

Appendix B

Landfill Gas Design Basis Memorandum

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List of Acronyms and Abbreviations

Army	U.S. Department of the Army
ARAR	Applicable or Relevant and Appropriate Requirements
DBM	Design Basis Memorandum
EPA	U.S. Environmental Protection Agency
GAC/KMnO ₄	Granular activated carbon and potassium permanganate
GCCS	LFG Collection and Control System
gpd	gallons per day
HDPE	High Density Polyethylene
LEL	lower explosive limit
LF	landfill
LFG	landfill gas
MBUAPCD	Monterey Bay Unified Air Pollution Control District
m ³ /Mg	cubic meter/milligrams
MMBtu/hr	British Thermal Unit/hour
MSL	mean sea level
OU2	Operable Unit 2
scfm	standard cubic feet per minute
SVE	Soil Vapor Extraction
VOC	Volatile Organic Compound
w.c.	water column

1.0 Introduction

This Design Basis Memorandum (DBM) summarizes the design basis to be incorporated into the construction plans and specifications for a landfill gas (LFG) treatment and control system for the Fort Ord Operable Unit 2 Landfill Areas. The design basis includes background information, project objectives and scope clarifications, site constraints, and initial values for the proposed engineering parameters. The primary objective of the DBM is to summarize the engineer's preliminary project approach for initial review, comment, and ultimate concurrence by the client's representatives. This DBM provides a tool to assure that the design approach is consistent with the client's objectives prior to expending substantial design efforts. This DBM was prepared for the U.S. Department of the Army (Army) by Shaw Environmental, Inc. (formerly IT Corporation) under the Total Environmental Restoration Contract II No. DACW05-96-D-0011.

1.1 Site Description

Fort Ord is a former U.S. Army installation that comprises approximately 46 square miles in northwestern Monterey County, California. In 1990, Fort Ord was placed on the U.S. Environmental Protection Agency (EPA) National Priority List, primarily due to volatile organic compounds (VOCs) found in groundwater beneath the Fort Ord Operable Unit 2 (OU2) Landfills. OU2 is a closed waste disposal facility, operated between 1960 and 1987 by the Army. OU2 was originally located north and south of Imjin Road in the Main Garrison Area. The facility consisted of six distinct landfill areas (Areas A through F). Area A, covering approximately 33 acres, was the only landfill north of Imjin Road and has been removed (clean closed). Areas B through F (south of Imjin Road) encompass approximately 120 acres.

Landfill Areas B through F are unlined landfills that have been closed with composite geomembrane and soil covers. Twenty-one passive LFG vents were installed through the final covers in the 5 landfill areas. Area F has an active LFG migration control system consisting of 11 perimeter vapor extraction wells extracting LFG from the sandy soils immediately east of the Area F waste limit. Eighteen additional perimeter wells have been proposed for installation, to completely encircle Area F. Granular activated carbon and potassium permanganate (GAC/KMnO₄) adsorption units are used to treat the LFG by removing the regulatory constituents of concern (primarily VOCs).

1.2 Objectives

The overall objective of the project is to design a cost-effective LFG collection and control system (GCCS) that is able to remove and treat a substantial portion of the VOCs being

generated in OU2. Based on current adsorbent replacement rates, the existing GAC/KMnO₄ combination may not be sufficiently cost-effective to provide a large scale, long-term control solution for LFG control from OU2. Thus, developing the required design parameters for thermal treatment alternatives will be given primary consideration in this DBM.

The Army has retained Shaw to design, permit, and prepare construction documents for an active GCCS. The primary objectives of the full-scale active GCCS are:

- To maximize LFG and VOC extraction from around landfill Area F.
- To reduce sub-surface transport of LFG and VOCs off-site and to groundwater.
- To comply with the applicable and/or relevant and appropriate requirements (ARARs) of local, state, and federal regulatory agencies.
- To treat and discharge the collected LFG and LFG condensate to minimize impacts on the public, the surrounding land uses, and the environment, in general.

2.0 Scope of Work

2.1 GCCS Design Approach

The GCCS project area has been defined as Landfill Areas E and F, for this phase of work. Areas E and F are the largest and youngest waste areas, and would be expected to be generating the bulk of the LFG produced by OU2. The preliminary GCCS design approach is assumed to be as follows:

1. LFG will be extracted from approximately 29 vertical LFG extraction wells installed for lateral migration control around the entire perimeter of Area F. These extraction wells will be operational before finalizing the GCCS design, in an interim effort to reduce ongoing VOC transport from Area F to groundwater. Based on recent monitoring data, the gas flows from the existing 11 well system have insufficient methane concentration to auto-combust in a thermal treatment system.
2. Potential sources of primary burner fuel under consideration for a thermal treatment system are:
 - an existing 600-foot long sub-cover gas collection trench installed in Area E
 - new interior LFG extraction wells in Area F
 - a propane storage tank with routine propane deliveries
3. The productivity of using LFG extracted from the interior of the landfill areas cannot be accurately estimated in theory, as the quantity, composition, and age of the disposed materials is very poorly documented. LFG productivity and cost-effectiveness of using the collection trench installed in Area E has been evaluated via a LFG field pumping test to determine the methane generation potential.
4. Cost analysis indicates that fueling with propane may be slightly more cost effective in the short-term (8 to 10 years) as compared to constructing additional LFG extraction wells in the interior of Area F. In the long-term (10 to 20 years), the cost of constructing interior wells could potentially pay back, in terms of reduced supplemental fuel and total removal of compounds of concern. An assumed requirement of five interior LFG wells was made for the preliminary cost evaluation.
5. In the thermal treatment unit, the extracted perimeter soil vapor will be discharged into the combustion zone of the main burners, such that the VOCs will be heated and destroyed to the required standards, before the exhaust gases released to the atmosphere.
6. Interim storage tanks will be provided at low points in the GCCS to collect condensate generated during the conveyance of the LFG. The condensate will be periodically pumped from the tanks into a water trailer and discharged to the headworks of the existing OU2 groundwater treatment system.

7. The GCCS design and installation will conform to the ARARs and current best site practices.

2.2 *Engineering Scope of Work*

The engineering scope of work includes:

1. Assisting site crew with field engineering of Area F perimeter system and Area E collector trench vent extensions (in progress)
2. Estimating theoretical methane generation potential from Area E and Area F
3. Initial sizing and selection specification for a cost-effective thermal treatment unit for treating gas from the Area F perimeter system
4. Preparing preliminary layout of a permanent thermal treatment facility
5. Preparing preliminary design layout of an (optional) interior LFG well system for Area F, to fuel a thermal treatment unit, assuming Area E collection trench has insufficient methane.
6. Preparing preliminary construction budget estimates for the thermal treatment facility and LFG well layouts.
7. Preparing final layout, connection details, technical specifications, and construction estimate for the thermal treatment facility, LFG wells and piping, and condensate system.

3.0 *Design Basis*

3.1 *Site Conditions*

- Landfill (LF) site location: Fort Ord OU2 Landfills,
Fort Ord, California
- LF type, classification: trench and fill, primarily MSW with
some potential for other military waste
- LF site property area: approximately 120 acres
- LF refuse area: Area F ~35 acres, Area E ~20 acres
- LF operation status: Closed
- LF cover 24” of foundation soil, linear-low-
density polyethylene
geomembrane, and 24” of vegetative
soil layer
- LF bottom liner No base liner
- First year of fill Approximately 1960 (Area A)
1970 for Area E
1977 for Area F
- Last year of fill: Approximately 1987 for Area F
Approximately 1977 for Area E
- Method of fill: Trench and fills (parallel trenches
approximately 30 feet wide, 10 to 15 feet
apart, and 10 to 30 feet deep)
- Waste in place: Total OU2 approximately 1,000,000
tons; Area F approximately 466,000
tons; Area E approximately 265,000
tons
- Waste density: 1,000 lbs/cy
- Elevation range of closure
mean sea level (MSL) Approximately 190 to 208 landfill surface: feet
(Area F)
- Elevation range of LF bottom: Approximately 180 to 203 feet MSL
(Area F)
- Total waste depth range: 10 to 30 feet

- Landfill side slope: Varies, 33 percent maximum, 2.8 percent minimum
- Passive LFG vents: 21 vents along top deck ridge lines of Areas B through F

3.2 *Surrounding Site Conditions*

- Nearest Residences north, west, east of Area A perimeter; approximately 320 feet to the southeast limit of Area F (approximately 2,250 feet from the LFG treatment facility location).
- Structures on site: None on Areas B through F
- Electrical power 100A, 480V, 3-phase electrical service is available at the existing LFG treatment facility.

3.3 *Geologic Structure*

- Principal geologic unit Sand dune, minimal fines
- Common rock types No bedrock at relevant depths

3.4 *Hydrogeologic Conditions*

- Groundwater elevation First encountered ~70 feet below ground surface.
- Groundwater flow West to east
- Leachate in Landfill Saturated waste zones are unlikely, due to transmissivity of surrounding sand.

3.5 *ARARs*

3.5.1 *Federal (RCRA Subtitle D) §258.23*

- CH₄ concentration standards
 - At property boundary: Less than 100 percent of the lower explosive limit (LEL)(5.0 percent by volume)
 - In onsite facility structures: Less than 25 percent of the LEL (1.25 percent by volume)
- Condensate: Not permitted to be returned to landfills without a composite liner

3.5.2 Monterey Bay Unified Air Pollution Control District (MBUAPCD)

The site capacity is less than 3.27 million cubic yards, and stopped receiving waste before 1987, therefore MBUAPCD Regulation IV, Rule 437 and Federal Landfill New Source Performance Standards (NSPS) do not apply.

MBUAPCD Regulation II (New Sources) and Regulation X (Toxic Air Contaminants) – Rule 207 and Rule 1000:

- Limit emissions of total and individual organic compounds (VOCs) such as: benzene, vinyl chloride, tetrachloroethene, trichloroethene, and methylene chloride.
- Most individual OCs: Less than 25 pound per day (lbs/day)
- Vinyl chloride: Less than 5.48 lbs/day
- Emission limits are expressed in terms of allowable increased risks of no more than 1 in 100,000 (health-based).

Compliance with the requirements of the MBUAPCD will be required prior to operating the treatment system.

3.6 Solid Waste Characterization Data

- Site specific data No site-specific records
- Waste inflow rates (tons/year) No available data
- Waste composition, moisture No available data content, percent
- Waste in place (1987): Approximately 466,000 tons in Area F, 265,000 tons in Area E

3.7 LFG Generation Prediction

Since landfill operating records do not exist, the potential LFG quantities requiring control will be estimated using a combination of methods:

1. Methane generation rates based on EPA LandGEM theoretical modeling ([Attachment 1](#)), using typical municipal solid waste assumptions:

- Waste-in-place mass: As assumed in Section 3.1
- Generation kinematics: $k = 0.03/\text{yr}$ (semi-arid area), $L_o = 100$ cubic meter/milligrams (m^3/Mg)
- Recovery efficiency: 85 percent

2. Extrapolation of soil vapor extraction rates based on the system flow for the eastern Area F perimeter system. These assumptions are:
 - Maximum LFG flow available: 140 standard cubic feet per minute (scfm)/50 hrs/week (spring, 2003)
 - Methane content: 6.8 percent
 - Radius of influence: 150 feet+
3. Data obtained from the Area E vent trench extraction flow testing (June 2003). These assumptions are:
 - Equilibrium LFG flow available: 11 scfm, continuous
 - Methane content: 28 percent

4.0 Design Criteria

4.1 LFG Thermal Treatment Capacities

Based on the ongoing site operations and the LFG generation modeling, thermal treatment equipment capacities may be required to cover a wide range of flow conditions, depending on the cost/benefit of extending the GCCS coverage. The resultant projections of LFG generation modeling are provided in [Attachment 1](#) and summarized in [Section 4.1.1](#).

4.1.1 LFG Design Methane / LFG Flow Data

**Table 1a – Theoretical LFG Flow Generation Estimates
EPA LandGEM Model**

Year	Area F Estimated Generation Rate (scfm)	Area E Estimated Generation Rate (scfm)	Total Area E & F Estimated Generation Rate (scfm)	Total Area E & F Estimated Recovery Rate @85% (scfm)
Current LFG Generation	94	41	135	115
2008	80	36	116	99
2013	70	31	101	86
2018	60	26	86	73

Note: Estimated generation rates assume 50 percent methane concentration, $k = 0.03 \text{ yr}^{-1}$, $L_0 = 100\text{m}^3/\text{Mg}$

**Table 1b – Theoretical Methane Flow Generation Estimates
EPA LandGEM Model**

Year	Area F Estimated Generation Rate (scfm)	Area E Estimated Generation Rate (scfm)	Total Area E & F Estimated Generation Rate (scfm)	Total Area E & F Estimated Recovery Rate @85% (scfm)
Current Methane Generation	47	20	67	57
2008	40	18	58	50
2013	35	15	50	43
2018	30	13	43	37

Note: Estimated generation rates assume 50 percent methane concentration, $k = 0.03 \text{ yr}^{-1}$, $L_0 = 100\text{m}^3/\text{Mg}$

The current estimated LFG extraction flows from existing facilities are summarized in [Table 2](#) below.

Table 2 – Current Landfill Gas Extraction Field Flows

Year	Area F (East) Estimated Extraction Rate (scfm)	Area F (Perimeter) Projected Extraction Rate (scfm)	Area E Vent Trench Estimated Extraction Rate (scfm)
Current (2003) Soil Vapor Extraction (SVE)	37	137	11
Current Methane	2.5	9.3	3

Note: Current Area F (East) extraction rate assumes 140 scfm over 198 hours operating per month at 6.8 percent methane concentration (average flow conditions, April through July, 2003).

Area F (Perimeter) projected extraction rate assumes extrapolation of Area F (East) rate to 24/7 operation.

Area E Vent extraction rate assumes equilibrium flow conditions attained during July 2003 field test.

The estimated required LFG treatment capacities, extrapolated from current estimated LFG extraction flows from existing facilities, are summarized in [Table 3](#) below.

Table 3 – Treatment System Capacity Extrapolations

Year	Area F (Perimeter) Estimated Extraction Rate @6.8% CH4 (scfm)	Area E Vent Trenches Estimated Extraction Rate @ 28% CH4 (scfm)	Area F Interior Wells Estimated Extraction Rate @ 50% CH4 (scfm)	Total Scenario Estimated Extraction Rate (scfm)	Resultant % Methane
Scenario 1, LFG Flows	137	11	NA	148	8.3
Scenario 1, Methane Flows	9.3	3	NA	12.3	
Scenario 2, LFG Flows	137	11	57	205	19.7
Scenario 2, Methane Flows	9.3	3	28	40.3	
Scenario 3, LFG Flows	69	11	62	142	28.0
Scenario 3, Methane Flows	5.7	3	31	39.7	
Scenario 4, LFG Flows	52	NA	47 (@ 25% CH4)	99	16
Scenario 4, Methane Flows	4.3	NA	11.5	15.8	

Scenario 1: Area F perimeter SVE wells + Area E vent trenches.

Scenario 2: Area F perimeter SVE wells + Area E vent trenches + Area F interior wells

Scenario 3: Area F perimeter SVE wells @ 50% reduced extraction rate+ Area E vent trenches + Area F interior wells

Scenario 4: Area F perimeter SVE wells @ 50% reduced extraction rate + Area F interior wells, 2013 projection

Area F Interior Wells extraction rate estimate assumes 75% recovery efficiency of residual of LandGEM estimate, after perimeter system capture.

4.1.2 VOC Treatment Basis

The current estimated VOC mass throughputs for existing facilities are summarized in [Table 4a](#) below.

Table 4a – Current Area F Extraction Flow VOC Estimates

Year	Area F (East) Estimated Concentration ($\mu\text{g}/\text{m}^3$)	Area F (East) Estimated Concentration (ppmv as hexane)	Area F (East) Estimated Extraction Rate (lbs/day)	Area F (Perimeter) Estimated 24/7 Extraction Rate (lbs/day)
2001 TO-14 VOCS	15,600	4.4	0.041	0.15
2001 vinyl chloride	1,400	0.5	0.0053	0.019
Total NMOC (assumed @3x TO-14 VOCs)	46,800	13.1	0.123	0.46

The estimated VOC treatment throughput, extrapolated from current estimated LFG extraction flows from existing facilities, are summarized in [Table 4b](#) below.

Table 4b – Treatment System VOC Capacity Extrapolations

Year	Area F (East) Estimated Extraction Rate (27% on-line) (lbs/day)	Area F (Perimeter) Estimated Extraction Rate (100% on line) (lbs/day)	Area F (Perimeter+Interior) + Area E trenches Estimated Extraction Rate (100% on line) (lbs/day)
2003 methane	2.5 scfm	9.3 scfm	40.3 scfm
2001 TO-14 VOCS	0.041	0.15	0.66
2001 vinyl chloride	0.0053	0.02	0.085
Total NMOC (assumed @3x TO-14 VOCs)	0.123	0.46	1.98

VOC mass flows are assumed to be proportional to extracted volume of methane, based on 2001 VOC concentrations and 2003 LFG extraction flows from 11 eastern test wells in Area F.

4.2 Thermal Treatment System Selection

Two types of thermal systems are in widespread use for treatment of LFG and soil vapor VOCs, the enclosed ground flare and the recuperative thermal oxidizer. The enclosed ground flares are generally of larger capacity, and are typically used where sufficient methane is available in the waste gas to auto-combust and destroy all the associated VOCs. The recuperative thermal

oxidizer is generally used for smaller, more dilute hydrocarbon waste gas streams, which typically require supplemental fueling to maintain the temperature conditions for VOC destruction.

The proposed enclosed ground flare is designated Best Available Control Technology for municipal landfill emissions, by the EPA. The proposed flare design has a capacity for 100 scfm LFG as primary burner fuel, plus 150 scfm of dilute soil vapor as combustion air. These quantities are near the low end of the capacity range for enclosed flares.

Many thermal oxidizer manufacturers target treatment of dilute VOC streams in the size range under consideration. Typically, supplementary fuel (propane or natural gas) is required, to maintain stable combustion conditions. The proposed thermal oxidizer design has a capacity of 200 scfm of dilute soil vapor. With a soil vapor methane concentration of approximately 2 percent by volume, the manufacturer estimates that additional fuel equivalent to approximately 20 gallons per day of propane will be required to maintain proper combustion temperature. Environmental thermal oxidizers are typically fabricated of lighter weight materials than enclosed flares, are slightly more complex, and thus tend to have shorter operating lives.

The permanent LFG treatment facility for OU2, Area F has been designed around an enclosed LFG flare, assuming that sufficient LFG methane is available from the proposed Area F interior wells. A supplementary propane supply will also be included in the facility design. If sufficient methane becomes unavailable, supplementary propane can be added to enrich the fuel mixture or a recuperative thermal oxidizer may be readily substituted for the enclosed flare equipment package.

4.2.1 Updated Cost Analysis

The cost analysis for the two thermal treatment alternatives has been updated, based on current conditions, equipment manufacturer quotes, and actual unit costs for LFG system construction. LFG system construction estimates have been prepared for three alternative installation elements and are included in [Attachment 4](#):

- Installation of an enclosed LFG ground flare (assuming sufficient LFG methane is available for fueling the primary burners)
- Installation of a recuperative thermal oxidizer with supplemental propane fueling (assuming sufficient LFG methane is not available.)
- LFG collection system expansion with 5 extraction wells in the western interior of Area F

The construction cost estimates were combined with realistic operating costs to provide total life-cycle costs for the most probable LFG system operating scenarios for OU2 ([Attachment 5](#)). The results of these analysis are summarized in [Table 5](#).

Table 5 - LFG Treatment Cost Update Summary

Treatment Construction / Operations Scenario	Project Size (scfm)	Initial Capital Cost (\$)	10-Year Total Costs (\$)	20-Year Total Costs (\$)	20-Year NPV @ I = 3% (\$)
Thermal Oxidizer w/ propane supply	SVE: 200	86,800	681,000	1,500,000	1,106,000
Enclosed Flare w/ Area F interior LFG wells	SVE: 150 LFG: 100	252,000	728,000	1,383,000	1,061,000

NPV = net present value of 20 year series of annual costs, assuming the discount rate for deferred funding at 3% per annum.

Based on this life-cycle cost analysis, the most cost-effective treatment option is contingent on sufficient LFG methane production being available from the proposed interior wells in Area F. If sufficient LFG methane is not available from Area F to sustain auto-combustion in an enclosed flare, the thermal oxidizer would likely be more cost effective, due to more efficient auxiliary fuel usage. The thermal oxidizer is also more cost effective over shorter life cycles, due to potentially high initial cost of installing LFG wells in a military landfill. The thermal oxidizer, operating primarily on supplemental propane, may also entail less potential downside risk, due to the undefinable quantity and quality of LFG in Area F, both currently and in the future.

4.3 Enclosed Flare Selection Criteria

If a conventional LFG flare is specified as the thermal treatment unit, the following selection requirements are applicable:

- Enclosed flare (no exposed flame) required
- Flare emission performance and monitoring features should comply with applicable federal, state, and local regulatory requirements
- Cylindrical or conical welded shell, for even heat distribution
- Large self-cleaning burner orifices, to minimize cleaning requirements
- Minimum primary fuel concentration of 25 percent methane-equivalent is required to guarantee 98 percent VOC destruction efficiency in an enclosed flare
- Select thermal oxidizer unit to handle current flow rates from [Table 3](#), Scenario 1 (minimum expansion):

- Current flow: approximately 148 scfm at 8.3 percent methane in 2003 [0.75 British Thermal Unit/hour (MMBtu/hr)]
- Select enclosed flare to handle current maximum flow rates from [Table 3](#), Scenario 2:
 - Maximum flow: approximately 205 scfm at 20 percent methane in 2003 (2.5 MMBtu/hr)
- Select enclosed flare to handle minimum flow rates from [Table 3](#), Scenario 4:
 - Minimum flow: approximately 99 scfm at 16 percent methane in 2018 (0.8 MMBtu/hr)
- Overall turndown range required (in heat capacity), 2.5 to 1.0 MMBtu/hr = 2.5:1

4.3.1 Blower Criteria

For conveying the soil vapor from the proposed 29 perimeter wells around landfill F:

- Selection requirements: 1 existing centrifugal blower with the following design flow rate and pressure specifications.
- Flow rate, maximum: 150 scfm
- Flow rate, minimum: 90 scfm
- Discharge pressure required at maximum flow rate: +10 inch water column (w.c.)
- Discharge pressure required at minimum flow rate: +4 inch w.c.
- Vacuum required at maximum flow rate: -70 inch w.c.
- Vacuum required at minimum flow rate: -40 inch w.c.
- Blower construction must be spark-proof and rated for combustible gas
- Blower motor to be totally enclosed, fan cooled

A second smaller blower will be required to convey the primary fuel LFG from the landfill interior, separately from SVE, to maintain required primary combustion zone conditions.

4.3.2 LFG Equipment Controls

The thermal equipment controls are to be based on use of programmable logic controller, to reduce manual operations labor.

- Auto start/stop on timer
- Auto start/stop after power failure
- Flame safeguard control
- Auto opening of LFG and SVE inlet valves by compressed air
- Auto closure of LFG and SVE inlet valves by compressed spring
- Auto shutdown and alarm indication/transmission on main flame failure, high temperature, blower surge, and power failure
- Alarm indicator/transmission on, propane low pressure, low temperature
- Auto alarm with remote notification to client designated personnel
- Continuous LFG flow metering and recording
- Continuous stack temperature monitoring and recording

4.3.3 Equipment Construction

- LFG blower(s), condensate knockout pot, thermal combustion device, all associated piping, valves and fittings, and electrical control panel to be mounted on a heavy-duty structural steel skid.
- Single-phase and 3-phase electrical service are available onsite.

4.3.4 Facility Access and Appearance

- Chain link fence with wind screen on three sides, to enclose the treatment facility
- Gravel all-weather driveway to be provided from access road to treatment equipment location

4.3.5 Equipment Location

Thermal equipment location to be finalized based on analysis of site conditions, including:

- Power service availability
- Accessibility for vehicles and operators
- Low public visibility
- Locate central to LFG main headers from Areas E and F

- Maintain minimum 50-foot clearance from overhead construction (power poles, cables, trees, etc.)
- Prevailing wind and potential exhaust plume dispersion

4.3.6 *Equipment Foundation Requirements*

- Provide cast-in-place concrete slab on grade for anchoring of blower/flare skid
- Slab design calculations required ([Attachment 6](#)), based on equipment dead and live loads, and site soil conditions
- Preliminary soil bearing capacity review is required, based on site soils

4.4 *LFG Collection System*

4.4.1 *LFG Wells*

The perimeter LFG wells for Area F have been previously designed by others. Interior LFG wells will be positioned in the likely locations of soil berms between fill trenches (high ground on past aerial photographs). Other design criteria for the interior LFG wells are as follows:

- | | |
|--------------------------------------|---|
| • General location: | Top deck crown of Area F |
| • Maximum LFG well spacing: | Approximately 300 to 400 feet, on center |
| • Setback from edge of refuse: | Approximately 200 feet minimum |
| • LFG well boring diameter: | 12-18 inches |
| • LFG well boring depth, maximum: | 70 feet b.g.s. or minimum 20 feet above groundwater table |
| • LFG well boring depth, range: | 50 to 70 feet |
| • LFG well perforated casing length: | Well depth minus 20 feet |
| • LFG well casings: | |
| - Size, perf. (bottom) section: | 4-inch |
| - Size, top section: | 4-inch |
| - Materials, bottom: | High Density Polyethylene (HDPE), SDR-17 |
| - Materials, top: | HDPE, SDR-17 |
| • Monitoring: | Access to casing interior; sample port at wellhead. Wellhead to include provisions for flow and vacuum control, gas constituent monitoring and temperature monitoring |

- LFG well boring backfill:
 - Bottom to 1-foot above perf. casing: 1 – 3 inch washed rounded stone
 - Over washed rock: 2-foot thick bentonite seal
 - Over bentonite seal: Fine-grained on-site soil
 - Over fined grained soil: Second 2-foot thick bentonite seal, integrated with final cover membrane

4.4.2 LFG Collection System Piping

- Material: Pipe: HDPE SDR-17
Fittings: HDPE SDR-11
- Size: 4-inch to 6-inch
(to minimize friction losses between wells and treatment facility per calculations in [Attachment 3](#))
- Construction: Shallow trench with 6-18 inches of compacted native soil cover
- Routing: Perimeter piping to be on native soil (outside limit of waste) except at select locations. Route piping to facilitate drainage of condensate to minimum number of low point collection sumps and to keep wells and lateral pipes free draining.
- Pipe slopes:
 - Inside limits of waste: 4 percent minimum
 - Outside limit of waste: 0.5 percent minimum
- Valves: Wafer-type PVC butterfly valves on main piping, enclosed in valve box. Viton seat and seals, stainless steel shafts
- No automated valve actuation for header switching.
- Pressure and flow monitoring ports to be installed in hand holes every 250 to 350 feet along header, to enable pressure profile measurements and to help locate GCCS air leaks.

- Vaults Lightweight, reinforced concrete or thermoplastic composites, to match existing facilities.
- Vault lids Lightweight, salt-air-corrosion resistant, locking lids

4.5 *Condensate Collection*

4.5.1 *Field Condensate Drainage*

- GCCS lateral piping on the waste surface shall be aligned to take advantage of the top deck grades to provide gravity drainage of condensate from interior wells to the main LFG header. Condensate flow through control valves shall be concurrent with LFG flow where possible.
- GCCS header piping shall be aligned to minimize the number of low spots for condensate accumulation.
- Header drain points shall be down-facing tees, minimum 4-inch diameter.

4.5.2 *Condensate Conveyance and Processing*

- Condensate collection system will consist of a small sub-grade sump, located at every low spot in the LFG header.
- Sump/tank will be cross-linked polyethylene, capacity to allow 14-day storage of maximum anticipated condensate production, for tributary wells.
- Provide sump/tank with (air sealed) connections for condensate inlet pipe, pump hose quick-connectors, venting, and 8-inch flange stub for future pump installation.
- Sump/tank will be installed in outer dual-containment, consisting of concrete pipe section with cast-in-place concrete floor.
- Condensate will be manually pumped from the collection sump and trucked to existing OU2 groundwater treatment facility for treatment. Provide gravel driveway access to each sump location.
- Sump/tanks inlet shall be designed to allow future retrofit with dedicated condensate pumping system.

4.6 *LFG Condensate Generation Estimates*

Condensate generation estimates are based on LFG generation estimates in Section 3.7 and calculation of liquid formation, assuming the LFG is saturated at the well head. The calculations of total condensate are provided in [Attachment 2](#) and the results are summarized in [Table 6](#) below. Specific capacity requirements for each condensate sump location will be estimated by proportioning the estimated total condensate generation rate over the number of tributary wells.

**Table 6 –LFG Condensate Generation Estimates
Based on EPA LandGEM Model**

Year	Area F EPA with AP-42 LFG Extraction (scfm)	Area E EPA with AP-42 LFG Extraction (scfm)	Area F Max. Condensate Generation (gpd)	Area E Max. Condensate Generation (gpd)	Total Max. Condensate Generation (gpd)	Actual Condensate Generation (gpd)
2003 (current)	94	NA	43	NA	43	15 (leg A @ 96 hrs/week)
2008	80	36	37	16	53	NA
2013	70	31	32	14	46	NA
2018	60	26	27	12	39	NA

Attachment 1
LFG Generation Model Results

Attachment 1 List

4 Fort LF
Operating Procedures

4 Fort LF

Model Results					
Year	Refuse In Place (Mg)	Methane Emission Rate (Mg/yr)	Methane Emission Rate (Cubic m/yr)	Methane (scfm)	LFG (scfm)
2004	4.23E+05	4.53E+02	6.79E+05	46	91
2005	4.23E+05	4.40E+02	6.59E+05	44	89
2006	4.23E+05	4.27E+02	6.40E+05	43	86
2007	4.23E+05	4.14E+02	6.21E+05	42	83
2008	4.23E+05	4.02E+02	6.02E+05	40	81
2009	4.23E+05	3.90E+02	5.85E+05	39	79
2010	4.23E+05	3.79E+02	5.67E+05	38	76
2011	4.23E+05	3.67E+02	5.51E+05	37	74
2012	4.23E+05	3.57E+02	5.34E+05	36	72
2013	4.23E+05	3.46E+02	5.19E+05	35	70
2014	4.23E+05	3.36E+02	5.03E+05	34	68
2015	4.23E+05	3.26E+02	4.88E+05	33	66
2016	4.23E+05	3.16E+02	4.74E+05	32	64
2017	4.23E+05	3.07E+02	4.60E+05	31	62
2018	4.23E+05	2.98E+02	4.46E+05	30	60
2019	4.23E+05	2.89E+02	4.33E+05	29	58
2020	4.23E+05	2.80E+02	4.20E+05	28	56
2021	4.23E+05	2.72E+02	4.08E+05	27	55
2022	4.23E+05	2.64E+02	3.96E+05	27	53
2023	4.23E+05	2.56E+02	3.84E+05	26	52
2024	4.23E+05	2.49E+02	3.73E+05	25	50
2025	4.23E+05	2.41E+02	3.62E+05	24	49
2026	4.23E+05	2.34E+02	3.51E+05	24	47
2027	4.23E+05	2.27E+02	3.41E+05	23	46
2028	4.23E+05	2.21E+02	3.31E+05	22	44
2029	4.23E+05	2.14E+02	3.21E+05	22	43
2030	4.23E+05	2.08E+02	3.11E+05	21	42
2031	4.23E+05	2.02E+02	3.02E+05	20	41
2032	4.23E+05	1.96E+02	2.93E+05	20	39
2033	4.23E+05	1.90E+02	2.85E+05	19	38
2034	4.23E+05	1.84E+02	2.76E+05	19	37
2035	4.23E+05	1.79E+02	2.68E+05	18	36
2036	4.23E+05	1.74E+02	2.60E+05	17	35
2037	4.23E+05	1.68E+02	2.52E+05	17	34
2038	4.23E+05	1.63E+02	2.45E+05	16	33
2039	4.23E+05	1.59E+02	2.38E+05	16	32
2040	4.23E+05	1.54E+02	2.31E+05	15	31

Operating Procedures

Model Parameters					
Lo : 100.0 0 m ³ / Mg ***** Use r Mode Selecti * k : 0.0300 1/yr ***** User Mod e Selection ***** NMOC : 400 0.00 ppmv ***** User Mode Selection ***** Methane : 50.0000 % volume Carbon Dio xide : 50.0000 % vol ume					
Landfill Parameters					
Landfill type No Co-Disposal Year Opene d : 1969 Current Year : 1978 CYear: 1979 Capacity : 240404 Mg Average Acceptance Rate Rec from Current Year to Closu re Year : 3005 /year					
Model Results					
Year	Refuse In Place (Mg)	Methane (Mg/yr)	Emission Rate (Cubic m/yr)	Methane (scfm)	LFG (scfm)
1970	0.00E+00	0.00E+00	0.00E+00	0	0
1971	3.01E+04	6.01E+01	9.02E+04	6	12
1972	6.01E+04	1.19E+02	1.78E+05	12	24
1973	9.02E+04	1.75E+02	2.63E+05	18	35
1974	1.20E+05	2.30E+02	3.45E+05	23	46
1975	1.50E+05	2.84E+02	4.25E+05	29	57
1976	1.80E+05	3.35E+02	5.03E+05	34	67
1977	2.10E+05	3.86E+02	5.78E+05	39	78
1978	2.40E+05	4.34E+02	6.51E+05	44	87
1979	2.40E+05	4.21E+02	6.32E+05	42	85
1980	2.40E+05	4.09E+02	6.13E+05	41	82
1981	2.40E+05	3.97E+02	5.95E+05	40	80
1982	2.40E+05	3.85E+02	5.77E+05	39	78
1983	2.40E+05	3.74E+02	5.60E+05	38	75
1984	2.40E+05	3.63E+02	5.44E+05	37	73
1985	2.40E+05	3.52E+02	5.28E+05	35	71
1986	2.40E+05	3.42E+02	5.12E+05	34	69
1987	2.40E+05	3.32E+02	4.97E+05	33	67
1988	2.40E+05	3.22E+02	4.82E+05	32	65
1989	2.40E+05	3.12E+02	4.68E+05	31	63
1990	2.40E+05	3.03E+02	4.54E+05	30	61
1991	2.40E+05	2.94E+02	4.41E+05	30	59
1992	2.40E+05	2.85E+02	4.28E+05	29	57
1993	2.40E+05	2.77E+02	4.15E+05	28	56
1994	2.40E+05	2.69E+02	4.03E+05	27	54
1995	2.40E+05	2.61E+02	3.91E+05	26	52
1996	2.40E+05	2.53E+02	3.79E+05	25	51
1997	2.40E+05	2.46E+02	3.68E+05	25	49

Operating Procedures

Model Results					
Year	Refuse In Place (Mg)	Methane (Mg/yr)	Emission Rate (Cubic m/yr)	Methane (scfm)	LFG (scfm)
1998	2.40E+05	2.38E+02	3.57E+05	24	48
1999	2.40E+05	2.31E+02	3.47E+05	23	47
2000	2.40E+05	2.24E+02	3.36E+05	23	45
2001	2.40E+05	2.18E+02	3.27E+05	22	44
2002	2.40E+05	2.11E+02	3.17E+05	21	43
2003	2.40E+05	2.05E+02	3.07E+05	21	41
2004	2.40E+05	1.99E+02	2.98E+05	20	40
2005	2.40E+05	1.93E+02	2.90E+05	19	39
2006	2.40E+05	1.88E+02	2.81E+05	19	38
2007	2.40E+05	1.82E+02	2.73E+05	18	37
2008	2.40E+05	1.77E+02	2.65E+05	18	36
2009	2.40E+05	1.71E+02	2.57E+05	17	34
2010	2.40E+05	1.66E+02	2.49E+05	17	33
2011	2.40E+05	1.61E+02	2.42E+05	16	32
2012	2.40E+05	1.57E+02	2.35E+05	16	32
2013	2.40E+05	1.52E+02	2.28E+05	15	31
2014	2.40E+05	1.48E+02	2.21E+05	15	30
2015	2.40E+05	1.43E+02	2.15E+05	14	29
2016	2.40E+05	1.39E+02	2.08E+05	14	28
2017	2.40E+05	1.35E+02	2.02E+05	14	27
2018	2.40E+05	1.31E+02	1.96E+05	13	26
2019	2.40E+05	1.27E+02	1.90E+05	13	26
2020	2.40E+05	1.23E+02	1.85E+05	12	25
2021	2.40E+05	1.20E+02	1.79E+05	12	24
2022	2.40E+05	1.16E+02	1.74E+05	12	23
2023	2.40E+05	1.13E+02	1.69E+05	11	23
2024	2.40E+05	1.09E+02	1.64E+05	11	22
2025	2.40E+05	1.06E+02	1.59E+05	11	21
2026	2.40E+05	1.03E+02	1.54E+05	10	21
2027	2.40E+05	9.98E+01	1.50E+05	10	20
2028	2.40E+05	9.69E+01	1.45E+05	10	20
2029	2.40E+05	9.40E+01	1.41E+05	9	19
2030	2.40E+05	9.13E+01	1.37E+05	9	18
2031	2.40E+05	8.86E+01	1.33E+05	9	18
2032	2.40E+05	8.59E+01	1.29E+05	9	17
2033	2.40E+05	8.34E+01	1.25E+05	8	17
2034	2.40E+05	8.09E+01	1.21E+05	8	16
2035	2.40E+05	7.85E+01	1.18E+05	8	16
2036	2.40E+05	7.62E+01	1.14E+05	8	15
2037	2.40E+05	7.40E+01	1.11E+05	7	15
2038	2.40E+05	7.18E+01	1.08E+05	7	14
2039	2.40E+05	6.97E+01	1.04E+05	7	14
2040	2.40E+05	6.76E+01	1.01E+05	7	14

Attachment 2
Condensate Generation Estimates

Attachment 2 List

LFG Condensate Estimates – 60 scfm
LFG Condensate Estimates – 70 scfm
LFG Condensate Estimates – 80 scfm
LFG Condensate Estimates – 94 scfm
California Temperature Normals

Project Name: FORT ORD LANDFILL - OU2 AREA F
Project No.: 783751-05150100

Date: 2/10/2003
By: SN

**LFG CONDENSATE ESTIMATE
LFG CONTROL SYSTEM
DAILY GENERATION - SUMMARY TABLE**

PERIOD:	WINTER			SPRING			SUMMER			FALL		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	10	12	62.2	12	14	66.3	14	12	70.5	1
AVG. LOW	14	44.7	17	12	45.1	14	10	49.9	12	12	52.4	1
DAILY TOTAL			27			27			25			2

PERIOD:	3 DAY WORST CASE			3 DAY BEST CASE		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	10	12	70.5	11
AVG. LOW	14	44.7	17	12	52.4	14
DAILY TOTAL			27			24

LFG FLOW DATA	
MAX. SYSTEM VACUUM	-70 in. w
MAX. SYSTEM PRESSURE	15 in. w
AVG. LFG WELL TEMP.	95 °F
MAX. LFG FLOW	60 scfm

Project Name: FORT ORD LANDFILL - OU2 AREA F
Project No.: 783751-05150100

Date: 2/10/2003
By: SN

**LFG CONDENSATE ESTIMATE
LFG CONTROL SYSTEM
DAILY GENERATION - SUMMARY TABLE**

PERIOD:	WINTER			SPRING			SUMMER			FALL		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	12	12	62.2	15	14	66.3	16	12	70.5	13
AVG. LOW	14	44.7	20	12	45.1	17	10	49.9	14	12	52.4	16
DAILY TOTAL			32			31			30			29

PERIOD:	3 DAY WORST CASE			3 DAY BEST CASE		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	12	12	70.5	13
AVG. LOW	14	44.7	20	12	52.4	16
DAILY TOTAL			32			29

LFG FLOW DATA	
MAX. SYSTEM VACUUM	-70 in. w.c.
MAX. SYSTEM PRESSURE	15 in. w.c.
AVG. LFG WELL TEMP.	95 °F
MAX. LFG FLOW	70 scfm

Note: denotes user input value

Project Name: FORT ORD LANDFILL - OU2 AREA F
Project No.: 783751-05150100

Date: 2/10/2003
By: SN

**LFG CONDENSATE ESTIMATE
LFG CONTROL SYSTEM
DAILY GENERATION - SUMMARY TABLE**

PERIOD:	WINTER			SPRING			SUMMER			FALL		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	14	12	62.2	17	14	66.3	18	12	70.5	14
AVG. LOW	14	44.7	23	12	45.1	19	10	49.9	16	12	52.4	18
DAILY TOTAL			37			36			34			33

PERIOD:	3 DAY WORST CASE			3 DAY BEST CASE		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	14	12	70.5	14
AVG. LOW	14	44.7	23	12	52.4	18
DAILY TOTAL			37			33

LFG FLOW DATA	
MAX. SYSTEM VACUUM	-70 in. w.c.
MAX. SYSTEM PRESSURE	15 in. w.c.
AVG. LFG WELL TEMP.	95 °F
MAX. LFG FLOW	80 scfm

Note: denotes user input value

Project Name: FORT ORD LANDFILL - OU2 AREA F
Project No.: 783751-05150100

Date: 2/10/2003
By: SN

**LFG CONDENSATE ESTIMATE
LFG CONTROL SYSTEM
DAILY GENERATION - SUMMARY TABLE**

PERIOD:	WINTER			SPRING			SUMMER			FALL		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	16	12	62.2	20	14	66.3	21	12	70.5	17
AVG. LOW	14	44.7	27	12	45.1	22	10	49.9	19	12	52.4	22
DAILY TOTAL			43			42			40			38

PERIOD:	3 DAY WORST CASE			3 DAY BEST CASE		
	HRS.	@ TEMP (F)	FLOW (gpd)	HRS.	@ TEMP (F)	FLOW (gpd)
AVG. HIGH	10	61.6	16	12	70.5	17
AVG. LOW	14	44.7	27	12	52.4	22
DAILY TOTAL			43			38

LFG FLOW DATA	
MAX. SYSTEM VACUUM	-70 in. w.c.
MAX. SYSTEM PRESSURE	15 in. w.c.
AVG. LFG WELL TEMP.	95 °F
MAX. LFG FLOW	94 scfm

Note: denotes user input value

CALIFORNIA

TEMPERATURE NORMALS (DEG F)

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
LOS ANGELES CIVIC CTR 2400 LT	NORMAL MAX	67.7	69.4	69.5	72.3	73.3	78.3	84.0	84.0	82.7	79.0	72.0	67.0	75.1
	NORMAL MIN	50.0	50.0	50.0	50.0	50.0	61.1	64.0	64.0	62.7	60.0	57.0	50.0	55.9
	NORMAL MEDIAN	58.0	60.0	60.0	60.0	60.0	65.0	70.0	70.0	67.0	65.0	60.0	55.0	60.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LOS BANOS 1000 LT	NORMAL MAX	64.5	67.7	67.7	74.3	82.1	89.6	95.6	94.0	88.0	79.0	65.1	54.5	75.7
	NORMAL MIN	35.0	35.0	42.6	46.1	56.6	56.6	70.0	70.0	60.0	44.0	35.0	35.0	48.1
	NORMAL MEDIAN	45.0	45.0	45.0	45.0	57.0	73.0	73.0	73.0	65.0	50.0	40.0	40.0	52.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LOS GATOS 1700 LT	NORMAL MAX	58.6	62.7	65.4	70.5	75.9	81.8	85.7	85.7	82.0	77.0	68.0	55.0	72.0
	NORMAL MIN	37.0	37.0	41.1	43.0	46.7	50.0	55.0	55.0	50.0	44.0	37.0	30.0	40.0
	NORMAL MEDIAN	47.0	47.0	47.0	47.0	50.0	50.0	55.0	55.0	50.0	44.0	37.0	30.0	40.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MADERA 0800 LT	NORMAL MAX	53.0	61.4	66.7	74.2	82.0	91.6	97.0	96.1	90.0	80.4	65.0	50.0	76.2
	NORMAL MIN	35.0	35.0	41.9	46.1	56.6	56.6	70.0	70.0	60.0	44.0	35.0	35.0	48.1
	NORMAL MEDIAN	44.0	44.0	44.0	44.0	57.0	73.0	73.0	73.0	65.0	50.0	40.0	40.0	52.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MANZANITA LAKE 0800 LT	NORMAL MAX	42.6	43.5	44.3	51.0	60.8	69.9	78.3	77.0	70.0	60.0	47.0	42.0	57.0
	NORMAL MIN	21.0	21.0	22.7	27.1	34.0	41.1	47.0	44.0	44.0	44.0	44.0	44.0	44.0
	NORMAL MEDIAN	31.0	31.0	31.0	31.0	34.0	41.1	47.0	44.0	44.0	44.0	44.0	44.0	44.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MARICOPA 0800 LT	NORMAL MAX	56.3	63.0	68.1	75.0	84.0	92.3	97.8	95.9	89.6	80.0	65.0	50.0	77.1
	NORMAL MIN	35.0	35.0	41.9	46.1	56.6	56.6	70.0	70.0	60.0	44.0	35.0	35.0	48.1
	NORMAL MEDIAN	45.0	45.0	45.0	45.0	57.0	73.0	73.0	73.0	65.0	50.0	40.0	40.0	52.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MARYSVILLE 0900 LT	NORMAL MAX	53.3	61.5	66.6	73.5	82.5	90.2	96.0	94.3	88.0	79.1	64.1	54.4	75.4
	NORMAL MIN	37.0	37.0	41.1	43.0	46.7	50.0	55.0	55.0	50.0	44.0	37.0	30.0	40.0
	NORMAL MEDIAN	45.0	45.0	45.0	45.0	50.0	50.0	55.0	55.0	50.0	44.0	37.0	30.0	40.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MC CLOUD 0700 LT	NORMAL MAX	47.3	49.9	53.3	56.0	60.8	70.0	75.1	82.0	86.0	79.0	65.0	46.0	65.0
	NORMAL MIN	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	NORMAL MEDIAN	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MECCA FIRE STATION 1700 LT	NORMAL MAX	70.1	75.5	80.4	87.9	95.2	103.4	107.3	106.2	101.3	91.0	78.0	70.0	89.0
	NORMAL MIN	38.1	38.1	40.0	45.0	55.0	67.1	73.0	73.0	65.0	50.0	44.0	44.0	55.0
	NORMAL MEDIAN	54.0	54.0	54.0	54.0	57.0	65.0	70.0	70.0	65.0	50.0	44.0	44.0	55.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MERCED MUNICIPAL AP 1700 LT	NORMAL MAX	54.5	62.3	67.4	74.9	83.7	91.4	96.9	95.0	90.0	80.0	65.0	50.0	75.0
	NORMAL MIN	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
	NORMAL MEDIAN	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MINERAL 0800 LT	NORMAL MAX	41.9	43.9	46.0	52.9	62.6	71.7	80.5	80.0	72.0	62.0	47.0	41.0	58.0
	NORMAL MIN	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	NORMAL MEDIAN	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MITCHELL CAVERNS 1600 LT	NORMAL MAX	54.2	67.5	61.1	69.2	78.2	88.4	93.7	91.1	84.1	74.0	60.0	50.0	70.0
	NORMAL MIN	37.0	37.0	41.1	43.0	46.7	50.0	55.0	55.0	50.0	44.0	37.0	30.0	40.0
	NORMAL MEDIAN	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MODESTO 2400 LT	NORMAL MAX	53.5	61.9	67.1	73.8	81.5	88.9	94.3	92.4	87.5	78.0	65.0	53.0	74.7
	NORMAL MIN	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
	NORMAL MEDIAN	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MOJAVE 1600 LT	NORMAL MAX	55.4	62.4	65.0	71.6	80.6	90.4	97.4	95.5	89.0	79.1	65.0	50.0	75.0
	NORMAL MIN	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
	NORMAL MEDIAN	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MONTEREY 1800 LT	NORMAL MAX	55.0	61.5	61.0	64.4	64.1	66.0	68.1	65.5	71.9	70.1	64.0	59.0	65.1
	NORMAL MIN	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
	NORMAL MEDIAN	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	MID OBS TIME ADJ MAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MID OBS TIME ADJ MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NOTE: 1. ADJUSTMENT FACTORS WILL ADJUST TEMPERATURE TO MIDNIGHT OBSERVATION TIME.
2. TIME APPEARING UNDER STATION NAME IS CURRENT OBSERVATION TIME.

Attachment 3
Pipe Size Calculations

Attachment 3 List

Pressure Drop Chart for LFG Flow through Lateral

Pressure Drop Chart for LFG Flow through Piping - Leg B (4 to 6 inch header)

Pressure Drop Chart for LFG Flow through Piping - Leg B (6 inch header)

Pressure Drop Chart for LFG Flow through Piping - Leg C (4 to 6 inch header)

PRESSURE DROP CHART FOR LFG FLOW THROUGH LATERAL

Project: 783751-05149810

Fort Ord - Area F

Head loss calculation estimate for 350 ft 3" HDPE SDR-17 lateral

2/5/2003

$H_{100} = 2.74 * (q / ((d^{12})^{2*3.14/4}))^{1.9} / d^{1.22}$ (equation used to develop the Crane friction loss chart)

where: H_{100} =friction pressure drop in 100 ft of pipe, inch W.C.

q=gas flowrate,cu ft/min

d=internal diameter of pipe, inches

Flow at or between point or node	IPS pipe size inch	d pipe size inch	pipe length feet	minor losses feet	L total equiv. length	qt trib. flow scfm	v velocity f/s	H100 headloss in 100 ft inch W.C.	HL headloss in "L" ft inch W.C.	HL process units inch W.C.	HL total inch W.C.	Pv suction max. inch W.C.	NUMBER OF MINOR LOSSES				
													hard tees	soft tees	elbows	open valves	red./exp.
EW												0.00					
	3	3.088	350	36	386	100	32.1	2.40	9.25	0.00	9.25				3	1	1
Header												-9.25					
EW												0.00					
	3	3.088	350	36	386	20	6.4	0.11	0.43	0.00	0.43				3	1	1
Header												-0.43					
EW												0.00					
	3	3.088	350	36	386	25	8.0	0.17	0.66	0.00	0.66				3	1	1
Header												-0.66					

**PRESSURE DROP CHART FOR LFG FLOW THROUGH PIPING - LEG B
(4 TO 6 INCH HEADER)**

Project: 783751-05149810

Fort Ord - Area F

Head loss calculation estimate for current treatment equipment location, 700 ft. away from Leg B - Current flowrate operation,
w/4 VS85-300 GACs, 5 VS55-200 ZK6;
4-inch hose between treatment vessels; Head losses based on maximum pressure drops provided by site for October 1, 2001.
2/5/2003 Blower at exhaust end of process.

H100=2.74*(q/((d*12)^2*3.14/4))^1.9/d^1.22 (equation used to develop the Crane friction loss chart)
where: H100=friction pressure drop in 100 ft of pipe, inch W.C.
q=gas flowrate,cu ft/min
d=internal diameter of pipe, inches

Flow at or between point or node	IPS pipe size inch	d pipe size inch	pipe length feet	minor losses feet	L total equiv. length	qt trib. flow scfm	qT flow rate acfm	v velocity f/s	H100 headloss in 100 ft inch W.C.	HL headloss in "L" ft inch W.C.	HL process units inch W.C.	HL total inch W.C.	Pv suction max. inch W.C.	NUMBER OF MINOR LOSSES				
														hard tees	soft tees	elbows	open valves	red./exp.
EW12													-3.00					
	4	3.97	210	43	253	14	14	2.7	0.02	0.04	0.00	0.04				3	1	
EW13													-3.04					
	4	3.97	210	7	217	14	28	5.5	0.06	0.13	0.00	0.13			1			
EW14													-3.17					
	4	3.97	210	7	217	14	42	8.2	0.13	0.29	0.00	0.29			1			
EW15													-3.46					
	4	3.97	210	7	217	14	56	11.0	0.23	0.50	0.00	0.50			1			
EW16													-3.96					
	4	3.97	210	7	217	14	71	13.7	0.35	0.76	0.00	0.76			1			
EW17													-4.72					
	4	3.97	210	7	217	14	85	16.5	0.50	1.08	0.00	1.08			1			
EW18													-5.80					
	4	3.97	210	7	217	14	99	19.3	0.67	1.46	0.00	1.46			1			
EW19													-7.26					
	4	3.97	210	7	217	14	114	22.1	0.87	1.89	0.00	1.89			1			
EW20													-9.15					
	4	3.97	210	13	223	14	129	25.0	1.10	2.46	0.00	2.46			2			
EW21													-11.61					
	4	3.97	210	26	236	14	144	27.96	1.36	3.22	0.00	3.22			1	2		
EW22													-14.83					
	6	5.845	700	39	739	14	160	14.30	0.24	1.76	0.00	1.76		1	1			
kop in													-16.58					
	4	4	4	79	83	0	161	30.68	1.61	1.34	2.00	3.34		1		3	1	6
GAC 1/3													-19.93					
	4	4	4	11	15	0	81	15.47	0.44	0.06	2.50	2.56						4
GAC 2/4													-22.49					
	4	4	12	69	81	0	82	15.57	0.44	0.36	2.50	2.86		1		2	1	6
KMnO4-1													-25.35					
	4	4	6	16	22	0	164	31.38	1.68	0.37	8.00	8.37						6
KMnO4-2													-33.72					
	4	4	6	46	52	0	168	32.09	1.75	0.91	8.00	8.91				3		6

**PRESSURE DROP CHART FOR LFG FLOW THROUGH PIPING - LEG B
(4 TO 6 INCH HEADER)**

Project: 783751-05149810

Fort Ord - Area F

Head loss calculation estimate for current treatment equipment location, 700 ft. away from Leg B - Current flowrate operation,
w/4 VS85-300 GACs, 5 VS55-200 ZK6;
4-inch hose between treatment vessels; Head losses based on maximum pressure drops provided by site for October 1, 2001.
2/5/2003 Blower at exhaust end of process.

$H_{100} = 2.74 * (q / ((d * 12)^2 * 3.14 / 4))^{1.9} / d^{1.22}$ (equation used to develop the Crane friction loss chart)

where: H_{100} = friction pressure drop in 100 ft of pipe, inch W.C.

q = gas flowrate, cu ft/min

d = internal diameter of pipe, inches

Flow at or between point or node	IPS pipe size inch	d pipe size inch	pipe length feet	minor losses feet	L total equiv. length	qt trib. flow scfm	qT flow rate acfm	v velocity f/s	H100 headloss in 100 ft inch W.C.	HL headloss in "L" ft inch W.C.	HL process units inch W.C.	HL total inch W.C.	Pv suction max. inch W.C.	NUMBER OF MINOR LOSSES				
														hard tees	soft tees	open elbows valves	red./exp.	
KMnO4-3													-42.63					
	4	4	6	46	52	0	172	32.87	1.84	0.95	8.00	8.95				3		6
KMnO4-4													-51.59					
	4	4	6	46	52	0	176	33.70	1.92	1.00	8.00	9.00				3		6
KMnO4-5													-60.59					
	4	4	6	46	52	0	181	34.58	2.02	1.05	8.00	9.05				3		6
blower 1 in													-69.64					
	4	4	8	5	13	0	186	35.50	2.12	0.28	-70.00	-69.72						2
Accuflo													0.08					
	3	3	10	4	14	0	154	52.30	6.30	0.88	0.00	0.88						2
exhaust													-0.80					
TOTALS			2868	536.7	3405	154				19.35	47.0	68.83						

**PRESSURE DROP CHART FOR LFG FLOW THROUGH PIPING - LEG B
(6-INCH HEADER)**

PROJECT: 783751-05149810

Fort Ord - Area F

Head loss calculation estimate for current treatment equipment location, 700 ft. away from Leg B - Current flowrate operation, w/4 VS85-300 GACs, 5 VS55-200 ZK6; 6-inch header; 4-inch hose between treatment vessels; Head losses based on maximum pressure drops provided by site for October 1, 2001.

2/5/2003 Blower at exhaust end of process.

$H_{100} = 2.74 * (q / ((d * 12)^2 * 3.14 / 4))^{1.9} / d^{1.22}$ (equation used to develop the Crane friction loss chart)

where: H_{100} = friction pressure drop in 100 ft of pipe, inch W.C.

q = gas flowrate, cu ft/min

d = internal diameter of pipe, inches

Flow at or between point or node	IPS pipe size inch	d pipe size inch	pipe length feet	minor losses feet	L total equiv. length	qt trib. flow scfm	qT flow rate acfm	v velocity f/s	H100 headloss in 100 ft inch W.C.	HL headloss in "L" ft inch W.C.	HL process units inch W.C.	HL total inch W.C.	Pv suction max. inch W.C.	NUMBER OF MINOR LOSSES			
														hard tees	soft tees	open elbows valves	red./exp.
EW12													-3.00				
	6	5.85	210	63	273	19	19	1.7	0.00	0.01	0.00	0.01				3	1
EW13													-3.01				
	6	5.85	210	10	220	19	38	3.4	0.02	0.03	0.00	0.03			1		
EW14													-3.05				
	6	5.85	210	10	220	19	57	5.1	0.03	0.07	0.00	0.07			1		
EW15													-3.12				
	6	5.85	210	10	220	19	77	6.8	0.06	0.13	0.00	0.13			1		
EW16													-3.25				
	6	5.85	210	10	220	19	96	8.6	0.09	0.20	0.00	0.20			1		
EW17													-3.45				
	6	5.85	210	10	220	19	115	10.3	0.13	0.28	0.00	0.28			1		
EW18													-3.72				
	6	5.85	210	10	220	19	134	12.0	0.17	0.37	0.00	0.37			1		
EW19													-4.10				
	6	5.85	210	10	220	19	154	13.7	0.22	0.48	0.00	0.48			1		
EW20													-4.58				
	6	5.85	210	20	230	19	173	15.5	0.27	0.63	0.00	0.63			2		
EW21													-5.21				
	6	5.85	210	39	249	19	192	17.19	0.34	0.84	0.00	0.84			1	2	
EW22													-6.05				
	6	5.845	700	39	739	19	212	18.99	0.41	3.01	0.00	3.01		1	1		
kop in													-9.06				
	4	4	4	79	83	0	214	40.85	2.77	2.31	2.00	4.31		1		3	1
GAC 1/3													-13.37				
	4	4	4	11	15	0	108	20.65	0.76	0.11	2.50	2.61					4

**PRESSURE DROP CHART FOR LFG FLOW THROUGH PIPING - LEG B
(6-INCH HEADER)**

PROJECT: 783751-05149810

Fort Ord - Area F

Head loss calculation estimate for current treatment equipment location, 700 ft. away from Leg B - Current flowrate operation, w/4 VS85-300 GACs, 5 VS55-200 ZK6; 6-inch header; 4-inch hose between treatment vessels; Head losses based on maximum pressure drops provided by site for October 1, 2001.

2/5/2003 Blower at exhaust end of process.

$H_{100} = 2.74 * (q / ((d * 12)^2 * 3.14 / 4))^{1.9} / d^{1.22}$ (equation used to develop the Crane friction loss chart)

where: H100=friction pressure drop in 100 ft of pipe, inch W.C.

q=gas flowrate,cu ft/min

d=internal diameter of pipe, inches

Flow at or between point or node	IPS pipe size inch	d pipe size inch	pipe length feet	minor losses feet	L total equiv. length	qt trib. flow scfm	qT flow rate acfm	v velocity f/s	H100 headloss in 100 ft inch W.C.	HL headloss in "L" ft inch W.C.	HL process units inch W.C.	HL total inch W.C.	Pv suction max. inch W.C.	NUMBER OF MINOR LOSSES				
														hard tees	soft tees	open elbows	valves	red./exp.
GAC 2/4													-15.98					
	4	4	12	69	81	0	109	20.78	0.77	0.62	2.50	3.12		1		2	1	6
KMnO4-1													-19.10					
	4	4	6	16	22	0	219	41.90	2.91	0.64	8.00	8.64						6
KMnO4-2													-27.74					
	4	4	6	46	52	0	224	42.86	3.04	1.58	8.00	9.58				3		6
KMnO4-3													-37.32					
	4	4	6	46	52	0	230	43.97	3.19	1.66	8.00	9.66				3		6
KMnO4-4													-46.98					
	4	4	6	46	52	0	236	45.15	3.35	1.74	8.00	9.74				3		6
KMnO4-5													-56.73					
	4	4	6	46	52	0	243	46.41	3.53	1.84	8.00	9.84				3		6
blower 1 in													-66.56					
	4	4	8	5	13	0	250	47.75	3.73	0.50	-70.00	-69.50						2
Accuflo													2.94					
	3	3	10	4	14	0	208	70.49	11.11	1.55	0.00	1.55						2
exhaust													1.38					
TOTALS			2868	597.8	3466	209				16.07	47.0	67.95						

**PRESSURE DROP CHART FOR LFG FLOW THROUGH PIPING - LEG C
(4 TO 6 INCH HEADER)**

Project: 783751-05149810

Fort Ord - Area F

Head loss calculation estimate for current treatment equipment location, 700 ft. away from Leg C - Current flowrate operation,
w/4 VS85-300 GACs, 5 VS55-200 ZK6;

4-inch hose between treatment vessels; Head losses based on maximum pressure drops provided by site for October 1, 2001.

2/5/2003 Blower at exhaust end of process.

$H_{100} = 2.74 * (q / ((d * 12)^2 * 3.14 / 4))^2 * 1.9 / d^{1.22}$ (equation used to develop the Crane friction loss chart)

where: H100=friction pressure drop in 100 ft of pipe, inch W.C.

q=gas flowrate,cu ft/min

d=internal diameter of pipe, inches

Flow at or between point or node	IPS pipe size inch	d pipe size inch	pipe length feet	minor losses feet	L total equiv. length	qt trib. flow scfm	qT flow rate acfm	v velocity f/s	H100 headloss in 100 ft inch W.C.	HL headloss in "L" ft inch W.C.	HL process units inch W.C.	HL total inch W.C.	Pv suction max. inch W.C.	NUMBER OF MINOR LOSSES				
														hard tees	soft tees	elbows	open valves	red./exp.
EW29	4	3.97	200	43	243	21	21	4.1	0.04	0.09	0.00	0.09	-3.00			3	1	
EW28	4	3.97	200	7	207	21	42	8.2	0.13	0.27	0.00	0.27	-3.09		1			
EW27	4	3.97	200	7	207	21	64	12.3	0.29	0.59	0.00	0.59	-3.36		1			
EW26	4	3.97	200	7	207	21	85	16.5	0.50	1.03	0.00	1.03	-3.95		1			
EW25	6	5.85	200	10	210	21	106	9.5	0.11	0.23	0.00	0.23	-4.98		1			
EW24	6	5.85	200	24	224	21	128	11.4	0.15	0.35	0.00	0.35	-5.21		1	1		
EW23	6	5.85	200	10	210	21	149	13.3	0.21	0.43	0.00	0.43	-5.56		1			
Tee	6	5.845	700	29	729	0	149	13.4	0.21	1.52	0.00	1.52	-5.99	1				
kop in	4	4	4	79	83	0	150	28.62	1.41	1.18	2.00	3.18	-7.51	1		3	1	6
GAC 1/3	4	4	4	11	15	0	75	14.42	0.38	0.06	2.50	2.56	-10.69					4
GAC 2/4	4	4	12	69	81	0	76	14.52	0.39	0.32	2.50	2.82	-13.24	1		2	1	6
KMnO4-1	4	4	6	16	22	0	153	29.24	1.47	0.32	8.00	8.32	-16.06					6
KMnO4-2	4	4	6	46	52	0	156	29.88	1.53	0.80	8.00	8.80	-24.38			3		6
KMnO4-3	4	4	6	46	52	0	160	30.58	1.60	0.83	8.00	8.83	-33.18			3		6
KMnO4-4													-42.01					

**PRESSURE DROP CHART FOR LFG FLOW THROUGH PIPING - LEG C
(4 TO 6 INCH HEADER)**

Project: 783751-05149810

Fort Ord - Area F

Head loss calculation estimate for current treatment equipment location, 700 ft. away from Leg C - Current flowrate operation,
w/4 VS85-300 GACs, 5 VS55-200 ZK6;

4-inch hose between treatment vessels; Head losses based on maximum pressure drops provided by site for October 1, 2001.

2/5/2003 Blower at exhaust end of process.

$H_{100} = 2.74 * (q / ((d * 12)^2 * 3.14 / 4))^{1.9} / d^{1.22}$ (equation used to develop the Crane friction loss chart)

where: H100=friction pressure drop in 100 ft of pipe, inch W.C.

q=gas flowrate,cu ft/min

d=internal diameter of pipe, inches

Flow at or between point or node	IPS pipe size inch	d pipe size inch	pipe length feet	minor losses feet	L total equiv. length	qt trib. flow scfm	qT flow rate acfm	v velocity f/s	H100 headloss in 100 ft inch W.C.	HL headloss in "L" ft inch W.C.	HL process units inch W.C.	HL total inch W.C.	Pv suction max. inch W.C.	NUMBER OF MINOR LOSSES				
														hard tees	soft tees	open elbows	valves	red./exp.
KMnO4-5	4	4	6	46	52	0	164	31.32	1.67	0.87	8.00	8.87	-50.88			3		6
	4	4	6	46	52	0	168	32.10	1.75	0.91	8.00	8.91				3		6
blower 1 in													-59.79					
	4	4	8	5	13	0	172	32.93	1.84	0.25	-70.00	-69.75						2
Accuflo													9.96					
	3	3	10	4	14	0	143	48.74	5.51	0.77	0.00	0.77						2
exhaust													9.19					
TOTALS			2168	504.6	2673	147				9.55	47.0	68.98						

Attachment 4
Construction Cost Estimates

Attachment 4 List

Costs for Gas Collection Construction 2003

Gas Collection and Control System – Flare Construction

Gas Collection and Control System – Thermox Construction

Gas Collection and Control System – Area F Wellfield Construction

OU-2 LANDFILL FORMER FORT ORD, CALIFORNIA

COSTS FOR GAS COLLECTION CONSTRUCTION 2003

ITEM / DESCRIPTION	FLARE SYSTEM	WELLFIELD SYSTEM	TOTAL FLARE+WELLS	THERMOX SYSTEM
DRILLING (5 wells in central Area F)	\$0	\$30,166	\$30,166	\$0
PIPELINE (from Area F wells to treatment facility)	\$0	\$40,336	\$40,336	\$0
VALVES AND VAULTS	\$0	\$5,625	\$5,625	\$0
TREATMENT EQUIPMENT PACKAGE	\$112,800	\$0	\$112,800	\$45,586
EQUIPMENT INSTALLATION SITE WORK	\$35,795	\$0	\$35,795	\$43,295
ENGINEERING AND DOCUMENTATION	\$2,000	\$3,900	\$5,900	\$2,000
SUBTOTAL	\$150,595	\$80,026	\$230,621	\$90,881
P&O	\$14,005	\$7,442	\$21,448	\$8,452
TOTAL	\$164,600	\$87,469	\$252,069	\$99,333

**GAS COLLECTION AND CONTROL SYSTEM
SCHEDULE OF VALUES
OU-2 LANDFILL - FORMER FORT ORD, CALIFORNIA
FLARE CONSTRUCTION
Submitted By: EMCON/OWT Solid Waste Services**

<u>DESCRIPTION</u>	<u>UNIT</u>	<u>QTY</u>	<u>UNIT PRICE</u>	<u>TOTAL</u>	<u>SUBTOTAL</u>
<u>DRILLING</u>					
MOBILIZATION	EA		3,500.00	-	
WELL DRILLING 18" DIAMETER	LF		30.00	-	
WELL CASING / COMPLETION	LF		28.00	-	
GRAVEL (1-3")	TON		20.00	-	
BENTONITE GROUT	SACK		8.50	-	
ON-SITE TRUCKING	DAY		550.00	-	
UXO CLEARANCE	DAY		1,000.00	-	
MATERIAL FREIGHT	LS		800.00	-	-
<u>PIPELINE INSTALLATION</u>					
MOBILIZATION	EA		6,000.00	-	
2" PIPE MATERIAL (HDPE SDR 17)	LF		0.65	-	
2" PIPE INSTALL (shallow trench)	LF		6.00	-	
2" PIPE INSTALL (road crossing)	LF		8.00	-	
4" PIPE MATERIAL (HDPE SDR 17)	LF		1.35	-	
4" PIPE INSTALL (shallow trench)	LF		11.00	-	
4" PIPE INSTALL (road crossing)	LF		14.00	-	
6" PIPE MATERIAL (HDPE SDR 17)	LF		2.60	-	
6" PIPE INSTALL (shallow trench)	LF		11.00	-	
6" PIPE INSTALL (road crossing)	LF		14.00	-	
6" X 6" X 4" LATERAL CONNECTION	EA		58.00	-	
4" X 2" CONDENSATE TANK CONNECTIO	EA		38.00	-	
OTHER FITTINGS (allowance) Estimate @ 2.5% of Pipeline Cost To be Provided at Cost Plus 10%	LS		-	-	
ROAD CROSSING MATERIAL (12" CMP)	LF		25.00	-	
ON-SITE TRUCKING	DAY		550.00	-	
SAND BEDDING	TON		-	-	
MATERIAL FREIGHT	LS		1,200.00	-	-

<u>DESCRIPTION</u>	<u>UNIT</u>	<u>QTY</u>	<u>UNIT PRICE</u>	<u>TOTAL</u>	<u>SUBTOTAL</u>
<u>VALVES AND VAULTS</u>					
BUTTERFLY VALVE 6" (shallow trench)	EA		1,450.00	-	
BUTTERFLY VALVE 4" (shallow trench)	EA		2,900.00	-	
LANDTEC 2" WELLHEADS	EA		450.00	-	
MONITORING PORT	EA		45.00	-	
CONCRETE VAULT W/ALUMINUM LID	EA		1,050.00	-	
CONCRETE HAND HOLE W/ALUMINUM LID	EA		120.00	-	
MATERIAL FREIGHT	LS		800.00	-	
<u>CONDENSATE TANK</u>					
CONDENSATE SUMP W/ CONTAINMENT	EA		4,000.00	-	-
<u>ENCLOSED FLARE / BLOWER EQUIPMENT PACKAGE (LFG SPECIALTIES, INC.)</u>					
100 CFM LFG ENCLOSED FLARE (W/CON	EA	1	39,100.00	39,100	
BLOWER SKID UNIT (W/CONTROLS)	EA	1	64,750.00	64,750	
START-UP TECHNICIAN	DAYS	3	750.00	2,250	
START-UP TECHNICIAN EXPENSES	DAYS	3	400.00	1,200	
EQUIPMENT SHIPPING ALLOWANCE	EA	1	5,500.00	5,500	
SALES TAX ON FLARE PURCHASE	LS	0	-	-	<u>112,800</u>
<u>MISCELLANEOUS FLARE SITE WORK</u>					
MOBILIZATION	EA	1	4,000.00	4,000	
ENGINEERED FOUNDATION SUB-GRADE	CY	20	40.00	800	
CONCRETE FOUNDATIONS	CY	15	370.00	5,550	
EQUIPMENT PACKAGE INSTALLATION LA	HR	40	150.00	6,000	
CRANE RENTAL	HR	8	250.00	2,000	
EQUIPMENT AREA PIPING & FITTINGS	LS	1	1,800.00	1,800	
ELECTRICAL LABOR ALLOWANCE	HR	80	85.00	6,800	
ELECTRICAL MISC. MATERIALS ALLOWA	LS	1	2,200.00	2,200	
SUPPLEMENTAL FUEL SUPPLY	LS	0	7,500.00	-	
1-1/2" AB, 6" THICK	SF	1630	1.50	2,445	

<u>DESCRIPTION</u>	<u>UNIT</u>	<u>QTY</u>	<u>UNIT PRICE</u>	<u>TOTAL</u>	<u>SUBTOTAL</u>
CHAIN LINK FENCE	LF	138	20.00	2,760	
GATE (DOUBLE SWING, 12')	LF	24	60.00	1,440	<u>35,795</u>
<u>ENGINEERING AND DOCUMENTATION</u>					
CONCRETE SAMPLING / TESTING	EA	4	200.00	800	
SURVEYING	HR	0	150.00	-	
AS-BUILTS	LS	1	1,200.00	1,200	<u>2,000</u>
<u>CONSTRUCTION COST TOTAL:</u>				----- 150,595	----- 150,595
BONDING	%	2.3	3,463.69	3,464	
CONTRACTOR PROFIT & OVERHEAD	%	7	10,541.65	10,542	14,005
<u>CONTRACT TOTAL:</u>				----- 164,600	-----

**GAS COLLECTION AND CONTROL SYSTEM
SCHEDULE OF VALUES
OU-2 LANDFILL - FORMER FORT ORD, CALIFORNIA
THERMOX CONSTRUCTION
Submitted By: EMCON/OWT Solid Waste Services**

<u>DESCRIPTION</u>	<u>UNIT</u>	<u>QTY</u>	<u>UNIT PRICE</u>	<u>EXTENSION</u>	<u>SUBTOTAL</u>
<u>DRILLING</u>					
MOBILIZATION	EA		3,500.00	-	
WELL DRILLING 18" DIAMETER	LF		30.00	-	
WELL CASING / COMPLETION	LF		28.00	-	
GRAVEL (1-3")	TON		20.00	-	
BENTONITE GROUT	SACK		8.50	-	
ON-SITE TRUCKING	DAY		550.00	-	
UXO CLEARANCE	DAY		1,000.00	-	
MATERIAL FREIGHT	LS		800.00	-	\$ -
<u>PIPELINE INSTALLATION</u>					
MOBILIZATION	EA		6,000.00	-	
2" PIPE MATERIAL (HDPE SDR 17)	LF		0.65	-	
2" PIPE INSTALL (shallow trench)	LF		6.00	-	
2" PIPE INSTALL (road crossing)	LF		8.00	-	
4" PIPE MATERIAL (HDPE SDR 17)	LF		1.35	-	
4" PIPE INSTALL (shallow trench)	LF		11.00	-	
4" PIPE INSTALL (road crossing)	LF		14.00	-	
6" PIPE MATERIAL (HDPE SDR 17)	LF		2.60	-	
6" PIPE INSTALL (shallow trench)	LF		11.00	-	
6" PIPE INSTALL (road crossing)	LF		14.00	-	
6" X 6" X 4" LATERAL CONNECTION	EA		58.00	-	
4" X 2" CONDENSATE TANK CONNECTION	EA		38.00	-	
OTHER FITTINGS (allowance) Estimate @ 2.5% of Pipeline Cost To be Provided at Cost Plus 10%	LS		-	-	
ROAD CROSSING MATERIAL (12" CMP)	LF		25.00	-	
ON-SITE TRUCKING	DAY		550.00	-	
SAND BEDDING	TON		-	-	
MATERIAL FREIGHT	LS		1,200.00	-	\$ -

<u>DESCRIPTION</u>	<u>UNIT</u>	<u>QTY</u>	<u>UNIT PRICE</u>	<u>EXTENSION</u>	<u>SUBTOTAL</u>
<u>VALVES AND VAULTS</u>					
BUTTERFLY VALVE 6" (shallow trench)	EA		1,450.00	-	
BUTTERFLY VALVE 4" (shallow trench)	EA		2,900.00	-	
LANDTEC 2" WELLHEADS	EA		450.00	-	
MONITORING PORT	EA		45.00	-	
CONCRETE VAULT W/ALUMINUM LID	EA		1,050.00	-	
CONCRETE HAND HOLE W/ALUMINUM LID	EA		120.00	-	
MATERIAL FREIGHT	LS		800.00	-	
<u>CONDENSATE TANK</u>					
CONDENSATE SUMP W/ CONTAINMENT	EA		4,000.00	-	\$ -
<u>THERMOX / BLOWER EQUIPMENT PACKAGE (King, Buck Technology)</u>					
300 CFM SVE THERMOX (W/CONTROLS)	EA	1	29,436.00	29,436	
BLOWER SKID UNIT (W/CONTROLS)	EA	1	11,500.00	11,500	
START-UP TECHNICIAN	DAYS	3	750.00	2,250	
START-UP TECHNICIAN EXPENSES	DAYS	3	400.00	1,200	
EQUIPMENT SHIPPING ALLOWANCE	EA	1	1,200.00	1,200	
SALES TAX ON FLARE PURCHASE	LS	0	-	-	\$ 45,586
<u>MISCELLANEOUS FACILITY SITE WORK</u>					
MOBILIZATION	EA	1	4,000.00	4,000	
ENGINEERED FOUNDATION SUB-GRADE	CY	20	40.00	800	
CONCRETE FOUNDATIONS	CY	15	370.00	5,550	
EQUIPMENT PACKAGE INSTALLATION LABOR	HR	40	150.00	6,000	
CRANE RENTAL	HR	8	250.00	2,000	
EQUIPMENT AREA PIPING & FITTINGS	LS	1	1,800.00	1,800	
ELECTRICAL LABOR ALLOWANCE	HR	80	85.00	6,800	
ELECTRICAL MISC. MATERIALS ALLOWANCE	LS	1	2,200.00	2,200	
SUPPLEMENTAL FUEL SUPPLY	LS	1	7,500.00	7,500	
1-1/2" AB, 6" THICK	SF	1630	1.50	2,445	

<u>DESCRIPTION</u>	<u>UNIT</u>	<u>QTY</u>	<u>UNIT PRICE</u>	<u>EXTENSION</u>	<u>SUBTOTAL</u>
CHAIN LINK FENCE	LF	138	20.00	2,760	
GATE (DOUBLE SWING, 12')	LF	24	60.00	1,440	<u>\$ 43,295</u>
<u>ENGINEERING AND DOCUMENTATION</u>					
CONCRETE SAMPLING / TESTING	EA	4	200.00	800	
SURVEYING	HR	0	150.00	-	
AS-BUILTS	LS	1	1,200.00	1,200	<u>\$ 2,000</u>
<u>CONSTRUCTION COST TOTAL:</u>				-----	-----
				90,881	90,881.00
BONDING	%	2.3	2,090.26	2,090	
CONTRACTOR PROFIT & OVERHEAD	%	7	6,361.67	6,362	8,452
<u>CONTRACT TOTAL:</u>				-----	-----
				99,333	

GAS COLLECTION AND CONTROL SYSTEM
SCHEDULE OF VALUES
OU-2 LANDFILL - FORMER FORT ORD, CALIFORNIA
AREA F WELLFIELD CONSTRUCTION
Submitted By: EMCON/OWT Solid Waste Services

<u>DESCRIPTION</u>	<u>UNIT</u>	<u>QTY</u>	<u>UNIT PRICE</u>	<u>TOTAL</u>	<u>SUBTOTAL</u>
<u>DRILLING</u>					
MOBILIZATION	EA	1	3,500.00	3,500	
WELL DRILLING 18" DIAMETER	LF	300	30.00	9,000	
WELL CASING / COMPLETION	LF	300	28.00	8,400	
GRAVEL (1-3")	TON	20	20.00	396	
BENTONITE GROUT	SACK	73	8.50	620	
ON-SITE TRUCKING	DAY	5	550.00	2,750	
UXO CLEARANCE	DAY	5	1,000.00	5,000	
MATERIAL FREIGHT	LS	1.00	500.00	500	<u>30,166</u>
<u>PIPELINE INSTALLATION</u>					
MOBILIZATION	EA	1	3,000.00	3,000	
2" PIPE MATERIAL (HDPE SDR 17)	LF	120	0.65	78	
2" PIPE INSTALL (shallow trench)	LF	120	6.00	720	
2" PIPE INSTALL (road crossing)	LF	0	8.00	-	
4" PIPE MATERIAL (HDPE SDR 17)	LF	200	1.35	270	
4" PIPE INSTALL (shallow trench)	LF	200	11.00	2,200	
4" PIPE INSTALL (road crossing)	LF	0	14.00	-	
6" PIPE MATERIAL (HDPE SDR 17)	LF	1,993	2.60	5,182	
6" PIPE INSTALL (shallow trench)	LF	1,913	11.00	21,045	
6" PIPE INSTALL (road crossing)	LF	80	14.00	1,120	
6" X 6" X 4" LATERAL CONNECTION	EA	5	58.00	290	
4" X 2" CONDENSATE TANK CONNECTION	EA	1	38.00	38	
OTHER FITTINGS (allowance) Estimate @ 2.5% of Pipeline Cost To be Provided at Cost Plus 10%	LS	1	842.00	842	
ROAD CROSSING MATERIAL (12" CMP)	LF	80	25.00	2,000	
ON-SITE TRUCKING	DAY	5	550.00	2,750	
SAND BEDDING	TON	0	-	-	
MATERIAL FREIGHT	LS	1.00	800.00	800	<u>40,336</u>
<u>VALVES AND VAULTS</u>					
BUTTERFLY VALVE 6" (shallow trench)	EA	1	1,450.00	1,450	

BUTTERFLY VALVE 4" (shallow trench	EA	0	2,900.00	-
LANDTEC 2" WELLHEADS	EA	5	450.00	2,250
MONITORING PORT	EA	3	45.00	135
CONCRETE VAULT W/ALUMINUM LID	EA	1	1,050.00	1,050
CONCRETE HAND HOLE W/ALUMINUM LID	EA	2	120.00	240
MATERIAL FREIGHT	LS	1.00	500.00	500

CONDENSATE TANK

CONDENSATE SUMP W/ CONTAINMENT	EA		4,000.00	-	<u>5,625</u>
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ENCLOSED FLARE / BLOWER EQUIPMENT PACKAGE (LFG SPECIALTIES, INC.)

100 CFM ENCLOSED FLARE (W/CONTROLS	EA		39,100.00	-	
BLOWER SKID UNIT (W/CONTROLS)	EA		64,750.00	-	
START-UP TECHNICIAN	DAYS		750.00	-	
START-UP TECHNICIAN EXPENSES	DAYS		400.00	-	
EQUIPMENT SHIPPING ALLOWANCE	EA		5,500.00	-	
SALES TAX ON FLARE PURCHASE	LS		-	-	<u>-</u>

MISCELLANEOUS FLARE SITE WORK

MOBILIZATION	EA		4,000.00	-	
ENGINEERED FOUNDATION SUB-GRADE	CY		40.00	-	
CONCRETE FOUNDATIONS	CY		370.00	-	
EQUIPMENT PACKAGE INSTALLATION LAE	HR		150.00	-	
CRANE RENTAL	HR		250.00	-	
EQUIPMENT AREA PIPING & FITTINGS	LS		1,800.00	-	
ELECTRICAL LABOR ALLOWANCE	HR		85.00	-	
ELECTRICAL MISC. MATERIALS ALLOWAN	LS		2,200.00	-	
SUPPLEMENTAL FUEL SUPPLY	LS		7,500.00	-	
1-1/2" AB, 6" THICK	SF		1.50	-	
CHAIN LINK FENCE	LF		20.00	-	
GATE (DOUBLE SWING, 12')	LF		60.00	-	<u>-</u>

ENGINEERING AND DOCUMENTATION

CONCRETE SAMPLING / TESTING	EA		200.00	-	
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SURVEYING	HR	16	150.00	2,400	
AS-BUILTS	LS	1	1,500.00	1,500	<u>3,900</u>
<u>CONSTRUCTION COST TOTAL:</u>				----- 80,026	----- 80,026
BONDING	%	2.3	1,840.61	1,841	
CONTRACTOR PROFIT & OVERHEAD	%	7	5,601.85	5,602	7,442
<u>CONTRACT TOTAL:</u>				----- 87,469	-----

Attachment 5
Life Cycle Cost Analysis

Attachment 5 List

Table 1	Landfill Gas treatment Life Cycle Cost Analysis – Option 1: Thermal Oxidizer
Table 2	Landfill Gas treatment Life Cycle Cost Analysis – Option 2: Enclosed LFG Flare 5 Interior Wells
Table 3	Landfill Gas treatment Life Cycle Cost Analysis – Option 2: Enclosed LFG Flare Area E Collector Trench

TABLE 1
FORT ORD OU2 LANDFILL - AREA F
LANDFILL GAS TREATMENT LIFE CYCLE COST ANALYSIS
THERMAL TREATMENT OPTION 1: THERMAL OXIDIZER

DESCRIPTION: 29 PERIMETER WELLS, LOW BTU SVE, TREATED IN THERMAL OXIDIZER WITH PROPANE MAIN BURNER.														
(A) PROJECT DESIGN LIFE (YEARS)					20		(F) ANNUAL O & M LABOR AND SOURCE TEST (\$)					33,900		
(B) FUEL GAS USAGE - CONTINUOUS PILOT (gals/hr)					0.8		(G) ANNUAL O & M SUPPLIES (\$)					2,500		
(C) EQUIPMENT REPLACEMENT LIFE (YEARS)					5		(H) FACILITY ELECTRIC USAGE (brake hp)					5.0		
(D) FIRST COST - INSTALLATION (\$)					99,300		(I) FUEL GAS BUY RATE (\$/gal) propane					1.3		
Recup. thermox: 49,800 Sitework: 39,800					(J) ELECTRICITY BUY RATE (\$/kWhr)					0.15				
Propane sitework: 7,500					(K) ELECTRICITY AND FUEL ESCALATION RATE (%)					4				
Engr.: 2,200					(L) GENERAL INFLATION RATE (%)					3				
					(M) EQUIPMENT ON-LINE TIME (%)					100				
(E) NATURAL GAS USE														
Max. methane: 4 percent vol.														
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	EQUIP. DESIGN FLOW CAPACITY (SVE)	EXPECTED SVE METHANE CONC.	EXPECTED SVE VOC MASS	EXPECTED VINYL CHLORIDE MASS	EXPECTED METHANE DEFICIT	EXPECTED LFG HEAT DEFICIT	ELEC. USE (AVERAGE)	LPG USE	UTILITY COST	ADSORBENT COSTS	ROUTINE MON. AND OPS. COST	TOTAL O & M COST	TOTAL CAPITAL COST	TOTAL COST
YEAR	scfm	%v	lb/day	lb/day	%v	gals/hr	kWhr/day	gals/day	\$/yr	\$/yr	\$/yr	(7) + (8) +(9) \$/yr	\$/yr	(10) + (11) \$/yr
2003	150	4	0.041	0.0053	0.0	0.8	90	19.2	14,012	0	33,900	47,912	99,300	147,212
2004	150	4	0.041	0.0053	0.0	0.8	90	19.2	14,572	0	34,917	49,489	0	49,489
2005	150	4	0.041	0.0053	0.0	0.8	90	19.2	15,155	0	35,965	51,119	0	51,119
2006	150	4	0.041	0.0053	0.0	0.8	90	19.2	15,761	0	37,043	52,805	0	52,805
2007	150	4	0.041	0.0053	0.0	0.8	90	19.2	16,392	0	38,155	54,546	0	54,546
5-YEAR TOTALS									75,891	0	179,980	255,871	99,300	355,171
2008	150	4	0.041	0.0053	0.0	0.8	90	19.2	17,047	0	39,299	56,347	24,900	81,247
2009	150	4	0.041	0.0053	0.0	0.8	90	19.2	17,729	0	40,478	58,208	0	58,208
2010	150	4	0.041	0.0053	0.0	0.8	90	19.2	18,438	0	41,693	60,131	0	60,131
2011	150	4	0.041	0.0053	0.0	0.8	90	19.2	19,176	0	42,944	62,119	0	62,119
2012	150	4	0.041	0.0053	0.0	0.8	90	19.2	19,943	0	44,232	64,175	0	64,175
10-YEAR TOTALS									168,225	0	388,626	556,851	124,200	681,051
2013	150	4	0.041	0.0053	0.0	0.8	90	19.2	20,741	0	45,559	66,299	24,900	91,199
2014	150	4	0.041	0.0053	0.0	0.8	90	19.2	21,570	0	46,926	68,496	0	68,496
2015	150	4	0.041	0.0053	0.0	0.8	90	19.2	22,433	0	48,333	70,766	0	70,766
2016	150	4	0.041	0.0053	0.0	0.8	90	19.2	23,330	0	49,783	73,114	0	73,114
2017	150	4	0.041	0.0053	0.0	0.8	90	19.2	24,264	0	51,277	75,540	0	75,540
2018	150	4	0.041	0.0053	0.0	0.8	90	19.2	25,234	0	52,815	78,049	24,900	102,949
2019	150	4	0.041	0.0053	0.0	0.8	90	19.2	26,244	0	54,400	80,643	0	80,643
2020	150	4	0.041	0.0053	0.0	0.8	90	19.2	27,293	0	56,032	83,325	0	83,325
2021	150	4	0.041	0.0053	0.0	0.8	90	19.2	28,385	0	57,712	86,097	0	86,097
2022	150	4	0.041	0.0053	0.0	0.8	90	19.2	27,293	0	59,444	86,737	0	86,737
20-YEAR TOTALS									415,012	0	910,906	1,325,918	174,000	1,499,918

Assumptions:

- (A) Costs for perimeter collection well system are equal for all alternatives and not included.
(C) No salvage value after 5 years
(D) Includes 34K for thermal oxidizer (H2Oil Technology), 53K for installation
(F) Does not include condensate collection and treatment costs.

- (F) Includes monthly well monitoring and reporting
(G) Reserve fund for miscellaneous repair parts
(H) Average motor horsepower in use during system operation
(M) Assumes system flow is maximized to minimize operating periods.

TABLE 2
FORT ORD OU2 LANDFILL - AREA F
LANDFILL GAS TREATMENT LIFE CYCLE COST ANALYSIS
THERMAL TREATMENT OPTION 2: ENCLOSED LFG FLARE

DESCRIPTION: 29 PERIMETER WELLS, LOW BTU SVE, TREATED IN FLARE WITH LFG MAIN BURNER FED FROM 5 INTERIOR WELLS.																
(A) PROJECT DESIGN LIFE (YEARS)					20					(F) ANNUAL O & M LABOR AND SOURCE TEST (\$)					33,900	
(B) FUEL GAS USAGE (therms/hr)					0					(G) ANNUAL O & M SUPPLIES (\$)					2,500	
(C) EQUIPMENT REPLACEMENT LIFE (YEARS)					10					(H) FACILITY ELECTRIC USAGE (brake hp)					5.0	
(D) FIRST COST - INSTALLATION (\$)					252,000					(I) FUEL GAS BUY RATE (\$/gal) propane					1.3	
Flare: EF3.52014					124,000 Sitework: 39,000					(J) ELECTRICITY BUY RATE (\$/kWhr)					0.15	
Engr: 6,000					Interior wells: 33,000					(K) ELECTRICITY AND FUEL ESCALATION RATE (%)					4	
Piping and Vaults: 50,000					propane: 0					(L) GENERAL INFLATION RATE (%)					3	
										(M) EQUIPMENT ON-LINE TIME (%)					100	
(E) NATURAL GAS USE																
Min. flare methane: 30 percent vol.																
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)		
	EQUIP. DESIGN FLOW CAPACITY (SVE) scfm	EXPECTED LFG METHANE CONC. %v	EXPECTED SVE VOC MASS lb/day	EXPECTED VINYL CHLORIDE MASS lb/day	EXPECTED METHANE DEFICIT %v	EXPECTED LFG HEAT DEFICIT therms/hr	ELEC. USE (AVERAGE) kWhr/day	MINIMUM 30% METHANE LFG FLOW scfm	UTILITY COST \$/yr	ADSORBENT COSTS \$/yr	ROUTINE MON. AND OPS. COST \$/yr	TOTAL O & M COST (7) + (8) +(9) \$/yr	TOTAL CAPITAL COST \$/yr	TOTAL COST (10) + (11) \$/yr		
YEAR	scfm	%v	lb/day	lb/day	%v	therms/hr	kWhr/day	scfm	\$/yr	\$/yr	\$/yr	\$/yr	\$/yr	\$/yr		
2003	150	30	0.041	0.0053	0.0	0.0	119	50	6,535	0	33,900	40,435	252,000	292,435		
2004	150	30	0.041	0.0053	0.0	0.0	119	50	7,068	0	34,917	41,985	0	41,985		
2005	150	30	0.041	0.0053	0.0	0.0	119	50	7,351	0	35,965	43,315	0	43,315		
2006	150	30	0.041	0.0053	0.0	0.0	119	50	7,645	0	37,043	44,688	0	44,688		
2007	150	30	0.041	0.0053	0.0	0.0	119	50	7,951	0	38,155	46,106	0	46,106		
5-YEAR TOTALS									36,550	0	179,980	216,530	252,000	468,530		
2008	150	30	0.041	0.0053	0.0	0.0	119	50	8,269	0	39,299	47,568	6,000	53,568		
2009	150	30	0.041	0.0053	0.0	0.0	119	50	8,600	0	40,478	49,078	0	49,078		
2010	150	30	0.041	0.0053	0.0	0.0	119	50	8,944	0	41,693	50,636	0	50,636		
2011	150	30	0.041	0.0053	0.0	0.0	119	50	9,301	0	42,944	52,245	0	52,245		
2012	150	30	0.041	0.0053	0.0	0.0	119	50	9,673	0	44,232	53,905	0	53,905		
10-YEAR TOTALS									81,336	0	388,626	469,962	258,000	727,962		
2013	150	30	0.041	0.0053	0.0	0.0	119	50	10,060	0	45,559	55,619	6,000	61,619		
2014	150	30	0.041	0.0053	0.0	0.0	119	50	10,463	0	46,926	57,388	0	57,388		
2015	150	30	0.041	0.0053	0.0	0.0	119	50	10,881	0	48,333	59,214	0	59,214		
2016	150	30	0.041	0.0053	0.0	0.0	119	50	11,316	0	49,783	61,100	0	61,100		
2017	150	30	0.041	0.0053	0.0	0.0	119	50	11,769	0	51,277	63,046	0	63,046		
2018	150	30	0.041	0.0053	0.0	0.0	119	50	12,240	0	52,815	65,055	6,000	71,055		
2019	150	30	0.041	0.0053	0.0	0.0	119	50	12,729	0	54,400	67,129	0	67,129		
2020	150	30	0.041	0.0053	0.0	0.0	119	50	13,239	0	56,032	69,270	0	69,270		
2021	150	30	0.041	0.0053	0.0	0.0	119	50	13,768	0	57,712	71,481	0	71,481		
2022	150	30	0.041	0.0053	0.0	0.0	119	50	14,319	0	59,444	73,763	0	73,763		
20-YEAR TOTALS									202,121	0	910,906	1,113,027	270,000	1,383,027		

Assumptions:

- (A) Costs for perimeter collection well system are equal for all alternatives and not included.
- (C) No salvage value after 5 years
- (D) Includes initial treatment equipment and installation sitework. Interior vent system includes connecting 5 new interior wells with 200 lf of 4-inch pipe and 2000 lf of 6-inch header.
- (F) Does not include condensate collection and treatment costs.
- (F) Includes monthly well monitoring and reporting.
- (G) Reserve fund for miscellaneous repair parts
- (H) Average motor horsepower in use during system operation
- (M) Assumes system flow is maximized to minimize operating periods.

**TABLE 3
FORT ORD OU2 LANDFILL - AREA F
LANDFILL GAS TREATMENT LIFE CYCLE COST ANALYSIS
THERMAL TREATMENT OPTION 2: ENCLOSED LFG FLARE**

DESCRIPTION: 29 PERIMETER WELLS, LOW BTU SVE, TREATED IN FLARE WITH LFG MAIN BURNER FED FROM AREA E COLLECTOR TRENCH, ONLY.														
(A) PROJECT DESIGN LIFE (YEARS)					20		(F) ANNUAL O & M LABOR AND SOURCE TEST (\$)					33,900		
(B) FUEL GAS USAGE (therms/hr)					0		(G) ANNUAL O & M SUPPLIES (\$)					1,500		
(C) EQUIPMENT REPLACEMENT LIFE (YEARS)					10		(H) FACILITY ELECTRIC USAGE (brake hp)					5.0		
(D) FIRST COST - INSTALLATION (\$)					165,000		(I) FUEL GAS BUY RATE (\$/gal) propane					1.3		
Flare: EF3.52014 124,000 Sitework:					39,000		(J) ELECTRICITY BUY RATE (\$/kWhr)					0.15		
Engr: 2,000 Interior wells:					0		(K) ELECTRICITY AND FUEL ESCALATION RATE (%)					4		
Piping and Vaults: 0 propane:					0		(L) GENERAL INFLATION RATE (%)					3		
							(M) EQUIPMENT ON-LINE TIME (%)					100		
(E) NATURAL GAS USE														
Min. flare methane: 30 percent vol.														
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	EQUIP. DESIGN FLOW CAPACITY (SVE)	EXPECTED LFG METHANE CONC.	EXPECTED SVE VOC MASS	EXPECTED VINYL CHLORIDE MASS	EXPECTED METHANE DEFICIT	EXPECTED LFG HEAT DEFICIT	ELEC. USE (AVERAGE)	MINIMUM 30% METHANE LFG FLOW	UTILITY COST	ADSORBENT COSTS	ROUTINE MON. AND OPS. COST	TOTAL O & M COST	TOTAL CAPITAL COST	TOTAL COST
YEAR	scfm	%v	lb/day	lb/day	%v	therms/hr	kWhr/day	scfm	\$/yr	\$/yr	\$/yr	(7) + (8) +(9) \$/yr	\$/yr	(10) + (11) \$/yr
2003	150	30	0.041	0.0053	0.0	0.0	119	50	6,535	0	33,900	40,435	165,000	205,435
2004	150	30	0.041	0.0053	0.0	0.0	119	50	7,068	0	34,917	41,985	0	41,985
2005	150	30	0.041	0.0053	0.0	0.0	119	50	7,351	0	35,965	43,315	0	43,315
2006	150	30	0.041	0.0053	0.0	0.0	119	50	7,645	0	37,043	44,688	0	44,688
2007	150	30	0.041	0.0053	0.0	0.0	119	50	7,951	0	38,155	46,106	0	46,106
5-YEAR TOTALS									36,550	0	179,980	216,530	165,000	381,530
2008	150	30	0.041	0.0053	0.0	0.0	119	50	8,269	0	39,299	47,568	6,000	53,568
2009	150	30	0.041	0.0053	0.0	0.0	119	50	8,600	0	40,478	49,078	0	49,078
2010	150	30	0.041	0.0053	0.0	0.0	119	50	8,944	0	41,693	50,636	0	50,636
2011	150	30	0.041	0.0053	0.0	0.0	119	50	9,301	0	42,944	52,245	0	52,245
2012	150	30	0.041	0.0053	0.0	0.0	119	50	9,673	0	44,232	53,905	0	53,905
10-YEAR TOTALS									81,336	0	388,626	469,962	171,000	640,962
2013	150	30	0.041	0.0053	0.0	0.0	119	50	10,060	0	45,559	55,619	6,000	61,619
2014	150	30	0.041	0.0053	0.0	0.0	119	50	10,463	0	46,926	57,388	0	57,388
2015	150	30	0.041	0.0053	0.0	0.0	119	50	10,881	0	48,333	59,214	0	59,214
2016	150	30	0.041	0.0053	0.0	0.0	119	50	11,316	0	49,783	61,100	0	61,100
2017	150	30	0.041	0.0053	0.0	0.0	119	50	11,769	0	51,277	63,046	0	63,046
2018	150	30	0.041	0.0053	0.0	0.0	119	50	12,240	0	52,815	65,055	6,000	71,055
2019	150	30	0.041	0.0053	0.0	0.0	119	50	12,729	0	54,400	67,129	0	67,129
2020	150	30	0.041	0.0053	0.0	0.0	119	50	13,239	0	56,032	69,270	0	69,270
2021	150	30	0.041	0.0053	0.0	0.0	119	50	13,768	0	57,712	71,481	0	71,481
2022	150	30	0.041	0.0053	0.0	0.0	119	50	14,319	0	59,444	73,763	0	73,763
20-YEAR TOTALS									202,121	0	910,906	1,113,027	183,000	1,296,027

Assumptions:

- (A) Costs for perimeter collection well system are equal for all alternatives and not included.
- (C) No salvage value after 5 years
- (D) Includes initial treatment equipment and installation sitework. Interior vent system includes connecting 5 new interior wells with 200 lf of 4-inch pipe and 2000 lf of 6-inch header.
- (F) Does not include condensate collection and treatment costs.
- (F) Includes monthly well monitoring and reporting.
- (G) Reserve fund for miscellaneous repair parts
- (H) Average motor horsepower in use during system operation
- (M) Assumes system flow is maximized to minimize operating periods.

Attachment 6
Blower/Flare Foundation Calculation

Attachment 6 List

Blower/Flare Skid Foundation Stability

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BLOWER/FLARE SKID FOUNDATION STABILITY

Required:

Determine the blower/flare skid foundation requirements based on the design loading conditions expected at the site. Site soils are described as silty sand, with some gravel.

Method:

Determine applicable loading on the blower/flare skid foundation system in accordance with the 97 *Uniform Building Code* (UBC), and design the foundation to withstand those design loads.

Blower/flare skid stability calculations include the following:

1. Wind loading calculations
2. Earthquake loading calculations
3. Comparison of wind and earthquake loadings to determine maximum design load
4. Determination of foundation dimensions required to offset maximum design loading
5. Soil bearing pressure calculation
6. Concrete foundation stability and reinforcement design
7. Anchor bolt design for critical loading

Solution:

1. Wind loading calculations

UBC, Section 1618, Eqn 20-1: $P = C_e C_q q_s I_w$

Where:

P	= design wind pressure, psf
C _e	= Height, exposure, & gust factor coefficient (UBC, Table 16-G)
C _q	= pressure coefficient (UBC, Table 16-H)
q _s	= wind stagnation pressure (UBC, Table 16-F)
I _w	= wind importance factor (UBC, Table 16-K)

And:

L _S	= blower/flare skid length, ft
H _S	= incremental skid height (corresponds to UBC, Table 16-G), ft
V _{n,w}	= wind shear force acting on skid, lb
V _{f,w}	= shear load design factor for wind loading (Section 1612)
V _{u,w}	= factored wind shear force, lb
h	= moment arm to F from skid base, ft
M _{n,w}	= wind overturning moment acting on skid, lb-ft
M _{f,w}	= load design factor for wind loading (Section 1612)
M _{u,w}	= factored wind overturning moment, lb-ft

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Wind Loading, Exposure C

L _S (ft)	H _S (ft)	C _e	C _q ¹	q _s ²	I _w ³	P (psf)	V _{n,w} (lb)	h (ft)	M _{n,w} (lb-ft)
8	6.5	1.06	1.3	16.4	1.00	22.6	1,175	3.3	3,819
8	0.5	1.06	0.8	16.4	1.00	13.9	56	4.0	223
8	0.5	1.06	0.8	16.4	1.00	13.9	56	0.3	14
4	15	1.06	0.8	16.4	1.00	13.9	834	7.5	6,258
4	3.5	1.13	0.8	16.4	1.00	14.8	208	16.8	3,487
Σ							2,328		13,801

Notes: ¹ C_q selected for chimney.
² q_s selected based on Figure 16-1 (wind speed of 80 mph).
³ I_w selected for miscellaneous structures.

M _{n,w} =	13,801	lb-ft
M _{f,w} =	1.3	
M _{u,w} =	17,941	lb-ft

V _{n,w} =	2,328	lb
V _{f,w} =	1.3	
V _{u,w} =	3,027	lb

Wind Loading, Exposure D

L _S (ft)	H _S (ft)	C _e	C _q ¹	q _s ²	I _w ³	P (psf)	V _{n,w} (lb)	h (ft)	M _{n,w} (lb-ft)
0	0	1.06	0.8	16.4	1.00	13.9	0	0.0	0
Σ							0		0

M _{n,w} =	0	lb-ft
M _{f,w} =	1.3	
M _{u,w} =	0	lb-ft

V _{n,w} =	0	lb
V _{f,w} =	1.3	
V _{u,w} =	0	lb

Notes: ¹ C_q selected for chimney.
² q_s selected based on Figure 16-1 (wind speed of 80 mph).
³ I_w selected for miscellaneous structures.

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2. Earthquake loading calculations

Define:

$V_{n,e}$	= total design lateral force or shear at the skid base, lb
$V_{f,e}$	= shear load design factor for earthquake loading
$V_{u,e}$	= factored earthquake shear force, lb
Z	= seismic zone factor (UBC, Table 16-I)
I	= importance factor (UBC, Table 16-K)
C_a	= seismic coefficient (UBC, Table 16-Q)
W	= total seismic dead load (UBC, Section 1630.1.1), lb
N_a	= near source factor used in the determination of C_a (UBC, Tables 16-S and 16-U)

1997 UBC, Section 1634, Eqn 34-1: $V_{n,e} = 0.7C_aIW$ (for rigid structures)
 Where: $T < 0.06s$
 $\rho = 1$ (Section 1634.1.2)
 $W = 8,200$ lb (weight of skid)

For Seismic Zone 4:
 $Z = 0.40$ (Table 16-I)
 Soil type assumed = S_D (Table 16-J)
 $I, I_p, I_w = 1$ (Table 16-K, for misc. structures)
 No irregularities (Tables 16-L and M)
 From maps of known active faults,
 Source -B Fault (Table 16-U)
 Therefore, $C_a = 0.44 N_a$ (Table 16-Q)
 $N_a = 1.3$ (Table 16-S, source B dist. < 2 km)
 $N_v = 1.6$ (Table 16-T, source B dist < 2 km)

Seismic coefficient, $C_a = 0.572$

Base Shear, $V_{n,e} = 3,283$ lb

Moment Arm, $h_m = 12$ feet

Earthquake overturning moment:

$$M_{n,e} = V_{n,e}h_m$$

Where:

$M_{n,e}$	= earthquake overturning moment acting on skid, ft-lb
$M_{f,e}$	= moment design factor for earthquake loading
$M_{u,e}$	= factored earthquake overturning moment, ft-lb

$M_{n,e} = 39,399$ lb-ft
$M_{f,e} = 1.0$
$M_{u,e} = 39,399$ lb-ft

$V_{n,e} = 3,283$ lb
$V_{f,e} = 1.0$
$V_{u,e} = 3,283$ lb

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3. Determine maximum design loadings

ASD Loading Condition	M_n (lb-ft)	V_n (lb)
Wind, Exposure C	13,801	2,328
Wind, Exposure D	0	0
Earthquake	39,399	3,283

LRFD Loading Condition	M_u (lb-ft)	V_u (lb)
Wind, Exposure C	17,941	3,027
Wind, Exposure D	0	0
Earthquake	39,399	3,283

4. Foundation dimension calculations (8' x20' skid)

Maximum design load: $M_n = 39,399 \text{ lb-ft}$

An iterative solution procedure is used to determine optimum foundation dimensions.

Variable description:

L_f = foundation length, ft
 W_f = foundation width, ft
 t = foundation thickness, in
 γ_c = unit weight of concrete, pcf
 w = weight of foundation, lb
 L_m = foundation moment arm, ft
 W = blower/flare skid weight, lb
 M_o = resisting moment, lb-ft
 $M_{o,f}$ = dead load design factor (Section 1612)
 $M_{o,eff}$ = effective resisting moment, lb-ft
 FS = factor of safety against overturning (minimum of 1.5)

Foundation Resisting Moment

$L_f = 23 \text{ ft}$
 $W_f = 11 \text{ ft}$
 $t = 8 \text{ in}$
 $\gamma_c = 150 \text{ pcf}$

 $w = 25,300 \text{ lb}$
 $L_m = 4 \text{ ft}$

Flare Skid Resisting Moment

$W = 8,200 \text{ lb}$
 $L_m = 5.5 \text{ ft}$

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$$M_o = 101,200 \text{ lb-ft} \qquad M_o = 45,100 \text{ lb-ft}$$

$\Sigma M_o =$	146,300 lb-ft
$M_{o,f} =$	1.0
$M_{o,eff} =$	146,300 lb-ft

$$FS = \frac{M_{o,eff}}{M_n} \qquad \boxed{FS = 3.71} \text{ OK}$$

5. Soil bearing pressure calculations for the foundation designed in (4)

$$\begin{aligned} W &= 8,200 \text{ lb} \\ w &= 25,300 \text{ lb} \\ M_n &= 39,399 \text{ lb-ft} \\ L_f &= 23 \text{ ft} \\ W_f &= 11 \text{ ft} \\ e &= Mn/(W+w) = 1.2 \text{ ft} \end{aligned}$$

Maximum pressure on soil assuming uniform support under slab (ASD):

$$q = 2(W+w)/(3L_f(W_f/2-e)) = \boxed{225 \text{ psf}}$$

Maximum pressure on soil under slab assuming edge support only:

$$\Sigma M_B = M_n - R_A L_f + 0.5 W L_f + 0.5 w L_f = 0$$

Solve equation for R_A :

$$\begin{aligned} R_A &= (M_n + 0.5 L_f (W + w)) / L_f \\ R_A &= 20,332 \text{ lb} \quad (\text{ASD}) \end{aligned}$$

$$\Sigma F_y = R_A + R_B - W - w = 0$$

Solve equation for R_B :

$$\begin{aligned} R_B &= -R_A + W + w \\ R_B &= 13,168 \text{ lb} \quad (\text{ASD}) \end{aligned}$$

Assume uniform load distribution along edges of slab:

$$\begin{aligned} r_A &= R_A / W_f \\ r_B &= R_B / W_f \\ r_A &= 884 \text{ lb/ft} \\ r_B &= 573 \text{ lb/ft} \quad (\text{ASD}) \end{aligned}$$

Assume r_A acts over a 12" wide strip at the edge of the foundation:

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BLOWER/FLARE SKID FOUNDATION STABILITY

$r_A =$	884	psf
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 $\leq P_{all}, OK$

Allowable soil bearing pressure (UBC, Table 18-I-A):

Assume silty sand, with gravel (SM):

$P_{all} =$	1,500	psf
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6. Concrete foundation stability and reinforcement design for foundation designed in (4)

- M_i = Internal foundation moment at edge of skid (LRFD), lb-ft
- V_i = Internal foundation shear at edge of skid, lb
- r_{AU} = Design load at edge of foundation (LRFD), lb/ft
- W_f = Foundation width, ft
- L_f = Foundation length, ft
- W_s = Skid width, ft

$$r_{AU} = V_{f,w} r_A = 1149 \text{ lb/ft}$$

Using edge support determine V_i :

$$\Sigma F_y = V_i - r_{AU} = 0$$

$V_i =$	1,149	lb
---------	-------	----

Determine need for shear reinforcement:

$$V_c = 2f_c^{1/2}bd \quad (\text{UBC, Section 1911.3, Eqn 11-3})$$

- Where:
- V_c = Shear strength of concrete, lb
 - f_c = Compressive strength of concrete, psi
 - b = Unit width of foundation, in
 - d = Distance from compression face to centroid of reinforcing steel, in

$$f_c = 3,000 \text{ psi}$$

$$b = 12 \text{ in}$$

$$d = 3.8 \text{ in}$$

$$V_c = 4,930 \text{ lb}$$

Apply strength reduction factor for shear strength of concrete:

$$\phi = 0.85$$

$\phi V_c =$	4,190	lb
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 $> V_i, \text{ Reinforcing not required}$

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Using uniform support determine M_i :

$$\begin{aligned} W_f &= 11 \text{ ft} \\ W_s &= 8 \text{ ft} \end{aligned}$$

$$L_{R1} = 0.5 (W_f - W_s)$$

$L_{R1} = 1.5 \text{ ft}$

$$M_i = M_{f,w} q(L_{R1})^2/2$$

$M_i = 328 \text{ ft-lb/ft width}$

Determine need for flexural reinforcement, Section 1909 (9-8):

$$M_c = (7.5 f_c^{1/2} I) / c_t$$

Where:

- M_c = Flexural strength of concrete, ft-lb
- f_c = Compressive strength of concrete, psi
- I = Moment of inertia of unit width of foundation = $bt^3 / 12$, in^4
- b = Unit width of foundation, in
- c_t = Distance to tension face = $t/2$, in
- t = Foundation thickness, in

$$\begin{aligned} f_c &= 3,000 \text{ psi} \\ b &= 12 \text{ in} \\ t &= 8 \text{ in} \end{aligned}$$

$I = 512 \text{ in}^4$
$c_t = 4 \text{ in}$

$M_c = 52,581 \text{ lb-in}$
$4,382 \text{ lb-ft}$

Apply strength reduction factor for flexural strength of concrete:

$$\phi = 0.9$$

$\phi M_c = 3,944 \text{ lb-ft}$

> M_i , Flexural reinforcement not required.

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BLOWER/FLARE SKID FOUNDATION STABILITY

Design temperature reinforcement:

$$A_s = 0.0018bt$$

$$b = 12 \text{ in}$$

$$t = 8 \text{ in}$$

$A_s = 0.17 \text{ in}^2$

Dimensions for ASTM A615 Standard Reinforcing Bars			
Bar No.	Diameter (in)	Area (in ²)	Weight (lb/ft)
#3	0.375	0.11	0.376
#4	0.500	0.20	0.668
#5	0.625	0.31	1.043
#6	0.750	0.44	1.502
#7	0.875	0.60	2.044
#8	1.000	0.79	2.670
#9	1.128	1.00	3.400
#10	1.270	1.27	4.303
#11	1.410	1.56	5.313
#14	1.693	2.25	7.650
#18	2.257	4.00	13.600

Based on above table, try: #4

$A_{\#4} = 0.20 \text{ in}^2$

Determine flexural strength of reinforced slab:

ϕM_n = Flexural strength of concrete slab modified by reduction factor

$$a = A_s f_y / 0.85 f_c b$$

$$f_y = 60000 \text{ psi}$$

$$d_b = 0.5 \text{ in}$$

$$d = 3.75 \text{ in}$$

$$a = 0.39 \text{ in}$$

$$\phi M_n = 0.9 A_s f_y (d - a/2)$$

$\phi M_n = 3199 \text{ ft-lb}$	> Mi, OK
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Based on above calculations:

Use 1-#4 Grade 60 Steel Bar @ 12" OCEW for Skid Foundation
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7. Anchor bolt design (4 bolts assumed to anchor skid)

Anchor bolts are designed for tensile strength, shear strength, and the effects of combining both tension and shear design loads.

Determine design tensile loading on anchor bolts caused by overturning moment:

$$T = \frac{M_u}{W_s} - 0.9W/2$$

$$P_u = \frac{T}{n}$$

M_u = design moment (LFRD), lb-ft
 W_s = skid width, ft
 W = equipment weight, lb
 P_u = tensile force on each bolt, lb
 T = total tensile force on bolts, lb
 n = number of bolts on one side of skid

$$M_u = 39,399 \text{ lb-ft}$$

$$W_s = 8 \text{ ft}$$

$$W = 8,200 \text{ lb}$$

$$n = 2$$

$$T = 1,235 \text{ lb}$$

$P_u = 617 \text{ lb/bolt}$

Assume the following anchor bolt and material strength characteristics:

Bolt head diameter, $d = 0.938$ in (min 1.5 times shank diameter)
 Bolt shank diameter, $a = 0.625$ in
 Bolt embedment length, $h = 5.00$ in
 Compressive strength of concrete, $f'_c = 3,000$ psi
 Tensile strength of bolt, $f'_s = 60,000$ psi

Design strength in tension (UBC, Section 1923.3.2):

$$P_{ss} = 0.9A_b f'_s$$

P_{ss} = allowable tensile load on bolt, lb
 A_b = bolt minimum cross-sectional area, in²
 f'_s = tensile strength of bolt, psi

$$A_b = 0.202 \text{ in}^2$$

$P_{ss} = 10,908 \text{ lb}$

> P_u , OK

a, in	Ab, in2
0.500	0.126
0.625	0.202
0.750	0.302
0.875	0.419
1.000	0.551

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$$\phi P_c = \phi \lambda 4 A_p f_c^{1/2}$$

P_c = pullout capacity in concrete, lb

ϕ = strength-reduction factor

λ = concrete type coefficient

A_p = projected area of assumed failure surface, in²

$$A_p = 19.63 \text{ in}^2$$

$$\phi = 0.65$$

$$\lambda = 1$$

$\phi P_c =$	2,796	lb	$>P_u$, OK
$P_c =$	4,302	lb	

Determine design shear loading on anchor bolts caused by lateral load:

Assume total shear force will be carried equally by all anchor bolts.

$$V_u = 3,283 \text{ lb (from determination of design loading)}$$

$$N = 2 \text{ bolts}$$

$V_u =$	1,642	lb/bolt
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Design strength of anchors in shear (UBC, Section 1923.3.3)

$$V_{ss} = 0.75 A_b f_s$$

$$A_b = 0.202 \text{ in}^2$$

$V_{ss} =$	9,090	lb	$>V_u$, OK
$V_c =$	8,851	lb	

$$\phi V_c = 800 \phi \lambda A_b f_c^{1/2}$$

$\phi V_c =$	5,753	lb	$>V_u$, OK
$V_c =$	8,851	lb	

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Check anchor bolt design for combined loading (UBC, Section 1923.3.4)

The following ratios are considered in accordance with the UBC to determine the adequacy of the anchor bolt size and embedment.

- (1) $P_u / \phi P_c < 1$
- (2) $V_u / \phi V_c < 1$
- (3) $[(P_u / P_c)^{1.67} + (V_u / V_c)^{1.67}] / \phi < 1$
- (4) $(P_u / P_{ss})^2 + (V_u / V_{ss})^2 < 1$

$$\begin{aligned}
 P_u &= 617 \text{ lb/bolt} \\
 P_{ss} &= 10,908 \text{ lb} \\
 P_c &= 4,302 \text{ lb} \\
 V_u &= 1,642 \text{ lb/bolt} \\
 V_{ss} &= 9,090 \text{ lb} \\
 V_c &= 8,851 \text{ lb}
 \end{aligned}$$

(1)	0.22	< 1.00	OK
(2)	0.29	< 1.00	OK
(3)	0.08	< 1.00	OK
(4)	0.04	< 1.00	OK

The assumed anchor bolt dimensions are acceptable. Anchor bolt dimensions are shown below.

Bolt head diameter =	0.938	in
Bolt shank diameter =	0.625	in
Embedment length =	5.00	in

Blower/Flare Skid Foundation Design Summary

Slab	Length	23 ft
	Width	11 ft
	Thickness	8 in
	Reinforcement	1-#4 GR 60 STL @ 12" OCEW
	Material	3,000 psi concrete
Anchor Bolts	Bolt Head Diameter	0.938 in
	Bolt Shank Diameter	0.6250
	Embedment	5.00 in
	Material	F1554 GR 36 STL Galvanized