---	140	---	R to 140	140	---	---
	70%	---	---	---	---	---	---	R to 212	---	---	---
	100%	N	N	C to 73	N	120	---	---	120	---	---
	Gas	---	---	---	---	---	---	R to 104	---	---	---
Hydrogen H_2	Gas	---	73	140	140	140	140	R to 248	140	194	---
Hydrogen Cyanide HCN	--	---	---	73	140	---	---	---	---	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Hydrogen Fluoride, Anhydrous HF	--	---	C	73	N	---	---	---	---	---	---
Hydrogen Peroxide $H_2 O_2$	3%	---	---	---	---	---	---	---	---	---	R to 73
	10%	---	---	---	---	---	---	R to 212	---	---	---
	30%	---	---	---	---	---	---	R to 212	---	C to 104	---
	50%	---	180	73	140	140	N	R to 212	140	---	---
	90%	---	180	C to 73	140	73	N	---	73	---	---
Hydrogen Phosphide (Type I) PH_3	--	---	73	---	140	140	140	---	140	---	---
Hydrogen Sulfide $H_2 S$	Dry	---	180	150	140	140	140	R to 248	140	---	---
	Wet	---	180	---	140	140	---	---	140	---	---
Hydrogen Sulfite H_2SO_3	10%	---	---	---	---	140	---	R to 248	140	---	---
Hydroquinone $C_6 H_4 (OH)_2$	Sat’d	---	180	---	140	140	140	---	---	140	---
Hydroxylamine Sulfate $(NH_2 OH)oH_2 SO_4$	--	---	180	---	140	140	---	---	140	---	---
Hypochlorous Acid HOCl	10%	73	180	73	140	140	140	---	140	---	---
	70%	---	---	---	---	---	---	R to 212	---	---	---
Inks	--	---	---	140	---	140	---	---	140	---	---
Iodine I_2	10%	N	73	73	N	C to 120	N	R to 176	C to 120	---	---
Isobutyl Alcohol $(CH_3)_2 CHCH_2 OH$	--	C to 73	C to 73	73	---	140	---	---	140	---	---
Isooctane $(CH_3)_3 CCH_2 CH(CH_3)_2$	--	---	---	C to 73	---	73	---	---	73	---	---
	Liquid	---	---	---	---	---	---	R to 212	---	---	---
Isopropyl Acetate $CH_3 COOCH(CH_3)_2$	--	N	N	---	---	73	---	---	73	---	---
Isopropyl Alcohol $(CH_3)_2 CHOH$	--	---	C to 180	212	140	140	140	C to 212	140	---	R to 73
Isopropyl Ether $(CH_3)_2 CHOCH(CH_3)_2$	--	---	N	C to 73	N	73	---	---	73	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
JP-4 Fuel*	--	---	C to 73	C to 73	140	73	---	---	73	---	---
JP-5 Fuel*	--	---	C to 73	C to 73	140	73	---	---	73	---	---
Kerosene*	--	73	73	C to 140	140	C to 140	C to 73	---	C to 140	---	---
Ketchup	--	---	---	---	73	---	---	---	---	---	---
Ketones	--	N	N	C to 73	N	73	---	---	73	---	---
	Work Sol	---	---	---	---	---	---	---	R to 302	---	---
Kraft Liquors	--	73	180	---	140	120	140	---	120	---	---
Lactic Acid CH_3 CHOHCOOH	10%	---	---	---	---	---	---	R to 140	---	---	---
	20%	---	---	---	---	---	---	---	---	---	R to 73
	25%	73	180	212	140	140	140	---	140	---	---
	80%	N	C to 180	140	73	140	---	---	140	---	---
	Liquid	---	---	---	---	---	---	R to 212	---	R to 194	---
Lard Oil	--	---	C to 180	---	140	C to 120	73	---	C to 120	---	---
Latex	--	---	---	140	---	140	---	---	140	---	---
Lauric Acid $CH_3\ (CH_2\ )_{10}$ COOH	--	---	180	140	140	120	---	---	120	---	---
Lauryl Chloride (Type I) $CH_3(CH_2)_{10}CH_2Cl$	--	---	73	---	140	120	73	R to 248	120	---	---
Lead Acetate $Pb(C\ H_3\ COO\ )_2\ o3H_2\ O$	Sat'd	---	180	180	140	140	140	R to 212	140	---	---
Lead Chloride $PbCl_2$	--	---	180	140	140	120	---	---	120	---	---
Lead Nitrate $Pb(NO_3\ )_2$	Sat'd	---	180	140	140	120	---	---	120	---	---
Lead Sulfate $PbSO_4$	--	---	180	140	140	120	---	---	120	---	---
Lead Tetraethyl $C_8H_{20}Pb$	--	---	---	---	---	---	---	R to 212	---	---	---
Lemon Oil	--	---	N	C to 73	---	---	---	---	---	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Lemon Juice	--	---	---	---	---	C to 140	---	---	C to 140	---	---
Ligroin	--	---	---	140	---	---	---	---	---	---	---
Lime Slurry	--	---	---	---	---	140	---	---	140	---	---
Lime Sulfur	--	---	73	73	73	120	140	---	120	---	---
Linoleic Acid $CH_3 (CH_2)_4 (CH=CHCH_2)_2(CH_2)_6 COOH$	--	---	180	180	140	---	73	---	---	---	---
Linoleic Oil (Type I)	--	---	---	---	140	---	73	---	---	---	---
Linseed Oil	--	73	C to 180	140	140	R to 73	73	R to 248	R to 73	194	---
Liqueurs	--	---	---	140	140	120	140	---	120	---	---
Lithium Bromide LiBr	--	---	---	140	140	140	---	---	140	---	---
Lithium Chloride LiCl	--	---	---	140	140	120	---	---	120	---	---
Lithium Hydroxide LiOH	--	---	---	140	---	120	---	---	120	---	---
Lubricating Oil (ASTM #1)	--	---	180	C to 140	140	73	140	R to 248	73	---	---
Lubricating Oil (ASTM #2)	--	---	180	C to 140	140	73	140	---	73	---	---
Lubricating Oil (ASTM #3)	--	---	180	C to 140	140	73	140	---	73	---	---
Magnesium Carbonate $MgCO_3$	--	120	180	212	140	140	140	R to 212	140	---	---
Magnesium Chloride $MgCl_2$	Sat'd	120	180	140	140	140	140	R to 140	140	---	---
	50%	---	---	---	---	---	---	R to 212	----	194	---
Magnesium Citrate $MgHC_6 H_5 O_7 o5H_2 O$	--	---	180	---	140	140	---	---	140	---	---
Magnesium Hydroxide $Mg(OH)_2$	Sat'd	160	180	180	140	140	140	R to 212	140	---	---
Magnesium Nitrate $Mg(NO_3)_2 o2H_2 O$	--	160	180	212	140	140	140	R to 248	140	---	---
Magnesium Oxide MgO	--	160	---	---	---	---	---	---	---	---	---
Magnesium Sulfate $MgSO_4 o7H_2 O$	--	160	180	212	140	140	140	R to 212	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Maleic Acid HOOCCH=CHCOOH	Sat’d	160	180	140	140	140	140	R to 140	140	---	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
	10%	---	---	---	---	---	---	R to 140	---	---	---
Malic Acid $COOHCH_2$ CH(OH)COOH	--	---	180	140	140	140	140	---	140	---	---
Manganese Sulfate $MnSO_4 \bullet 4H_2 O$	--	---	180	180	140	140	---	---	140	---	---
Margarine	Work Sol.	---	---	---	---	---	---	R to 248	---	---	---
Mercuric Chloride $HgCl_2$	--	---	180	180	140	140	140	---	140	---	---
	Sat’d	--	---	---	---	---	---	R to 212	---	---	---
Mercuric Cyanide $Hg(CN)_2$	Sat’d	---	180	140	140	140	140	R to 212	140	---	---
Mercuric Sulfate $HgSO_4$	Sat’d	---	180	140	140	140	---	---	140	---	---
Mercurous Nitrate $HgNO_3 \bullet 2H_2 O$	Sat’d	---	180	140	140	140	140	---	140	---	---
	10%	---	---	---	---	---	---	R to 212	---	---	---
Mercury Hg	Liquid	---	180	140	140	140	140	R to 248	140	194	---
Methane CH_4	--	N	73	73	140	140	---	---	140	140	---
Methanol (Methyl Alcohol) CH_3 OH	--	---	N	180	140	R to 140	140	---	R to 140	---	---
	5%	---	---	---	---	---	---	R to 140	---	---	---
	Liquid	---	---	---	---	---	---	C to 176	R to 140	---	R to 176
Methoxyethyl Oleate CH_3 OCH_2 CH_2 $OOCC_{17}H_{33}$	--	---	---	---	73	---	---	---	---	---	---
Methyl Acetate CH_3 CO_2 CH_3	--	N	N	140	N	C to 120	---	---	C to 120	---	---
Methyl Acrylate CH_2 $=CHCOOCH_3$	Tech Pure	---	---	---	---	140	---	---	140	---	---
Methyl Amine CH_3 NH_2	--	---	N	N	N	---	---	---	---	---	---
Methyl Bromide CH_3 Br	--	---	N	N	N	C to 73	---	---	C to 73	R to 68	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Methyl Butyl Ketone $CH_3CO(CH_2)_3CH_3$	Liquid	---	---	---	---	---	---	C to 122	---	---	---
Methyl Cellosolve $HOCH_2\ CH_2\ OCH_3$	--	---	N	73	N	C to 120	---	---	C to 120	---	---
Methyl Chloride $CH_3\ Cl$	Dry	N	N	N	N	C to 120	N	---	C to 120	R to 68	---
Methyl Chloroform CH_3CCl_3	--	N	N	C to 73	N	C to 120	---	---	C to 120	---	---
Methyl Ethyl Ketone (MEK) $CH_3\ COC_2\ H_5$	100%	N	N	73	N	N	73	C to 68	R to 140	C to 140	R to 73 C to 176
Methyl Isobutyl Carbinol $(CH_3\ )_2\ CHCH_2\ CH(CH_3\ )OH$	--	---	N	---	N	---	---	---	---	---	---
Methyl Isobutyl Ketone $(CH_3\ )_2\ CHCH_2\ COCH_3$	--	N	N	73	N	73	---	---	73	---	---
Methyl Isopropyl Ketone $CH_3\ COCH(CH_3\ )_2$	--	---	N	---	N	73	---	---	73	---	---
Methyl Methacrylate $CH_2{=}C(CH_3\ )COOCH_3$	--	---	N	---	73	140	---	R to 68	140	---	---
Methyl Sulfate $(CH_3\ )_2\ SO_4$	--	---	73	C to 73	73	140	---	---	---	68	---
Methylene Bromide $CH_2\ Br_2$	--	---	N	N	N	C to 120	---	---	C to 120	---	---
Methylene Chloride $CH_2\ Cl_2$	100%	---	N	N	N	N	73	C to 104	N	---	C to 176
Methylene Chlorobromide $CH_2\ ClBr$	--	---	N	--	N	---	---	---	---	---	---
Methylene Iodide $CH_2\ I_2$	--	---	N	N	N	C to 120	---	---	C to 120	---	---
Methylsulfuric Acid $CH_3\ HSO_4$	--	---	180	140	140	---	---	---	---	---	---
Milk	--	160	180	212	140	140	140	R to 212	140	194	---
Mineral Oil	--	73	180	C to 140	140	R to 73	C to 73	R to 212	C to 176	---	---
Molasses	--	---	180	140	140	140	140	---	140	---	---
Monochloroacetic Acid $CH_2ClCOOH$	50%	---	---	140	140	140	---	---	140	---	---
Monochlorobenzene $C_6\ H_5\ Cl$	Tech Pure	---	N	73	N	C to 120	---	---	C to 120	---	---
Monoethanolamine $HOCH_2\ CH_2\ NH_2$	--	---	---	---	N	---	---	---	---	---	---
Motor Oil	--	---	180	C to 140	140	R to 140	---	---	R to 140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Morpholine $C_4 H_8 ONH$	--	---	---	140	---	140	---	---	140	---	---
Mustard, Aqueous	Work. Sol.	---	---	---	---	---	---	R to 248	---	---	---
N-methyl Pyrrolidone C_5H_9NO	100%	---	---	---	---	---	---	---	---	---	C to 73
Naphtha	--	---	73	73	140	73	73	R to 122	C to 176	R to 140	---
Naphthalene $C_{10} H_8$	--	---	N	73	N	73	73	---	73	R to 194	---
Natural Gas	--	73	---	73	140	140	73	---	140	---	---
Nickel Acetate $Ni(OOCCH_3)_2 \bullet 4H_2 O$	--	---	---	73	---	140	---	---	140	---	---
Nickel Chloride $NiCl_2$	Sat'd	160	180	180	140	140	140	R to 212	140	---	---
Nickel Nitrate $Ni(NO_3)_2 o6H_2 O$	Sat'd	160	180	180	140	140	140	R to 248	140	---	---
Nickel Sulfate $NiSO_4$	Sat'd	160	180	180	140	140	140	R to 212	140	---	---
Nicotine $C_{10} H_{14} N_2$	--	---	180	---	140	140	140	---	140	---	---
Nicotinic Acid $C_5H_4 NCOOH$	--	---	180	---	140	140	140	R to 212	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Nitric Acid HNO_3	5%	---	---	---	---	---	---	R to 176	C to 140	N	---
	10%	C to 73	180	180	140	73	C to 73	R to 212	C to 140	---	---
	20%	---	---	---	---	---	---	R to 212	C to 140	---	---
	25%	---	---	---	---	---	---	R to 212	C to 140	---	---
	30%	N	R to 130	140	140	73	N	R to 212	C to 140	---	---
	35%	---	---	---	---	---	---	---	C to 140	---	---
	40%	N	R to 120	73	140	73	N	C to 248	140	---	---
	50%	N	110	N	100	C to 73	N	---	140	---	---
	65%	---	---	---	---	---	---	C to 248	---	---	---
	70%	N	100	N	73	C to 73	N	---	C to 73	---	---
	85%	---	---	---	---	---	---	N	---	---	---
	95%	---	---	---	---	---	N	---	---	---	---
	100%	N	N	N	N	N	N	---	N	---	---
Nitrobenzene $C_6H_5NO_2$	100%	N	N	C to 140	N	N	---	R to 122	N	---	---
Nitroglycerine $CH_2NO_3CHNO_3CH_2NO_3$	--	---	---	---	N	73	---	---	73	---	---
Nitroglycol $NO_3(CH_2)_2NO_3$	--	---	---	---	N	---	---	---	---	---	---
Nitrous Acid HNO_2	10%	---	180	C to 73	140	73	---	---	73	---	---
Nitrous Oxide N_2O	--	---	73	73	73	73	---	---	73	---	---
n-Octane C_8H_{18}	--	---	C to 73	---	---	---	---	---	---	---	---
Oleic Acid $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	--	160	180	73	140	C to 140	150	R to 248	C to 140	R to 140	---
Oleum x H_2SO_4 oySO_3	--	N	N	N	N	N	N	N	N	---	---
Olive Oil	--	160	C to 180	73	140	140	---	R to 248	R to 68	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Oxalic Acid HOOCCOOHo2H_2O	50%	160	180	140	140	140	140	---	140	---	---
	10%	---	---	---	---	---	---	R to 140	---	R to 140	---
	Sat'd	---	---	---	---	---	---	R to 122	---	---	---
Oxygen Gas O_2	--	160	180	N	140	140	---	R to 212	140	R to 140	---
Ozone O_3	--	---	180	C to 73	140	C to 120	---	---	C to 120	C to 68	---
	Sat'd	---	---	---	---	---	---	R to 68	---	---	---
Palm Oil	--	---	---	73	---	140	---	---	140	---	---
Palmitic Acid CH_3 $(CH_2)_{14}$ COOH	10%	73	73	180	140	120	150	---	120	---	---
	70%	---	73	180	73	120	---	---	120	---	---
Paraffin C_{36} H_{74}	--	73	180	140	140	C to 140	---	R to 212	C to 140	---	---
Peanut Oil	--	---	C to 180	140	---	---	---	R to 248	---	---	---
n-Pentane CH_3 $(CH_2)_3$ CH_3	--	N	C to 180	N	C to 140	C to 120	---	---	C to 120	---	--
Peracetic Acid CH_3 COOOH	40%	N	---	73	73	---	---	---	---	---	---
Perchloric Acid (Type I) $HClO_4$	10%	---	---	---	---	---	---	R to 212	---	---	---
	20%	---	---	---	---	---	---	R to 212	---	---	---
	15%	---	180	140	73	140	C to 73	---	140	---	---
	70%	73	180	C to 73	73	73	N	R to 212	73	---	---
Perchloroethylene (tetrachloroethylene) Cl_2 C=CCl_2	--	N	N	C to 73	C to 140	C to 120	---	C to 212	C to 120	C to 68	---
Perphosphate	--	---	73	140	73	---	---	---	---	---	---
Petroleum Ether	--	---	---	---	---	---	---	R to 212	---	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Phenol $C_6 H_5 OH$	--	N	73	73	73	140	73	---	140	N	---
	5%	---	---	---	---	---	---	---	R to 248	---	---
	50%	---	---	---	---	---	---	R to 176	---	---	---
	90%	---	---	---	---	R to 140	---	---	R to 140	---	---
	Solid	---	---	---	---	---	---	C to 122	---	---	---
Phenylhydrazine $C_6H_5 NHNH_2$	--	---	N	N	N	C to 120	---	R to 104	C to 120	---	---
Phenylhydrazine Hydrochloride $C_6H_5NHNH_2 \cdot HCl$	10%	---	---	---	---	---	---	R to 140	---	---	---
Phosphine PH_3	Gas	---	---	---	---	---	---	R to 104	---	---	---
Phosphoric Acid $H_3 PO_4$	10%	---	180	212	140	140	140	---	140	---	---
	50%	73	180	212	140	140	73	R to 212	140	C to 104	---
	75%	---	---	---	---	---	---	R to 212	---	---	---
	85%	---	180	212	140	73	---	C to 284	73	---	---
	98%	---	---	---	---	---	---	R to 212	---	---	---
Phosphoric Anhydride $P_2 O_5$	--	---	73	73	73	---	---	---	---	---	---
Phosphorous (Red)	--	---	---	---	73	140	---	---	140	---	---
Phosphorous (Yellow)	--	--	---	---	73	140	---	---	140	---	---
Phosphorus Oxychloride $POCl_3$	Liquid	---	---	---	---	---	---	R to 68	---	---	---
Phosphorus Pentoxide $P_2 O_5$	--	---	73	73	73	140	---	---	140	---	---
Phosphorus Trichloride PCl_3	--	--	N	73	N	120	C to 73	C to 122	120	---	---
Photographic Solutions	--	---	180	140	140	140	140	---	140	---	---
Phthalic Acid $C_6 H_4 (COOH)_2$	--	---	---	140	C to 140	140	---	---	140	---	---
	Susp.	---	---	---	---	---	---	R to 212	---	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Picric Acid $C_6 H_2 (NO_2)_3 OH$	10%	N	N	73	N	73	73	R to 212	73	C to 68	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
	Sat’d.	---	---	---	---	---	---	R to 212	---	---	---
Pine Oil	--	---	N	140	---	R to 73	---	---	R to 73	---	---
Plating Solutions (Brass)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Cadmium)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Chrome)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Copper)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Gold)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Lead)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Nickel)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Rhodium)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Silver)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Tin)	--	---	180	140	140	140	C to 73	---	140	---	---
Plating Solutions (Zinc)	--	---	180	140	140	140	C to 73	---	140	---	---
Potash (Aq) KOH	Sat’d	---	180	---	140	140	---	---	140	---	---
Potassium Alum $AlK (SO_4)_2 o12H_2 O$	--	---	180	---	140	140	---	---	140	---	---
Potassium Aluminum Sulfate $AlK (SO_4)_2 o12H_2 O$	--	---	180	180	140	---	C to 73	---	---	---	---
Potassium Amyl Xanthate $CH_3(CH_2)_4OC(=S)\text{-}S.K$	--	---	---	---	73	---	---	---	---	---	---
Potassium Bicarbonate $KHCO_3$	Sat’d	---	180	140	140	140	140	R to 212	140	---	---
Potassium Bi- chromate $K_2 Cr_2 O_7$	Sat’d	---	180	140	140	---	C to 73	R to 212	---	---	---
	40%	---	---	---	---	---	---	R to 212	---	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Potassium Bisulfate $KHSO_4$	--	---	180	212	140	140	---	R to 212	140	---	---
Potassium Borate $K_2 B_4 O_7 o4H_2 O$	--	--	180	140	140	140	140	R to 212	140	---	---
Potassium Bromate $KBrO_3$	--	---	180	212	140	140	140	R to 212	140	---	---
	10%	---	---	---	---	---	---	---	R to 212	---	---
Potassium Bromide KBr	--	---	180	212	140	140	140	R to 248	140	---	---
Potassium Carbonate $K_2 CO_3$	--	73	180	180	140	140	140	N	140	---	---
Potassium Chlorate (Aqueous) $KClO_3$	--	160	180	212	140	140	140	N	140	---	---
Potassium Chloride KCl	--	160	180	212	140	140	140	R to 212	140	---	---
Potassium Chromate $K_2 CrO_4$	--	---	180	212	140	140	140	---	140	---	---
Potassium Cyanide KCN	--	---	180	180	140	140	140	R to 212	140	---	---
Potassium Dichromate $K_2 Cr_2 O_7$	Sat'd	--	180	180	140	140	140	---	140	---	---
Potassium Ethyl Xanthate $KS_2 COC_2 H_5$	--	---	---	---	73	---	---	---	---	---	---
Potassium Ferricyanide $K_3 Fe(CN)_6$	--	---	180	180	140	140	140	R to 248	140	---	---
Potassium Ferrocyanide $K_4 Fe(CN)_6 o3H_2 O$	--	---	180	180	140	140	---	R to 248	140	---	---
Potassium Fluoride KF	--	---	180	180	140	140	140	R to 212	140	---	---
Potassium Hydroxide KOH	4%	---	---	---	---	---	---	C to 104	---	---	---
	10%	---	---	---	---	---	---	R to 176	---	---	---
	20%	---	---	---	---	---	---	R to 176	---	---	---
	25%	160	180	212	140	R to 140	140	---	R to 140	---	---
	45%	---	---	---	---	---	---	---	---	---	R to 73
	50%	---	---	---	---	---	---	R to 176	---	C to 104	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Potassium hydrogen Sulfite $KHSO_3$	10%	---	---	---	---	---	---	R to 140	---	---	---
	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Potassium Hypochlorite $KClO$	--	160	180	---	140	120	---	---	120	---	---
	3%	---	---	---	---	---	---	R to 212	---	---	---
Potassium Iodide KI	--	---	180	73	73	140	---	R to 212	140	---	---
Potassium Nitrate KNO_3	--	160	180	140	140	140	140	---	140	C to 104	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
Potassium Orthophosphate H_2KPO_4	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Potassium Perborate KBO_3	--	---	180	140	140	140	140	---	140	---	---
Potassium Perchlorate $KClO_4$	--	---	180	140	140	140	140	---	140	---	---
Potassium Permanganate $KMnO_4$	10%	---	180	73	140	140	140	R to 176	140	---	---
	20%	---	---	---	---	---	---	R to 212	---	---	---
	25%	---	180	73	73	140	---	---	140	---	---
	30%	---	---	---	---	---	---	R to 212	---	---	---
	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Potassium Persulfate $K_2 S_2 O_8$	--	---	180	140	140	140	140	R to 176	140	---	---
Potassium Sulfate $K_2 SO_4$	--	160	180	180	140	140	140	R to 212	140	194	---
Potassium Sulfide $K_2 S$	--	---	180	140	---	140	140	68	140	---	---
Potassium Sulfite $K_2 SO_3 o2H_2 O$	--	---	180	140	---	140	---	---	140	---	---
Propane $C_3 H_8$	--	---	73	73	140	140	73	R to 248	140	140	---
Propargyl Alcohol $HC{\equiv}CCH_2 OH$	--	---	C to 180	140	140	140	140	---	140	---	---
Propionic Acid $CH_3 CH_2 CO_2 H$	--	N	N	140	---	140	---	R to 140	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Propyl Alcohol (Type I) $CH_3CH_2CH_2OH$	--	73	C to 73	140	140	R to 140	140	R to 122	R to 140	---	---
Propylene Carbonate $C_4H_6O_3$	100%	---	---	---	---	---	---	---	---	---	R to 73
Propylene Dichloride $CH_3 CHClCH_2 Cl$	100%	---	N	N	N	N	---	---	N	---	---
Propylene Oxide $CH_3 CHCH_2 O$	--	---	N	73	N	140	---	---	140	---	---
Pyridine $N(CH)_4 CH$	--	---	N	C to 140	N	73	---	R to 68	73	C to 68	---
Pyrogallic Acid $C_6 H_3 (OH)_3$	--	---	---	---	73	--	--	---	---	---	---
Quinone $C_6 H_4 O_2$	--	---	---	140	---	140	---	---	140	---	---
Rayon Coagulating Bath	--	---	180	---	140	140	140	---	140	---	---
Salicylaldehyde $C_6 H_4 OHCHO$	--	---	---	73	N	120	---	---	120	---	---
Salicylic Acid $C_6 H_4 (OH)(COOH)$	--	---	---	140	140	140	---	R to 212	140	---	---
Selenic Acid Aq. $H_2 SeO_4$	--	---	180	---	140	140	140	---	140	---	---
Silicic Acid $SiO_2 onH_2 O$	--	---	180	140	140	140	140	R to 212	140	---	---
Silicone Oil	--	---	180	212	73	73	---	---	73	---	---
Silver Acetate $AgCH_3COO$	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Silver Chloride $AgCl$	--	160	180	140	140	---	---	---	---	---	---
Silver Cyanide $AgCN$	--	---	180	180	140	140	140	R to 212	140	---	---
Silver Nitrate $AgNO_3$	--	160	180	180	140	R to 140	C to 73	---	R to 140	---	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
Silver Sulfate $Ag_2 SO_4$	--	160	180	140	140	140	C to 73	---	140	---	---
Soaps	--	73	180	140	140	R to 140	140	---	R to 140	---	---
Sodium Acetate $CH_3 COONa$	Sat'd	---	180	212	140	140	140	R to 212	140	---	---
Sodium Alum $AlNa(SO_4)_2 o12H_2 O$	--	---	180	---	140	---	---	---	---	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Sodium Aluminate $Na_2 Al_2 O_4$	Sat'd	---	---	---	140	---	---	---	---	---	---
Sodium Benzoate $C_6 H_5 COONa$	--	---	180	140	140	140	140	---	140	---	---
	35%	---	---	---	---	---	---	R to 68	---	---	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
Sodium Bicarbonate $NaHCO_3$	--	73	180	212	140	140	140	R to 212	140	---	---
Sodium Bisulfate $NaHSO_4$	--	73	180	140	140	140	140	---	140	---	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
Sodium Bisulfite $NaHSO_3$	--	---	180	140	140	140	---	---	140	---	---
Sodium Borate (Borax) $Na_2 B_4 O_7 o10H_2 O$	Sat'd	160	180	180	140	140	140	---	140	---	---
Sodium Bromide $NaBr$	Sat'd	120	180	140	140	140	140	---	140	---	---
	50%	---	---	---	---	---	---	R to 248	---	---	---
Sodium Carbonate $Na_2 CO_3$	--	73	180	212	140	140	140	N	140	R to 140	---
Sodium Chlorate $NaClO_3$	Sat'd	---	180	140	73	140	140	N	140	---	---
Sodium Chloride $NaCl$	---	120	180	212	140	140	140	---	140	---	---
	Sat'd	---	---	---	---	---	---	R to 212	---	194	---
	10%	---	---	---	---	---	---	R to 212	---	---	R to 176
Sodium Chlorite $NaClO_2$	25%	---	180	73	N	140	---	---	140	---	---
Sodium Chromate $Na_2 CrO_4 o4H_2 O$	--	120	180	140	---	140	---	R to 176	140	---	---
Sodium Cyanide $NaCN$	--	---	180	180	140	140	140	R to 212	140	---	---
Sodium Dichromate $Na_2 Cr_2 O_7 o2H_2 O$	Sat'd	---	180	---	140	---	---	---	---	---	---
	20%	---	180	180	140	140	140	---	140	---	---
	50%	---	---	---	---	---	---	R to 212	---	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Sodium Ferricyanide $Na_3 Fe(CN)_6 o2H_2 O$	Sat'd	---	180	140	140	140	140	---	140	---	---
Sodium Ferrocyanide $Na_3 Fe(CN)_6 o10H_2 O$	Sat'd	---	180	140	140	140	140	---	140	---	---
Sodium Fluoride NaF	--	120	180	180	140	140	140	R to 212	140	---	---
Sodium Hydrogen Sulfite $NaHSO_3$	50%	---	---	---	---	---	---	R to 212	---	---	---
Sodium Hydroxide NaOH	1%	---	---	---	---	---	---	---	R to 140	---	---
	5%	---	---	---	---	---	---	C to 68	---	---	---
	15%	120	180	212	140	140	140	---	R to 140	---	---
	30%	120	180	212	140	R to 140	140	N	R to 140	---	---
	40%	---	---	---	---	---	---	---	R to 140	---	---
	50%	120	180	212	140	140	140	---	140	C to 104	---
	60%	---	---	---	---	---	---	---	R to 140	---	---
	70%	120	180	212	140	140	140	---	140	---	---
Sodium Hypochlorite $NaOClo5H_2 O$	--	120	180	73	73	140	140	---	140	---	N
	2% Cl	---	---	---	---	---	---	R to 212	---	---	---
	12.5% Cl	---	---	---	---	---	---	R to 68	---	---	---
Sodium Iodide NaI	--	---	180	---	140	---	---	---	---	---	---
Sodium Metaphosphate $(NaPO_3)n$	--	---	180	120	140	---	---	---	---	---	---
Sodium Nitrate $NaNO_3$	Sat'd	160	180	180	140	140	140	R to 212	140	---	---
Sodium Nitrite $NaNO_2$	--	160	180	73	140	140	140	R to 212	140	---	---
Sodium Palmitate $CH_3 (CH_2)_{14}COONa$	5%	---	180	140	140	---	---	---	---	---	---
Sodium Perborate $NaBO_3 o4H_2 O$	--	120	180	73	140	73	---	---	73	---	---
Sodium Perchlorate $NaClO_4$	--	---	180	212	140	140	---	---	140	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Sodium Peroxide $Na_2\ O_2$	10%	---	180	---	140	140	---	---	140	---	---
Sodium Phosphate $NaH_2\ PO_4$	Acid	120	180	212	140	140	140	R to 140	140	---	---
	Alkaline	---	120	180	212	140	140	---	140	---	---
	Neutral	---	120	180	212	140	140	---	R to 212	---	---
Sodium Silicate $2Na_2\ OoSiO_2$	--	---	180	140	140	140	140	---	140	---	---
	10%	---	---	---	---	---	---	R to 140	---	---	---
	50%	---	---	---	---	---	---	R to 212	---	---	---
Sodium Sulfate Na_2SO_4	Sat'd	160	180	212	140	140	140	R to 212	---	---	---
	0.10%	---	---	---	---	---	---	R to 140	---	---	---
Sodium Sulfide Na_2S	Sat'd	160	180	212	140	140	140	---	140	C to 104	---
Sodium Sulfite Na_2SO_3	Sat'd	160	180	212	140	140	140	R to 212	140	---	---
Sodium Thiosulfate $Na_2S_2O_3o5H_2O$	--	---	180	180	140	140	140	---	140	---	---
	50%	---	---	---	---	---	---	R to 248	---	---	---
Sour Crude Oil	--	---	---	140	140	---	---	---	---	---	---
Soybean Oil	--	---	---	73	---	140	---	---	140	---	---
Stannic Chloride $SnCl_4$	Sat'd	---	180	140	140	140	140	---	140	---	---
Stannous Chloride $SNCl_2$	15%	120	180	140	140	140	140	---	140	---	---
	Sat'd	---	---	---	---	140	---	---	140	---	---
Starch	--	---	180	140	140	140	---	---	140	---	---
Starch Solution	Sat'd	---	---	---	---	140	---	---	140	---	---
Stearic Acid $CH_3(CH_2)_{16}COOH$	--	---	180	73	140	120	150	---	120	C to 194	---
	100%	---	---	---	---	R to 120	---	---	R to 120	---	---

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Stoddard's Solvent	--	---	N	---	N	73	140	---	73	---	---
Styrene $C_6H_5CH=CH_2$	--	---	---	73	---	C to 73	---	---	C to 73	R to 104	---
Succinic Acid $COOH(CH_2)_2COOH$	--	---	180	140	140	140	---	---	140	---	---
Sugar $C_6H_{12}O_6$	Aq.	---	180	---	140	140	---	---	140	---	---
Sulfamic Acid HSO_3NH_2	20%	--	N	180	N	---	---	---	---	---	---
Sulfate Liquors (Oil)	6%	---	180	140	140	---	---	---	---	---	---
Sulfite Liquors	6%	73	180	---	140	140	---	---	---	---	---
Sulfur S	--	---	180	212	140	140	140	---	---	104	---
Sulfur Chloride S_2Cl_2	--	---	---	C to 73	---	---	---	---	---	---	---
Sulfur Dioxide SO_2	Gas Dry	N	73	140	140	140	---	---	140	---	---
	Gas Wet	N	N	140	73	120	73	N	120	---	---
Sulfur Trioxide SO_3	Gas Dry	---	---	---	140	N	---	N	N	C to 68	---
	Gas	---	N	---	73	N	---	N	---	---	---

******May not be fully applicable to pressurized applications******

Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	Concentration	ABS	CPVC	PP	PVC	PE	PB	PVDF	PEX	PA 11	PK
Sulfuric Acid H_2SO_4	5%	---	---	---	---	---	---	---	---	---	R to 73
	30%	120	180	180	140	140	140	R to 248	R to 140	---	N
	50%	73	180	140	140	120	C to 73	R to 212	R to 140	---	---
	60%	C to 73	180	73	140	120	C to 73	R to 248	---	---	---
	70%	C to 73	180	73	140	R to 120	C to 73	---	---	---	---
	80%	C to 73	180	73	140	R to 120	N	C to 248	---	---	---
	90%	C to 73	150	73	73	120	N	R to 212	---	---	---
	93%	N	140	C to 73	73	C to 73	N	---	---	---	---
	94% - 98%	N	130	C to 73	N	C to 73	N	C to 212	N	---	---
	100%	N	N	C to 73	N	C to 73	N	---	---	C to 194	---
Sulfurous Acid H_2SO_3	--	---	180	140	140	140	140	R to 212	140	---	---
Tall Oil	--	---	C to 180	180	140	120	---	---	120	---	---
Tannic Acid $C_{76}H_{52}O46$	10%	N	180	73	140	140	140	R to 212	140	---	---
	Sat'd	---	---	---	---	---	---	R to 212	---	---	---
Tanning Liquors	--	160	180	73	140	120	140	---	120	---	---
Tar	--	---	N	---	N	---	---	---	---	---	---
Tartaric Acid $HOOC(CHOH)_2COOH$	--	160	180	140	140	140	140	R to 248	140	---	---
	Sat'd	---	---	---	---	---	---	R to 248	R to 176	R to 194	---
Terpineol $C_{10}H_{17}OH$	--	---	---	---	C to 140	---	---	---	---	---	---
Tetrachloroethane $CHCl_2CHCl_2$	--	---	---	C to 73	C to 140	C to 120	---	---	C to 120	---	---
Tetrachloroethylene $Cl_2C=CCl_2$	--	N	N	C to 73	C to 140	C to 120	---	C to 212	C to 120	C to 68	---
Tetraethyl Lead $Pb(C_2H_5)_4$	--	---	73	73	73	---	---	---	---	68	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Tetrahydrofuran C_4H_8O	--	N	N	C to 73	N	C to 73	C to 73	C to 68	N	---	---
Tetralin $C_{10}H_{12}$	--	---	N	N	N	N	---	---	N	---	---
Tetra Sodium Pyrophosphate $Na_4P_2O_7o10H_2O$	--	---	180	---	140	---	---	---	---	---	---
Thionyl Chloride $SOCl_2$	--	---	N	N	N	N	140	N	N	---	---
Thread Cutting Oils	--	---	73	73	73	---	---	---	---	---	---
Tin (II) Chloride $SnCl_2$	--	---	---	---	---	---	---	R to 212	---	---	---
Tin (IV) Chloride $SnCl_4$	--	---	---	---	---	---	---	R to 212	---	---	---
Titanium Tetrachloride $TiCl_4$	--	---	---	140	C to 73	120	---	---	120	---	---
Toluene (Toluol) $CH_3C_6H_5$	--	N	N	C to 73	N	C to 120	N	---	C to 120	R to 140	R to 73
Tomato Juice	--	---	180	212	140	140	---	---	140	--	---
Transformer Oil	--	---	180	73	140	C to 120	---	---	C to 120	---	---
Transformer Oil DTE/30	--	---	180	---	140	R to 120	---	---	R to 120	---	---
Tributyl Citrate $C_{18}H_{32}O_7$	--	---	---	C to 73	73	C to 120	---	---	C to 120	---	---
Tributyl Phosphate $(C_4H_9)_3PO_4$	--	---	N	C to 140	N	73	---	---	73	R to 194	---
Trichloroacetic Acid CCl_3COOH	50%	---	---	140	140	140	---	R to 104	140	---	---
	10%	---	---	---	---	140	---	---	140	---	---
Trichlorobenzene $C_6H_3Cl_3$	--	---	---	---	---	---	---	R to 140	---	---	---
Trichloroethane $C_2H_3Cl_3$	--	---	---	---	---	---	---	---	---	---	R to 122
Trichloroethylene $CHCl{=}CCl_2$	--	N	N	N	N	C to 120	N	R to 176	C to 68	C to 68	R to 176
Triethanolamine $(HOCH_2CH_2)_3N$	--	C to 73	73	140	73	73	73	C to 104	73	---	---
Triethylamine $(C_2H_5)_3N$	--	---	---	N	140	73	---	---	73	---	---
Trimethylolpropane $(CH_2OH)_3C_3H_5$	--	---	---	140	73	C to 120	---	---	C to 120	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Trisodium Phosphate $Na_3PO_4 \bullet 12H_2O$	--	73	180	140	140	140	140	---	140	---	---
Turpentine	--	N	N	N	140	C to 120	C to 73	---	C to 120	R to 140	---
Urea $CO(NH_2)_2$	--	---	180	180	140	140	140	---	140	---	---
	10%	---	---	---	---	---	---	R to 212	---	---	---
	Sat'd	---	---	---	---	---	---	R to 176	---	C to 140	---
Urine	--	160	180	180	140	140	140	---	140	---	---
Vaseline (Petroleum Jelly)	--	---	N	140	N	120	---	---	120	---	---
Vegetable Oil	--	---	C to 180	140	140	R to 140	---	R to 248	R to 140	---	---
Vinegar	--	73	150	140	140	140	140	---	140	194	---
Vinyl Acetate $CH_3COOCH{=}CH_2$	--	---	N	73	N	140	---	C to 68	140	---	---
Water, Acid Mine H_2O	--	160	180	140	140	140	180	---	140	---	194
Water, Deionized H_2O	--	160	180	140	140	140	180	---	140	194	176
Water, Distilled H_2O	--	160	180	212	140	140	180	R to 248	140	194	---
Water, Potable H_2O	--	160	180	212	140	140	180	R to 248	140	194	---
Water, Salt H_2O	--	160	180	212	140	140	180	---	140	194	---
Water, Sea H_2O	--	160	180	212	140	140	180	R to 248	140	194	R to 176
Water, Soft H_2O	--	160	180	212	140	140	180	---	140	194	---
Water, Waste H_2O	--	73	180	212	140	140	180	---	140	194	---
Whiskey	--	---	180	140	140	140	140	R to 212	140	---	---
White Liquor	--	73	180	---	140	---	---	---	---	---	---
Wine	--	73	180	140	140	140	140	R to 248	140	---	---
Wines and Spirits	--	---	---	---	---	---	---	R to 212	---	---	---

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Plastics at Maximum Operating Temperature (F)

Chemical (Formula)	**Concentration**	**ABS**	**CPVC**	**PP**	**PVC**	**PE**	**PB**	**PVDF**	**PEX**	**PA 11**	**PK**
Xylene (Xylol) $C_6H_4(CH_3)_2$	--	N	N	N	N	N	N	C to 140	N	C to 194	---
Zinc Acetate $Zn(CH_3COO)_2o2H_2O$	--	---	180	---	---	---	---	---	---	---	---
Zinc Carbonate $ZnCO_3$	--	---	180	140	---	140	---	R to 212	140	---	---
Zinc Chloride $ZnCl_2$	--	120	180	180	140	140	---	---	140	---	---
	50%	---	---	---	---	---	---	---	---	C to 73	---
	Sat’d	---	---	---	---	---	---	R to 212	---	---	---
Zinc Nitrate $Zn(NO_3)_2o6H_2O$	--	160	180	180	140	140	140	---	140	---	---
	Sat’d	---	---	---	---	---	---	R to 212	---	---	---
Zinc Oxide ZnO	--	---	---	---	---	---	---	R to 212	---	---	---
Zinc Stearate $(CH_3(CH_2)_{16}COO)_2Zn$	--	---	---	---	---	---	---	R to 122	---	---	---
Zinc Sulfate $ZnSO_4o7H_2O$	--	160	180	212	140	140	140	---	140	---	---
	Sat’d	---	---	---	---	---	---	R to 212	---	---	---