FULL SCALE BIOREACTOR LANDFILL FOR CARBON SEQUESTRATION AND GREENHOUSE EMISSION CONTROL

Final Technical Progress Report

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ABSTRACT

The Yolo County Department of Planning and Public Works constructed a full-scale bioreactor landfill as a part of the Environmental Protection Agency's (EPA) Project XL program to develop innovative approaches for carbon sequestration and greenhouse emission control. The overall objective was to manage landfill solid waste for rapid waste decomposition and maximum landfill gas generation and capture for carbon sequestration and greenhouse emission control. Waste decomposition is accelerated by improving conditions for either the aerobic or anaerobic biological processes and involves circulating controlled quantities of liquid (leachate, groundwater, gray water, etc.), and, in the aerobic process, large volumes of air.

The first phase of the project entailed the construction of a 12-acre module that contained a 6-acre anaerobic cell, a 3.5-acre anaerobic cell, and a 2.5-acre aerobic cell at the Yolo County Central Landfill near Davis, California. The cells were highly instrumented to monitor bioreactor performance. Liquid addition commenced in the 3.5-acre anaerobic cell and the 6-acre anaerobic cell. Construction of the 2.5-acre aerobic cell and biofilter has been completed. The current project status and preliminary monitoring results are summarized in this report.

EXECUTIVE SUMMARY

Introduction

Organic materials in municipal solid waste (MSW) landfills decompose via microbial action to a gaseous mixture of methane and carbon dioxide, termed "landfill gas" (LFG). LFG is already widely used for power generation, with about 1000 MWe installed capacity in the U.S. However, LFG remains an underutilized renewable energy resource, with only about half of the United States' generated LFG being captured and less than 25% actually used for power generation (with the balance of collected gas flared). The main factors limiting LFG utilization are the very long, slow rates of waste decomposition and LFG generation in landfills, combined with inefficient recovery of the gas that is generated. Contributing factors are unpredictability of gas recovery, contaminants in LFG, and the economic limitations associated with smaller scale power generation from typical low-rate recovery.

Landfilling of MSW is considered by many environmentally concerned citizens and regulatory agencies as a less desirable technology to be avoided and limited as much as possible. However, landfills can be used for a much greater degree for treatment, essentially, composting of the waste they contain. Evolving sanitary landfill engineering practices now avoid many of the problems with historical landfill practice, in particular leachate contamination of groundwater. Other problems have remained in association with recent conventional practice. Recent conventional practice has mandated exclusion of moisture from landfills, keeping waste relatively dry and thereby depressing the metabolism of the microorganisms that degrade the organic fraction of MSW. This results in so-called dry-tomb landfills that require long-term post-closure monitoring and management because leachate and gas production will resume once the containment barrier is breached. This can leave an undesirable legacy for future generations.

These problems with recent conventional landfill practice can be overcome. The biological degradation and stabilization of waste in landfills can be greatly accelerated and completed in a few years by increasing microbial activity through increases in *in situ* moisture levels. Landfills wherein biodegradation of waste is enhanced through liquid additions are generally called "bioreactor landfills". In the earliest years, the bioreactor landfill used only leachate recycling. However, this proved insufficient to achieve maximum acceleration and breakdown of biodegradable organic matter. Rapid, complete, and permanent landfill stabilization requires further liquid addition to allow the anaerobic microbial processes to go to completion, producing an inert, stabilized residue. We call this process herein, "accelerated anaerobic composting".

The advantage of accelerated anaerobic composting technology (also termed the "controlled landfill bioreactor", and "controlled landfill" for convenience below) is that it mitigates the expected long-term environmental problems with current sanitary landfilling practices. Importantly, it also allows essentially complete LFG production and collection over a relatively short period of time. This allows for more economical LFG power generation. It also eliminates the great bulk of fugitive LFG emission that is normally experienced because of inefficient LFG collection. This fugitive LFG can otherwise be an important source of greenhouse methane emissions and a major source of local air pollutants.

This report details the design, construction, and operations of a full-scale landfill at the Yolo County Central Landfill using the accelerated anaerobic composting technology previously

demonstrated at this site during 1994 – 2002 (see below). The present project was supported by the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy (USDOE), in addition to cost-sharing by Yolo County and other state and federal agencies.

Landfill Bioreactor Technology and the Yolo County Project

The development of the bioreactor landfill technology started with laboratory work in the 1970's demonstrating that static reactors filled with organic matter from MSW could exhibit high rates of biodegradation and methane production. In summary, projections and experience with vessel-based MSW to methane technology have been adverse. Despite being practiced at numerous sites in the European Union today, methane from vessel-based MSW-to-methane conversion has proven very expensive; energy cost equivalent to $200/barrel oil. At the same time, controlled landfill bioreactor technology has been proving in tests at Mountain View, CA and Yolo County, CA to be a promising alternative for MSW-to-methane conversions.

Planning for the first Yolo County Controlled Bioreactor Landfill pilot-scale study started in 1989. With support from the California Energy Commission and the Department of Energy, with cost sharing from Yolo County and assistance from Sacramento County, two 9,000 ton pilot-scale landfill bioreactor landfill cells were constructed, one operated without and one with addition of supplemental liquids and liquid recirculation. Actual operations and monitoring were initiated in 1994 with the following operations sequence:

- Fill waste as received.
- Cover cells with surface membrane for high-efficiency gas capture; and liquid addition to the first (enhanced) cell, but not the second (control) cell.
- Capture of an estimated 90% or more of generated LFG was made possible by early installation of the gas capture cover system before liquid addition was initiated.

Results obtained with the enhanced versus control cells indicated the following key benefits of this approach:

- Over five-fold acceleration of methane production and recovery for maximum yield.
- Reduction of fugitive greenhouse methane emissions to <5% of generated LFG.
- Rapid and extensive volume reduction in the enhanced compared to the control cell.
- Waste stabilization (indicated by methane recovery, volume loss and other indicators) compared to the dry-tomb control.

These pilot-scale results suggested that LFG extraction and utilization would be much more economical, greenhouse gas emissions would be greatly reduced, landfill capacity increased, and aftercare minimized through the addition of moisture to engineered bioreactor landfills. A key finding was the feasibility of straightforward means for distributing liquid relatively evenly throughout the enhanced cell, on desired schedules. Moisture addition combined with significantly above ambient temperature resulted in accelerated biodegradation and methane generation, as well has highly desirable volume reduction in the landfilled waste.

This earlier success of the 9,000 ton pilot program at Yolo has now led to scale-up of the controlled landfill bioreactor approach to larger cells, which is the topic of this report.

Bioreactor cells totaling over 250,000 tons of waste are now constructed and are operating. The present project was supported by NETL.

The Yolo County Accelerated Anaerobic Composting Demonstration Project

Permitting and Regulatory Issues

Federal and California State regulations have, until recently, barred the addition of supplemental liquid other than leachate to a lined landfill module. This addition was essential for implementation of the controlled bioreactor landfill. Yolo County applied for, and was granted, special regulatory flexibility through the United States Environmental Protection Agency (EPA) XL Program, which stands for "eXcellence and Leadership." The XL program allows government and business entities to develop, cooperatively with EPA, innovative strategies to test prospectively better or more cost-effective ways of achieving environmental and public health protection.

Bioreactor Cell Design and Construction

Two new 6 and 3.5-acre methane enhanced anaerobic bioreactor cells were designed and constructed for this project. Extensive instrumentation and provisions for measurements have allowed the detailed study of waste decomposition and methane enhancement. Multipoint measurements within cells have included temperature, moisture, static head over the base liner, and liquid pore pressure. High accuracy flow recorders also provided accurate measurement of landfill gas recovery and liquid inflows and outflows. Careful measurement of MSW placed into the cells and gas and liquid measurements allowed gas recovery, liquid flows, and material balances to be quantified with high accuracy.

The majority of sensors and instrumentation were standard and commercially available. Moisture sensors that were leachate resistant were custom made by the project staff with either larger gypsum elements or plastic bead matrices. Breakage of instrumentation lead wires (reported in other large-scale bioreactor landfill tests) was avoided by combining strong protective housing and line slack or "snaking" to accommodate expected lead elongation with settlement. Yolo County staff, cooperating closely with local contractor, A-TEEM Electrical Engineering, developed a highly automated Supervisory Control and Data Acquisition (SCADA) system radio-linked to a host computer. This system has been upgraded and expanded as the project progressed, and has maintained state of the art status as software and instrumentation features have improved.

In addition to these sensors, instrumentation, and monitoring capabilities, the main design modifications relative to conventional landfill practice in the U.S. include:

- Base and drainage layer construction,
- Liquid addition methods and control,
- Gas collection methods and control,
- Surface liner and containment,
- Slope stability.

The construction of the cells included the installation of sensors, wires, pipes, wells for liquid introduction, and gas collection system. Other construction aspects key to the controlled landfill included precautions taken in placing cell elements that would undergo strain during decomposition and settlement.

Aerobic Bioreactor Landfill Tests

An additional component of work at Yolo has been assessment of greenhouse methane suppression by another means: aeration of the landfill, i.e. the aerobic landfill. This is essentially aerobic composting of landfill contents by introducing atmospheric air through the landfilled waste. Testing of this approach was, in part, for the Greenhouse Gas Abatement program of NETL of the U.S. Department of Defense (DOE) and in part for the California Integrated Waste Management Board (CIWMB).

An advantage of this approach is that a higher fraction of organic waste (particularly the normally significant lignin and woody lignocellulose) can be oxidized compared to the fraction of organic wastes that can be decomposed by anaerobic digestion. Thus, higher fractions of the landfilled waste can be destroyed, in turn, giving greater landfill life extension.

Disadvantages of this approach, however, include the amount of energy use required to operate the system and loss of methane energy production.

Operational Results

Internal cell temperatures

From the start of full-scale operations, elevated temperatures (about 110-140°F or 45-60°C, roughly 5-15°C higher than conventional) have been measured throughout the bulk waste in both cells. Waste temperatures inside the cells have remained constant and essentially independent of ambient temperature. These elevated temperatures, achieved at no additional effort or cost as a consequence of biological heat generation, contributed to the acceleration of the microbial degradation of the waste and methane production.

Moisture Flows and Waste Moisture Balances

Moisture additions (i.e. liquid infiltration) began in June 2002 and June 2003 in the 3.5 and 6-acre cells, respectively. Liquid infiltration has proceeded somewhat more slowly with these larger cells than with the earlier 9000-ton pilot-scale cells. The moisture sensors have indicated elevated moisture levels for the majority of the sensors. However, core samples suggested that moisture distribution was somewhat irregular. Liquid added to date has been 43 gal/ton in the 3.5-acre cell, and 21 gal/ton in the 6-acre cell, compared to 55 gal/ton in the 9,000-ton pilot-scale cell. Other findings included apparent permeability (deduced from moisture infiltration rates) of approximately 3×10^{-5} cm/sec. The issues encountered with liquid management included seeps and some variation in moisture content with the larger cells and were attributed to remnants of less-permeable cover soil. These issues should be resolvable in future designs and operations by following practices recommended in this report.

Leachate Head Over Base Liner

Liquid head over the base liner is a major regulatory concern, because of the potential for groundwater pollution and decreased slope stability. Observed head in the cells was 2 inches, under half of allowable limits under California regulations, and less than 20% of the maximum allowed under federal regulations.

Leachate Compositions

Composition of liquid leachate draining from the waste serves both to indicate the progress of waste decomposition and to show effectiveness of biological treatment in terms of reduction of normal leachate pollutants. Leachate pollutants have fallen, and key parameters, five-day biological oxygen demand, BOD_5 and pH, all indicate a stable ongoing methane production process. A number of leachate components including ammonia and dissolved salts have reached low and relatively stable levels.

Landfill Gas Composition and Recovery

A primary goal of this project was to generate LFG suitable for use in power generation. . Methane content from the recovered gas in both anaerobic cells quickly reached about 50% within 3 months after leachate additions started. This methane content is eminently suitable for fueling power generation. One very interesting phenomenon, not heretofore reported, was a sharp decline with time in the concentration of most of the volatile pollutants and other undesirable components in the collected landfill gas. Two components out of hundreds of trace components in LFG, mostly man-made, are decreasing benzene and hexane. Thus far, the observed decline in many such pollutants is up to ten-fold, and is attributed to a combination of biological decomposition and the compounds' evaporation and partitioning into the landfill gas.

Methane Generation and Analysis using Standard Model

Controlled generation of the maximum possible amount of landfill methane energy to supplement California, U.S. and world energy needs was a primary objective of this project. The two anaerobic full-scale cells have shown very encouraging methane enhancement, currently 4 to 7-fold, by comparison, to that expected from conventional landfill operation. Some variation in methane recovery was observed, not due to variation in LFG production, but due to extraction and vacuum variation, factors uniquely site specific to these pilot-scale cells (see report). From the northeast 3.5-acre and west 6-acre cells, methane recoveries of 78.3 and 77.5 million cubic feet would equate to 6,525 and 6,458 MWh, or a total close to 13 GWh electric at an estimated heat rate of 12,000 ft^3 of methane per MWh.

Figure ES-1 shows the normalized methane recovery per pound of MSW that would be expected, the initial 9000-ton enhanced cell, and the more recently started northeast and west-side cells described in the main text.

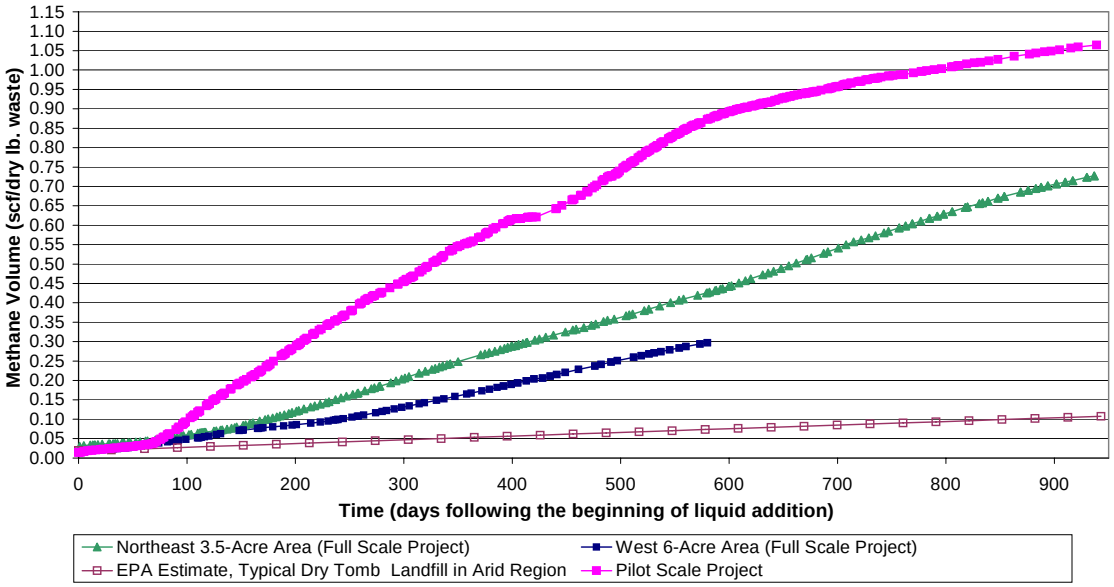


Figure ES-1. Comparisons among normalized methane production for conventional (brown), Yolo pilot-scale (magenta), northeast (green), and west (blue) accelerated anaerobic composting cells. Note enhancement of methane in pilot-scale, northeast, and west side versus conventional operation.

Methane Greenhouse Emission Abatement

Another major objective of this project was to demonstrate that this technology could reduce greenhouse gas emissions, principally methane gas, to a minimum. With very infrequent exceptions, surface combustible gas concentrations (the regulatory criterion for effectiveness) have been ten to 100-fold less than allowed by federal and state limits. This provides another major drive to the adoption of this improved energy technology.

Waste Core Sampling Results

Core samples of the landfilled waste have been tested for moisture, biochemical methane potential (BMP), and other characteristics. Up to this point in the addition process, moisture levels, though generally elevated, remained variable with location in the waste. Though enhancement results (see above) are encouraging, the core moisture results suggest need for longer-term leachate recirculation and moisture addition to better distribute moisture.

Settlement and Volume Loss

Waste volume loss and settlement are particularly important benefits to waste management jurisdictions because of prospects for increased landfill capacity and life extension. Full-scale cells, still in early stages of operation, show encouraging volume loss at much greater rates than that for a controlled dry-tomb cell. Through September 2004, settlement in the 3.5-acre cell has averaged 8.5%, and the 6-acre cell has averaged 4%.

Projected Energy Balance for Controlled Landfill

An estimated energy balance has been developed for this accelerated anaerobic composting (controlled bioreactor landfill) technology. The only significant incremental energy inputs over

conventional landfill operation are those for liquids and landfill gas pumping, which are under 1% of the total landfill gas energy output, a negligible amount. Nearly all landfill methane energy will be recovered. For comparison, it can be noted that the much more costly mixed vessel anaerobic digestion MSW-to-methane technology, used in Europe now, requiring careful waste separation, grinding, mixing, etc., and has very high parasitic energy inputs, from 35% up to over 100% of the methane produced. Hence, information to-date suggests bioreactor landfills will yield greater net energy than vessel processes (and at about tenfold less cost -- see Project Economics.

Maintenance

Maintenance needs were tracked. These included either routine needs or maintenance due to equipment breakdown, repairs of gas and liquid leaks, and membrane cover and gas flowmeters, among others. Some maintenance needs specific to bioreactor operations have included instrumentation maintenance and dealing with fouling of base liquid pressure sensors due to scale buildup by periodic withdrawal and cleaning. The liquid injection lines also clogged temporarily due to leachate pH increase, which resulted in precipitation of calcium carbonate and buildup of scale. Some simple chemical tests established that this scale was largely calcium carbonate and removal by citric acid gave excellent results.

Project Economics

In estimating energy or electricity costs from LFG, it must be recognized that landfills and LFG recovery are already required for most MSW disposal facilities. Thus, the cost factors in such an analysis are only the incremental costs that come with bioreactor operation as opposed to conventional operation. There are major waste management benefits other than energy that can easily justify all incremental costs. The cost analysis was based on the following:

- Bioreactor operations are justified by other benefits even without energy recovery.
- LFG capture using best available control technology is required, regardless of use.
- The recovered LFG is available for power production at low or no marginal cost.
- Thus, LFG has near-zero incremental cost since methane must be destroyed by some method, which an internal combustion or turbine engine does.

Power generation costs are mainly for the genset procurement and operation. The present report does not detail the capital and operating costs of engine-generator sets. Based on experiences of Waste Management, Inc. (WM), the following parameters are assumed for a "base case" landfill gas-to-energy project: 1,600 cubic feet per minute (CFM) of LFG, or 400,000 million Btu per year, generating 32 million kWh per year. For such a size plant, capital costs are $3.2 to $5 million ($800 to $1250/kWe), including site work, buildings, gas conditioning, power generation equipment, interconnections and other miscellaneous capital costs. For such a size plant, capital costs are $3.2 to $5 million ($800 to $1250/kWe), including site work, buildings, gas conditioning, power generation equipment, interconnections and other miscellaneous capital costs. At the best (largest) sites, the total cost to generate power was estimated by Waste Management to be in the range of 2.5 to 3.5 cents/kWh, assuming no value for the LFG. For smaller scales at smaller sites, an estimated range for generated power cost would be between 3 and 4.5 cents/kWh. This power generation cost range is similar to those of most other analyses

for LFG power generation, including prior work for the Yolo County project, and depends on factors such as cost of capital, scale, gas clean-up requirements, location and many other factors.

The costs of power production from controlled bioreactor landfills, as described herein, would be significantly lower than the cost of LFG-to-electricity production for a similar size conventional landfill. This is due to the fact that more LFG is generated and over a shorter period of time, allowing for larger generating equipment. There can be more reliable estimation and control of gas production (avoiding flaring excess LFG or installing superfluous generating capacity). Because of such factors, it is likely that substantially more renewable power, as much as 50% to 100% more, would be produced from the same waste than with conventional practice. A more precise estimate would require fixing many assumptions, such as location, scale, type of waste, etc. The prospect for and value of greenhouse gas abatement credits are currently small compared to the value of electricity generation. However, greenhouse credits and benefits may become more important drivers in the future.

As power generation from landfill bioreactors increases, continuing attention must be given to factors aside from economics. These include the regulatory treatment and allowances, incentives for renewable energy, the case for bioreactor energy that can be made on the basis of environmental benefits that are described in detail, and making sure that regulatory agencies recognize the overall benefits in a "balance sheet" approach.

Conclusions

This project's work consisted of construction and operation of controlled landfill bioreactor (accelerated anaerobic composting) cells by over ten-fold from the original pilot study. Implementation of the large-scale northeast 3.5-acre and west 6-acre cells was accompanied by collection of technical data that would provide the justification to satisfy the regulatory community and lead to the commercialization of this technology. This was accomplished through activities including:

- Construction of the bioreactor landfill through waste placement, and in-waste placement of piping and instrumentation followed by horizontal tires gas collection system, cover soil, geotextile, and synthetic cover liner for the bioreactor cells.
- Liquid addition with careful measurements of liquid flows and indicators of moisture.
- Operation with monitoring of all relevant parameters to the reporting date.
- Assessing methane energy recovery and volume reduction.
- Monitoring methane emissions and assessing greenhouse methane emission abatement.
- Development of model and kinetic parameters for the landfill bioreactor cells' methane production.
- Economic analysis.

A photograph of the completed northeast cell with newly installed cover is shown in Figure ES-2.

Figure ES-2. Northeast cell, shortly after geomembrane coverage, is in the foreground. The northeast cell footprint is approximately 300 ft by 500 ft, and it contains 78,000 tons of methane-enhanced waste. The scale is also indicated by a person walking up the cell cover near the lower left corner of the cell.

The current Yolo County Demonstration project will need to be monitored until the end of the decade, and beyond, to obtain the full benefit from this project. However, the results of this project can be applied well before then, as they fit within the data sets from other prior projects, in particular the earlier Yolo County Pilot Project. As expected, the moisture distribution was not as rapid and uniform as in the pilot cells, and thus, LFG generation and waste stabilization was somewhat slower than in the Pilot Project. It is expected that such factors would increase the period of full stabilization and completed LFG generation from about 10 years at the pilot-scale to 15 years for full-scale cells. This will not significantly affect the economics of such a process, including settling freeing up air space for additional waste deposition. This period of time is well within the planning horizon of most active landfills. In conclusion, the present project is providing quantitative, proof of benefits of controlled bioreactor landfills, over conventional landfill technology. The objectives have been met with some of the most important results being:

- Findings continue to evidence that bioreactors can provide greater energy benefits than conventional landfilling. Other benefits occur in terms of accelerated methane generation and highly efficient methane capture. Methane enhancement continues to be shown manageable and controllable.

- The program illustrates environmental (greenhouse) benefits in terms of reducing methane emissions to minuscule levels (generally under 1/100 of existing regulatory standards).

- The larger scale cells are demonstrating waste management benefits, in terms of accelerated volume loss and more rapid stabilization as evidenced by the conversion rates of waste organic to methane and subsidence.
- The full-scale cells are generally confirming the benefits seen in the pilot-scale on an over ten-fold larger scale.

Further benefits will be evident in the main body of the report.

As an energy technology, when applied to the huge amount of post-recycling mixed municipal waste that are landfilled in the U.S., analyses elsewhere show the controlled landfill bioreactor with major advantages over other related MSW-to-energy and MSW-to-fuels processes.

1 INTRODUCTION

Sanitary landfilling is the dominant method of solid waste disposal in the United States, accounting for about 217 million tons of waste annually (U.S. EPA 1997). The annual production of municipal solid waste in the United States has more than doubled since 1960. In spite of increasing rates of reuse and recycling, population and economic growth will continue to render landfilling as an important and necessary component of solid waste management.

In a bioreactor landfill, controlled quantities of liquid (leachate, groundwater, gray-water, etc.) are added to increase the moisture content of the waste. Leachate is then recirculated, as necessary, to maintain the moisture content of the waste at or near its moisture holding capacity. This process significantly increases the biodegradation rate of waste, and thus decreases the waste stabilization and composting time (5 to 10 years) relative to what would occur within a conventional landfill (30 to 50 years or more). If the waste decomposes (i.e. is composted) in the absence of oxygen (anaerobically), it produces landfill gas (biogas). Biogas is primarily a mixture of methane, a potent greenhouse gas, carbon dioxide, and small amounts of volatile organic compounds (VOC). This by-product of anaerobic landfill waste composting can be a substantial renewable energy resource that can be recovered for electricity or other uses. Other benefits of a bioreactor landfill composting operation include increased landfill waste settlement and a resulting increase in landfill capacity and life, improved opportunities for treatment of leachate liquid that may drain from fractions of the waste, possible reduction of landfill post-closure management time and activities, landfill mining, and abatement of greenhouse gases through highly efficient methane capture over a much shorter period of time than is typical of waste management through conventional landfilling.

1.1 Background and Site Overview

The Yolo County Central Landfill (YCCL) is an existing Class III non-hazardous municipal solid waste landfill. The site encompasses a total of 722 acres and is comprised of 17 distinct Class III solid waste management units and two Class II leachate surface impoundments. The YCCL is located at the intersection of Road 104 and Road 28H, 2 miles northeast of the City of Davis. The YCCL was opened in 1975 for the disposal of non-hazardous solid waste, construction debris, and non-hazardous liquid waste. Existing on-site operations include a landfill methane gas recovery and energy generation facility, a drop-off area for recyclables, a metal recovery facility, a wood and yard waste recovery and processing area, and a concrete recycling area.

There are approximately 28 residences scattered within a 2-mile radius of the landfill. The closest residence is located several hundred feet south of the landfill, on the south side of Road 29, south of the Willow Slough By-pass.

Groundwater levels at the facility fluctuate between 8 and 10 ft during the year, rising from lowest in the fall to highest in the spring. Water level data indicate that the water table level is typically 4 to 10 ft below ground surface during winter and spring months. During summer and fall months, the water table is typically 5 to 15 ft below ground surface. In January 1989, Yolo County constructed a soil/bentonite slurry cutoff wall to retard groundwater flow to the landfill site from the north. The cutoff wall was constructed along portions of the northern and western boundaries of the site to a maximum depth of 44 ft. The cutoff wall has a total length of 3,680 ft, 2,880 ft along the north side and 800 ft along the west. In the fall of 1990, irrigation practices to the north of the landfill site were altered to minimize the infiltration of water.

Additionally, sixteen groundwater extraction wells were installed south of the cutoff wall in order to lower the water table south and east of the wall, and to provide vertical separation between the base of the landfill and groundwater.

Prior to placement of the slurry wall and dewatering system, the groundwater flow direction was generally to the southeast. Under current dewatering conditions, the apparent groundwater flow paths are towards the extraction wells located along the western portion of the northern site boundary. In essence, a capture zone is created by the cone of depression created by the ground water extraction system, minimizing the possibility of off-site migration of contamination.

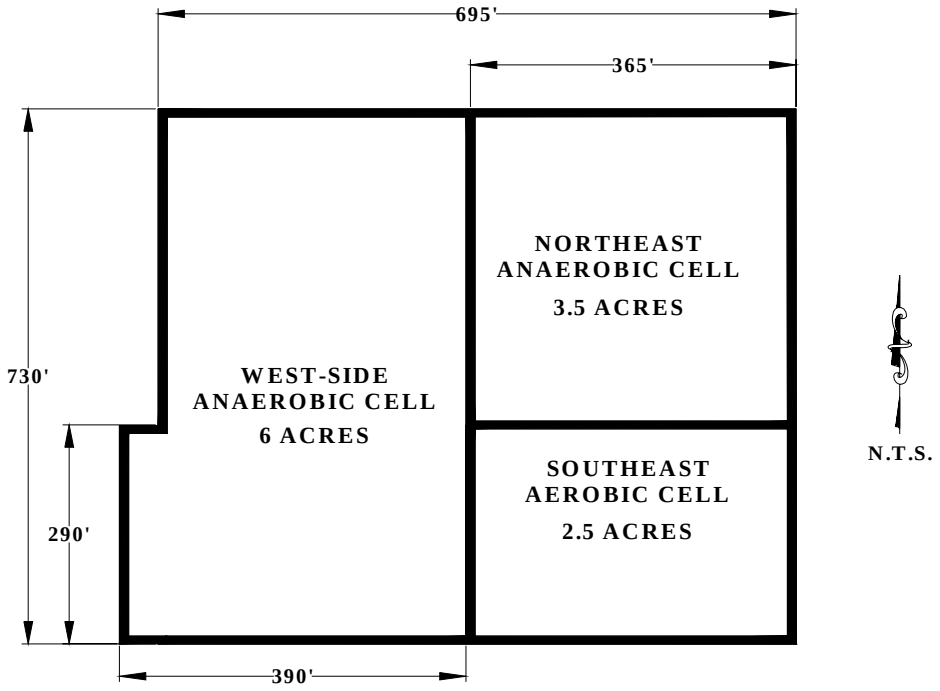
1.2 Project Description

The County of Yolo Planning and Public Works Department (Yolo County) has now scaled up its landfill bioreactor operations. The scale-up goal was to provide added technical and economic data, and provide solutions to the identified permitting conditions and other factors posing constraints to large-scale application and commercialization. This was to be accomplished by demonstrating the environmental and economic benefits of this technology and resolving technical issues. Another goal was to provide confidence regarding regulatory issues and constraints. In the first phase of this project, a 12-acre module was constructed containing a 6-acre cell and a 3.5-acre cell, which was operated anaerobically, and a 2.5-acre cell that was operated aerobically (Detail 1).

Co-sponsors of the project with Yolo County are the Public Interest Energy Research (PIER) program of the California Energy Commission (CEC), California Integrated Waste Management Board, Department of Energy, National Energy Technology Laboratory (NETL), the Solid Waste Association of North America (SWANA) and Institute for Environmental Management (IEM). As part of the Environmental Protection Agency (EPA) Project XL, which stands for "eXcellence and Leadership," Yolo County requested that U.S. EPA grant site-specific regulatory flexibility from the prohibition in 40 CFR 258.28 Liquid Restrictions, which may preclude addition of useful bulk or non-containerized liquid amendments. The County intended to use leachate and groundwater as their first option. In cases where sufficient groundwater, irrigation water, etc. might be lacking, then use of other supplemental liquids could be possible. For example gray-water from a wastewater treatment plant, septic waste, and food-processing wastes would be used. Liquid wastes such as these, that normally have no beneficial use, may instead have high value through their nutrient and organic content, beneficially enhancing the biodegradation of solid waste. However, for this Yolo County project, because sufficient groundwater and leachate was available, no other supplemental liquids were utilized.

Yolo County also requested similar flexibility on liquid amendments from California and local regulatory entities. Several sections of the California Code of Regulations (CCR), Title 27, Environmental Protection, address the recirculation of liquids in lined municipal solid waste landfills. While the regulations do not specifically endorse bioreactors, regulatory flexibility was provided by the State of California Title 27, Chapter 3, Subchapter 2, Article 2, Section 20200, Part (d)(3), Management of liquids at Landfills and Waste Piles. For additional information on this regulatory flexibility, see Section IV A of the Final Project Agreement (FPA) (Appendix F). In part as the result of Yolo County's program and project team communications with the U.S. EPA, greater Federal flexibility in liquids addition is being granted nationwide.

The State of California is in the process of increasing its own flexibility in line with federal guides.



Detail 1. Overview of Module 6D bioreactor cells

The project work plan consisted of construction, operation and collection of technical data that would satisfy the regulatory community and lead to the commercialization of this technology. This was to be accomplished through the following activities:

- Construction of the base liner system, leachate collection and removal system, tire operations layer, and installation of base layer instrumentation.
- Construction of the bioreactor landfill through waste placement and in-waste placement of piping and instrumentation (waste placement in the cells began in November 2000).
- Collection and analysis of waste samples for cellulose, hemicellulose, lignin and biochemical methane potential (BMP) to determine maximum remaining biodegradable material over time.
- Construction of all instrumentation and connection to the Supervisory Collection and Data Acquisition (SCADA) system.
- Connection of the liquid pumping system to the liquid injection piping and start of liquid addition to the waste.
- Placement of horizontal tire gas collection system, cover soil, geotextile, and synthetic cover liner for the bioreactor cells.

- Monitoring for methane emissions.
- Construction of the landfill gas collection system and connection of the system to power generation facility.
- Sampling and laboratory testing of leachate and landfill gas.
- Modeling of landfill bioreactor methane production.
- Data management, interpretation and reporting.
- Preparation of quarterly and annual reports and hold stakeholders meetings.

1.3 Project Goals and Objectives

The goal of this project was to provide technical data and solutions to the identified permitting constraints posed on this technology so that it could advance into the commercialization phase. Yolo County believes that with the demonstration of this project and acceptance of the bioreactor landfilling concept by U.S. EPA and the State of California, many other public and private landfill owners and operators will be able to implement this technology at other sites. The technology is expected to improve the economics of landfill gas-to-electricity by yielding more renewable landfill gas while providing many environmental benefits, not only for all regions of the U.S, but worldwide. Results from Yolo County's small-scale pilot-scale project have already been shared among many other jurisdictions as well as the private sector throughout the U.S. and internationally.

Project XL allows state and local governments, businesses and federal facilities to develop with U.S. EPA, innovative strategies to test better or more cost-effective ways of achieving environmental and public health protection. Through this program, EPA, in cooperation with state agencies and other stakeholders, allows regulatory flexibility to conduct experiments to demonstrate these prospective benefits. A Project XL Agreement and goals were developed as part of a joint statement of the plans, intentions and commitments of the EPA, the state of California, and Yolo County, to carry out this project

Through the EPA Project XL, Yolo County ultimately obtained regulatory flexibility from the federal and state regulatory agencies. This approval was based on accepted project performance goals, available controls, and environmental safeguards, which had already been demonstrated to a large degree in Yolo County's smaller-scale pilot project at the Yolo County Central Landfill.

CEC has also played an extremely helpful role in supporting the Yolo program since its inception (first planning in 1989). In fact, the initial pilot program startup support was through a contract with CEC's Energy Technologies Advancement Program (ETAP). Later, the combination of obvious severe shortfalls in California electricity generation, EPA's facilitation, and the California Integrated Waste Management Board support of the program, in conjunction with early pilot program successes, all combined to enable further support through the CEC. That supported work by CEC via the PIER program contract administered by the Sacramento Municipal Utility District (SMUD) is the subject of this report. This project's main objectives included the following:

- Acceleration of waste decomposition and leachate treatment, via liquid amendments and recirculation of leachate via a pipe network serving the waste mass. This was to be done while showing that recirculation could be accomplished without excessive leachate head build-up over the base liner. The ultimate objective is to accomplish rapid completion of composting, stabilization and generation of methane to the maximum practical yield.
- Efficient capture of nearly all generated methane, by withdrawing at slight vacuum from a freely gas-permeable shredded tire collection layer beneath low-permeability cover. The withdrawal is to be accomplished with negligible impact to the local air quality. Near-complete extraction with this approach has already been demonstrated in the 9,000-ton small-scale demonstration cell with the Yolo County demonstration project.
- Documentation of the capital and operations costs of a full-scale bioreactor and determination of the economic viability of its commercialization.
- Establish these environmental and renewable energy benefits to facilitate regulatory acceptance.

1.4 Historical Background

Earlier laboratory and field work

One process with long-recognized potential for adding a modest but significant increment of energy and natural gas for U.S. needs was the management of municipal solid waste (MSW) decomposition to provide a mix of methane and carbon dioxide, or "biogas". Although other approaches have been and are even being tried now, it has become clear based on a growing body of information that a promising MSW-to-methane approach for the U.S. is to manage the decomposition of waste in sanitary landfills to generate biogas termed "landfill gas". Some important elements of development along the path to the present Yolo program and controlled landfill technology are discussed below.

The earliest projections of controlled bioreactor landfills along the lines of the present Yolo program occurred in the early 1970's. The work leading to the Yolo program began with an investigation of methane generation from MSW by Dynatech R/D Company. The work was sponsored by the Consolidated Natural Gas Company of Ohio. It involved parallel components of (a) a major laboratory investigation of MSW-to-methane bioconversion in adaptations of conventional sewage digesters. Methane was to be generated in a process, which included grinding, stirring, a several week digestion period, and processing of all unconverted liquid and solid residues, and (b) a National Science Foundation (NSF) Grant of $500,000 to Dynatech R/D Company to conduct an engineering and economic analysis of such conversion.

The in-vessel MSW-to-methane conversions had been widely advocated, yet had never been closely examined for engineering and economic practicality. When the Dynatech R/D MSW-to-methane laboratory results were examined using the economic model developed under the auspices of the NSF, the envisioned (stirred tank) conversion was found to be both highly uneconomical and even energetically inefficient (i.e. the process consumed about as much energy as it produced). It was recognized on the basis of several lines of evidence that a more economic and energetically efficient MSW to methane process should be digesting waste in situ, in landfills themselves. The landfills would be suitably modified to optimize conditions for

biological conversion. Tests in unstirred, high-solids laboratory reactors generally confirmed this with even better gas yields than in stirred reactors. Projections showed both an order-of magnitude lower cost and lower parasitic energy requirements. A very early, fairly detailed publication out of Dynatech R/D Company was that of Augenstein et al. (1976) projecting MSW-to-methane digestion within the landfill or controlled landfilling.

The Dynatech publication projected a particular energy-focused bioreactor approach, which included methane enhancement details, yields and costs, high-efficiency gas capture, and a fairly detailed projection for its large-scale application (Augenstein et al. 1976). These early Dynatech R/D Company projections have, in general, been confirmed as technology has progressed. Early literature also included papers by John Pacey and co-workers, and collaboratively with Robert Ham of the University of Wisconsin on in-landfill bioreactors. Larger-scale tests were performed with the main objectives of decomposing waste and obtaining relevant measurements, although not on methane gas (EMCON Associates 1975). At the same time, work was performed on the "leachate recycle" approach by Dr. Fred Pohland and co-workers (Pohland 1975, 1980).

Earliest operations elsewhere that might be included in the category of bioreactors, often envisioned limited objectives. In most cases, a primary objective (i.e. Pohland et al. viewpoints) was to dispose of landfill leachate (liquid draining through waste) via the capacity of as received waste at moisture content around 20-25% to imbibe water up to moisture contents up to 35-45%. More rapid stabilization of waste and some remediation of leachate pollutants were also foreseen. This allowed beneficial use of leachate liquids, whose disposal would otherwise pose a problem. As time went on, the expanded objectives of various projects included (a) accelerated decomposition of waste, (b) volume reduction of waste thereby extending landfill life, (c) earlier stabilization of landfilled waste to avoid later care, and (d) maximization of energy and electricity recovery and minimization of methane (greenhouse gas) and pollutant emissions from landfilled waste.

The potential for augmenting biological decomposition of landfills was also recognized early on by EMCON Associates (San Jose, CA), under the direction of its president John Pacey. Concurrently with the work from Dynatech R/D Company, EMCON Associates had conducted a series of larger-scale test cell operations in Sonoma County, California.

As the potential for practical in-landfill MSW-to-methane digestion became evident with continuing tests, Dynatech R/D Company, in the late 1970's, prepared a proposal for large-scale testing of the controlled landfill bioreactor. Testing of concepts in this proposal was ultimately funded in Mountain View, CA by a consortium lead by Pacific Gas and Electric Company of California with fieldwork undertaken by EMCON Associates (San Jose, CA).

The Mountain View demonstration involved methane enhancement in 6 test cells and over 30,000 tons of waste over 4 years. Although some of its findings were preliminary, and some performance unexplained, the Mountain View project had one extremely important outcome. From optimizing conditions for decomposition, it was possible to obtain a several-fold (3 to 10-fold) increase in methane capture compared to expectations from similar masses of waste in conventional landfills. This project, therefore helped greatly to set the stage for further evaluations of controlled landfilling (as it was termed) for maximizing energy recovery from landfilled waste and was an important development on the way to the present program.

The evident benefits of optimizing landfill decomposition conditions set the stage for the Yolo County demonstration project.

1.5 Yolo Pilot-Scale Project – 1993 to Present

In 1989, Yolo County became interested in applying the controlled landfill bioreactor technology at their Central landfill. At the same time, Don Augenstein (while at EMCON) and John Pacey were interested in further advancing bioreactor technology. Proposals to operate a bioreactor were prepared at EMCON Associates (San Jose, CA) with encouragements from John Pacey, EMCON President. A final version of an extensive proposal was approved by the California Energy Commission in December 1991. Additional cost sharing support was also provided by Sacramento County, California. Work began approximately a year later after necessary permits and approvals were obtained.

The main objective of the initial Yolo County Pilot-Scale Demonstration Project was, as with Mountain View tests discussed elsewhere, to optimize a landfill bioreactor to enhance methane generation to the maximum possible yield. Another objective was to mitigate landfill methane emissions, whose adverse climate effects were increasingly well understood as a major factor in the climate picture (Augenstein 1992). Gas capture would be maximized through operational sequence and a surface gas capture design. Another general goal was to overcome some of the difficulties and problems that were encountered in the earlier tests at Mountain View. Important specific goals included:

- Careful and complete material balances on all components (waste, liquids, and gas) entering and leaving test cells.
- Extensive instrumentation and measurements of temperature, moisture, and pressure. This included provision for moisture and temperature throughout the waste mass, base liner integrity, and leachate composition.
- Use of a top surface over the waste of a shredded tires permeable layer. This was overlain by a polyethylene geomembrane to allow near complete (estimated 95-99%) gas capture throughout the experiment.
- More accurate and complete landfill methane capture measurements than in any previous and comparable work.
- Use of methods and materials that would be economically practical for as high a fraction of landfills as possible, both in the United States and around the world.
- An operational sequence to reduce early or "pre-gas collection" methane emissions. This was to be achieved by a sequence of filling, then surface tire layer coverage, then membrane coverage for gas capture. Only then, once waste was capped by cover for maximum gas capture, was liquid added to enhance and maximize methane generation.

1.5.1 Overview

The following provides an overview and summary of the pilot-scale test cells. Additional detailed information may be found elsewhere, particularly Yazdani (1997). Also see other symposium texts, including Yazdani and Augenstein (2001) and Yazdani et al. (2003).

The Yolo demonstration project involved building and operating two demonstration cells, containing about 9,000 tons of MSW each. One cell received liquid addition and recirculation and was the enhancement cell, while the other was operated as a typical dry-tomb control cell. Important features included:

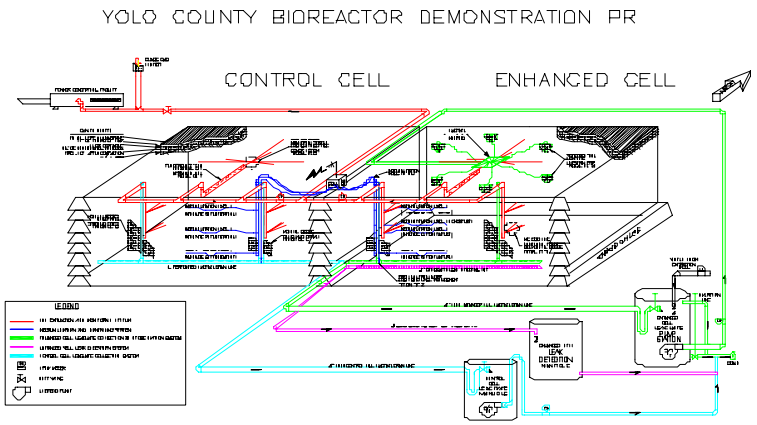
- A high-permeability leachate collection and recovery system (LCRS) under the waste to handle any likely rate of liquid leachate drainage that might be encountered.
- Multiple moisture and temperature sensors (over 50) emplaced while the pilot-scale cells were built to allow for accurate waste monitoring.
- The use of permeable greenwaste daily cover in lieu of soil to allow better liquid infiltration.
- A highly gas-conductive shredded tires layer just below the surface of the cell with permeability estimated at > 10^6 Darcys.
- A surface cover geomembrane to prevent gas emissions to the atmosphere and confine gas to the permeable shredded tire layer.
- Introduction and recirculation of liquids through multiple metered surface addition points spaced on approximately 25-ft centers to achieve (a) elevated moisture sensor readings, (b) a planned waste moisture content (around 40%), and (c) liquid outflow ratio of at least 50% of inflow.
- Gas extraction through application of slight vacuum (<0.5 inches of water) from the collection system to the permeable layer to withdraw gas as it is generated.

1.5.2 Waste Selection and Placement

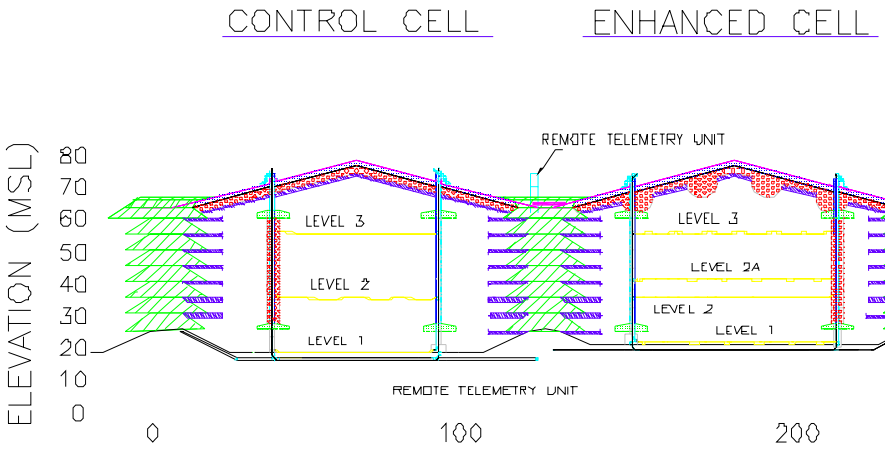
Waste were typical residential or commercial loads from packer truck collection routes serving households, small businesses, markets, etc. Tonnages were carefully logged. Loads that were inert (like wood or concrete) were diverted. Lifts were covered with greenwaste rather than more typical cover soil. This use of greenwaste for cover left waste permeable to later moisture additions, and allowed some limited initial composting, which elevated startup temperature as well. The test cells were filled between late 1994 and early 1995.

1.5.3 Important Features and Results

Specific features of the test cells, 100 ft by 100 ft by 40 ft deep are shown in the oblique view in Detail 2. Moisture and temperature sensors were located at 3 layers of the moisture added enhanced cell and 2 layers of the control cell. Cross-sections of cells with instrumentation are shown in Detail 3.



Detail 2. Yolo County bioreactor test cells demonstration project



Detail 3. Cross-section of test cells demonstration project

Both the enhanced and control cells experienced substantially elevated temperatures, around 45-55°C then falling and stabilizing to levels still well above ambient, around 40°C in the enhanced cell and 30°C in the control. Heat generation from methanogenesis is thought particularly important in the enhanced cell, which maintained its higher temperature while the control cell tended towards cooler temperatures after two years. Elevated waste temperature is a beneficial factor in enhancing methanogenesis.

The surface liquid addition method was effective based on the elevated moisture sensor readings with time and methane enhancement performance. Prior to this project, considerable modeling study had projected the need for rapid liquid additions for optimal moisture distribution into bioreactors. But, in this test, the liquid addition and recirculation were

relatively conservative. Liquid addition was slow and easily manageable at 0.2-0.6 gal/ft²-day. This helped in limiting head buildup over the base liner and minimizing waste instability effects due to liquid pore pressure, as well as limiting moisture-related factors like side seeps and increased lubricity/plasticity from increased moisture. This slow liquid addition would also minimize waste instability effects due to liquid pore pressure.

One early concern was that moisture distribution with slow additions and the multipoint distribution system would be incomplete. However, the moisture sensor readings quickly elevated at nearly all points in the waste, indicating good moisture distribution. Sensor moisture readings recorded in the interval from April 1995 to January 2003 are shown in Figure 1 below.

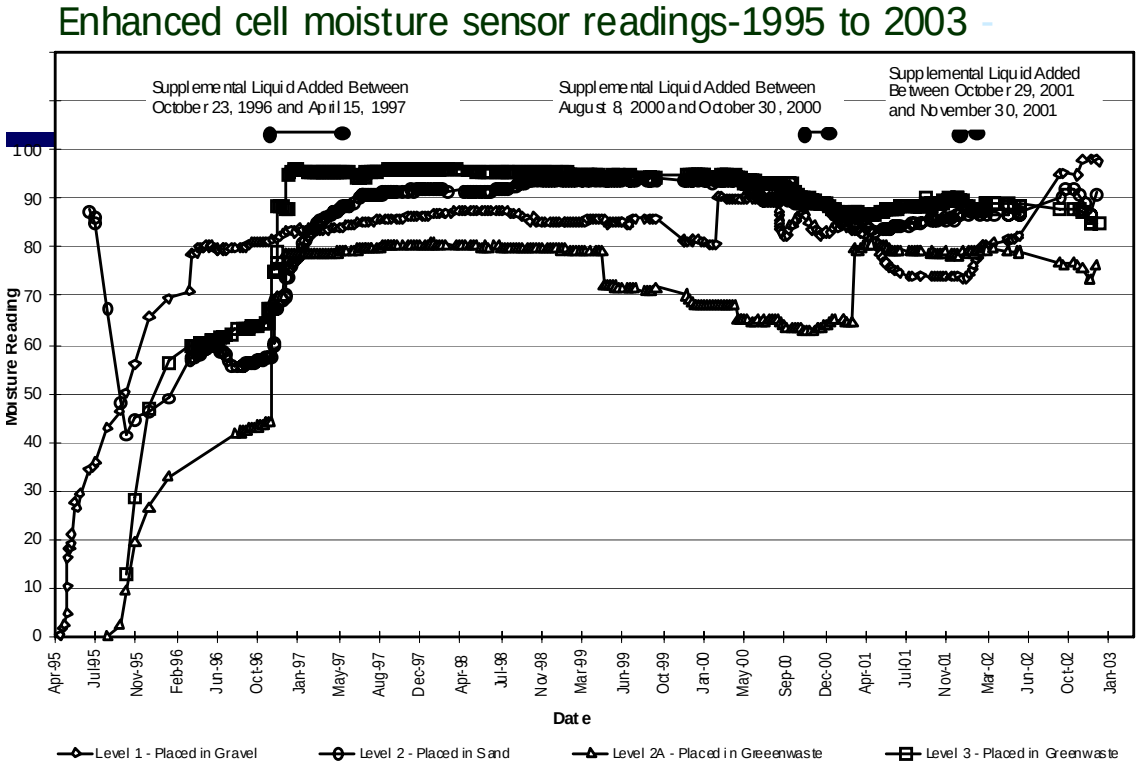


Figure 1. Moisture sensor readings versus time for moisture enhanced pilot-scale cell.

No liquid level buildup was seen in the injection pits, so liquid entered the waste easily, and most of the necessary liquid infiltration was accomplished within 3 months. Liquid permeability of the waste of over 3 x 10^{-5} cm/sec was estimated from these moisture permeation results. Core sampling data (not shown), as well as the gas results, confirmed that moisture distribution was excellent.

Figure 2 below (gas data from June 1996 to January 2005) shows the cumulated methane generation for the enhanced and control cells, with both of these compared to the normal generation expected for this mass of waste (the "normal" from the 19-landfill study of Vogt and

Augenstein (1997), and sources including EMCON). A methane recovery rate of over 5-fold that of conventional landfilling is one of the most important findings of the demonstration project. The accelerated methane recovery rates have major implications for improved methane energy recovery, and with high efficiency gas capture as in the demonstration, greenhouse gas emission and odor control.

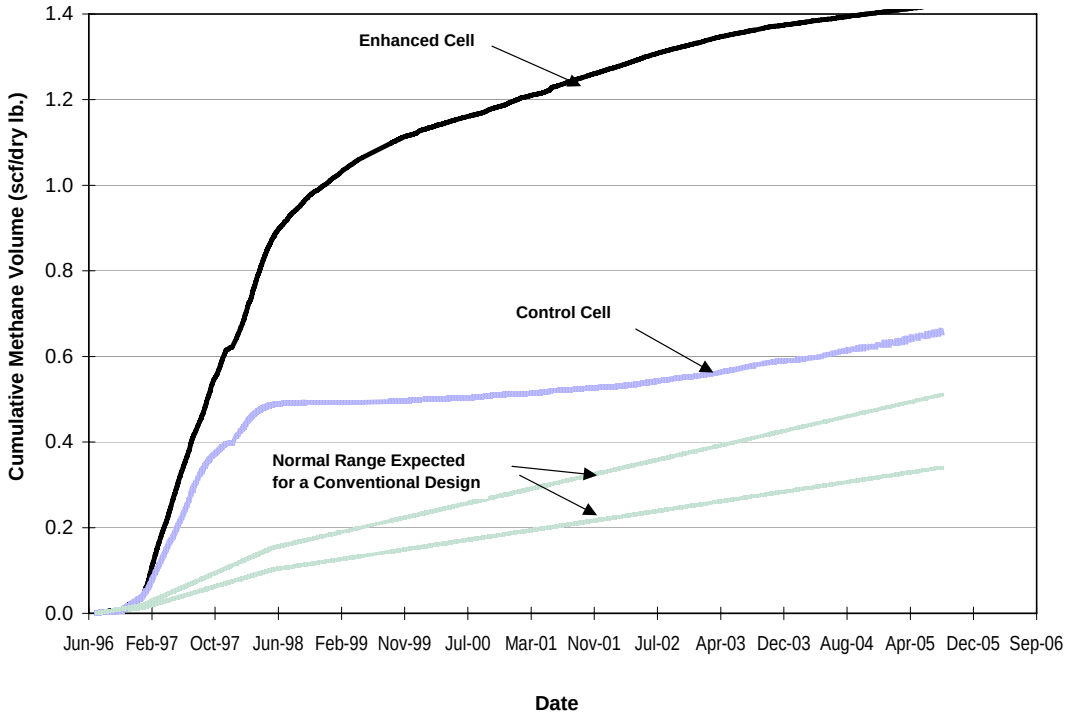


Figure 2. Cumulated methane recovery of pilot-scale 9000-ton enhanced bioreactor and control. Note the greatly accelerated methane recovery from the enhanced pilot cell relative to conventional and controls.

The methane generation behavior of the control cell started with rapid methane generation. However, the methane generation came to a near-complete stop quite suddenly, approximately a year after gas collection started. This rapid start is thought to be due to its initial elevated temperature in conjunction with its normal as-received moisture of around 18%. This observation supports the often-discussed expectation for dry-tomb landfills from which moisture is excluded. The slowing and limit to waste decomposition in the dry-tomb is confirmed by these control cell results. The confirmation of the dry-tomb phenomenon, wherein un-decomposed waste poses greater long-term risk, is another argument for the controlled bioreactor landfill.

The rapid conversion of solid material to gas in the enhanced cell is associated with rapid and pronounced reduction in waste volume. A photograph of the enhanced cell compared to the control is provided in Image 1. Volume loss of waste in the enhanced cell is pronounced, of the order of 20%. This fractional volume reduction in the moist, enhanced cell corresponded closely to the fraction of solids converted to gas. This volume loss can be extremely important

inasmuch as such waste shrinkage in the fill should translate in the long term into an ability of bioreactor landfills to accept substantially more waste than a conventional landfill. This translates not only to environmental benefit, but an economic benefit to landfill operators. The economic value of volume reduction and landfill life extension is comparable to the methane energy value, and will facilitate the controlled landfill process. Another very interesting observation is that added moisture as well as waste conversion to methane both seems required for volume reduction. Solids conversion to methane by itself, without added moisture (as occurred with dry waste in the control cell) gave little apparent volume reduction. Only the enhanced 9000-ton cell with moisture added showed the volume loss that might be expected based on the waste solids converted to gas. This is another argument for bioreactor operation via moisture enhancement.

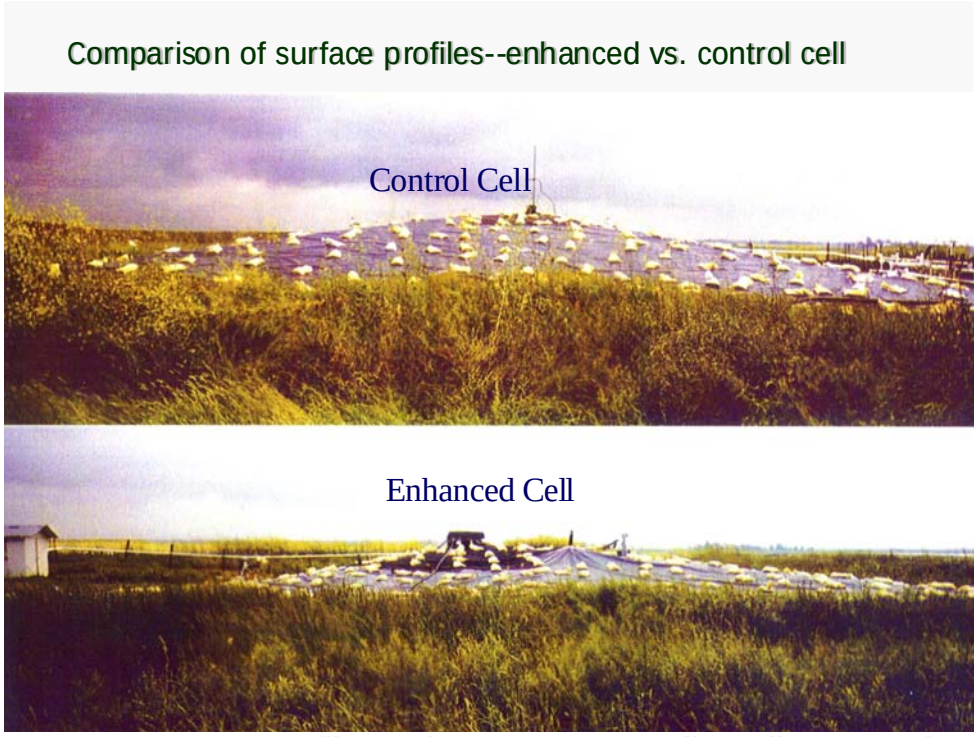


Image 1. Surface profiles of the two 9,000-ton pilot cells operated 1995 to present. Note the waste volume loss indicated by the subsidence of the methane-enhanced cell. This subsidence is due to the destruction of organic waste solids (like paper fractions and food) to form landfill gas.

The sensor readings, core moisture results, methane generation (methanogenesis), and volume reduction all indicate that it was possible for a slow, multi-point surface moisture addition approach (without deep injection wells) to give good moisture elevation throughout the mass of waste. This good moisture distribution with slow moisture percolation occurred despite studies indicating that much more rapid additions should be required. The liquid infiltration rates, even if infiltration should be slowed by compaction at greater depths, are still quite promising. And this moisture addition method is relatively economical and controllable.

The important outcomes of the Yolo pilot tests were (a) very substantial acceleration of methane recovery compared to the conventional landfill operation (Figure 2). And (b) as more waste solids were converted to methane, the volume of landfilled material lessened as seen in Image 1.

1.5.4 Conclusions

The Yolo County Bioreactor Pilot-Scale Project, still ongoing, has performed as well as hoped in virtually all respects. Among key benefits of greatest concern here was increased methane capture for energy and methane emission prevention. It is clearly evident the success here provided the basis for the scale-up to Yolo County's full-scale controlled landfill bioreactor application, which is the subject of this project report.

1.6 Other Relevant Large-Scale Demonstration Projects-- Past and Present

The following sections summarize some of the most relevant demonstration projects. The project attributes are either (a) focused on increased energy and electricity production and thus are the most closely comparable to the Yolo County Program, or (b) relevant in terms of being larger-scale demonstrations of accelerated waste decomposition in landfills.

1.6.1 Sonoma County, California

The Sonoma County project was one of the first studies on liquid addition and leachate recirculation. Summary of the Sonoma County project design can be found in Appendix A, Table 1. Five pilot-scale demonstration cells were constructed. Each cell contained about 500 tons of municipal solid waste and each had a clay cap (EMCON 1975). The cells were 49 ft by 49 ft by 10 ft deep. Various enhancement techniques were applied to each cell as shown in Appendix A, Table 1. Cell A was the project control, and therefore did not receive liquid. Cells B and E were initially brought to field capacity through the addition of water and septic pumping, but liquid additions did not continue. Cell C received daily additions of water, whereas cell D received daily additions of leachate (leachate recirculation). Between November 1971 and April 1974, leachate quality, gas composition and landfill settlement were the parameters monitored to determine the relative levels of waste stabilization. Results of the project indicated the level of waste decomposition was higher in the cells that had continual liquid addition (Leckie and Pacey 1979).

Landfill gas composition from cell C and cell D suggested favorable conditions for waste decomposition because the gas compositions stabilized at 50% methane. Unfavorable conditions for methane generation were indicated by the control cell, and cells A, B, and E. The gas composition for these cells was similar, all remained near 90% carbon dioxide (EMCON Associates 1975). Generally, gas composition indicated that liquid addition enhanced conditions for waste decomposition.

The leachate composition in both cells C and D showed declining organic strength. However, cell D provided the most rapid decline in chemical oxygen demand (Reinhart and Townsend 1997). The daily addition of water into cell C, without the recirculation of that water, generated large volumes of leachate that required treatment (Reinhart and Townsend 1997). On the other hand, the daily addition of water and the recirculation of leachate proved a beneficial means of treating the leachate in situ.

Landfill settlement showed the most significant benefits from leachate recirculation. The only leachate recirculation cell, cell D, showed a 20% reduction in height while other cells averaged only a 7.6% reduction in height (Reinhart and Townsend 1997). These settlement results, along with the gas and leachate composition results showed that while the addition of water can help decomposition, the greatest benefit was realized in this test through leachate recirculation.

1.6.2 Mountain View, California

This work started in part as a scale-up of laboratory work and engineering analysis at the Dynatech R/D Company in 1972 and was in a way an expansion on the Sonoma County project discussed previously.

The Mountain View demonstration was one of the earliest, and is still one of the most comprehensive, landfill enhancement projects. This project explored the effects of varying and optimizing those environmental components considered to affect activity of the anaerobic microorganisms. Several environmental conditions were varied including moisture, pH buffering, bacterial and nutrient supplementation with sludge amendments, and leachate recirculation.

The project's operation was managed by EMCON Associates (San Jose, CA) and a Ph. D. student, Costa Halvadakis, at Stanford University. The tests were initially funded by a consortium of stakeholders including the Pacific Gas and Electric Company, Southern California Gas and the U.S. Department of Energy. At Mountain View, six test cells were run at varying levels of moisture and amendments that included water, and varying levels of sewage sludge, and leachate (EMCON Associates 1987).

Six demonstration cells were constructed and each was filled with slightly over 5,000 tons of municipal solid waste. The cells were 100 ft by 100 ft by 47 ft deep. The amendment regime applied to each cell is shown in Appendix A, Table 2 and other findings from cell operation are included in Table 3. Cell F was the project control cell and received no amendments. Cells A, B, C, and E received sludge and buffers, and cell D received buffer only. Leachate recirculation was partial, and applied to cell A only. From June 1981 to December 1985, a variety of parameters were monitored to evaluate each enhancement regime.

Although the project is known as one of the most comprehensive of the field demonstration studies, some of the results conflict with other studies that use leachate recirculation techniques. For example, the total reported gas production rates were lower than the rates obtained in other studies. Several other anomalies were observed. One of the driest cells, D, reportedly generated the most landfill gas. Cell A produced less gas than cell C, in spite of the fact that the cells were identical except for the partial recirculation of leachate in cell A.

In contrast to the gas generation data, a BMP analysis of refuse samples showed (as expected based on fundamentals) more degradation in the leachate recirculation cell than in the control cell. Results are shown in Appendix A, Table 3. The recirculation cell had the lowest potential (0.35 standard cubic feet (scf) of methane per pound of dry refuse). The highest methane potential was found in the cell that had only negligible water infiltration, cell D, which had a potential of 1.93 scf of methane per pound of dry refuse (EMCON Associates 1987). These gas recovery and BMP results are inconsistent with one another. The temperature data showed heating above 60°C in every case where gas recovery interruptions were observed.

Thus, some difficulties and puzzling results were experienced in this project. However, final biochemical analyses of refuse samples provided evidence confirming recirculation success. Cell A, which had leachate recirculation, had relatively low volatile solids content, low cellulose content, low carbon-to-nitrogen ratios, and high carbon-to-phosphorus ratios. All of these are evidence for faster stabilization. On the basis of loss of volatile solids, waste decomposition and

methane generation were enhanced by moisture, sludge addition and leachate recirculation (Reinhart and Townsend 1997).

Although some of its findings were puzzling, this Mountain View project had one extremely important outcome. From optimizing conditions for decomposition, and careful gas recovery measurements, it was possible to obtain a several-fold (3 to 10-fold) increase in methane capture compared to expectations from similar masses of waste in conventional landfills. Therefore, this project more than any other, helped set the stage for the Yolo County Demonstration Project.

The chronology of cell construction through 4 years of operation is presented in the final project report by EMCON Associates and John Pacey (1985).

1.6.3 Delaware Solid Waste Authority

The Delaware Solid Waste Authority began employing one of the first large-scale applications of liquid leachate management and recirculation on a full-scale basis at its Central Solid Waste Management Center (CSWMC) in Sandtown, Delaware. Leachate recirculation began in 1982 on cells that were built in 1980 as a method to treat the vast quantities of leachate produced from close to 30 acres of waste (Vasuki 1993). Several recirculation methods were tested at this facility including surface flooding, spray irrigation, vertical recharge wells, and tiled infiltrators. Initially, techniques were not applied in a scientific manner and the information about the project is primarily qualitative. However, the project is invaluable as a preliminary evaluation of large-scale liquid recirculation techniques.

Surface flooding was determined impractical due to odor problems and the mess that it made (Vasuki 1993). The irrigation system was employed on a closed section of landfill where it also killed the existing vegetation, as well as created odors.

Vertical recharge wells were used to allow leachate to trickle down into the landfill and act as an aerobic filter (Vasuki 1993). This attempt was efficient compared to previous attempts, however the pea gravel that was used to fill the wells clogged in the presence of leachate precipitates (Vasuki 1993). Wells were redesigned for recirculation using large stones in a four-foot diameter perforated concrete cylinder (Vasuki 1993).

An infiltration filed located below the final cap and constructed from roof tile was utilized in the next system. The system also incorporated valves that allowed control of liquid inflow (Vasuki 1993). This system has worked well.

Gas generation rates are unavailable for the Delaware work. However, favorable conditions for waste decomposition were evidenced by low organic levels after about seven years (Reinhart and Townsend 1997). DSWA concluded qualitatively that leachate recirculation increased waste breakdown, settlement, and gas generation, and decreased cost of leachate treatment.

The DSWA also ran two 10,000-ton test cells where the waste decomposition was monitored, including test lots of waste in time capsules. However, the detailed data was less than expected, due to loss of instrumentation when the wire leads to in-waste sensors broke during operations. Gas capture was incomplete and appeared to be at best a small fraction of generation (or potential). An additional issue on review of the project was that the leachate recycled from relatively dry, as-received waste was limited, so that waste moisture apparently remained well

below field capacity. At the end of tests, pronounced decomposition of waste samples was seen in portions, but not all of the waste in the leachate recycle cell.

The literature on DSWA leachate recycle activities has been voluminous. A short overview of some activities was presented by Anne Germain, Head of Landfill Engineering at the DSWA, at the EPA February 2003 Workshop on Landfill Bioreactors, Arlington, VA, entitled "Bioreactors-Practical Experience".

1.6.4 United Kingdom and International Energy Agency Project and Report

Based on the results of the previous controlled landfill bioreactor studies, the objective of the Brogborough study was to further investigate the effect of waste density, air injection, waste amendments, and leachate recirculation (Croft and Fawcett 1993). The project consisted of six demonstration cells filled with between 16,000 and 22,000 tons of waste (Reinhart and Townsend 1997) (Appendix A, Table 4). Cell 1 was the project control while various enhancement techniques were applied to the remaining five. As outlined in Appendix A, Table 4, these were (a) low-density waste placement, (b) water and leachate recycle, (c) air injection, (d) sewage sludge and water addition, and (e) commercial and industrial waste addition.

Based on the landfill gas flow rate and methane composition, investigators stated that "results show that a mixture of nonhazardous commercial and industrial waste helped to promote degradation. This conclusion would, of course, depend on the typical industry waste brought to a specific landfill."

As methane production increased in each cell, the leachate composition decreased in organic strength and the pH level increased (Croft and Fawcett 1993). Settlement significantly impacted the integrity of the cap and gas recovery piping, which may have affected the gas recovery results (Reinhart and Townsend 1997).

This and other projects were further documented in the early 1990's by the International Energy Agency (IEA) Expert Working Group and Agencies in the United Kingdom Environmental Technology Support Unit (ETSU) of the UK Atomic Energy Agency for some time. These reports are available from IEA.

1.6.5 Buncombe County, North Carolina Bioreactor

Information on the Buncombe County Bioreactor was taken from the EPA Project XL website in the document "U.S. EPA Project XL Final Project Agreement" submitted in July 2000. The principal distinguishing feature of Buncombe County's approach is the alternating use of the same lines for both leachate injection and gas extraction. Other advantages and approaches are similar to those stated in other bioreactor projects, including Yolo's project XL. (Yolo County helped to advise and provide background for this project.) From recent discussions with Chris Gabel of Camp Dresser and McKee, the implementation of the Buncombe project has been delayed for reasons that were unforeseen at the outset, mainly due to existence of asbestos in old sections of the landfill. Construction of the project only began proceeding at the end 2004 as outlined in the proposal. In recent discussions with Chris Gabel, Project Manager at Camp Dresser and McKee, completion is anticipated in spring of 2005.

1.6.6 Corral Farm Landfill, Fauquier County, Virginia (from SCS Engineers website)

Fauquier County is also experimenting with bioreactor operation at their Corral Farm Landfill. The bioreactor portion of this project is managed by SCS Engineers and more information on the project can be obtained at http://www.scsengineers.com/Profiles/bioreactorprojects.html.

1.6.7 Other EPA Project XL Landfills--Virginia

Descriptions of other Virginia landfills can be found on the EPA XL project website, http://www.epa.gov/projectxl/virginialandfills/page6.htm. Reports include the following: the Prince Georges Landfill, Prince Georges County, and the Maplewood landfill, Amelia County.

Inspection of these reports showed that the design and operation of these projects were not focused so strongly on maximizing energy capture or on limiting emissions to their lowest possible level. Although these XL projects are, by regulatory standards, fully compliant with rules, data are being developed in other key areas such as liquids management slope stability analysis, etc. Gas recovery data are presented well by well but not summarized, so the report data would require further work for interpretation.

1.6.8 Other Recent Tests: Waste Management, Inc (WM) Tests: Outer Loop Landfill

Waste Management, Inc. (WM) is conducting bioreactor tests at its Outer Loop Landfill, Louisville, Kentucky. (WM reports it is conducting a number of other tests at other sites, for example the Prince Georges Landfill, Prince Georges County, and the Maplewood landfill, Amelia County (Websites for these are referenced above.) Its bioreactor program, in terms of effort, is reported by WM personnel to be the largest of any private waste company. Among important aspects of the WM program is its execution of a Cooperative Research and Development Agreement (CRADA) between WM and the U.S. EPA, which funds a great deal of supporting analytical work and work on environmental parameters of bioreactors at WM's bioreactor sites.

In its XL project information made publicly available, WM's primary focus has not been energy recovery, although this may change as the world energy picture changes. A major, overriding goal of WM to date has been waste volume reduction, which allows landfill life extension (i.e. increased capacity at existing landfills). Another goal is to develop a necessary base of operational knowledge and actual experience and effort to achieve the benefits associated with bioreactors. One approach used by WM is the "facultative landfill" in which a landfill sector is first aerated to elevate temperature to an optimum, and then allowed to produce methane anaerobically once that optimum temperature is established. A variation on this is to use wastewaters that have nitrified dissolved ammonia (treated leachate). WM has patented both the facultative landfill, and the use of nitrified, treated leachate in bioreactor landfills.

The results of the work done under the Waste Management/EPA Louisville Outer Loop CRADA are listed on the U.S. EPA website,
http://www.epa.gov/ORD/NRMRL/Pubs/600r03097/600r03097.html.

Another source of information is WM's website,
http://www.wm.com/wm/environmental/bioreactor/index.asp.

In terms of instrumentation, the Waste Management Outer Loop project is a commercial operation that is somewhat constrained for practical reasons, and it has been less intensively instrumented than was the Yolo Project. For example, from the report, temperature measurements are performed in two ways: from temperature of leachate exiting the waste and by placing a probe in waste sampled with a bucket auger. Determinations of waste moisture and other measurements were made by Dr. Morton Barlaz at North Carolina State University. These temperature and moisture measurements and other methods provide less in the way of detail on a less continuous basis than the sampling methods using embedded temperature and moisture sensors.

A strong focus of WM has been on subsidence and settlement at Outer loop, which is measured very accurately because of the monetary implications of added landfill space associated with volume loss during settlement. Data are also taken on regulatory compliance, particularly on factors such as head over the liner.

Waste management findings excerpted from their posted EPA report are summarized in Appendix A, Table 5.

As far as gas recovery is concerned, WM is overextracting on their wells, at least as suggested by methane concentrations that fell to as low as 20% because of air dilution. Instead of complete gas collection, the tests at Outer Loop have also, in part, been conducted to determine the efficacy of a surface biofilter in abating methane that approaches the waste surface, by bio-oxidation.

An approximate lower bound k value can be derived from the recorded gas recovery "time-averaged" over the entire reported measurement interval, of about 100 cubic feet per minute (CFM) of methane. The authors estimated that k is roughly 0.05 $year^{-1}$, or about 10-20% of that of the Yolo pilot-scale cell. Low k values may be a function of relatively cool waste temperature at around 25-35°C. This is much cooler than bulk waste temperature values seen in the Yolo County's Project. Temperature is extremely important, and operating at 30°C vs. 45°C would, by itself, be expected to slow methanogenic activity by over half. WM staff is well aware of this, and the intent is elevating temperature by initial aeration in its latest cells

WM has been examining methane emissions. The Outer Loop Landfill has been found generally in compliance by means of integrated surface scans. The emission of fugitive methane has been quantified by sophisticated Fourier transform infrared spectrophotometry at less than 10 CFM when tests were done, also indicating modest methane losses and that the landfill is compliant under regulations. All of this suggests that capture is efficient, and thus the fairly low value of k may be realistic.

To summarize, WM's objectives have been focused on aspects other than energy including volume loss and emissions. Additional information and overview of WM's approach can be obtained in the article by Carson and Green (2003).

1.6.9 New River Bioreactor Landfill (Florida)

The New River bioreactor involves experimental adaptations on an existing landfill, and adaptation of new landfill sections to meet research objectives. Some of the New River project's important features are:

- Vertical clusters of liquid injection wells (135 wells in 45 clusters). Piping enabled tests of both aerobic and anaerobic operation in different parts of the landfill.
- Exposed geomembrane cap.
- Gas collection from horizontal trenches beneath the cap and leachate collection system.
- Extensive moisture (resistivity based probes) and temperature instrumentation (332 thermocouples and 138 resistivity based moisture sensors).
- Ability to test shallow and deep waste permeability via liquid draining rates.
- Ability to test air permeability.

The parameters being measured at the New River Landfill are of fundamental value in understanding future operations of bioreactors. An example of one such parameter is waste permeability tests using infiltration rates of liquid from vertical wells. In terms of results on energy recovery, the landfill produces only a fraction of the gas potential that would be inherent from an 800 tons per day (TPD) waste inflow, (about 300-400 ft^3/ton vs. potential that we estimated at 3000 ft^3/ton). The situation is admittedly complicated by the partially aerobic operation. The New River project is in startup status, and much more high value data on waste management parameters and operations is anticipated to be forthcoming in future years of this project as operational experience is gained.

Recent information can be found from Reinhart et al. (2004) and the website, http://www.bioreactor.org/publications.htm, operated by the University of Florida. A presentation by the same group was made at the Third International Landfill Research Symposium, Sapporo, Japan, November 2004. Slide presentations will be available at http://lst.sb.luth.se/iclrs/web/symposia.html.

1.6.10 Anne Arundel County, Maryland

Information on the Anne Arundel County Millersville Landfill is available at the EPA Project XL web site at: http://www.epa.gov/projectxl/aarundel/index.htm. Although the project features have some general resemblance to the Yolo County project, the major focus is something other than energy.

1.6.11 Other Projects

Numerous other projects have been undertaken, but most differed from the Yolo Controlled Bioreactor Landfill operated for energy recovery. The basic lack in most operations was relevant measurements or publication of the effects of recycling.

In a multitude of projects, including past and ongoing experimental projects, examples of missing measurements and information that would be desirable included:

- Incomplete collection of landfill gas when generated.
- When leachate recycle was practiced, there were few measurements of where the added liquid actually went or how effective the addition was in terms of consequences for energy.
- Few measurements of other types, including temperature.

- In most cases no overall measurements of aspects now considered extremely important. Methane capture effectiveness and emission abatement and more recently, under subtitle D landfill rules, of leachate head over the base liner.
- The projects for energy recovery assessment were relatively short term (4 years at most) and were terminated (for a variety of reasons including lack of funding and landfill closure requirements) prior to waste degradation reaching completion.

1.7 Organization of Subsequent Sections of the Report

This report is organized into the main categories of design, construction, monitoring and data analysis, project operation and maintenance (O&M), economics, and conclusions. Where applicable, important data in the form of graphs or tables is included within the text, however, the majority of the data can be found in the appendices. Photographs, design drawings, and reports are also located in the appendices. For clarity and where data results differed, discussions of the bioreactor cells were separated into different sections.

2 PROJECT DESIGN AND CONSTRUCTION

The project was separated into three bioreactor cells, two cells were operated anaerobically and one aerobically. The cells have been designated as the northeast and west-side anaerobic cells and the southeast aerobic cell. This configuration allowed the northeast cell to be constructed and operated prior to completion of the west-side cell. In addition, experiences gained from the construction of the northeast cell were incorporated into the west-side cell.

2.1 Base Liner System

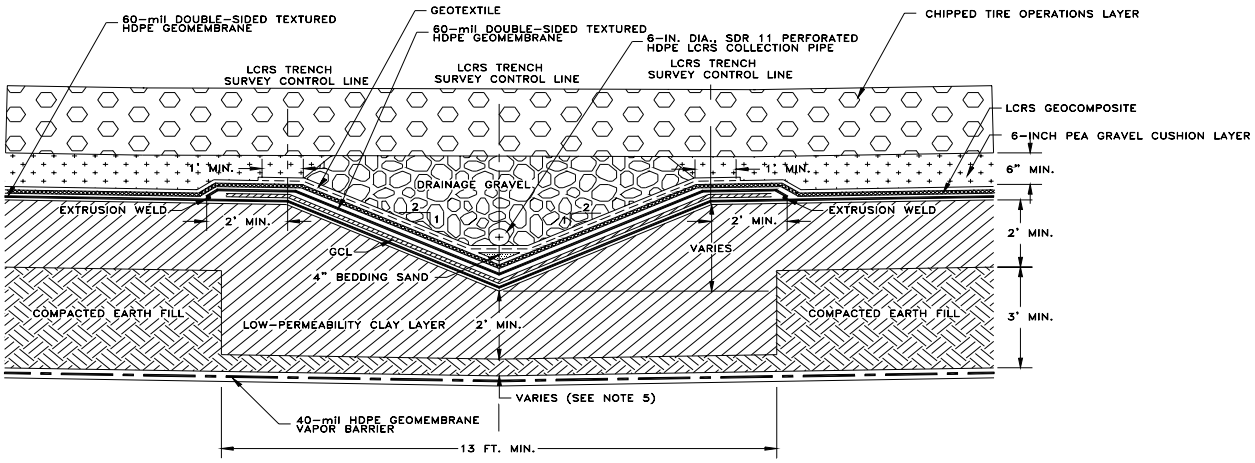
All three bioreactor cells share a common composite liner system designated the Module 6D primary liner. This composite liner system was designed to exceed the requirements of Title 27 of CCR and Subtitle D of the Federal guidelines.

The base layer of Module 6D has a ridge and swale configuration, enabling the west 6-acre cell to be hydraulically separated from the northeast 3.5 and southeast 2.5-acre cells. The base layer slopes 2% inward to two central collection v-notch trenches located on the southeast and southwest side of Module 6D (Detail 4). Each of the trenches drain at 1% to their respective leachate collection sumps located at the south side of the module.

The liner system within the collection trenches and sump areas was upgraded further to a double composite liner to account for infringement on the 5-ft groundwater offset and to minimize potential leakage in these critical collection areas where head on the primary liner will be at its greatest. The liner and leachate collection system in the collection trenches and sumps consists from top to bottom of a minimum of 2 ft of gravel drainage material, a protective geotextile, a blanket geocomposite drainage layer, a primary 60-mil high-density polyethylene (HDPE) liner, a geosynthetic clay liner (GCL) ($k < 5 \times 10^{-9}$ cm/sec), a secondary 60-mil HDPE liner, 2 ft of compacted clay (k< 6 x 10-9 cm/sec), a minimum of 0.5 ft of compacted earth fill ($k < 1 \times 10^{-8}$ cm/sec), and a 40-mil HDPE vapor barrier layer (Detail 4). The thickness of the compacted earth fill varies from a minimum at the south end of the trench of 0.5 ft to a maximum of about 2.5 ft at the upper, north end of the leachate collection trench. Leachate

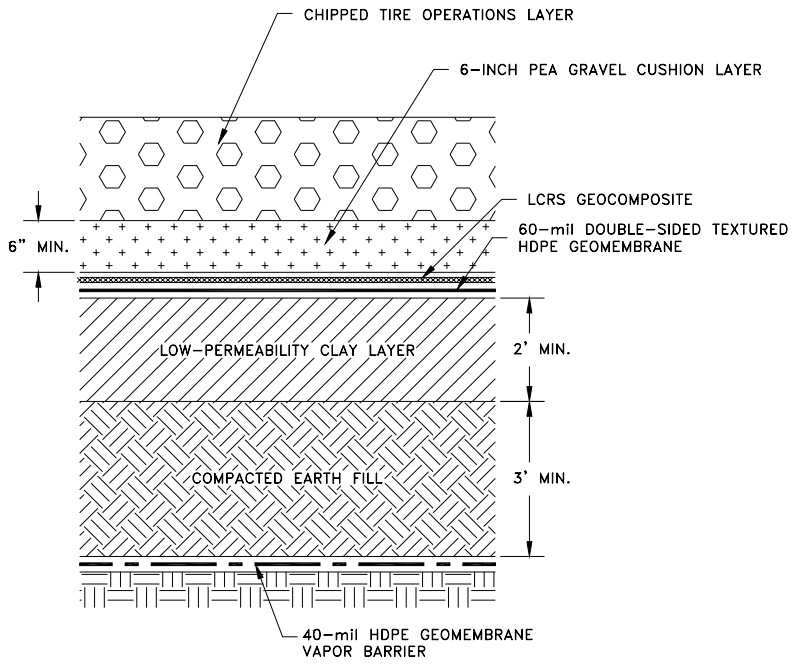
collection pipes were also placed in the collection trenches to transport leachate immediately to the sumps for recovery, removal, and recirculation, as needed.

As described above, the more rigorous Module D LCRS and liner system will outperform the Title 27 and Subtitle D prescriptive liner. The LCRS has been designed and constructed to be free-draining throughout the life of the module and will maintain less head over the primary liner system than prescribed by Title 27, Subtitle D, or the site specific Waste Discharge Requirements issued by the California Regional Water Quality Control Board.



Detail 4. Module D bottom liner and leachate collection trench cross-section

The Module D liner and leachate collection system consists, from top to bottom, of a 2-ft thick chipped tire operations/drainage layer (k> 1 cm/sec), 6 inches of pea gravel, a blanket geocomposite drainage layer, a 60-mil HDPE liner, 2 ft of compacted clay ($k<6 \times 10^{-9}$ cm/sec), 3 ft of compacted earth fill ($k< 1 \times 10^{-8}$ cm/sec), and a 40-mil HDPE vapor barrier layer (Golder 1999) (Detail 5). The chipped tire operations layer was not placed during initial liner construction, but was placed immediately before waste placement.



Detail 5. Module D bottom liner cross-section

The permeability of the clay liner, as constructed, was on average about 6 x 10^{-9} cm/sec and the earth fill averaged about 1 x 10^{-8} cm/sec. These two layers, in effect, provide a 5-ft thick composite liner. This fact, coupled with the lower permeability, will result in a significantly more effective barrier to leachate migration than the prescriptive liner system.

For design purposes, it was estimated that the peak liquid addition would be up to 10 gallons per minute (gpm) of liquid per 10,000 ft^2 (44 gpm/acre) of disposal area. Based on the demonstration cell performance, the amount of liquid added would be in the range of 30 to 50 gal/ton of waste. According to results of the bioreactor demonstration project by Moore et al. (1997), the average leachate generated during liquid introduction peaked at about 47% of the liquid delivery rate, which would equate to approximately 20 gpm/acre for the proposed program. Given a 6-acre drainage area, the total anticipated flow into any given sump would be approximately 120 gpm (173,000 gal/day).

Based on the estimated leachate production, drainage into the leachate collection layer would be about 4.6 x 10^{-4} gpm/ft^2 of disposal area. It is approximately 200 ft between the ridge and collection trench. Using these values, the peak flow through the geocomposite would be about 0.09 gpm per linear foot of trench. The geocomposite for Module 6D has a measured capacity of 1.0 gpm/ft (Golder 1999). Therefore, the geocomposite has over 10 times the capacity required under peak flow conditions.

Although clogging of the geocomposite layer was not anticipated, the LCRS was designed under the conservative assumption that geotextile clogging may occur. In the event that the geocomposite were to become clogged or otherwise nonfunctional, the chipped tire operations

layer with its high porosity would provide adequate drainage. Due to the large particle size of the chipped tires (>6 inches), the calculated effective permeability of the tires layer at the drainage slope of 0.02 was estimated to be well over 1.0 cm/sec. Given this value, it has a flow rate capacity on the order of 0.025 gpm per inch of thickness per 1-ft width. Therefore, at the calculated maximum inflow rate of 0.09 gpm per foot width, the head over the liner would not exceed 4 inches. Typically, collection systems are designed to maintain less than 1 ft of head over the liner. Therefore, this system has over three times the required flow capacity at the allowable prescriptive level of 1 ft.

In addition to the upgraded LCRS, the primary composite liner was better than the Title 27 prescriptive system. This was based on the reduced permeability, k, of the clay soil used during construction of the module. The permeability of the clay soil used in construction of Module 6D liner was significantly lower than the prescriptive 1×10^{-7} cm/sec. Based on the results of the laboratory testing performed during construction of Module 6D, the clay liner had an average permeability on the order of 6×10^{-9} cm/sec. Using standard leakage rate analyses by Giroud and Bonaparte (1989), the leakage from the Title 27 system (with 1 ft of head over a HDPE geomembrane and 1×10^{-7} cm/sec clay liner) would be 1×10^{-4} gpm from a standard 1-cm^2 hole in the liner. With the Module 6D liner (4 in of head over an HDPE geomembrane and 6×10^{-9} cm/sec clay liner), the leakage would be 5×10^{-6} gpm, less than 1/20 of the flow.

In the event leaks were to occur through the 5-ft thick primary composite liner, the vapor barrier would provide secondary containment. Secondary containment is not required by Title 27 or Subtitle D for conventional landfilling operations. As constructed, the vapor barrier would minimize further downward migration, and aid in detection of migrating leachate. The 40-mil HDPE vapor barrier was sloped to mirror the primary liner. Geocomposite strip drains were also installed diagonally across the top of the vapor barrier to act as drainage pathways to the pan lysimeter located immediately beneath each of the leachate collection sumps. The strip drains and lysimeter acted as a vadose zone monitoring system for early detection of leakage across the entire Module 6D disposal area. This added feature provided another level of protection to the groundwater that standard Title 27 systems do not have.

Monitoring of the base layer consisted of temperature, moisture, and pressure sensors placed on the liner and in the LCRS trenches. As part of the requirements specified under Waste Discharge Requirements in Order R5-2004-0134, Yolo County was required to monitor liquid buildup on the liner. Under typical landfilling, liquid buildup on a Class III composite liner system must be maintained to less than 1 ft. In order to gain approval from the California Regional Water Quality Control Board to operate Module 6D as a bioreactor, Yolo County must maintain less than 4 inches of liquid buildup on the Module 6D primary liner (CRWQCB 2000).

The majority of Module 6D primary liner system was constructed in 1999 by Nordic Construction. Construction quality oversight of the liner system was provided by Golder Engineering, who was also the design engineers. A separate third party contractor placed the pea gravel layer in 2000 and the daily waste placement contractor (B&D Geerts Construction) placed the shredded tire operations layer.

Sensors were placed on the geocomposite and covered with pea gravel prior to the placement of the chipped tire operations layer. Each sensor location on the base layer received a temperature sensor (thermistor), a linear low-density polyethylene (LLDPE) tube, and selected locations

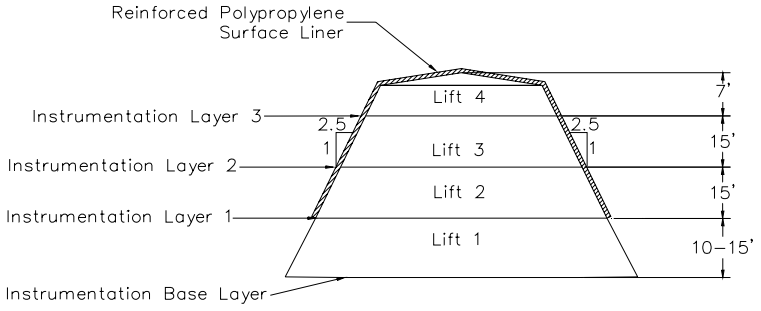
received a polyvinyl chloride (PVC) moisture sensor. Refer to Appendix D for the locations of the base liner sensors.

The Aerobic liner was constructed by first placing an approximate 10-foot lift of waste on the Module 6D liner. This first lift of waste acts as a buffer between the Module 6D primary liner and the aerobic cell. The waste was graded to promote drainage and a 60-mil HDPE geomembrane was installed to capture all leachate being generated by the aerobic cell. A sixteen-ounce geotextile was then placed on the membrane to act as a cushion for a shredded tire operations layer.

2.2 Waste Filling and Operations Layer

Waste placement in the northeast 3.5-acre cell began on January 13, 2001 and was completed on August 3, 2001. Waste was placed in four separate lifts with an approximate thickness of 15 ft (Detail 6). In general, all waste received at the landfill was deposited in the northeast cell with the exception of self-haul waste in the top two lifts. Because of the difficulties handling large volumes of self-haul vehicles in the limited area of the upper lifts, self-haul waste was not placed in lifts 3 and 4. The use of daily cover soil during waste filling was minimized to aid in the overall permeability of the waste. Whenever possible, greenwaste or tarps were used as alternative daily cover (ADC) and, in the event soil was placed (for example, access roads or tipping pad), the soil was removed prior to placing the next lift of waste. All side slopes were constructed at approximately 2.5-to-1 (horizontal to vertical) and received at least 1 ft of soil cover.

Following final placement of waste, final grading on the northeast 3.5-acre cell was performed in August and September of 2001 in anticipation of placement of the surface liner. Final grading consisted of placement of a 1-ft thick layer of soil over the waste utilizing a Caterpillar D6 LGP bulldozer.

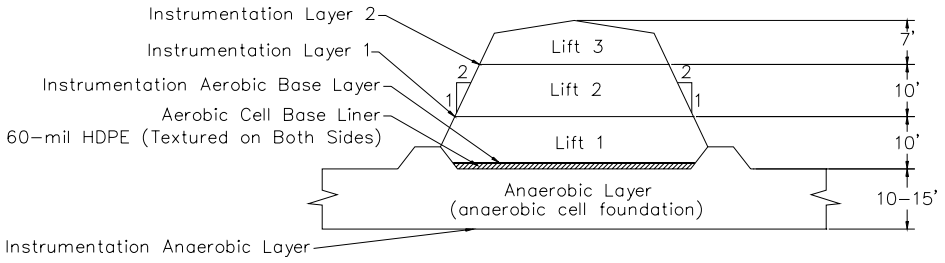


Detail 6. Northeast anaerobic cell cross-section

Waste placement in the southeast aerobic cell first began on November 14, 2000, with approximately 10-ft lift of waste placed on the Module 6D liner. This first lift of waste acted as a buffer between the Module 6D primary liner and the future aerobic cell. The waste was graded to promote drainage and a 60-mil HDPE geomembrane was installed to capture all leachate

being generated by the aerobic cell. A 16-oz geotextile was then placed on the membrane to act as a cushion for a shredded tire operations layer.

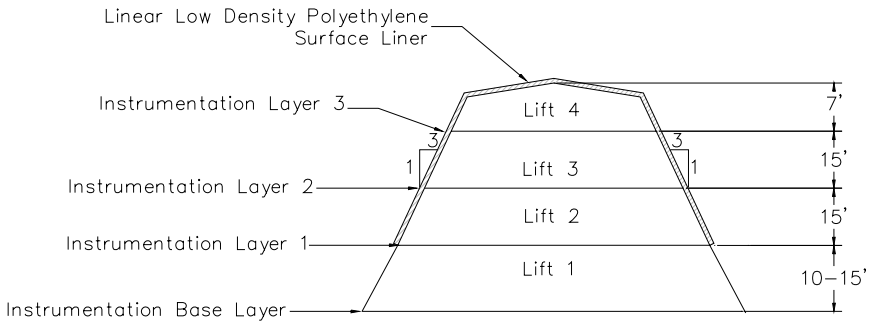
Waste placement in the aerobic cell occurred between August 8, 2001 and September 26, 2001. Waste was placed in three 10-ft lifts with 2-to-1 side slopes on the north, east, and west (internal side slopes), and a 3-to-1 side slope on the south (external side slope) as presented in Detail 7. Because of the limited tipping area of the aerobic cell, self-haul waste was excluded. The use of daily cover soil during waste filling was also minimized to aid in the overall permeability of the waste. Whenever possible, greenwaste or tarps were used as ADC and, in the event soil was placed (for example, access roads or tipping pad), the soil was removed prior to placing the next lift of waste. To further aid permeability of the waste, compaction was restricted to only 1 to 2 passes with a Caterpillar 826 compactor. Based on waste tonnage records and as-built topography, the in-place refuse density was approximately 800 lb/yd^3.



Detail 7. Cross-section of the Southeast aerobic cell

Waste placement for the west 6-acre cell began on March 8, 2001 and was completed on August 31, 2002. Waste was placed in four lifts of approximately 15-ft thickness with 2.5-to-1 side slopes on interior slopes and 3-to-1 on exterior slopes (Detail 8). All waste received at the landfill was deposited in the west 6-acre cell (i.e. no class of waste was excluded).

During the waste filling phase, it was necessary to construct an all-weather tipping pad (comprised of concrete rubble and dirt) on top of the first lift of waste along the west side of the module. When the subsequent lift of waste was placed over the pad area, rather than remove the pad material, it was incorporated in to the waste. We believe that this is one thing that led to leachate seeps, which are discussed later in Section 3.5.1.



Detail 8. Cross-section of west-side anaerobic cell

2.3 Waste Monitoring

Several parameters are important in maintaining proper operation of a bioreactor landfill. These parameters greatly influence the degradation process of the waste and the quality and quantity of the biogas produced. In order to obtain statistically valuable data, a grid was created for the distribution of sensors throughout the cell for each lift of waste. Each location received a temperature sensor, a LLDPE tube for pressure measurement, and a moisture sensor. The sensors were placed within the waste mass at each lift at spacings of 75 ft on center (Image 2). A total of 47 temperature sensors and 70 moisture sensors were placed in the northeast 3.5-acre cell. The southeast aerobic cell contained 59 temperature sensors and 52 moisture sensors. For the west-side anaerobic cell, equal numbers of temperature and moisture sensors were placed, totaling 126 sensors. Appendix A, Tables 6 and 7 give a summary of the sensors placed in the two anaerobic and the aerobic bioreactor cells, respectively. Appendix A, Table 8 gives a summary of sensors installed on the base liner

Image 2. Moisture, temperature, and tube installation

For protection, each wire and tube were encased in either a 1.25-in HDPE pipe or run inside the landfill gas (LFG) collection piping. Refer to Appendix D, Detail 1 for sensor location diagram.

2.3.1 Temperature

Temperature was monitored with thermistors (QT06005, Quality Thermistor, Inc., Boise, ID) with a temperature range of 0°C to 100°C to accommodate the temperature ranges expected in the anaerobic cells. To prevent corrosion, each thermistor was encased in epoxy and set in a stainless steel sleeve. All field wiring connections were made by first soldering the connection, then covering each solder joint with adhesive lined heat shrink tubing, and then encasing the joint in electrical epoxy. Changes in temperature were measured by the change in thermistor resistivity (ohms). As temperature increased, thermistor resistance decreased.

Sensors were placed within the waste on either a bedding of greenwaste (shredded yard waste), wood chips (chipped wood waste), bin fines (fine pieces of greenwaste), or pea gravel to protect against damage from the underlying waste. Sensors installed on the primary liner (prior to any waste placement) were placed on geocomposite and covered with pea gravel prior to the placement of the chipped tire operations layer.

As-built drawings showing the locations of the temperature sensors are located in Appendix D.

2.3.2 Moisture

Moisture levels were measured with PVC moisture sensors and gypsum blocks. Both the PVC moisture sensors and gypsum blocks were read utilizing the same meter (MM4, Electronics

Unlimited, Sacramento, CA). Moisture sensors were installed adjacent to temperature sensors and were placed in the same bedding material as the temperature sensors were.

The PVC sensors were designed by Yolo County and used successfully during the pilot-scale project (Yazdani et al. 1998). The design of the sensor consisted of perforated 2-in diameter PVC pipes with two stainless steel screws spaced 8 inches apart and attached to wires to form a circuit that included the gravel filled pipe. The sensor provided a general, qualitative assessment of the waste's moisture content. A reading of 0 to 40 equated to no free liquid, 40 to 80 equated to some free liquid, and 80 to 100 meant complete saturation.

The gypsum blocks are manufactured by Electronics Unlimited (Sacramento, CA) and are typically used for soil moisture determinations in agricultural applications. Gypsum blocks establish equilibrium with the media in which they are placed, and thus are reliable at tracking increases in the soil's moisture content. However, the gypsum block can take considerable time to dry, which may not reflect the drying of the surrounding environment. Gypsum blocks were only used in layer 2 of the northeast anaerobic cell.

As-built drawings showing the location of the moisture sensors are located in Appendix D.

2.3.2.1 Partitioning gas tracers

Measuring water in situ has proved to be difficult and expensive with existing technologies. While well drilling and analysis of solid waste samples can be used, this is an expensive, time consuming, and destructive procedure. The objective of this work was to evaluate the utility of the partitioning gas tracer test (PGTT) for measuring water. This was done using the southeast aerobic bioreactor. This technology may play a major role in advancing acceptance of bioreactor landfills and the associated reduction in greenhouse gas emissions.

2.3.3 Pressure

Pressure within cells was monitored with ¼-in inner diameter and 3/8-in outer diameter LLDPE sampling tubes. Each tube can be attached to a pressure gage and supplemental air source. By first purging the tube with the air source (to remove any liquid blockage), and then reading the pressure, an accurate gas and/or water pressure can be measured at each sensor location.

The installation was similar to that for the pilot-scale cells as described in project history. For protection, each wire and tube were encased in either a 1.25-in HDPE pipe or run inside the LFG collection piping.

Three LLDPE pressure-sensing tubes were installed in each of the leachate collection trenches. The tubes were installed inside a 2-in diameter PVC pipe for protection, and terminated at different points along the trenches.

Pressure transducers (Model PTX 1830, Druck, Inc., New Fairfield, CT) were installed at three locations adjacent to each leachate collection trench in the northeast and west-side anaerobic cells, and at two locations in the southeast aerobic cell. Additionally, tubes were installed that terminated adjacent to each of the pressure transducer locations. The pressure transducers provided an output current between 4 and 20 mA, which was directly proportional to pressure. Their pressure range was 0-1 pounds per square inch (psi) and had an accuracy of ±1% full-scale.

Pressure sensing tubes were installed at the same locations as temperature and moisture sensors on the base liner and within the northeast anaerobic and southeast aerobic cells, minus a few locations on the first and second lift. A total of 41 tubes were installed in the northeast anaerobic and 54 tubes in the southeast aerobic cell. Tubes were also installed in the west-side anaerobic cell, but only at select locations in each layer. A total of 13 tubes were installed in the west-side cell.

As-built drawings showing the location of pressure transducers and tubes are located in Appendix D.

2.4 Supervisory Control and Data Acquisition (SCADA) System

Efficient data monitoring and operation of the bioreactors were accomplished by using the SCADA system. All sensors were linked to the SCADA system for near real-time data collection and control. Data were transferred to a computer at the Woodland office by high frequency radio.

Major components of the SCADA system included two Allen-Bradley Model 5/05 small logic controllers (SLC), which controlled and monitored the raw data acquisition. Each SLC had a 10-slot rack capable of receiving up to ten different input or output (I/O) cards. Analog output cards (Allen-Bradley Model 1746-NI8, Rockwell Automation, Milwaukee, WI) were used to monitor flow meters, pressure transducers, temperature, and moisture sensors, all of which provided a signal of 0 to 5 V that was proportional to their reading. Because the large number of moisture and temperature sensors would have required a significant number of analog output cards (each card can accept 8 readings), Campbell Scientific multiplexers (Model AM416, Campbell Scientific, Inc., Logan, UT) were utilized to allow up to 16 temperature or moisture sensors to be connected to each analog output. Digital output cards (Allen-Bradley model 1746-OW16, Rockwell Automation, Milwaukee, WI) were used to power the multiplexers as well as control the leachate injection solenoid valves (both of which require 12 volt direct current (VDC) power. Finally, a digital input card (Allen-Bradley 1746-IB16, Rockwell Automation, Milwaukee, WI) was used to monitor leachate pump status and run time.

The user interface for the SCADA system was provided through a customizable program called Wonderware InTouch (Wonderware, Lake Forest, CA). This program received the raw data from the SLC and converted it to real world values such as "°C", "range of wetness", "flow rate in cubic ft/min", etc. The program also provided the interface for the user to change system components, such as valve position and alarm value levels.

At the heart of the system is a graphical display of the current status and readings of all of the sensors installed for the project. Display screens were first divided into modules (northeast, southeast, or west-side) and then into a separate screen for each lift of sensors. By clicking on the module and lift you are interested in, a screen is displayed providing current (within 15 min) data on both the temperature and moisture status of that lift. Additional screens exist to monitor the flow of leachate and landfill gas, liquid buildup on the liner, and leachate pump status. Various screens from Wonderware are included in Appendix C.

As data from the bioreactor were collected and stored on the SCADA computer, a file was created with all of the data for each day. These data can then be viewed in various graphing screens so that the operator can determine trends or analyze problems. Data collected by the

SCADA system can be exported to a spreadsheet program such as Excel for manipulation and graphing.

With each parameter, alarm values were set to indicate unusually high or low levels. In the event a particular sensor reached an alarm level, the color of that sensor, as displayed on the computer screen, changed to either orange or red, and the alarm condition was recorded in a separate alarm file.

Hardware installation for the northeast and southeast cells began in December 2001 and continued through March 2002, with system troubleshooting continuing through May 2002. Hardware installation for the west-side cell began in December 2002 and continued through January 2003, with system troubleshooting continuing through February 2003. All hardware components were installed in a shed located along the southern edge of Module 6D.

As-built drawings of the SCADA system are included in Appendix D.

2.5 Landfill Settlement Study and Surveying

Settlement in the waste cells was monitored on an annual basis to determine the amount of airspace recovery possible with bioreactor operation. This airspace recovery is extremely important because any increase in overall landfill capacity will not only increase the revenue potential of the landfill (because more waste can be put into a fixed volume), but also increase the life of the landfill by postponing (or even negating, should mining of the decomposed waste prove feasible) the need to construct a new landfill site.

This initial survey for the northeast anaerobic and southeast aerobic cell was performed on November 15, 2001, which was used as the reference for calculating the total settlement volume achieved. The second and third surveying events of the two cells were completed on January 16, 2003, and January 28, 2004, respectively. Both surveys included the generation of a topographic map with 1/2-ft contours for the second survey and 1-ft contours for the third. Both surveys had 4 cross-sections, and the re-surveying of 22 separate control points established on the surface liner for the northeast cell, and 14 control points for the southeast cell.

The first surveying event of the west-side cell was completed on January 16, 2003 and the second on January 28, 2004. Each survey included the generation of a topographic map with 2-ft contours, 8 cross-sections, and re-survey of 30 separate control points established on the liner.

Copies of settlement surveys are located in Appendix D.

2.6 Waste Field and Laboratory Analysis

2.6.1 Leachate

Leachate was monitored for the following field parameters: pH, electrical conductivity (EC), dissolved oxygen (DO), oxidation-reduction potential (ORP), total dissolved solids (TDS), and temperature. The following parameters were analyzed by a laboratory: dissolved solids, 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), organic carbon, nutrients (ammonia (NH_3), total Kjeldahl nitrogen (TKN), total phosphate (TP)), common ions, heavy metals and volatile organic compounds (VOC). For the first year, monitoring was conducted monthly during the first six months and quarterly for the following six months. After the first year, monitoring was conducted semi-annually (pH, conductivity, and flow rate

continued to be monitored on a monthly basis as required by the State of California's Waste Discharge Requirements in Order R5-2004-0134).

The parameters and frequency of leachate monitoring was developed based on prior experience gained at Yolo County during the operation of the pilot-scale project. A complete list of leachate monitoring parameters and frequencies can be found in Table 3 of the FPA, which is located in Appendix F.

2.6.2 Landfill Gas

For field-testing, landfill gas composition and flow were measured from the wellheads utilizing a GEM-500, and then later a GEM-2000 combustible gas meter (CES LANDTEC, Colton, CA). The GEM-500 and GEM-2000 are capable of measuring methane (CH_4) (either as a percent by volume or percent of the lower explosive limit), carbon dioxide (CO_2), and oxygen (O_2). A reading for balance gas was also provided, which was assumed to be nitrogen. Gas flow was measured by differential pressure across an orifice plate for both the northeast anaerobic and southeast aerobic cells, and with a 1/8-in pitot tube (Dwyer Instruments Inc., Michigan City, IN) for the west-side cell. A thermal gas flow meter installed in the main header pipelines on each bioreactor cell recorded the total flow and flow rate from each cell (8240MP (northeast cell) and 8840MP (southeast and west-side), Eldridge Products, Inc., Monterey, CA). The meters were calibrated for landfill gas and automatically corrected for temperature. Field-testing was performed on a weekly basis for both the northeast and west-side anaerobic cells, and the southeast aerobic cell.

Laboratory testing was performed quarterly with gas sampled using summa type canisters from the main header line. The following parameters were tested: fixed gases using Method CFR60A EPA 3C for methane, carbon dioxide, carbon monoxide, oxygen, nitrogen, Method EPA 15/16 for sulfur compounds, Method CFR60 EPA 25C Modified for non methane organic compounds (NMOC), and Method EPA-2 TO-15 for VOC. A complete list of LFG monitoring parameters and frequencies can be found in Table 3 of the FPA, which is located in Appendix F.

2.6.2.1 Biofilter fugitive emission testing

An issue of regulatory and other interest is how to accomplish the abatement of methane that can be emitted in fugitive gas from landfill operations. Of greatest relevance here is methane present in the gas emitted to the atmosphere from aerobic bioreactors. This is because the decomposition of waste in aerobic landfills has turned out to be, in significant part, anaerobic, and the exit gas contains a substantial quantity of methane.

One approach with promise is biofiltration. Gas is passed through a matrix, very often compost, supporting bacteria that can metabolize and remove undesired organic components such as methane in the gas. This is an accepted technique for removal of odorants and pollutants from exit gases from processes such as wastewater processing and industrial processes.

A biofilter was constructed in order to treat and further reduce methane content of the gas emitted from the 15,000-ton aerobic bioreactor cell. In summary, the biofilter consisted of a pile of compost about 5 ft deep and two areas each 2,000 ft^2 in surface area. Total biofilter volume was about 20,000 ft^3. The biofilter was moistened with surface sprinklers and buffered with limestone. The exit gas stream from the aerobic bioreactor was distributed into the base layers

of the biofilter and exited through the top. Gas introduction was via perforated piping designed in accordance with recommendations from Perry's Chemical Engineers' Handbook (2000), to ensure uniform flux and distribution of gas being treated over the biofilter footprint. The design was such that the retention time of gas within the biofilter was about 15 min. (Residence time depends on porosity and depth, which changed slowly with time.) A simplified schematic is shown below in Figure 3.

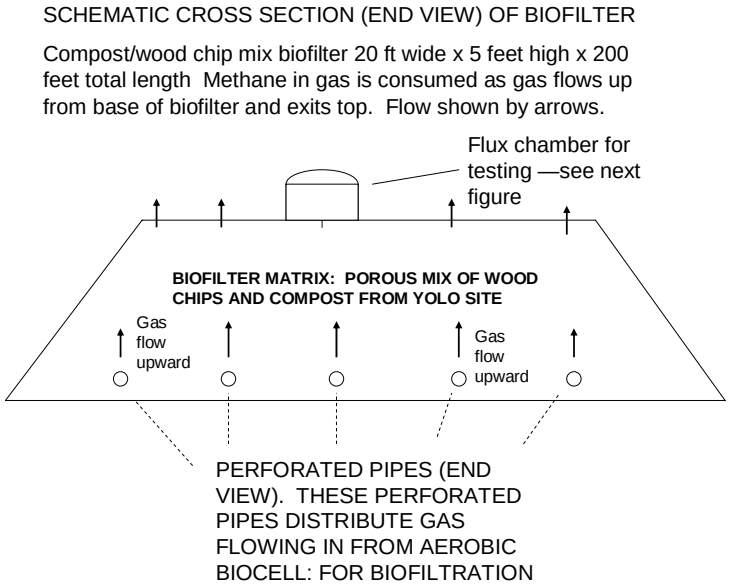


Figure 3. Typical biofilter cross-section

The testing of the efficiency of the biofilter was straightforward in principle. The efficiency was determined from the loss in methane from gas passing through the biofilter, by measuring the methane reduction in the exit gas compared to its concentration in the entrance gas. The primary testing method used and intended as definitive was that specified by the California Integrated Waste Management Board. This method used a flux chamber placed over the surface of the waste as shown in Figure 4. A flux chamber is lowered with edges sunk into the surface whose flux is to be tested. Pure sweep air was introduced into the flux chamber from a cylinder, at a rate, Q, that is several-fold (preferably 5 times or more) greater than the flux from the surface. The surface flux from the biofilter due to (about) 1,100 CFM blower air entering the nearly 5,000-ft^2 biofilter was about 2.9 in/min (7.5 cm/min by an on-the spot calculation). Air was introduced at a rate several times the surface flux, Q. See Appendix F for a detailed report.

This test procedure did not give results that looked sensible. The methane in the exit gas, as determined by the flux chamber method, exceeded the input to the biofilter. This result was clearly not possible. A composition test was also run on the compost to determine if low nutrient levels could account for apparently low conversion. Nitrogen levels were found to be low. Other potential reasons for the puzzling flux box test results are discussed later in section 3.6.7.

Figure 1: Schematic of flux test setup as conducted April 30, 2004 at YCCL aerobic landfill biofilter (not to scale)

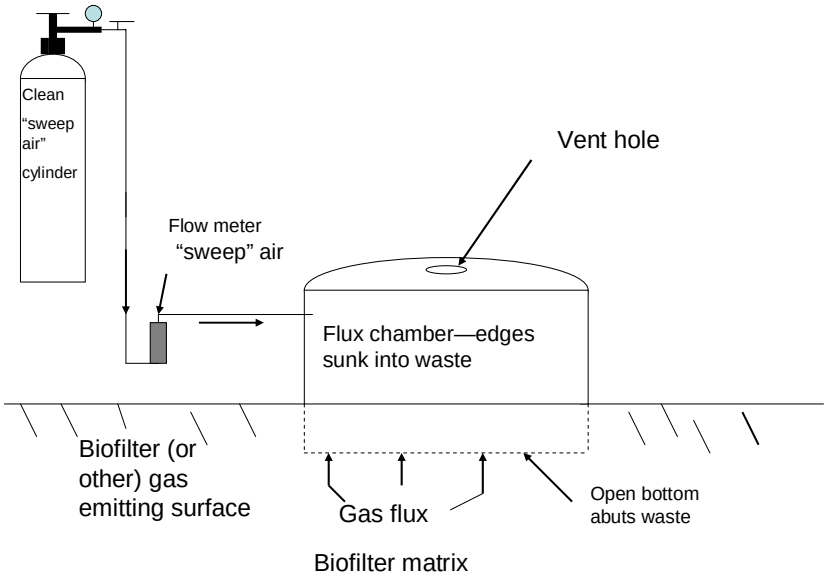


Figure 4. Flux test setup

Instead, test results that made more sense than flux box tests were those using Yolo County's own data obtained from the GEM methane meter. The methane meter showed concentrations of methane of over 2% in the header entering the injection line, and exit methane concentrations closer to 1%. The protocol was as follows:

Initial (early morning) tests on April 30, 2004. Using the GEM 500, the methane concentration in the header (inlet) pipe was measured. At the time of initial measurement, around 8 AM, the concentration was 2.5%. The subsurface readings of the GEM, over 1 ft down from the top or side surface of the biofilter, were within measurement accuracy possible, 2% by volume of the measurements. These measurements were conducted at three points considered representative, along the long surface of the biofilter. The GEM readings implied that the header was introducing about 2.5% methane gas into the biofilter. With over 2% methane in the gas 1 ft beneath the surface, (having traveled up over 80% of the way to the top of the biofilter) the biofilter would appear to be abating less methane than desired, probably under 20%,

$$= \frac{(2.5\% - 2.0\%)}{2.5\%} \qquad (1)$$

=20%.

Notes showed that later, at about 11 AM, a concentration of 1.1% methane was measured at 1 ft subsurface in the biofilter at measuring stations along the length of the biofilter. Given unchanged inlet concentration, this would imply that the abatement was more effective, from

2.5% down to 1.1%, or abating about half of the methane in the gas from the bioreactor in the later measurements. However, the results must be regarded as preliminary. Some of the variability in results was undoubtedly attributable to early startup status, after only a few days of exposure to exit gas from the aerobic bioreactor. Another source of variation was that temperature varied through the course of testing. Other sources of uncertainty included high biofilter porosity and air intrusion, which are discussed in section 3.6.6. A lessons-learned review has been carried out and approaches to better testing are planned as discussed in section 3.6.7.

Results of the three laboratory tests on liquid samples from the site, gas analysis, and a sample of the compost are presented in Appendix F. The laboratory test of the biofilter matrix showed that nitrogen-to-carbon ratio was low, and thus nitrogen may have been a limiting nutrient that could have been increased.

2.6.3 Waste Solids Sampling

Waste samples were collected prior to liquid addition and annually following liquid addition in each of the cells. The intent was to measure initially what the methane potential of the waste was and then, following liquid addition, to measure the progress of decomposition. The amount of samples to be collected was primarily based on cost. To get a statistically significant number of samples given the sizes of the bioreactor cells would have been extremely costly, and thus it was decided only limited sampling would occur.

Samples were sent to North Carolina State University (NCSU) for analysis to determine the amount of decomposition possible under accelerated anaerobic conditions.

Sampling was performed by drilling a bore using a 2-ft diameter solid stem auger. Samples were collected roughly at every 1.5-m (5-ft) vertical interval. However, there were times when the refuse began to fill in the hole during drilling, so there was the possibility of some commingling of the waste.

Excavated refuse was placed on a sheet of geomembrane liner and then multiple grab samples were collected from each pile for field measurement of pH and collection for laboratory analysis. Waste samples were placed in plastic bags that were packed in 113-L (30-gal) plastic drums for overnight shipment to the environmental engineering laboratory at NCSU. Once received at NCSU, samples were stored at 4°C until they were shredded with a slow-speed, high-torque shredder. After shredding, samples were stored at 4°C until moisture analysis by drying to constant weight at 65°C was performed.

Once samples were dried, they were analyzed for the concentrations of cellulose, hemicellulose, lignin, volatile solids (VS), and BMP. Cellulose and hemicellulose represent the major degradable components of refuse. In contrast, lignin is essentially recalcitrant under methanogenic conditions (Colberg 1988). Thus, its concentration will increase as cellulose and hemicellulose decompose. The BMP assay measures the methane potential of a sample under optimal conditions. Thus, the BMP decreases as refuse decomposition proceeds.

2.7 Surface Emissions

Under current federal guidelines (40 CFR 60.752), landfills exceeding a specific size must monitor for methane surface emissions and any reading in excess of 500 parts per million (ppm)

requires corrective action to be taken. The Yolo County Central Landfill is not currently required to test for methane surface emissions, however, as part of the FPA, the County has proposed to conduct quarterly surface scans to demonstrate the emissions from a controlled bioreactor landfill.

Methane emissions were monitored with a TVA-1000 Flame Ionization Detector (FID)/Photo Ionization Detector (PID) or similar instrument rented from Total Safety Inc. (Houston, TX). Under the FID setting, the TVA-1000 measures total organic compounds (measured as methane) in air in the parts per million and has a range of 1 to 10,000 ppm and an accuracy of plus or minus 25% of the reading or 2.5 ppm, whichever is greater.

Monitoring methods and procedures were conducted in conformance with 40 CFR 60.755, with the exception that a closer (more rigorous) monitoring traverse was utilized. Methane surface concentrations were monitored between five and ten centimeters above the surface cover along the perimeter of each cell and along a pattern that traverses the landfill at 15-m intervals (by comparison, 40 CFR 60.754 requires the traverse to be conducted at 30-m intervals). Background methane readings were taken 30 m upwind and 30 m downwind of the cell perimeter. Wind speed, wind direction, and air temperature were recorded by a Kestrel 2000 hand held meter at the time and location of the surface scans or obtained from the Davis weather station of the California Irrigation Management Information System (CIMIS). Barometric pressure was obtained from CIMIS and was the average barometric pressure of that day.

2.8 Liquid Addition and Pumping System

A liquid pumping system was designed for the addition, recirculation, and removal of liquid. A multiple pump system was used for both the northeast and west-side anaerobic bioreactors to allow for continued operation should one of the pumps fail, whereas a single pump was used for the southeast aerobic cell. Reliable operation of the pumps installed in the leachate collection sumps was critical to ensure no liquid build-up on the primary liner system. The operation of each of the pumps and their associate flow meters was linked to the SCADA system.

Within each leachate collection sump, two separate pumps were used. Each of the pumps was conservatively designed to remove twice the amount of liquid anticipated by each bioreactor cell. Under normal operation, the pumps were programmed for an alternating cycle to maintain similar duty cycles. However, if leachate flows increased above the capability of one pump, the second pump would automatically start to allow the rapid draining of the leachate collection sump.

The leachate addition pumps are located just to the south of the bioreactor cells at the leachate surface impoundments (leachate ponds). The leachate ponds were constructed several years ago to contain all of the leachate generated at the YCCL. As part of the original design and construction of these leachate ponds, a series of pumps and sprinkler emitters were installed to allow the evaporation of stored leachate. During the design of the bioreactor cells, these evaporation pumps were evaluated to determine if they would be adequate for providing supplemental liquid to the cells. The pumps flow and pressure capabilities were determined to be ideal for liquid addition, and thus were employed in the bioreactor project.

The injection system was designed for maximum leachate distribution by incorporating horizontal injection lines within each lift of waste in the northeast and southeast cells, and only between lifts 2 and 3, and 3 and 4 in the west-side cell Injection lines were spaced every 40 feet within each lift of waste with an additional line installed around the perimeter of the top deck of the module. Each injection lateral was connected to a 4-inch-diameter HDPE injection header. See Appendix D for drawings of the leachate injection lines.

Field tests were performed on the leachate injection laterals using one of the recirculation pumps and 3/32-in diameter holes. Based on these tests, the average flow rate per hole was approximately 1 gpm. In practice, actual flow rates achieved in individual laterals varied significantly and were sometimes significantly less than the original design values. The discrepancy between the design and actual achieved flow rates could be due to the backpressure exerted by the gravel and tires that were placed over the pipe or clogging of the holes with sediment. On several occasions the injection laterals were flushed, which did increase the flow substantially but still did not increase the flow rate to the original design value. It is possible that the flushing did dislodge some sediment, but some particles remained lodged in the perforations (holes drilled as described above) in the lateral injection line. Following this experience, hole diameter was increased to 1/8 or 1/4 in and spacing was decreased to 10 ft from spacing of 20 ft in the upper lifts of the west 6-acre cell.

An additional test was performed to determine the durability of the HDPE pipe under waste loading. To simulate waste conditions, a test pad was constructed with roughly 6 inches of greenwaste alternative daily cover (ADC) as bedding. A section of pipe was then covered with 2 ft of shredded tires and a D-8 size dozer was left on top for approximately 72 hours. The dozer was then removed and upon visual inspection, two slight depressions were observed on the sections of pipe that were directly under the tracks of the dozer. However, no other cracks or deflections were seen on the rest of the pipe. Calculations using Driscopipe Design software also confirmed that the HDPE pipe was acceptable for use under our expected waste load.

Throughout the course of the project, injection laterals have been periodically flushed (which is possible because the laterals extend completely through the waste) and to-date, all of the laterals remain functional and have not crushed.

Existing pumps and storage ponds were utilized for the addition of liquid to the cells. Construction of the leachate storage ponds (designated Waste Management Unit H (WMU H)) and a pumping system originally designed to evaporate leachate was completed in 1999. Subsequently, during the installation of the surface liners over each of the cells, a 4-in diameter HDPE header line was installed linking the leachate ponds to the injection laterals.

As-built drawings of the liquid pumping systems are located in Appendix D.

2.8.1 Horizontal Liquid Injection Lines

For the northeast 3.5-acre cell, horizontal liquid injection lines were installed in each lift of waste. Injection lines within the waste (between lifts 1 and 2, 2 and 3, 3 and 4) were placed approximately every 40 ft. Injection lines installed on top of lift 4 were installed every 25 ft, with an additional injection line following the perimeter of the top deck. Each injection line consisted of a 1.25-in diameter HDPE pipe placed horizontally (north to south), which extended completely through the waste. Each line was perforated by drilling a 3/32-in hole every 20 ft. A total of 8,130 ft of piping was installed with a total of 342 injection holes.

For the west 6-acre cell, horizontal liquid injection lines were installed between lifts 2 and 3, and 3 and 4 approximately every 40 ft. In addition, three injection lines were installed on top of lift 4, spaced every 25 ft. The pipes were placed horizontally (east to west), which extended completely through the waste. Each injection line was perforated by drilling 1/8 or 3/32-in holes every 10 or 20 ft (depending on which line). A total of 7,185 ft of injection piping was installed with a total of 321 injection holes.

Horizontal liquid injection lines in the southeast aerobic cell were also installed in each lift of waste. Injection lines within the waste (between lifts 1 and 2, 2 and 3) were placed horizontally (north to south) every 20 ft. Injection lines on top of lift 3 were placed east to west every 20 ft. Various combinations of 1¼-in-diameter chlorinated polyvinyl chloride (CPVC) and 1¼-in-diameter HDPE pipe were installed and perforated with 3/32–in-diameter holes spaced every 10 ft. Because of the elevated temperatures expected in the aerobic cell, CPVC was installed at selected locations as a redundancy in the event the HDPE piping fails failed (CPVC is rated for service at temperatures up to 200°F, however it is was approximately 4 times as expensive). A total of 4,780 ft of injection piping was installed with a total of 326 injection holes.

The area to receive the injection lines were first graded and then bedded with greenwaste to create a relatively smooth surface on which to install the lines. The lines were then installed and snaked to allow for future settlement. Injection holes were drilled in the pipe and each hole was covered with pea gravel to help prevent clogging. Finally, the line was covered with shredded tires to protect it from waste placement (as well as facilitate landfill gas collection).

Each of the injection laterals was connected to a 4-in-diameter HDPE injection header. For the southeast aerobic and northeast anaerobic cells, flow was controlled with solenoid valves. However, the solenoid valves in the northeast cell were removed due to leaks at the valves as well as the mechanical saddle connections between the laterals and the header (discussed further in section 4). For the west-side cell, flow was controlled through manual valves and individual rates and the total were monitored at each lateral with a meter. Each of the cells has a flow meter to monitor the total flow into the cells.

As-built drawings of the liquid injection lines are located in Appendix D.

2.9 Landfill Gas Collection and Removal System

A landfill gas LFG collection system was designed to enable maximum gas recovery from the bioreactor cells. The gas collection system incorporated horizontal LFG collection lines between each lift of waste and directly under the surface liner. LFG collection lines consisted of various combinations of alternating 4 and 6-in diameter schedule-80 PVC pipe as well as several variations of corrugated HDPE pipe. In each case, shredded tires were used as the permeable medium. Gas collection lines between layers were spaced approximately 40 ft apart and lines directly under the surface liner were spaced at 25-ft intervals. Design drawings of the LFG system are located in Appendix D.

Sizing of the main header line for each of the cells was done based on the following assumptions:

- The minimum required vacuum at well was 10 inches of water.

- The maximum available vacuum was 25 inches of water for the northeast cell, 27.5 inches of water for the west-side cell (which is roughly half the actual available vacuum from gas-to-energy facility).
- The maximum flow rates expected from each of the cells were proportional to the original pilot-scale project. This corresponded to a design flow rate for the northeast cell of 350 CFM, west-side cell of 831 CFM.

The results of the sizing analysis indicated that a 6-in-diameter header line would be required for the northeast cell and a combination of an 8-in and 6-in pipe would meet the requirements of the west-side cell.

Additional design constraints and considerations included the use of selected anchorage points and expansion fittings to allow movement of the pipe due to thermal expansion and contraction. In addition, the piping layout was designed to allow any condensate to drain back into the landfill or towards the gas-to-energy facility, thus there was no need for condensate sumps.

The bioreactor LFG removal system was connected to the existing gas collection network at the landfill. The connection point was located at the southwest corner of the west-side cell. From that point, gas was conveyed a short distance to the gas-to-energy facility.

Each LFG collection line was connected to an LFG collection header that conveyed the gas to the on-site LFG-to-energy facility (Image 3). Each LFG collection line incorporated a valve capable of controlling flow and a port for monitoring gas composition, temperature, pressure, and flow rate.

The gas collection system associated with the northeast cell was constructed concurrently with the installation of the surface cover system by the same contractor. Construction occurred during the fall of 2001.

The gas collection system associated with the west-side cell was completed by Yolo County staff following the installation of the surface cover system in December 2002.

The gas collection system for the aerobic cell was designed such that gas could be collected and routed to the gas-to-energy facility (if operated anaerobically) or collected through the use of a separate blower and routed to a biofilter for odor control (if operated aerobically). The aerobic blower station and main header collection pipe was designed to operate at approximately 1000 scfm with a suction vacuum of 90 inches of water and a discharge pressure of 10 inches of water. Construction of the blower station was completed in June 2003 (Appendix C), and the biofilter was completed in September 2003.

As-built drawings of the gas collection system are located in Appendix D.

Image 3. LFG collection lines connected to the main header on the west 6-acre cell.

2.9.1 Horizontal Landfill Gas Collection System

For the northeast cell, horizontal LFG collection lines were installed between each lift of waste and directly under the reinforced polypropylene geomembrane (RPP) geomembrane cover. LFG collection lines consisted of various combinations of alternating 4 and 6-in–diameter, schedule-80 PVC pipe as well as several variations of corrugated HDPE pipe. A total of sixteen LFG collection lines were installed.

For the west-side cell, LFG collection lines were installed between lifts 2 and 3, 3 and 4, and on top of lift 4 in the cell. The LFG collection lines consisted of various combinations of alternating 4 and 6-in diameter schedule-80 and schedule-40 PVC pipe, as well as several variations of corrugated metal pipe and electrical conduit. A total of eighteen LFG collection lines were installed.

The southeast aerobic cell air collection lines consisted of various combinations of alternating 4 and 6–inch-diameter CPVC pipe and 6 and 8–in-diameter corrugated metal pipe. A total of 11 horizontal air collection lines were installed.

Each air collection line was connected to a 12-in-diameter air collection header that conveyed the gas to an on-site blower and biofilter. Each air collection line incorporated a pre-manufactured wellhead capable of controlling flow and monitoring flow rate, temperature and pressure.

A summary of gas collection lines for the northeast, west-side, and southeast cells are provided in Appendix A, Tables 9 through 11. As-built drawings are located in Appendix D.

2.10 Surface Liner Cover System

A final cover system for the northeast and west-side bioreactor cell was designed to allow for maximum landfill gas recovery and emissions control. Yolo County retained the services of Vector Engineering (Vector) to design the surface membrane covers for each of the bioreactor cells. A complete copy of Vector's design report is included in Appendix E.

Based on the life expectancy of the project, it was determined that the surface liner materials would be exposed for at least 5 years. The selected liner material must be able to withstand ultraviolet (UV) exposure as well as other climatic and operational conditions such as wind uplift, rain, temperature fluctuations, foot traffic, and billowing of off-gases. Based on the findings, Vector recommended a 36-mil RPP as the preferred choice for an exposed geomembrane cover (Vector 2001). Reinforced polypropylene offered distinct advantages over the other potential material including long service life (a 20-yr warranty was obtained), superior strength due to the nylon reinforcement, and low thermal expansion and contraction.

Because the west-side cell was built following the northeast cell, experience from the northeast cell determined that a more cost effective geomembrane would be sufficient. Thus, a 40-mil LLDPE geomembrane material was selected for the west-side cell.

Each of the surface covers was designed to incorporate a series of anchor trenches at the top and bottom of the cells in addition to a surface ballast system (ropes and sandbags) to ensure the stability of the liner against a design wind speed of 90 miles per hour (mph).

Since the operation of an aerobic bioreactor at the Yolo County Central Landfill was first considered, two methods of air management for oxygen delivery have been discussed. One method was to push air into the landfill and the other was to apply a vacuum and draw air through the landfill. Both methods have advantages and disadvantages. However, Yolo County decided that the best alternative was to leave the aerobic cell covered with soil and greenwaste (shredded yard waste), but without an impermeable geomembrane, so that air could be drawn through the waste by applying a vacuum. In this way, air will enter through the cell surface and migrate to horizontal pipelines to which a vacuum is applied. Alternate operations plans could include using some of the installed pipelines as vents and others for vacuum.

Yolo County had intended to cover the aerobic cell with an exposed geomembrane with a biofilter at the top of the cell to provide some treatment of the off-gas. However, the weight of the geomembrane that would have been placed on the aerobic cell along with the weight of a sandbag surface ballast system would result in a pressure equivalent to only 0.17 inches of water. Calculations indicated that the required pressure present in the cell to force the air through the waste, to the top of the cell, and through the biofilter would result in a great deal of ballooning of the surface liner. Additionally, the expected high settlement rate would create a great deal of maintenance difficulties for the geomembrane surface liner.

Yolo County developed a design for a geomembrane surface liner for the aerobic cell and advertised for bids on the construction. The bids received were very expensive and not within the budget of the project. As a result of both the technical and economic difficulties encountered, it was decided that leaving the aerobic cell without a geomembrane liner was the preferred approach.

2.11 Landfill Slope Stability Analysis

Vector Engineering performed the Landfill slope stability analysis. Stability was modeled using the program PCSTABL5M for a saturated waste density of 85 lb/ft^3. Results of the analysis indicated that the slopes of the bioreactor cells could be constructed with up to a 2-to-1 (horizontal to vertical) slope and still have a factor of safety of 1.4. A complete copy of the stability report is included in Appendix G.

2.12 Aerobic Cell Biofilter

Two separate biofilters were constructed, each approximately 100 ft long and 20 ft wide. Piping to convey the aerobic cell gas was installed directly on the biofilter base, which was composed of approximately 1 ft of wood chips. Two 1-ft lifts of biofilter media, composed of approximately six parts wood chips to one part compost, were placed above the base. Between each of these lifts, 10 temperature sensors and 10 moisture sensors were installed. A final 2-ft lift of biofilter media was placed on top the biofilter. Limestone was sprinkled between each lift as a buffering agent to balance the pH of the biofilter media, which will tend to become more acidic during operation.

2.13 Quality Assurance Procedures

Quality assurance procedures are necessary for maintaining the integrity of the data. All data were obtained and analyzed following strict guidelines discussed in the following sections.

2.13.1 Laboratory QA/QC and Instrument Calibration

Gas and leachate laboratory analyses are currently performed by Sequoia Analytical and were previously performed by Sevren Trent Laboratory. A quality assurance program was developed by the laboratory, which was designed to ensure that the data produced conformed to the standards set by the state and/or federal regulations. Important documentation of the samples from their collection to their analysis is achieved through the Chain-of-Custody form, which remains with the sample throughout the process. Sample handling, analytical methods, and instrument calibration are discussed in their assurance program manual, which can be found at the following link, http://www.sequoialabs.com/Content/Sequoia-QAM.pdf.

2.13.2 Field QA/QC and Instrument Calibration

Field quality assurance/quality control (QA/QC) and instrument calibration for all environmental monitoring of leachate followed protocol outlined in the Yolo County Division of Integrated Waste Management, Sampling and Analysis Procedures for Water Quality Monitoring.

Before each use, the GEM 500 (or GEM 2000) was field calibrated following the instructions outlined by the manufacturer. Calibrations were documented and kept at the same storage facility as the equipment. In an event an odd (defined as values outside the normal range seen) gas reading was measured, the instrument was recalibrated. In addition, the GEM was also annually sent back to the manufacturer for factory recalibration.

Prior to shipment of the TVA-1000, Total Safety, Inc. calibrated their rental equipment. No field calibration of the equipment was necessary, and readings were taken following the instructions manual accompanying it.

2.13.3 Record Management

All data collected for the project were stored on the main server for Yolo County, Integrated Waste Management. This is to ensure no loss of data since backup systems for the server were always active.

Data collected using the SCADA system were recorded onto two computers; one was located at the landfill and the other at the Woodland office. Data were downloaded from the SCADA files and managed in Excel. This process was facilitated by a software program known as Report Builder, which allowed for easy transfer of the data.

Weekly gas field readings were downloaded from the GEM 500 (or GEM 2000) and saved onto the computer at the landfill. A copy was saved onto a 3.5-in floppy and downloaded onto the computer at the Woodland office, where it was then integrated into a main Excel spreadsheet created for gas readings for each of the bioreactor cells.

Leachate field readings were manually recorded and entered into the main Excel spreadsheet for leachate. Laboratory analysis data obtained from the laboratory were also manually entered into the spreadsheet. All leachate data entered were inspected for errors by Yolo County staff. A main database known as Adept was also used for organizing and validating all leachate data.

Surface emission data were directly downloaded from the equipment and stored on the computer at the Woodland office.

3 PROJECT RESULTS AND DISCUSSION

3.1 Tonnage, Composition, and Compaction

Wastes accepted by the YCCL include residential, commercial, industrial, demolition, agricultural, dewatered sewage sludge, grits and screenings, treated medical waste, non-friable asbestos, inerts, and shredded tires. An itemized list of waste types and amounts placed in each of the bioreactor cells can be found in Appendix A, Table 12. Waste placement commenced in the northeast 3.5-acre bioreactor on January 13, 2001 and was completed on August 3, 2001. Waste placement commenced in the west 6-acre bioreactor on March 8, 2001 and was completed on August 31, 2002.

Table 1 below provides a summary of the amount of waste placed in each cell, along with the initial waste density and the effective waste density as of the last complete topographic survey conducted on January 28, 2004. It was the intent of this project to test bioreactor operation at a field-scale level and as such, typical standard of practice procedures were used to compact the waste. Waste were placed in loose lifts not exceeding 2 ft with either a Caterpillar D-7 or D-8 dozer, and then was compacted with 3 to 5 passes for the two anaerobic cells, and 1 to 2 passes for the aerobic cell, using a Caterpillar 826C sheep foot compactor.

As presented in Table 1 below, the initial density of the northeast 3.5-acre cell was less than the west 6-acre cell, although the same waste filling procedures were utilized in both. The lower initial density of the 3.5-acre cell was most likely due to the geometry of the cell that incorporated more side slopes (which are harder to compact) to interior area than did the west 6-acre cell. This lower initial density may have added in the more effective liquid permeation of the 3.5-acre cell. Wastes accepted by the YCCL include residential, commercial, industrial, demolition, agricultural, dewatered sewage sludge, grits and screenings, treated medical waste,

non-friable asbestos, inerts, and shredded tires. Waste placement commenced in the northeast and west-side anaerobic bioreactors on January 13, 2001 and March 8, 2001, respectively. The northeast was completed on August 3, 2001, and the west-side on August 31, 2002. Waste placement in the southeast aerobic cell occurred between August 8, 2001 and September 26, 2001.

Table 1. Summary of waste tonnage and compaction

Module	Total waste placed (tons)	Total greenwaste ADC used (tons)	Initial volume of cell (yd^3)	Initial density of waste (lbs/yd^3)	Volume of cell as of 1/28/04 survey (yd^3)	Density of waste as of 1/28/04 survey (lbs/yd^3)
Northeast anaerobic cell	65,104	11,060	132,295*	984	123,760	1052
West-side cell	166,294	27,570	324,209**	1026	315,290	1055
Southeast aerobic cell	11,942	2,169	35,529*	672	32,597	733

* Initial survey was conducted on 11/15/2002

** Initial survey was conducted on 1/16/2003

3.2 Waste Temperature Over Time

Temperatures were monitored through an array of thermistors placed throughout the waste. Thermistors respond to changes in temperature through changes in resistance with increasing temperatures corresponding to decreasing resistance. Measured resistance can be converted to temperature through a calibration equation provided by the manufacturer. Following initial installation, sensors were read manually utilizing a Model 26 III Multimeter manufactured by Fluke Corporation (Fluke Corporation, Everett, WA). Beginning in March 2002, readings were collected through the SCADA system.

The average temperature for the northeast 3.5-acre cell over time is provided in Appendix B, Figure 1. The drops and subsequent rebound in temperature (for instance Layer 3 around March 2003) is the typical response to liquid addition to that layer. Typical waste temperatures have remained between 40 and 50°C (with the exceptions of some drops corresponding to liquid addition) for the last several years. Temperatures in this range are typical of anaerobic decomposition.

The average temperature for the west 6-acre cell over time is provided in Appendix B, Figure 2. Typical waste temperatures have remained between 40 and 50°C for the last several years. Temperatures in this range are typical of anaerobic decomposition.

Both the northeast 3.5-acre and west 6-acre cell temperatures, ranging from 40-60°C in Figures 1 and 2 (Appendix B) are well above the ambient air outside the cells. Such elevated temperatures are consistent with many other bioreactor results. The temperature elevation is due to exothermic (heat-generating) biochemical reactions that take place as waste

decomposition proceeds. These reactions begin during filling when there is some limited initial open-air composting and are followed by exothermic anaerobic reactions.

An important feature of the measured temperatures is their independence over time from the surrounding ambient temperature. This is a prediction of the basic heat transfer equations governing temperature loss and temperature deep within large masses of any type that are exposed to varying temperatures at their surface. These correlations predict that the interior temperatures of such large bodies will change only slowly, exactly as seen in Figures 1 and 2 (Appendix B), and do not vary significantly from lift to lift (with the major gap of 10°C at most in the northeast cell).

The rate of waste decomposition to methane is well known to be strongly temperature dependent. For example, a temperature elevation from 20 to 40°C, with all other things being equal, can in and of itself raise decomposition rates by over 3-fold. The stability of the deeper internal temperature means that methane generation perturbations due to ambient temperature fluctuations will be minimal. A uniform temperature throughout the cells will be helpful in reducing temperature related variations in methane generation within the cells.

Appendix B, Figure 3 is aerobic cell's temperature versus time plot. As presented in this plot, the temperature of the aerobic cell has generally decreased over time. This is due to the very limited aerobic operation of the cell (due to difficulties discussed in Section 3.12). If significant air were to be entrained into the waste we would expect temperatures to become elevated to within the range of 50 to 60°C.

3.3 Waste Moisture Content & Uniformity of Water

Moisture distribution within the cells was monitored through an array of moisture sensors that were installed during the waste placement phase. The majority of moisture sensors utilized were of the PVC type with a few gypsum sensors installed in layer 2 of the northeast 3.5-acre cell.

During the pilot-scale project, Yolo County conducted laboratory tests with the PVC sensors to determine the relationship between the multimeter readings and the presence of free liquid in the PVC sensor. These sensors were not designed to measure that actual moisture content of the waste but rather give an indication of moisture arrival at each location. It was determined that a meter reading of less than 40% corresponded to an absence of free liquid. A reading between 40 and 80% corresponds to the presence of free liquid in the PVC pipe but less than saturated conditions. Readings of greater than 80% indicate saturated conditions; i.e. the PVC sensor is full of liquid.

Following initial installation, sensors were read manually. In March 2002, automated data collection began with the SCADA system.

3.3.1 Northeast anaerobic cell

Since the start of full-scale liquid addition in June 2002, the average moisture levels in all layers have increased to the some free liquid or completely saturated zones as presented in Appendix B, Figure 4.

Optimum operation of a bioreactor landfill requires the moisture content of the waste be raised to near field capacity. Based on the previous pilot-scale project, the addition of 55 gallons of

liquid per ton of waste resulted in greatly accelerated anaerobic activity. Through the end of October 2004, a total of 2,809,490 gal of supplemental liquid has been added to the northeast 3.5-acre cell. With a total of 65,104 tons of waste in the cell, about 43 gal/ton of waste has been added. Table 2 below provides a summary by layer for the amount of liquid added.

Table 2. Northeast cell moisture addition by layer

Layer	Amount of waste (as received tons)	Volume of liquid added (gal)	Volume of liquid added per ton (gal/ton)
1	22,984	1,119,179	48.7
2	21,935	930,876	42.4
3	14,657	516,657	35.2
4	5,528	282,888	51.2

The moisture content of the waste can be calculated with the above information and initial waste moisture data gathered from the first sampling event. From the first waste sampling event (see section 3.8), conducted on June 4-5, 2002, the initial moisture content of the waste prior to liquid addition was measured at an average of 18.37%. The simplified equation for calculating moisture content on a wet waste basis is:

$$PMC = \left(\frac{L_0 + P + LA - LCH}{M + LA + P - LCH} \right) \times 100 \qquad (2).$$

Where:

PMC = estimated potential moisture content of waste mass (%)

L_o = initial weight of water (lbs)

M = total waste mass on an as received basis (lbs)

P = total precipitation (lbs)

LA = total liquids added to the waste mass, including recirculated leachate (lbs)

LCH = total leachate collected (lbs)

Assumptions:

1. Precipitation was assumed to be zero for the northeast anaerobic cell because the waste sampling event for which L_o was based occurred after the module was covered with a geomembrane liner, thus no precipitation has entered the waste.
2. All of the leachate that has been collected from the cell was recirculated. Therefore, the term "LA-LCH" can be simplified to be only the liquid added to the cell, L.
3. Because alternative daily cover (greenwaste) was utilized in the cell and will also absorb liquid, "M" must include the mass of the waste as well as the greenwaste ADC.

Givens:

1. Total waste in the northeast cell = 65,104 tons
2. Total greenwaste ADC in northeast cell = 11,060 tons
3. Total waste + greenwaste = 76,164 tons = 152,328,000 lbs
4. Initial moisture content of waste = 18.37%
5. Initial weight of water = (152,328,000*0.1837) = 27,982,653 lbs
6. Amount of water added = 2,849,601 gal = 23,756,671 lbs

Solution:

Given the above assumptions, the equation can be simplified to:

$$PMC = \left(\frac{L_0 + L}{M + L}\right) \times 100 \qquad (3)$$

$$= \left(\frac{27{,}982{,}653 + 23{,}756{,}671}{152{,}328{,}000 + 23{,}756{,}671}\right) \times 100$$

$$= 29.38\%.$$

The calculated moisture content is 29.25%, (rounded, 29.3%). Other very small corrections would be required to account for solids loss by digestion, and water loss by consumption and evaporation. At present early in operation, it is calculated that corrections for all reasons are well under 1% i.e. moisture content lies between 28 and 29%. However, corrections will become more important as conversion proceeds.

This moisture content is low compared to the results from the CEC pilot-scale cell, which by core samples (considered a reliable indicator) averaged 35%. However, the embedded sensors for the northeast 3.5-acre cell showed (Appendix B, Figure 4) that moisture reached nearly all sensors. The explanation for these low moisture uptakes in combination with good moisture distribution has been considered by the project team. First, all of the sensors were located in the tires layer right next to the leachate line. Faster moisture flow to sensors in this area compared to the rest of the waste would not be surprising. In addition, it seemed very likely that more compacted, and deeper waste would have lower interstitial pore volume than the shallower waste in the earlier pilot-scale cells. Simply put, in the full-scale cells, there were less pore volume per ton due to higher compaction. It takes less liquid per ton to fill what is likely a lower pore volume, in other words a given moisture addition "goes farther". Landfill gas would be expected to displace liquid occupying the pore space, spreading the added liquid further. This behavior of added liquid is an important topic as it relates to how much liquid is needed, and relates to liquid addition "targets" such as required additions (for example in gallons per ton) that should be the goals for methane enhancement. Although there have been modeling efforts elsewhere by the University of Florida and Geosyntec, among others, needs for liquid are hard to model. For this project, observation of the actual liquid uptake of the waste,

in gallons per ton, is valuable information that cannot be predicted by any present modeling exercise.

3.3.2 West-side anaerobic cell

Since the start of full-scale liquid addition in June 2003, the average moisture levels in all layers have increased to the "some free liquid" or "completely saturated" zones as presented in Appendix B, Figure 5. The "completely saturated" moisture content at which some free liquid just starts to drain from the waste is defined as moisture at "field capacity".

Through the end of October 2004, a total of 3,436,946 gal of supplemental liquid has been added to the west 6-acre cell. With a total of 166,294 tons of waste in the cell, about 20.7 gal/ton of waste has been added. Table 3 below provides a summary by layer for the amount of liquid added. Note that waste tonnage per lift was not tracked for the 6-acre cell; therefore volume per lift is not calculated.

Table 3. West-side cell moisture addition by layer

Layer*	Volume of liquid added (gal)
2	656,823
3	917,008
4	2,141,535

*No liquid injection piping was installed in layer 1

From the first waste sampling event (see section 3.8) conducted on June 4-5, 2002, the initial moisture content of the waste prior to liquid addition was 22.54%. The same equation and assumptions as for the northeast cell were used to calculate the potential moisture content in the west 6-acre cell. For assumption 1, though the waste sampling event for which Lo was based upon occurred prior to the module being covered with a geomembrane liner, the sampling did occur during the summer and the unit was covered that fall. In addition, the CIMIS weather database for Davis was checked and the precipitation during that time was negligible. Thus, the assumption of zero precipitation was still valid.

Givens:

1. Total waste in the west-side cell = 166,294 tons
2. Total greenwaste ADC in west-side cell = 27,570 tons
3. Total waste + greenwaste = 193,864 tons = 387,728,000 lbs
4. Initial moisture content of waste = 22.54%
5. Initial weight of water = (387,728,000*0.2254) = 87,393,891 lbs
6. Amount of water added = 3,562,414 gal = 29,710,532 lbs

Solution:

$$PMC = \left(\frac{L_0 + L}{M + L} \right) \times 100 \qquad (3)$$

$$= \left(\frac{87,393,891 + 29,710,532}{387,728,000 + 29,710,532,} \right) \times 100$$

= 28.05%.

3.3.3 Southeast aerobic cell

Since the start of full-scale liquid addition in November 2003, the average moisture levels in all layers have increased to the "some free liquid" or "completely saturated" zoned as presented in Appendix B, Figure 6.

Through the end of March 2005, a total of 322,931 gal of supplemental liquid has been added to the southeast aerobic cell. With a total of 11,942 tons of waste in the cell, about 27.0 gal/ ton of waste has been added. Table 4 below provides a summary by layer for the amount of liquid added.

Table 4. Southeast aerobic cell moisture addition by layer

Layer	Volume of liquid added (gal)
1	172,907
2	115,699
3	34,326

From the first waste sampling event (see section 3.8), conducted on June 5, 2002, the initial moisture content of the waste prior to liquid addition was measured at an average of 17.91%. Equation 3 and assumptions as for the northeast cell were used to calculate the potential moisture content in the southeast aerobic cell.

Givens:

1. Total waste in the southeast aerobic cell = 11,942 tons
2. Total greenwaste ADC in the southeast aerobic cell = 2,169 tons
3. Total waste + greenwaste = 14,111 tons = 28,222,000 lbs
4. Initial moisture content of waste = 17.91%
5. Initial weight of water = (28,222,000*0.1837) = 5,184,381 lbs
6. Amount of water added = 322,931 gal = 2,693,244 lbs

Solution:

$$PMC = \left(\frac{L_0 + L}{M + L} \right) \times 100 \qquad (3)$$

$$= \left(\frac{5,184,381 + 2,693,244}{28,222,000 + 2,693,244} \right) \times 100$$

= 25.48%.

3.3.3.1 Partitioning gas tracers

Field trials of the PGTT technology were conducted in May 2004 in the Yolo County aerobic bioreactor. The tracer gases (helium, conservative; and difluoromethane, partitioning) were injected at 104.4 L/min (Test #1) and 121.5 L/min (Test #2) through pre-existing monitoring tubes emplaced in the landfill. Gases were extracted in nearby horizontal gas collection lines, and samples collected in borosilicate glass bottles and transported to the University of Delaware for analysis. Gas chromatography was used to measure difluoromethane (DFM) (flame ionization detector) and helium (thermal conductivity detector) in gas samples. The locations of two tracer tests are shown below in Figure 5. Both tests sampled were approximately 250 ft^3 of solid waste located 10 to 17.5 ft below the topmost surface of the landfill.

Measured tracer breakthrough curves are shown for both PGTT in Figure 6. For Test #1, there was an obvious lag in the transport of DFM with respect to helium. This DFM tracer, which partitions into water, was slowed and attenuated by water in the solid waste. The lag in DFM travel and reduction in DFM peak concentration is barely perceptible in the raw data from Test #2, suggesting less water in the solid waste sampled during this tracer test.

Based on the data shown in Figure 6 and measured landfill temperatures, the water saturation in the solid waste was estimated using the mean tracer arrival times determined from the moment of analysis (Imhoff et al. 2003). For Test #1, the fraction of the pore space filled with water was 29%, while the moisture content, the mass of water divided by total wet mass of solid waste, was estimated to be 28%. To compute the moisture content, the porosity and bulk density of the solid waste were estimated to be 0.5 and 510 kg/m^3, respectively. For Test #2, the fraction of the pore space filled with water was 7.1%, while the moisture content was estimated to be 6.9%, using the same estimates for porosity and bulk density used for Test #1. Thus, the solid waste was relatively moist in the region sampled for Test #1, but much drier in the Test #2 region.

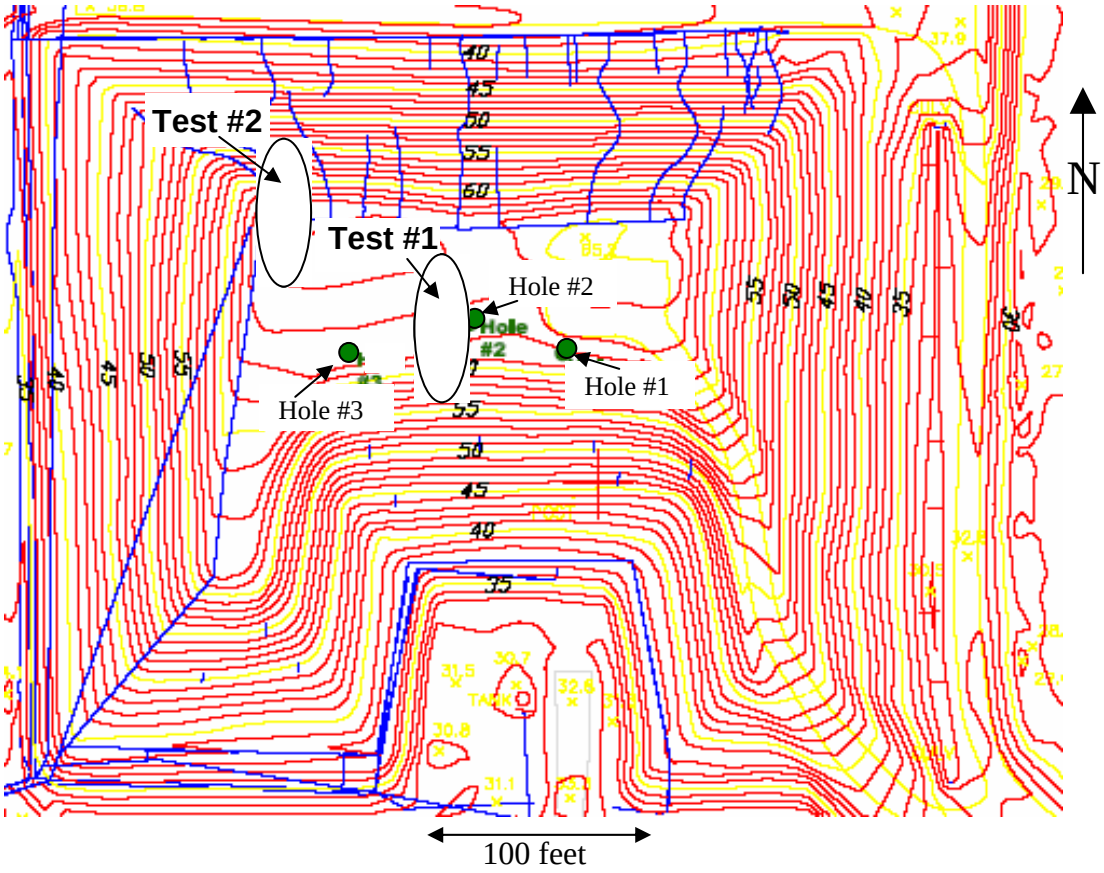


Figure 5. Plan view of Yolo County aerobic bioreactor cell. Circled regions indicate regions sampled during PGTT #1 and #2. Locations of three vertical cores (hole #1, #2, and #3) for measuring moisture content gravimetrically are also shown.

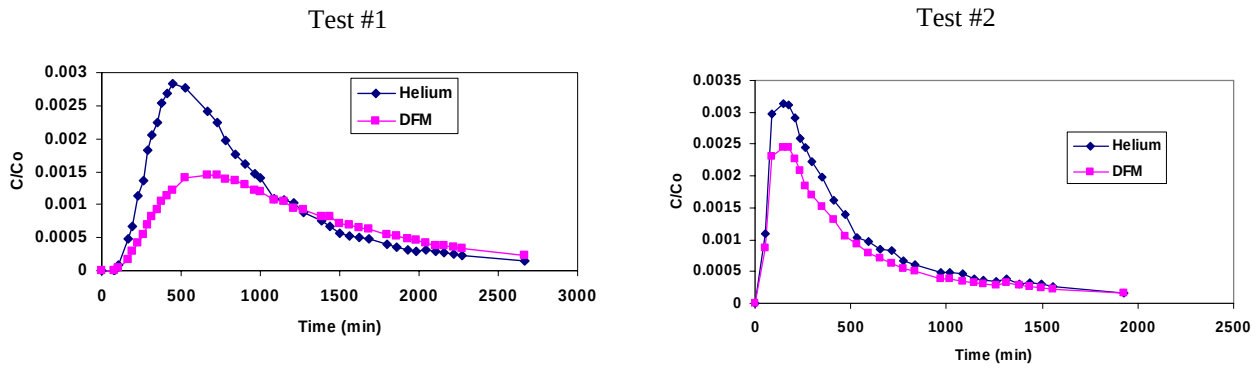


Figure 6. Tracer test results from Tests #1 and #2.

Following the PGTTs, cores were removed at three locations shown in Figure 5. Moisture contents were determined for solid waste samples collected from 10 to 15 ft below the topmost surface of the landfill, which is similar to the depth sampled by the PGTTs. The moisture contents for the solid waste sampled from these three cores at this depth were 32%, core #1; 27%, core #2; and 6%, core #3.

Because core #2 was located on the edge of the region sampled by Test #1, it was reasonable to compare core #2 results with Test #1. The moisture content from core #2 was almost identical to that from Test #1: gravimetric moisture content of 27%, core sample, versus 28%, PGTT. While Test #2 was not close to any of the three cores, it was on the west side of the bioreactor cell and was most similar in location to core #3, which was also located on the edge of the landfill. Both Test #2 and core #3 measured small moisture contents: gravimetric moisture content of 6%, core sample, versus 6.9% PGTT. Thus, the waste was not nearly as moist on the west side of the landfill as it was in the center or on the east side. The waste was also much drier than anticipated, since leachate was actively recirculated in the bioreactor before the field tests.

The variability of moisture content measured by PGTT was consistent with variability determined from three cores at the same depth. Core samples from 10 to 15-ft depth showed moisture contents varying from 6 to 32%, while the two tracer tests in different regions of the bioreactor showed moisture contents of 6.9 and 28%. Moisture contents of the cores and from PGTT were both lower on the west side of the cell. Thus, the distribution of water determined by PGTT was reasonable and was consistent with the gravimetric measurements.

3.4 Liquid Levels Over the Base Liner

To date, liquid build-up on the base liner has not been insignificant. The base liner under the bioreactor cells is continuous, however it is hydraulically separated such that leachate draining from each of the cells cannot commingle (see Section 2.1). The California Regional Water Quality Control Board (CRWQCB) has limited the liquid level over the base liner to less than the typically allowed 12 inches. If liquid levels on the base liner exceed 4 inches, the County must inspect the leachate pumps for correct operations and/or make adjustments to the injection system to reduce the level to below 4 inches. If liquid levels exceed 10 inches, liquid addition must cease. Liquid level over the aerobic liner is also monitored, however, since this is a secondary liner, no level restrictions have been imposed by the CRWQCB.

Figures 7 and 8 in Appendix B provide graphs of the liquid level over the base liner . To date, the highest leachate level recorded has been just under 2 inches in each of the cells. It, however, must be noted that only minimal leachate has been generated by the west cell and as such, the capacity of the LCRS has not truly been tested.

The graph of the liquid level on the aerobic liner in presented in Figure 9 of Appendix B. As presented in this graph, liquid levels on the aerobic liner have been greater than that of the primary base liner. This is attributed to two factors. First, because the aerobic liner was constructed on waste, which has a tendency to settle, the LCRS trench is likely to have settled and does not provide the same drainage capacity as when it was constructed. Secondly, a u-trap was installed in the LCRS pipe to prevent air intrusion into the cell and several instances were observed when an air lock had developed in this u-trap that prevented the pipe from

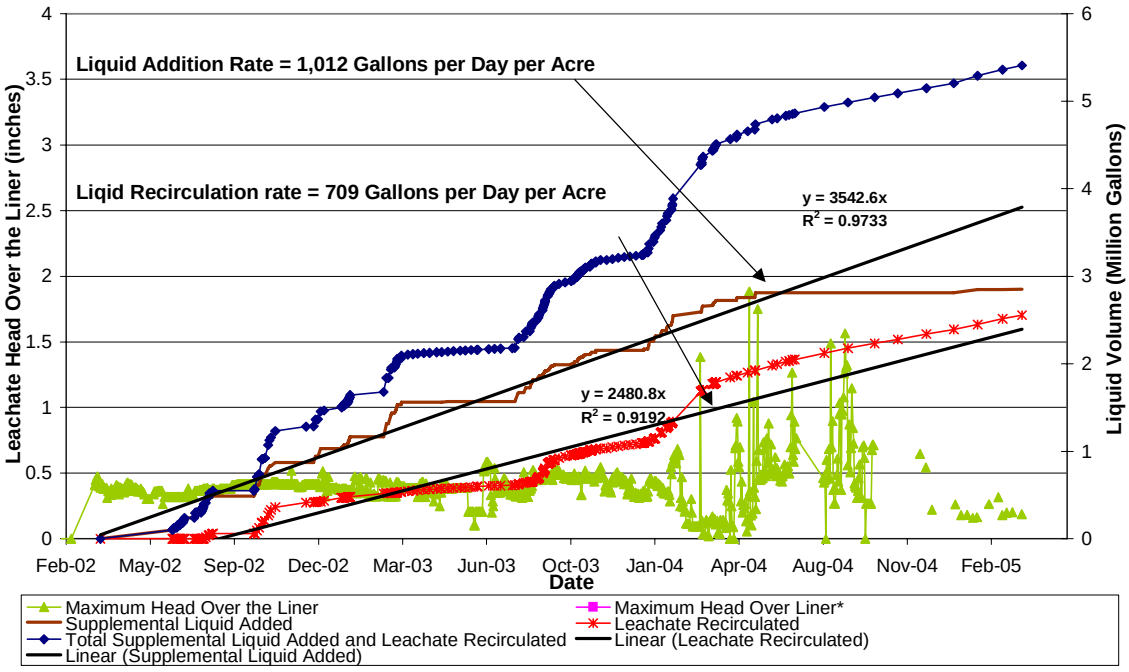
draining until sufficient liquid had built up to overcome the air lock. It is suspected that the periodic peaks in liquid level observed is due to the air lock phenomenon.

In August 2004, two out of the three pressure transducers located on the base liner began indicating large, random, fluctuating pressure readings. We suspected that these pressure transducers had failed. Pressure was monitored from the tubes that were installed adjacent to the pressure transducers and was found to be stable and significantly less than the pressure transducers. The pressure transducers were attempted to be removed, however the cable that the transducers were attached broke and we were not able to remove the transducers. The County is currently looking at options to perform a video inspection of the pipe and confirm the lack of liquid buildup and cause of the cable break.

3.5 Leachate

3.5.1 Addition and Recirculation

Figure 7 below presents the cumulative leachate addition and recirculation volumes to the northeast 3.5-acre cell. Figure 10 in Appendix B presents the average daily recirculation (which is equivalent to the flow through the LCRS system). Based on the results of the original CEC pilot-scale cells, the County predicted in the FPA that the maximum leachate recirculation for the bioreactor could be as high as 20 gpm/acre. It is useful to note for reference here that this represents a liquid infiltration rate of 3 x 10^{-5} cm/sec, and obviously requires an average waste permeability of at least this. Showing workability of any infiltration rate (in terms of how well and how fast moisture distributes) also represents very useful information. Given the 3.5-acre size of the cell, this 20 gpm/acre would correspond to a maximum flow potential of 70 gpm. As presented in the graph, the average flow to-date was approximately 1,031 gal/day-acre (2.5 gpm).



In August 2004, two out of the three pressure transducers began giving erratic readings that were not supported by pressure tubes, and in October 2004, the third pressure transducer reported readings above 10 in of H20. Maximum Head Over Liner* curve was created using data from the pressure tubes.

Figure 7. Northeast anaerobic cell liquid recirculation and addition volumes

Figure 8 below presents the cumulative leachate addition and recirculation volumes to the west 6-acre cell. Figure 11 in Appendix B presents the average daily recirculation (which is equivalent to the flow through the LCRS system). Given the 6-acre size of the cell, this would correspond to a maximum flow potential of 120 gpm.

Liquid addition to the west 6-acre cell was initially begun at an aggressive rate to determine if there was an upper limit to liquid addition. During this first phase, addition averaged approximately 17,000 gal/acre-day (or 71 gpm for the entire cell). Following this initial addition, leachate seeps (i.e. liquid exiting the side slopes) were discovered along the west side of the cell in July of 2003. Leachate addition was stopped and a drainage trench was installed along the toe of the slope in the area where the seep had occurred. The function of the trench was to allow any leachate that drained down the side of the cell, a path to the Module 6D LCRS. Leachate addition was then restarted, however additional seeps appeared. Eventually, it was necessary to install a drainage trench along the entire west side of the west 6-acre cell.

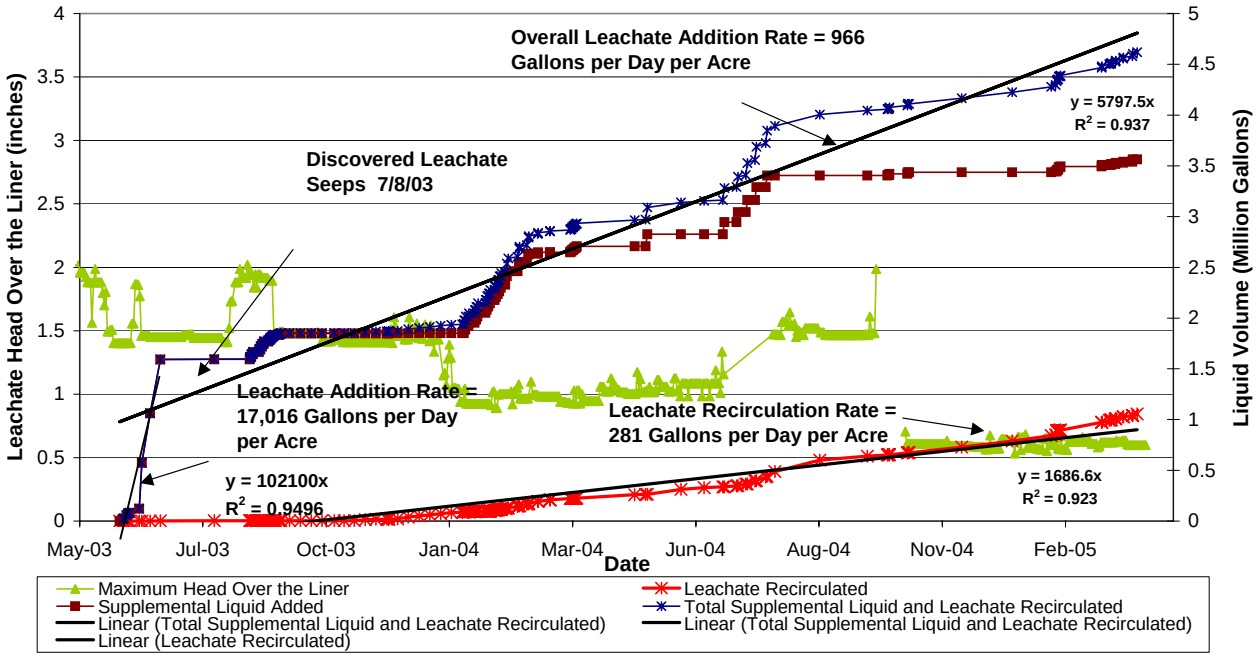
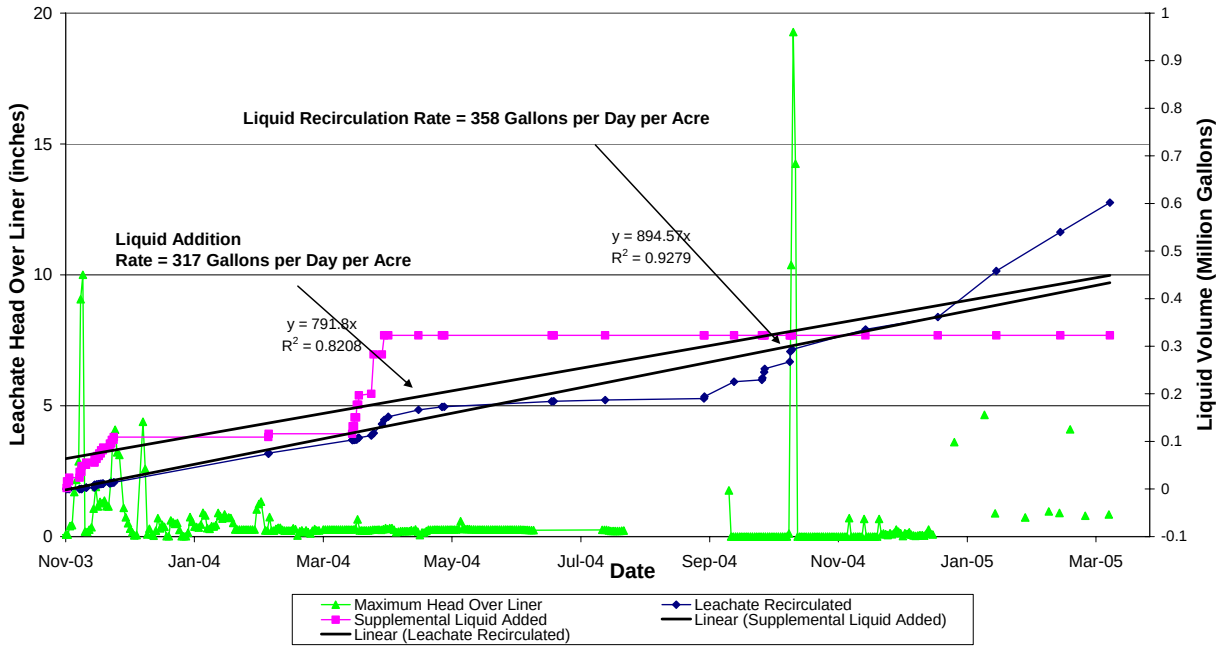


Figure 8. West-side cell liquid recirculation and addition volumes

Figure 9 below presents the cumulative leachate addition and recirculation volumes to the southeast aerobic cell. Figure 12 in Appendix B presents the average daily recirculation for the southeast aerobic cell. Given the 2.5-acre size of the southeast cell, this would correspond to a maximum flow potential of 50 gpm.



Note: In March 2004, one out of the two pressure transducers under the southeast cell began giving erratic readings that were not supported by pressure tube readings. In August 2004, both pressure transducers were removed and recalibrated. The one that was previously giving erratic readings was determined to have failed and removed from the system. In January 2005, the other sensor failed, thus maximum head over liner curve was created using pressure tube data.

Figure 9. Southeast aerobic cell liquid recirculation and addition volumes

Leachate addition and recirculation rates and volumes for the bioreactors cells have been lower than originally predicted during the development stage of the FPA. Two main factors have attributed to this, the first being remnant soil cover impeding the vertical permeability, and the second was the physical geometry of the cell and the natural tendency for horizontal permeability to be greater than vertical.

During the construction of the bioreactor cells, it was necessary to place daily cover soil in areas of traffic or where subsequent lifts of waste would not be placed for more than 7 days. Because the cover soil, which was on-site clay, would have a tendency to limit liquid movement, every attempt was made to remove or break up the soil layer prior to placement of the next lift of waste. In addition, a large wet-weather deck constructed of soil and concrete rubble was installed on top of the first lift of waste in the west 6-acre cell. This wet-weather deck was also not removed, but was broken up and incorporated into the waste.

It was hoped that the measures taken to break up the cover soil would be sufficient, however we suspect that the remains of the wet-weather deck constructed in the west 6-acre cell contributed significantly to the leachate seep problem discussed in section 4.1.1.

The other significant factor that has limited the rate at which liquid can be added was the geometry of the cells. Because of factors unique to the YCCL, the base liner for the cells was essentially installed at the existing surrounding grade of the site (rather than being an excavated pit). As a result of this, the waste cells, are in essence, an above ground pyramid. It was well established that the horizontal permeability of waste was greater than the vertical permeability and as such, the geometry of the cells lends itself to the possibility of leachate seeps. At sites where cells were excavated below ground, seeps would not be an issue because any horizontal

movement of liquid would be intercepted by the sidewalls of the primary liner and would then drain to the LCRS.

3.5.2 Field Parameters (pH, EC, ORP, DO, TDS, and Temperature)

Leachate characteristics depend on the composition of waste, age of waste, rate and chemistry of water added, and the waste buffering capacity. The pH of leachate from the northeast 3.5-acre area has remained between 7.02 and 8.16 within the last year, which is considered in the optimum range. The optimum pH environment for methanogens is within the range of 6.8 to 8.5. The high pH source liquid added in this project is generally not typical of most landfills, but is rather site specific to the YCCL due to high pH of groundwater and leachate. At landfills with different source liquid characteristics, in particular buffering ability (i.e. alkalinity of liquids used), the pH of bioreactor leachate could be different.

Graphs of the leachate field parameters for the anaerobic and aerobic bioreactor cells can be found in Appendix B, Figures 13 and 15.

For both bioreactor cells, the pH at above 7.0 suggests minimal presence of organic acids, acetic, propionic and butyric acids, etc. These acids are first formed early in the breakdown of solid organic materials and are intermediates in the digestion (methane conversion) process. The acids are then consumed and converted to methane. Low acid levels and pH above 7 indicates a healthy, well functioning digestion process. A pH above 7 also means that these organic acids, which are potential leachate pollutants, are being successfully remediated.

A steadily rising leachate temperature simply reflects the transfer of heat from the waste as the leachate passes through. The leachate temperatures are much lower relative to the waste, but this is due to the contact with the cool base liner and underlying soil.

The significant dissolved oxygen levels in leachate indicated low leachate respiratory activity, likely due to low levels of aerobic organisms combined with the refractory nature of organics in the leachate. The dissolved solids and conductivity in any pre-existing liquid (like construction water) in the LCRS would be expected to be low. As liquid leachate begins to drain from the bulk of the waste, the leachate will carry with it dissolved salts and soluble solids from the waste, causing the dissolved solids and conductivity of the leachate to increase. This expected rise in dissolved solids and conductivity as a function of time can be seen in Appendix B, Figure 13. A rise in ORP was also observed (Appendix B, Figure 13).

Normally in wastewater treatment processes, the ratio of BOD_5/COD is used as a measure of wastewater biodegradability (Tchobanoglous et al. 1993). Ratios of BOD_5/COD below 0.10 are generally associated with leachate from properly decomposing landfills, and indicate that the remaining leachate soluble organics are not readily biodegradable. The ratio of BOD_5/COD for the northeast 3.5-acre cell is presented in Figure 10 below and is typical of a landfill in this phase. The BOD_5/COD ratios below 0.1 are to be expected; even when waste decomposition is not complete as is the case with the northeast 3.5-acre cell. The best available indicator, landfill gas produced, suggests that waste decomposition is proceeding in a satisfactory manner. Another important indicator, leachate pH, as noted above, likewise suggests that decomposition is proceeding in a satisfactory manner.

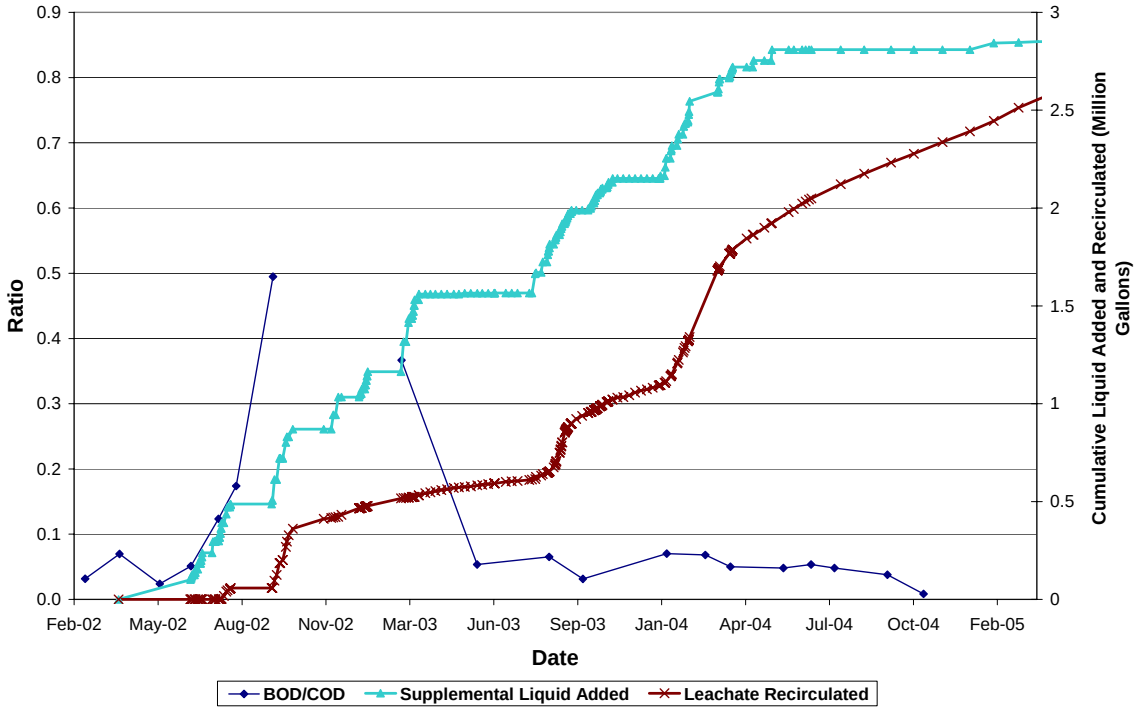


Figure 10. Northeast cell – BOD_5/COD over time

In Appendix A, Table 13, an anomaly existed for the October 17, 2002 sampling event wherein the BOD_5 value of 3,000 mg/L was higher than the COD value of 1,810 mg/L. BOD_5 values should not be higher than COD. This result was attributed to laboratory error and was excluded from our analysis.

The high biodegradability of the leachate from the northeast cell between September 2002 and March 2003 corresponds to what is a well-known process sequence that takes place in landfill, where initial high levels of organic acids are formed and consumed quickly for a period of several months. Following the initial spike, BOD_5 levels declined and stabilized between 100 and 150 mg/L, which were in the range of what was measured in the pilot-scale cell over the same time period. It is unclear the cause of the sudden increase in BOD_5 (770 mg/L) and decrease in COD (970 mg/L) in March 2005 sampling event.

To date, BOD_5 and COD levels in the west 6-acre cell have approached those recorded in the northeast 3.5-acre area. Unlike the northeast 3.5-acre area, the west 6-acre area has exhibited some large variations in BOD_5/COD ratio. In general, there typically occurs a fairly low base level of BOD_5 that is not biodegradable in leachate. In addition (as seen in Figure 11), there are transient increases in other anaerobically biodegradable components that are subsequently consumed. Typically organic acids are formed in the anaerobic decomposition process, particularly during early stages. These are variable over time in exiting leachate. Being readily degradable they will contribute to BOD_5. The net result of this can be quite variable BOD_5/COD that are not typical of long term operation. In alternate terms, amounts of fresh high-organic content leachate "breaking through" contribute to variations in BOD_5/COD. Still,

the degree of variation is high. Given the still relatively early operation of the cell, we expect BOD_5/COD ratios to stabilize as waste decomposition progresses.

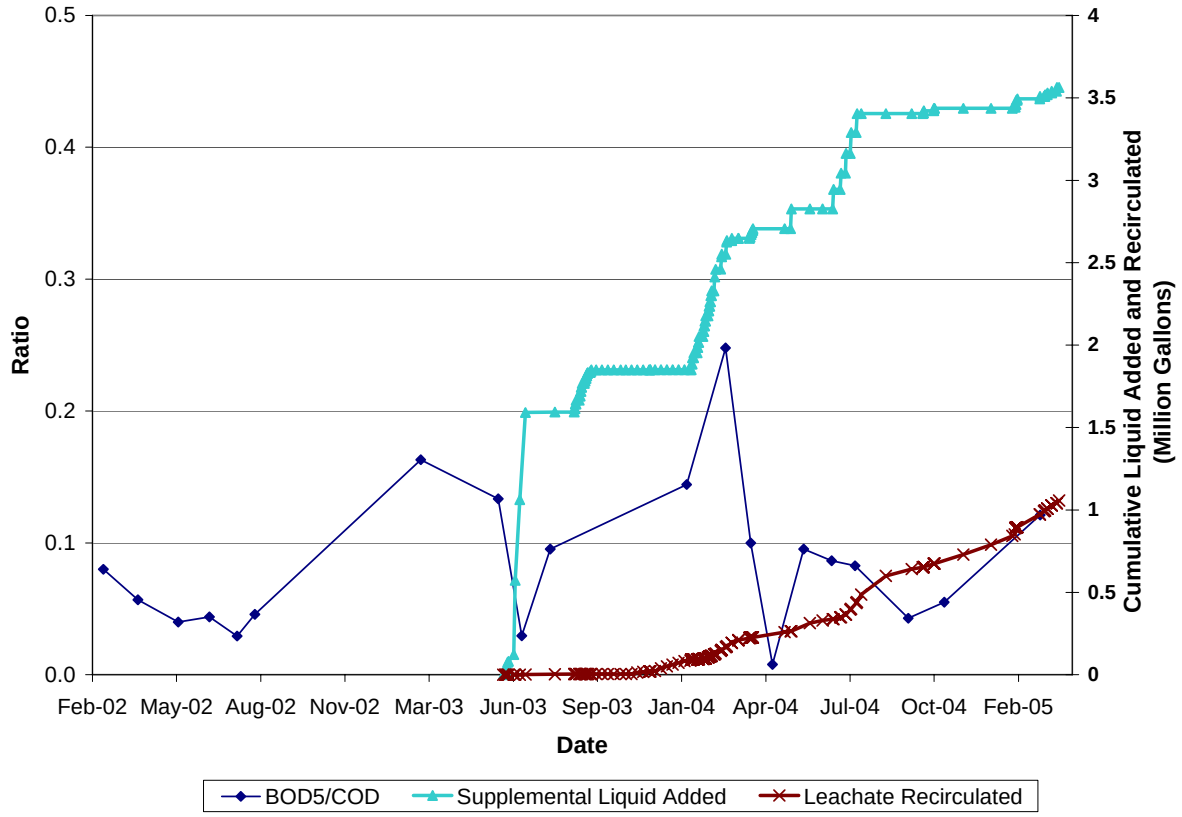


Figure 11. West-side cell – BOD_5/COD ratio

The BOD_5/COD ratio for the aerobic cell generally follows the pattern of the northeast cell showing an initial spike following the beginning of liquid addition followed by relatively low (less than 0.10) BOD_5/COD ratios during subsequent sampling.

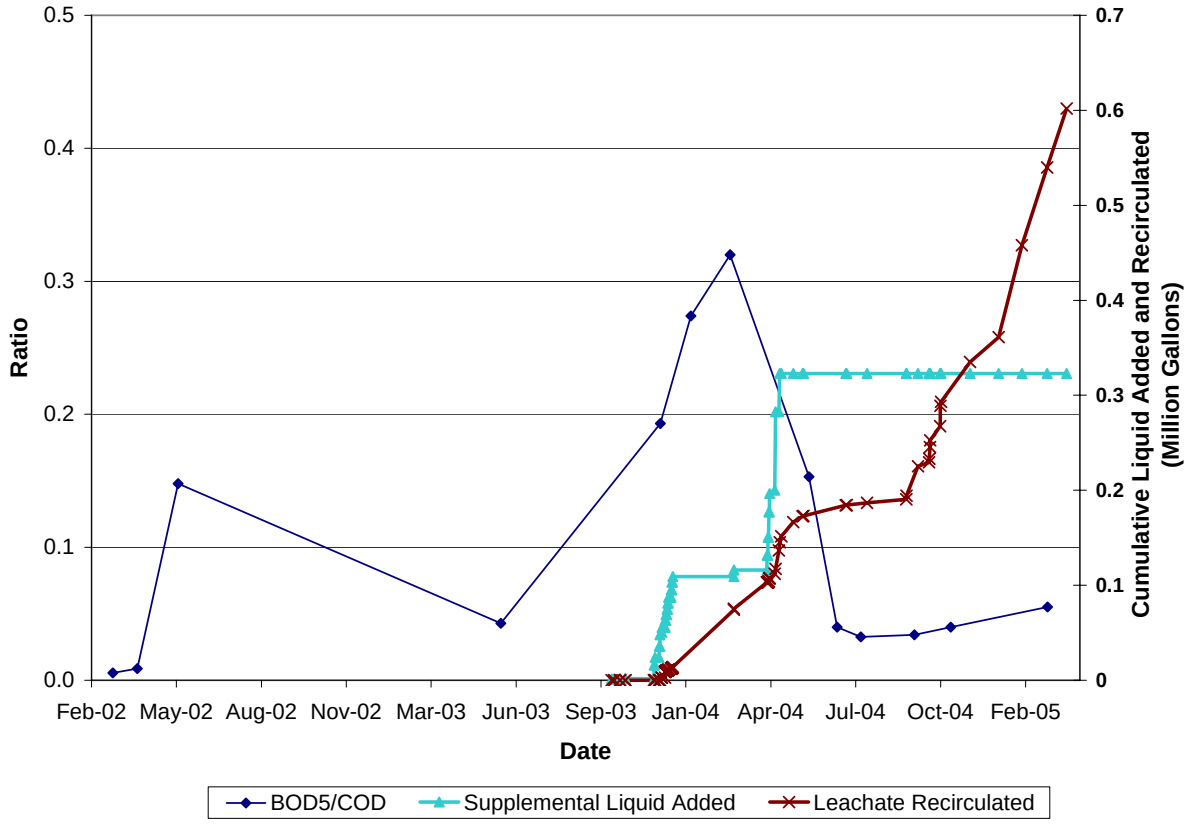


Figure 12. Southeast aerobic cell - BOD_5/COD ratio

3.5.3 Leachate Total Organic Carbon

In digestion processes, the conversion of certain degradable organic components, most notably cellulose, frees and solubilizes other organic materials that were bound to the cellulose. These organic materials, which is mostly derived from wood lignin or lignin like components, and such things as tannins, appears in solution. It is typically difficult for microorganisms to degrade it. (A rather similar mix of compounds appears in and darkens the liquid held within peat in peat bogs.) It is likely that newsprint, comprised of fibers of grounded wood/lignin, could be a major source of this material, but this is somewhat speculative. This unknown dissolved organic COD is evidently quite resistant to aerobic oxidation, as the leachate recycled from the leachate holding pond, which had been exposed to air for the better part of a year, still contained almost as much COD as the leachate exiting the cell.

Another component of refractory dissolved carbon that would appear as COD, but not BOD_5, is VOC compounds that are resistant to aerobic biodegradation. The main one of these that appeared transiently is methyl tertiary butyl ether (MTBE), which is a gasoline additive and can escape into the environment. Graphs of TOC over time for the bioreactor cells can be found in Appendix B, Figures 16 through 18.

3.5.4 Leachate Nitrogen

The rising nitrogen in the leachate is a consequence of degradation of nitrogenous waste, principally food wastes, although other materials (i.e. small amounts of sewage sludge, disposable diapers, and the like) also contribute. Nitrogen (principally from amine groups of amino acids) surplus needed to form the anaerobic organisms is freed as wastes break down and appears in solution. The behavior of nitrogen levels seen here are entirely typical of the nitrogen documented in landfill leachate elsewhere. However, it is to be noted that the rise in nitrogen is faster here because of the purposeful management of the landfill to speed biological activity.

Graphs of nitrogen content over time for the bioreactor cells can be found in Appendix B, Figures 19 through 21.

3.5.5 Leachate Phosphate and Other Nutrients

In contrast to ammonia nitrogen, the nitrate nitrogen drops to zero. It has been shown in work by Professor Morton Barlaz (NCSU) that this nitrate nitrogen is readily reduced as an electron acceptor. Thus, as the oxygen is used (and elemental nitrogen is formed), the free nitrite/nitrate levels are expected to be low.

The phosphorous levels represent the free phosphorus, which is likely from food wastes. The phosphorus in solution is released during waste breakdown, and is in excess of the amount needed by the anaerobic organisms. Graphs of leachate nutrients over time for both of the bioreactor cells can be found in Appendix B, Figures 22 through 24.

3.5.6 Leachate Semi-Volatile and Volatile Organic Compounds

Dissolved volatile organic compound (VOC) concentrations are presented in Appendix B, Figures 25 through 27. VOC (including the anaerobically biodegradable VOCs: acetone, 2-Butanone (MEK), and 4-Methyl-2-pentanone (MIBK)) levels in the northeast 3.5–acre cell leachate follow a similar trend to BOD_5 with initial levels being low, then rising to a peak in October 2002 and then falling again as leachate recirculation continued and as anaerobically degradable VOCs were consumed or otherwise removed. The anaerobic degradation of those VOCs that disappear by conversion to methane is typified by the example of acetone bioconversion to biogas,

$CH_3COCH_3 + H_2O \rightarrow 2CH_4 + CO_2$.

Similar reactions apply to MTBE. Another mechanism that applies to volatile compounds that cannot anaerobically biodegrade is the stripping of sparingly soluble compounds such as benzene. As VOCs, they have significant vapor pressures. They partition (evaporate) into the generated landfill gas and are collected with it. This is a very efficient method for collecting volatile organic compounds (like alkane hydrocarbons--propane, gasoline fractions) that are not biodegradable. The falling VOC levels in both the leachate and the collected landfill gas confirm that a combination of these mechanisms is at work. Altogether, this cleanup of the VOCs comprises an environmental benefit when the landfill gas is used for energy (or disposed by flaring) and the VOCs are destroyed.

3.5.7 Dissolved Metals

As bioreactor operation continues, the concentrations of dissolved metals in the leachate are expected to decline. Dissolved metals have a tendency to precipitate out as acids are then consumed and pH increases. Figure 29 in Appendix B presents the percentage change in dissolved metal concentration from the initial February 2002 samples for several important constituents for the northeast 3.5-acre cell. As presented in the graph, each of these metals showed a relative decrease in metal concentration over the first several sampling events, then as injected water percolated through the waste and reached the LCRS system, each of the constituents increased in concentration (although actual concentrations of the various dissolved metals are still relatively low, see Appendix A, Tables 13 through 15). In addition to the potential water quality impacts of high dissolved metals concentrations, dissolved metals can also be toxic to bacteria growth and retard landfill gas production. Further data will be required to demonstrate if dissolved metals reduce in concentration, continue to remain above baseline levels, or rise in concentration.

The analyzed metals concentrations were somewhat variable as seen in Appendix B, Figure 28. The pH in the range of 7 to 8 is close to the optimum for keeping all metals of concern to a minimum. Another thing to note is that there has been no evidence of metal toxicity in these or any known landfill experiments.

Appendix B, Figure 31 presents the percentage change in dissolved metals concentration from the initial February 2002 samples for the west 6-acre area for several important constituents (other constituents were omitted from the graph because of extremely low or non-detect levels). As presented in the graph, each of these metals showed an initial decrease in metal concentration over the first sampling events. This pattern is similar to that observed in the northeast 3.5-acre cell prior to significant leachate being generated by the cell. As the leachate generation increased, the organic acids also increased while the pH decreased, causing the levels of chromium and cobalt to increase as they were solubilized. This spike in dissolved metals was similar to that observed in the 3.5-acre cell.

In aerobic operation, organic acid constituents could be removed and pH would tend toward neutral more rapidly as the organic acids are oxidized. Thus, aerobic activity would be expected to neutralize acidity and reduce the dissolved metal levels more rapidly. Except for a spike in chromium between April 2003 and February 2004, metals levels remained much lower in the aerobic cell than in the anaerobic cells (Appendix B, Figures 32 and 33).

3.6 Landfill Gas Quantity and Composition Analysis

Background samples of landfill gas were collected from the northeast 3.5- acre area and west-side 6-acre area in March 2002 prior to liquid addition to the bioreactor cells. Since March 2002, landfill gas has been sampled from the northeast 3.5-acre area on a quarterly basis. Since March 2003, landfill gas has been sampled from the west 6-acre area on a quarterly basis. The southeast aerobic cell was sampled on a quarterly basis in 2003, but due to testing of the biofilter and blower station, no sampling was done from the cell in 2004 until December.

Analytical results are presented in Appendix A, Tables 16 through 18. As time progressed, the LFG methane content stabilized toward a range of 45-55% as expected.

3.6.1 Landfill Gas Flow Rate

Average landfill gas flow rate from each of the bioreactor cells is presented below in Figures 13 through 15. In each case, flow rate has dramatically increased following leachate injection and, following the initial increase, remained relatively stable.

As evident in the figures below, landfill gas recovery rate has fluctuated at times. These fluctuations, however, are not due to any intrinsic variation in generation, but rather can be attributed to several factors. The most important of which is the human factor in adjusting a gas extraction system. When adjusting a gas system, you are trying to match extraction exactly to generation, which, in practice, is extremely difficult to do. What more commonly happens is the system either slightly under or over extracts compared to the rate at which gas was generated. (Another way to state this is that the draw on gas can vary as engine gas use varies.) When this happens, the system is adjusted again to compensate, which in turn requires another compensation, and so forth. The other factor that is responsible for some of the most extreme variations is attributed to partial or complete shutdown of the gas-to-energy facility.

Under practical operating conditions at a landfill where multiple cells are producing landfill gas, the day-to-day variations in extraction from each of the cells (or individual wells) would have a tendency to cancel each other out such that the overall extraction would be much more consistent, which is the case at the YCCL.

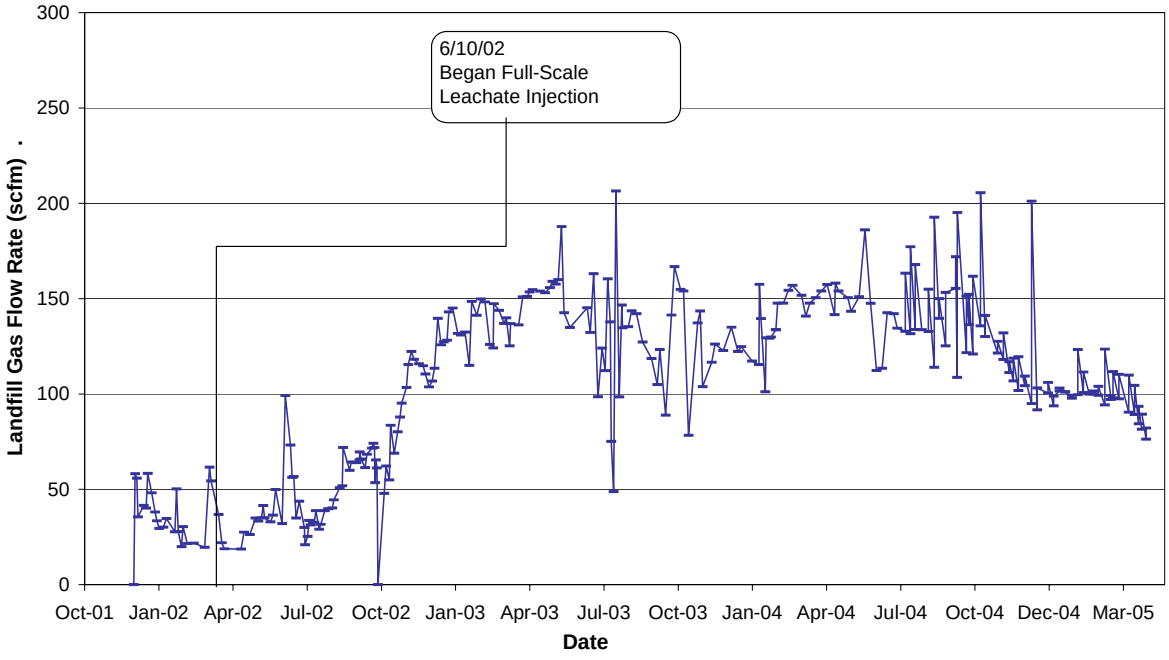


Figure 13. Northeast cell average daily flow rate

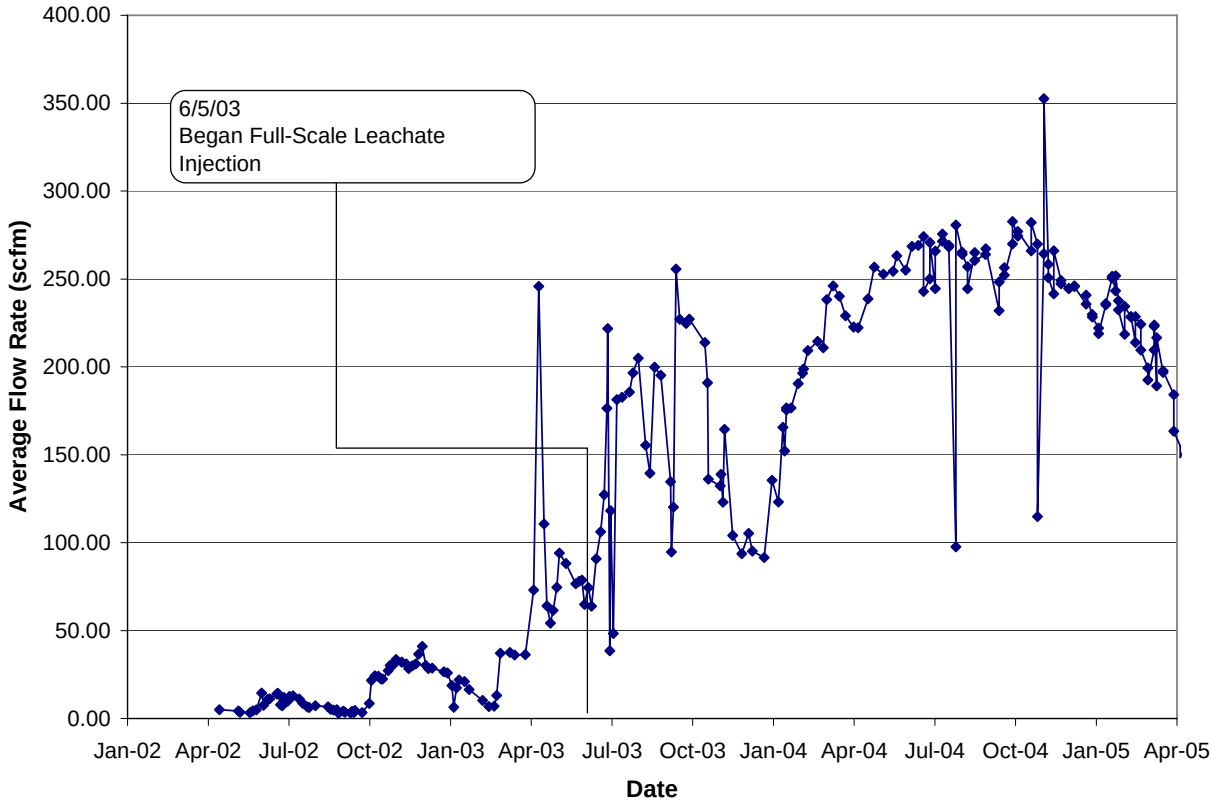


Figure 14. West-side cell average daily flow rate

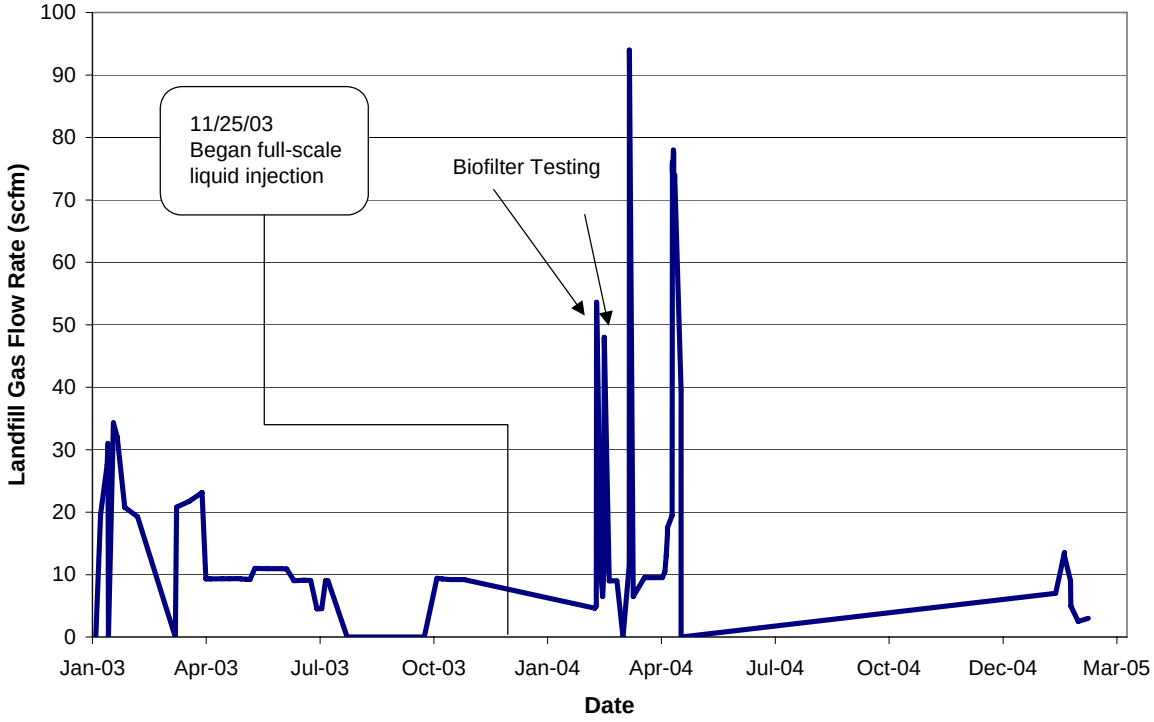


Figure 15. Southeast aerobic cell average daily flow rate

3.6.2 Landfill Gas Volume

Appendix B, Figure 34 presents the landfill gas flow rate and cumulative methane collected from the northeast 3.5-acre area. As presented in this figure, the volume of landfill gas collected from the northeast 3.5-acre area significantly increased following the beginning of full-scale liquid addition in June 2002. In conjunction with this increased flow rate, methane concentration in the landfill gas also increased from 40 ±5% to 50 ±5%.

Appendix B, Figure 35 presents the landfill gas flow rate and cumulative methane collected from the west 6-acre cell. Examination of the cumulative methane production curve indicates that gas production in this cell can be generally broken down into three phases: prior to surface liner installation (May 2002 to October 2002), following surface liner installation and shortly after leachate injection began (October 2002 to June 2003), and following leachate injection (June 2003 through the present).

Figure 16 presents the cumulative methane generated per pound of dry waste for both the northeast 3.5-acre and west 6-acre cell. This number is used as a gage to determine the progress of decomposition, and the values obtained can be utilized by other landfills to estimate landfill gas production. Through October 2004, the cumulative methane generated per dry ton of waste was approximately 0.685 ft^3/lb for the northeast 3.5-acre cell. Comparing this to the estimated maximum methane potential of municipal solid waste of 1.4 ft^3/lb, the northeast 3.5-acre cell has undergone 48.9% of its estimated potential decomposition. Based on the EPA Landfill Gas Generation model, a typical dry-tomb landfill would be expected to produce approximately 0.10

ft³/lb of dry waste over the same time period. This translates to a nearly 7-fold increase over a typical dry-tomb cell. The total methane generation between December 2001 and October 2004 from the northeast 3.5-acre cell was approximately 78.3 million scf of methane, which is equivalent to approximately 12,426 barrels of oil or 6,525 MW-hr of electricity (at 12,000 ft³ methane per MW-hr).

Also included in Figure 16 is the cumulative methane generated per pound of dry waste from the west 6-acre cell. Through October 2004, the cumulative methane generated per dry ton of waste was approximately 0.26 ft³/lb. Comparing this to the estimated maximum methane potential of municipal solid waste of 1.4 ft³/lb, the west 6-acre cell has undergone 18.6% of its decomposition. Based on the EPA Landfill Gas Generation model, a typical dry-tomb landfill would be expected to produce approximately 0.07 ft³/lb of dry waste over the same time period. This translates to a nearly 4-fold increase over a typical dry-tomb cell. The total methane generation from the west 6-acre cell between May 2002 and October 2004 was approximately 77.5 million scf, which is equivalent to approximately 12,299 barrels of oil or 6,548 MW-hr of electricity.

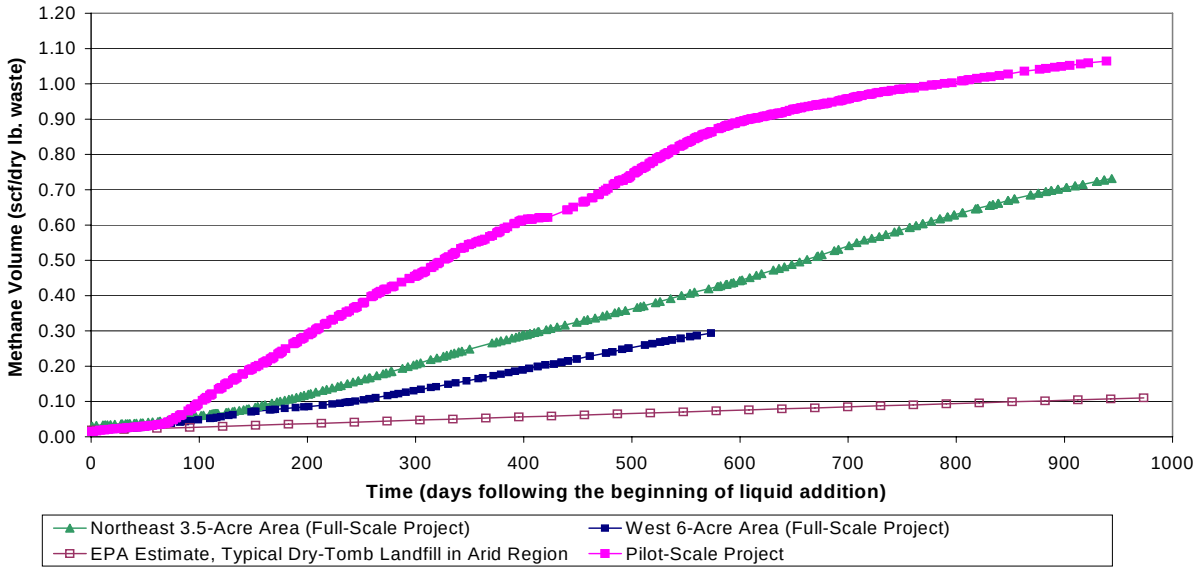


Figure 16. Cumulative methane per dry pound of waste from the northeast 3.5-acre, the west 6-acre cell, previous pilot-scale project, and what would typically be expected in a dry-tomb landfill

The normalized methane generation rates (or in alternate technical terms, rate constants) for the northeast and west 6-acre cells have thus been very encouraging, several-fold higher than would be expected for the same masses of waste if they were conventionally landfilled. Some slightly added methane might have come from decomposition of the "greenwaste" ADC, but this material (chipped twigs, leaves and the like) gives relatively low methane yields, under half that of waste, and small amounts of methane could not have materially altered the pronounced difference between the bioreactors' and conventional yields. The normalized methane productivities are lower than for the smaller demonstration cell, but this is considered in part

due to type of waste and the slower infiltration of liquid into the waste mass. The project team believes that in future commercial operation, it should be possible to improve the methane rates seen for the northeast and west side cells even further. Improved leachate recirculation rates and more rapid infiltration should be attainable by substituting more permeable and readily available daily cover material for the cover soil that somewhat impeded liquid infiltration, and better cell geometry which may be possible at other landfills.

3.6.3 Landfill Gas Methane, Carbon Dioxide, and Oxygen Content

Landfill gas constituent composition over time is plotted in Figures 37 through 39 in Appendix B. The landfill gas composition at around 50% methane ±5% is acceptable for all landfill gas adapted equipment operation, including electricity generation that is of most interest. The variations in concentration are largely due to variations in extraction vacuum or draw.

3.6.4 Landfill Gas Collection System Pressure

Appendix B, Figures 40 through 42 illustrate the variations in the extraction system vacuum over time for each of the cells.

The gas extraction system for the west 6-acre cell has been operated at variable vacuum and on average at a lower system vacuum than the northeast cell. This is an unintended consequence of extraction system features and varying engine operations and fuel use at the landfill. This may, in part, be one of the reasons that the west 6-acre cell has had greater surface emissions than the northeast 3.5-acre cell (although still relatively low). For comparison purposes, the average emission (over all surface scans) for the 6-acre cell was 3.2ppm versus 0.8 ppm for the 3.5-acre cell.

3.6.5 Landfill Gas Collection System Temperature

Landfill gas temperature is monitored at each wellhead either with a temperature probe that is permanently installed in the wellhead or with an auxiliary probe to the GEM-500.

As material balances are made, the moisture loss can be determined from the content of water in the saturated gas at the temperature at which gas leaves the system. Because the extraction line condensate drains back into the cell and is not lost, this may require gas temperature measurements where the gas actually leaves away from the well, where the water vapor escapes.

Up to now, corrections for water vapor loss were minor, which is to say that adjusting for maximum conceivable loss would change calculated moisture content by under 0.2%. Gas temperatures fluctuated between 50 and 90°F, and waste temperatures averaged around 110°F.

3.6.6 Landfill Gas Condensate

The landfill gas collection system was designed and installed to eliminate the need to remove condensate from the system. Lateral piping ran uphill to a main collection header so any condensate that collected in that section would drain back into the waste. The header line then gravity drained to the landfill gas-to-energy facility where condensate was removed and discharged to the landfill's LCRS.

This, and any similar condensate return arrangement, has advantages at Yolo and for other commercial operations. First, it is expected under normal circumstances that all condensate in

the header will drain back into the waste. This can limit liquid loss and maximize retention of liquid in the cell. Also, it eliminates any need to handle the condensate that is instead returned to the cell.

Solids converted to gas will, to a close approximation, be equal to the weight of landfill gas leaving the system. The design of the condensate system is such that much condensate returns to the cell. Later in the project, measurements and corrections for water loss as vapor in the gas will be carried out.

3.6.7 Results of Biofilter Fugitive Emissions Testing for Southeast Cell

3.6.7.1 Comments on biofiltration emissions test results

Attempts to determine biofilter effectiveness proved to be challenging. Plainly, there were measurement difficulties. Among the best evidence for these was the anomalous calculation of methane leaving the biofilter that was higher than methane entering the biofilter. Summarizing memoranda on the possible causes, there were several plausible reasons for these results, and several ways to improve testing in the future.

Some of the reasons for the biofiltration test results are as follows:

1. The biofilter matrix had permeability far higher than that to which the flux test was normally applied. In general, the flux box approach was applied to soils or waste with 100 to 100,000 times lower permeability. The Yolo County team estimated the permeability of the 1-cm particle bed to range from 1 to 5 million Darcys. This meant that gas could enter or escape around the buried edge of the chamber, or other flow related artifacts could occur. A thin polyethylene bag with porous material (10 mil would give 10 dynes/cm^2) placed over the exit of the flux chamber would actually provide enough backpressure to block gas exit and alter flow. The upshot was that this particular flux test, although endorsed as acceptable by regulators and workable under other conditions, was suspect under these conditions.

2. With such low flow resistance, it was also shown that wind pressure swept ambient air through the biofilter. This may have contributed to the decreased subsurface (1-ft down) methane concentration as seen later in the day of testing.

3.6.7.2 Improving measurements of biofiltration effectiveness

Reliance on tracer. One method to improve future assessment of methane reduction is to make use of a tracer. The methane concentration can be most accurately determined against any tracer gas within gas entering the biofilter, that is itself accurately measurable and that passes through the biofilter largely unchanged. Carbon dioxide happens to be one of the most convenient tracers since it will change very little on passage through the biofilter (and with a little algebraic work, the CO_2 resulting from methane destruction can be accounted for). This will be the measurement approach in future work.

Appropriate parallel laboratory tests. Appropriate laboratory tests are another avenue for more accurately determining methane removal rates. For the biofilter itself, the short residence time of exposure of methane containing gas to the biofilter results in uncertainty, when conversions are low. A more accurate determination of biofiltration can be taken by holding methane/air mixtures in the presence of biofilter matrix for much longer periods of an hour or day in laboratory conditions.

3.6.7.3 Other factors affecting and routes to improving biofilter effectiveness

The biofilter was designed with gas distribution, buffering, residence time, and matrix. Nonetheless effectiveness was low. Possible explanations for an apparent initially low biofilter effectiveness and ways for overcoming them are as follows:

1. Short term of operation and need for more acclimatization of biofilter to methane containing gas. The biofilter had been operated for only a period of two weeks when the tests were conducted. Significant time is normally required for the microbial population to grow and become maximally active, and this time requirement may lie anywhere between days to months, depending on the compound to be biofiltered. Thus, activity should improve by allowing sufficient time for outgrowth of the necessary methanotrophic bacterial activity, and initial results such as these to be regarded as preliminary only.

2. Nutrient deficiency and adding nutrients. The soil analysis indicated a carbon–to-nitrogen level that at between 45:1 to 50:1 ratio was lower than the recommended 35:1 ratio. Higher nitrogen levels would benefit the biofilter. Nitrogen was being added in the form of urea.

3.6.7.4 Aerobic cell operational schedule as a limitation

In operating the aerobic landfill cell, issues arose that have necessitated considerable shutdown time. The shutdowns were necessary for dealing with carbon monoxide (CO) and to carry out remedial measures. Upon aerobic bioreactor cell startup, March 2004 the aerobic cell was providing gas to the biofilter and enabling the biofiltration assessments described above. At the same time, exit gas from the aerobic bioreactor was being routinely analyzed for CO. In early November 2003, CO was detected in the exit gas from the aerobic bioreactor. To summarize the ensuing sequence of events:

1. The composition of gas from each extraction line was tested individually for CO. The interest was in finding whether the CO was fairly uniform among all exit lines, or whether it was more variable. Higher variability would increase the likelihood that the source of CO was a small fire or combustion zone starting in the aerobic cell. A zone of combustion would elevate the CO level in the vicinity of the nearest individual extraction line more than elsewhere. The concentration did in fact vary, suggesting that the source of CO was a small fire. If the source of CO was combustion, which is still not proven, then the amount of waste combusted was less than 100 lbs and may have been as low as 10 lbs. This estimate is based on the low level of CO in the exit gas and total CO seen.

2. Upon concluding that a fire was at least a possible cause of observed CO, the gas extraction from the aerobic biocell was turned off to limit oxygen to the fire.

3. It was decided to address the CO and presumed fire problem by injecting liquid nitrogen into the line with the highest CO, which would be closest to the fire. A nearby supplier of liquid nitrogen was located (name of company, Vacaville, CA). About 40,000 lbs of liquid nitrogen were pumped into the gas collection line nearest the presumed fire.

After liquid nitrogen injection into the aerobic biocell, exit CO was transiently reduced. But, the liquid nitrogen did not eliminate CO and it slowly increased to levels of over 60 ppm. Liquid nitrogen had reduced the level of CO reading by a factor of 10.

4. Over the next several months, it was decided to slowly and carefully add more water to the aerobic cell. Water addition was still ongoing with level of added moisture being tracked by sensors. Further aeration was deferred due to other project demands, but will be added soon.

3.6.7.5 Implications of biofilter results for methane abatement by landfill surface biocovers

Another application of biofiltration for methane abatement is as a biocover on landfills, where methane emissions are abated in the biocover matrix as described above. It needs to be noted here that Yolo County's biofilter was considerably different from those of proposed landfill biocovers. Most importantly, the retention time in the biofilter in this set of Yolo County tests was about 15 minutes. The typical residence time in surface biocover to reduce methane in gas exiting a landfill surface is 10-100 times as long. Thus, there is every likelihood that fugitive methane abatement in landfill biocover will exceed that of the biofilter as applied at Yolo County, because biocovers on landfills will have greater times to accomplish fractional methane abatement. This is verified based on the surface emissions test results from the surface of the aerobic cell that have shown no emissions to date.

3.7 Surface Liner Emissions Monitoring

3.7.1 Northeast anaerobic cell

Scans to detect methane surface emissions from the northeast 3.5-acre cell have been performed quarterly since April 2002. Figure 43 in Appendix B provides a three-dimensional representation of the surface emissions from the northeast 3.5-acre cell for each of the scanning events. Note that the graph has multiple pages, and also that a wide range of vertical calibrations exists across the range of graphs. No emissions were detected during surface scans performed in April 2002 and January 2003 or during a rescan in September 2003. Therefore, plots could not be created for those scanning events.

The detection of surface emissions in June and September 2002 may have been due to emissions from waste placement activities in the west 6-acre area or from construction activities in Module D Phase II construction, which involved exposing waste from an adjacent unit to facilitate base liner installation. Methane surface emissions detected in March and April 2003 can also be attributed to background emissions detected on the west 6-acre area. Note that the September 2003 and November 2004 use different scales than the other surface plots. This is due to emissions of over 200 ppm for September 2003 and 75 ppm for November 2004. Again, it was concluded that the emissions were probably a direct result of the active waste placement in the adjoining Module D Phase II. This was confirmed by performing a rescan for the September 2003 event, which resulted in no emissions detected.

Emissions throughout the 3.5-acre area appeared to have a high degree of randomness. One contributing factor was change in wind currents during the surface scan, which could have transported methane from adjacent areas, resulting in the detection of surface emissions (apparent hot spots) that were not detected in background measurements. The fact that the hot spots often appeared to move would confirm this explanation that methane was drifting in from outside the measured area. For various reasons, a true hot spot would tend to remain fixed in location. Otherwise, in general, though the scans are useful, they are only qualitative indicators of emissions.

Surface scan measurements can track down areas of higher emissions with reasonable accuracy. The high emissions from a given landfill surface area will result in elevated combustible gas readings at the locations of higher emissions. However, the surface scan readings are more qualitative than quantitative. Without good or easy alternatives, regulatory agencies (EPA and California) have chosen combustible gas measurements as the best and most practical indicators to give feedback on control effectiveness. (Emissions of LFG containing methane will be referred to here simply as methane.)

Reasons the surface scans tend to be qualitative indicators include:

- Methane surface readings will vary inversely with depth of the convective boundary layer over the landfill. This boundary layer depth easily varies several-fold, for example from 10 ft on a cool morning, to over 100 ft as, later in the day. Solar heating greatly increases mixed layer depth.
- Combustible gas readings vary inversely with wind (breeze) speed that sweeps away methane to greater or lesser extents. Wind speeds can vary ten-fold even while remaining within prescriptive limits of a 5 mph maximum. A realistic example is variation from 0.5 mph to 5 mph.
- As noted above, flow of methane from adjacent areas of the landfill can result in methane detections that are not representative of emissions coming from the area being monitored.
- Surface emissions can vary over short time periods of hours or days because of barometric fluctuations. Normal barometric fluctuations expand and contract void gas and this, in turn, results in short term variations in surface LFG flux.

All of these factors combined will result in the following:

- At constant emission rate per unit area, measured surface concentrations can vary by over an order of magnitude.
- At constant surface emission readings, (for example, 50 ppm) the underlying flux giving rise to the reading may vary by an order of magnitude.

All of these factors can lead to issues of spatial and temporal variations and repeatability that should be kept in mind when reviewing surface scan results.

Despite the inherent uncertainties in the surface scan in quantifying emissions, the surface scans are valuable. Much experience across the U.S. shows that data from emission scans as conducted in this project are extremely useful in such areas as tracking down cover leaks. (Yolo experience in successfully finding leaks is documented later.) To some extent, surface scans can also be made more quantitative. Taking readings while avoiding convection problems under well-defined conditions can lessen uncertainties in the emission data. This includes taking early morning measurements under stable and slow wind speeds, and in conditions of steady barometer readings. These precautions were also taken as much as practical when performing scans.

The average and maximum surface emissions from the northeast 3.5-acre area are presented below in Table 5. As presented in this table, the highest single emission detected from this cell

was 209.8 ppm and the highest average emission detected was 5.2 ppm. Both of these occurred in November 2004 and are attributed to adjacent waste placement activities. The areas of significant emissions were rescanned with the highest emission being 80 ppm along the east perimeter of the cell, which is again adjacent to the active waste placement area. Average emissions were calculated by taking a weighted average of emissions detected along the entire scan. For example, if the entire traverse of the surface scan were 1000 m and surface emissions of 100 ppm were detected along 200 m of that traverse, the average surface emission would be,

average emission = (800 m*0 ppm + 200 m*100 ppm)/1000 m = 20 ppm (4).

Table 5. Summary of surface scans for the northeast cell

Date performed	Weighted average emissions (ppm)	Maximum emission (ppm)	Average vacuum applied by LFG extraction system (inches of water)
4/3/02	0	0	-0.10
06/06/02*	1.1	9	-0.54
9/19/02	0.25	8	-0.54
1/7/03	0	0	-7.5
3/19/03	0.18	10	-14.5
4/15/03	0.08	6.7	-7.5
9/25/03	3.7	209.8	-15.9
9/29/03	0	0	-15.9
12/17/03	0.24	7.0	-8.3
1/29/04	0.14	10.3	-6.4
4/21/04	0.10	25.3	-9.3
8/4/04	0.32	21.1	-6.3
11/18/04	5.2	79.8	-8.15
3/24/05	2.7	35.8	-11.5

* First date after liquid addition

3.7.2 West-side anaerobic cell

As presented in Table 6 below, higher emissions were detected on the west 6-acre area. This can also be seen in Appendix B, Figures 44, in which the emission scale is from 0 to 650 ppm. Note that the maximum value presented for the August 2004 scan was over 1000 ppm, but the figure shows a maximum peak of roughly 650 ppm. This discrepancy is due to the interpolation method used by the plotting program, which was used to produce the surface plots. Before a plot is produced, grid nodes are generated and data points closer to the grid nodes are given more weight than points farther from the nodes. The points in between the grid nodes are then obtained by interpolation to give a smooth surface.

Table 6. Summary of surface scans for the west-side cell

Date performed	Weighted average emissions (ppm)	Maximum emissions (ppm)	Average vacuum applied by LFG extraction system (inches of water)
4/3/02	0.84	50	No vacuum applied
6/6/02	6.5	37	-0.08
9/19/02	4.2	124	-0.36
1/8/03*	0.70	30	-3.2
3/19/03	5.8	85	-0.55
4/15/03	2.1	126	-1.05
9/29/03**	0.64	59.3	-1.98
12/17/03	10.4	404.50	-0.76
1/29/04	1.96	636.6	-1.2
4/21/04	0.96	84.7	-1.2
8/4/04	3.79	1052.9	-2.9
11/18/04	1.04	59.3	-1.34
3/24/05	3.97	67.5	-7.50

*Cover system installed, ** First date after liquid addition

In April 2002, higher emissions were detected because the west 6-acre cell was still under construction and a surface cover system had not been installed. In June 2002, the LCRS was connected on an interim basis to the header line that conveyed landfill gas to the onsite LFG-to-energy facility. Monitoring during the June 2002 scan indicated lower surface emissions than the previous scan, but still elevated compared to the northeast 3.5-acre area. This was most likely because waste placement activities were still underway and a cover system had not been installed. In December 2002, the cover system was completed and the average emissions detected during the January scan declined. By March 2003, the gas collection system had been completed and applied to the landfill gas collection system to increase the flow rate from 16 standard cubic feet per minute (scfm) to 44 scfm. In April 2003, the average emissions detected decreased, even though higher emissions were detected on the east face of the cell. The source of the high emissions was generally traced to unsealed areas on the cell (less than 1 in) where piping penetrated the surface liner. In response to these emissions, three additional wells were opened and placed under suction in the area where the surface emissions were detected (increasing the LFG flow rate from 38 scfm to 99 scfm). Prior to the surface scan in September 2003, the pipe penetrations were sealed with expanding foam. While the average of emissions detected in September 2003 was lower than previous surface scans, surface emissions were not completely eliminated because small leaks still existed at the junctions between the foam and the liner.

Similar conclusions (as presented for the northeast 3.5-acre area) regarding the status of the surface cover in relation to the amount of surface emission can be drawn for the west 6-acre area. Prior to September 2003, no significant ballooning was observed on the west 6-acre area while the LFG collection system was shutdown. This was most likely because any excess gas buildup was escaping out the small gaps between the liner and piping (which would result in higher surface emission measurements). Subsequently, the pipe penetrations were sealed with expansion foam. As a result, during a gas collection system shutdown in September 2003, positive pressure built up under the surface cover, causing the liner to slightly balloon. These observations in combination with the September 2003 surface scan indicated that the foam was effective at reducing emissions,

however foam sealing was not completely effective at eliminating them. In December 2003, Yolo County permanently sealed the pipe penetrations on the west 6-acre area by extrusion welding permanent boots made of HDPE liner to the surface liner. This was done in hopes of eliminating any surface emissions coming from the pipe penetrations, however this again proved not completely effective at eliminating surface emissions.

In general, when there is no highly conductive layer beneath the cover, gas flow analysis indicates that increased vacuum in some cases could partially, but not completely, eliminate local areas of positive pressure under the cover. The sealing of the cover openings in one area can result in increased emissions in other areas. (These emissions are estimated as small, probably 1-3% of generation). For the west 6-acre cell, excess gas production under particular areas will tend to find an exit somehow. The exit is often through other interstices or small perforations, often nearby, in the surface cover. One solution is to provide additional wells under the emitting area, or using a highly conductive layer, such as loose waste or shredded tires under the cover to even out pressure, so that a slightly negative pressure can be maintained beneath the entirety of the cover footprint.

In September 2004, the County installed two additional gas collection wells under the surface liner along the east edge of the cell in the continued effort to reduce surface emissions. The subsequent November 2004 surface scan indicated reduced peak and average emissions relative to the August 2004 scan.

Because small gaps existed between the surface liner and piping exiting the cell, the surface emissions detected from the west 6-acre cell were more dependant on the suction applied by the landfill gas extraction system. Appendix B, Figure 46 compares the average surface emissions to the average suction applied to the landfill gas system. With the exception of the August 2004 scan, surface emissions were reduced when higher levels of suction were applied to the system.

3.7.3 Southeast aerobic cell

In the case of the southeast aerobic cell, the air emissions were, on the whole, rather similar in nature to the anaerobic cells. However, it must be noted that there was a high degree of scatter in emissions measured from all cells, and the aerobic cell, in contrast to the aneaerobic cells was not covered, which may have acted to increase emissions despite lower methane productivity.

Table 7. Summary of surface scans for the southeast aerobic cell

Date performed	Weighted average emissions (ppm)	Maximum emissions (ppm)	Average vacuum applied by LFG extraction system (inches of water)
04/03/02	0	0	0.0
06/06/02	2.17	8	0.0
09/20/02	0.13	3	0.0
04/30/03	0.64	3.6	-0.1
09/29/03	0.43	48.9	0.0
12/17/03*	1.12	38.4	0.0
01/23/04	4.3	209.7	0.0
4/27/04	2.6	176	Gas collection system not operating
8/23/04	0.79	18.4	Gas collection system not operating
11/18/04	7.88	146.9	Gas collection system not operating

***** First date after liquid addition

3.8 Waste Solids Sampling

3.8.1 Testing and results

Waste samples have been collected prior to liquid addition and following each year of liquid addition. These samples were then sent to North Carolina State University where they were analyzed for moisture, cellulose, lignin, and BMP. The laboratory BMP test is a standard measure of the amount of decomposition that is possible for a particular waste sample under anaerobic conditions. The other measurements are also standard for assessing biochemical conditions and status of decomposition of wastes. Full analytical results are located in Appendix A, Table 19 and are plotted in Figures 47 through 52 in Appendix B.

The first sampling event occurred on June 4 and 5, 2002, the second event on July 15 and 16, 2003, and the third on June 3 and 4, 2004. Samples of refuse were excavated to evaluate the extent of water addition and solids decomposition in the bioreactor cell. A 0.61-m (2-ft) diameter solid stem auger was used to core through the waste and collect samples. Samples were collected roughly at every 1.5-m (5-ft) vertical interval. Images of the sampling events are shown in Appendix C.

As presented below in Figure 17, the waste samples have indicated an increase in moisture content in the northeast 3.5-acre cell over the last 3 years. During the first sampling event, the average moisture content of the waste was 18.4%. Based on samples collected during the third event, the moisture content of the waste averaged 40.8%. This measured moisture content was substantially greater than the calculated moisture content of 29.3% calculated under Section 3.3.1. Figure 18 presents the moisture content of the waste from the west 6-acre cell. Trends are not distinct, although results do indicate an increase in moisture over the pre-liquid addition sampling event. The differences are attributed to only a limited number of samples being collected, which were likely not representative. The substantial point-to-point heterogeneity of landfilled MSW is well recognized and very much evident in this case. The heterogeneity of samples is discussed more below. Figure 19 presents the moisture content of the waste from the

aerobic cell. Moisture content has increased in the aerobic cell from an initial average of 18.8 % in the first sampling event to an average of 25.7% in the third sampling event.

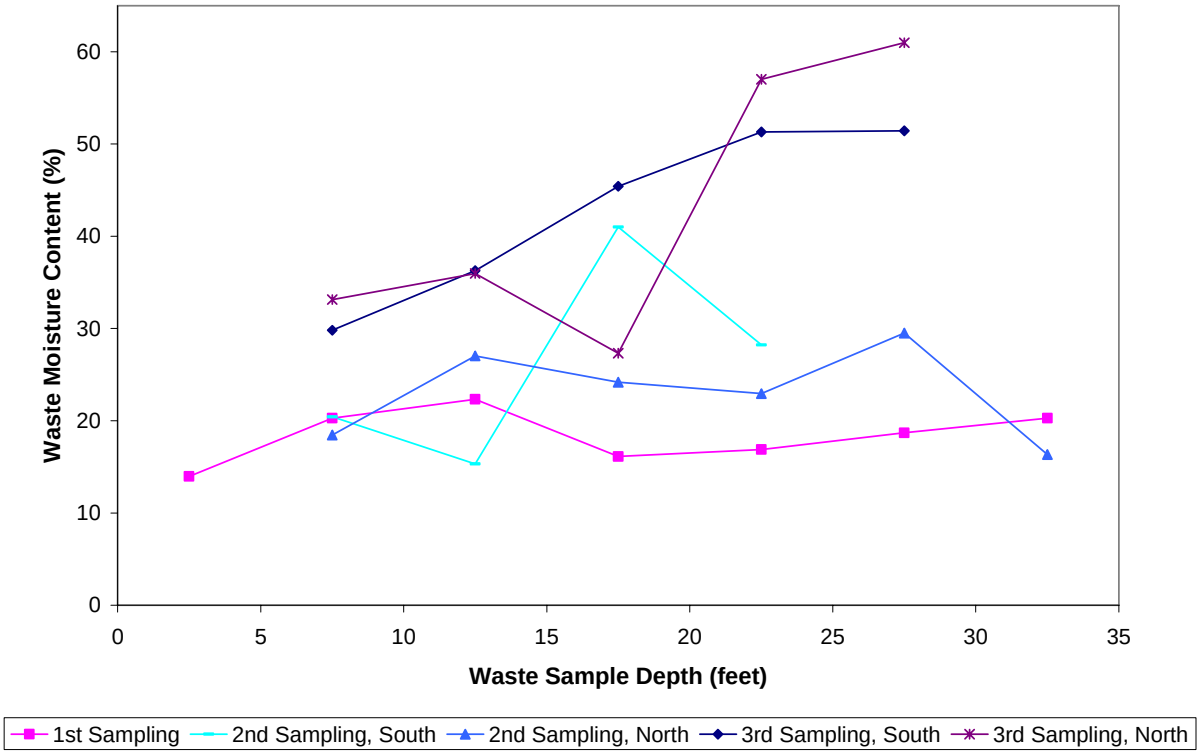


Figure 17. Waste moisture content for the northeast cell

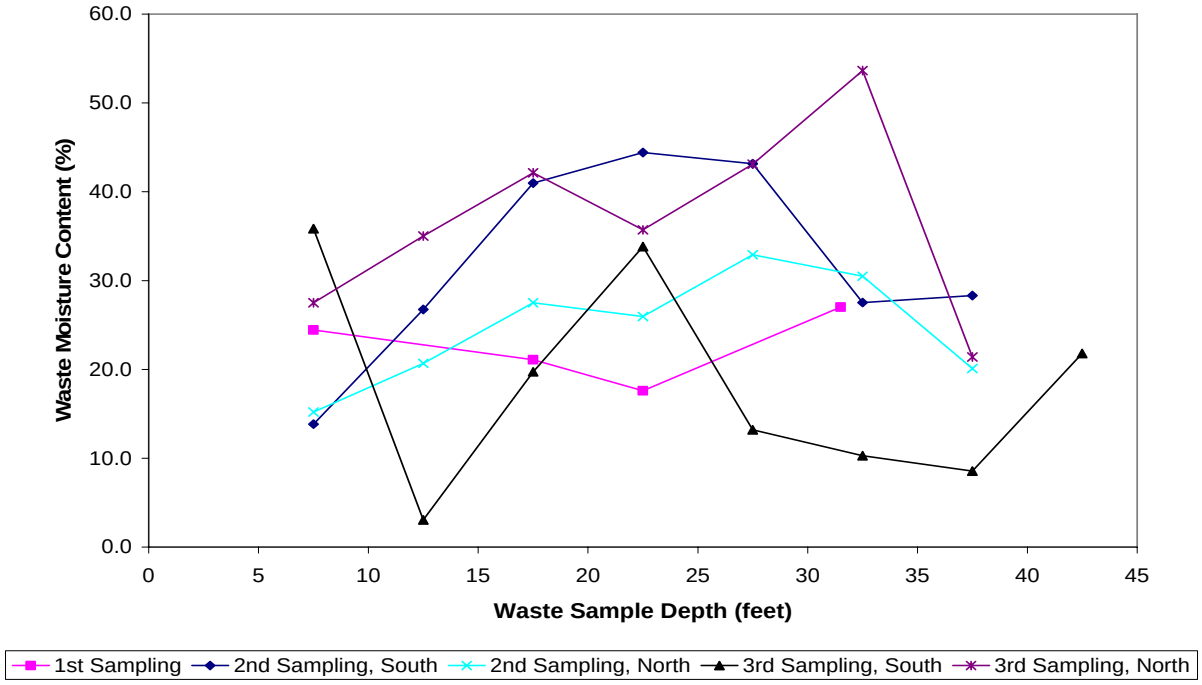


Figure 18. Waste moisture content for the west-side cell

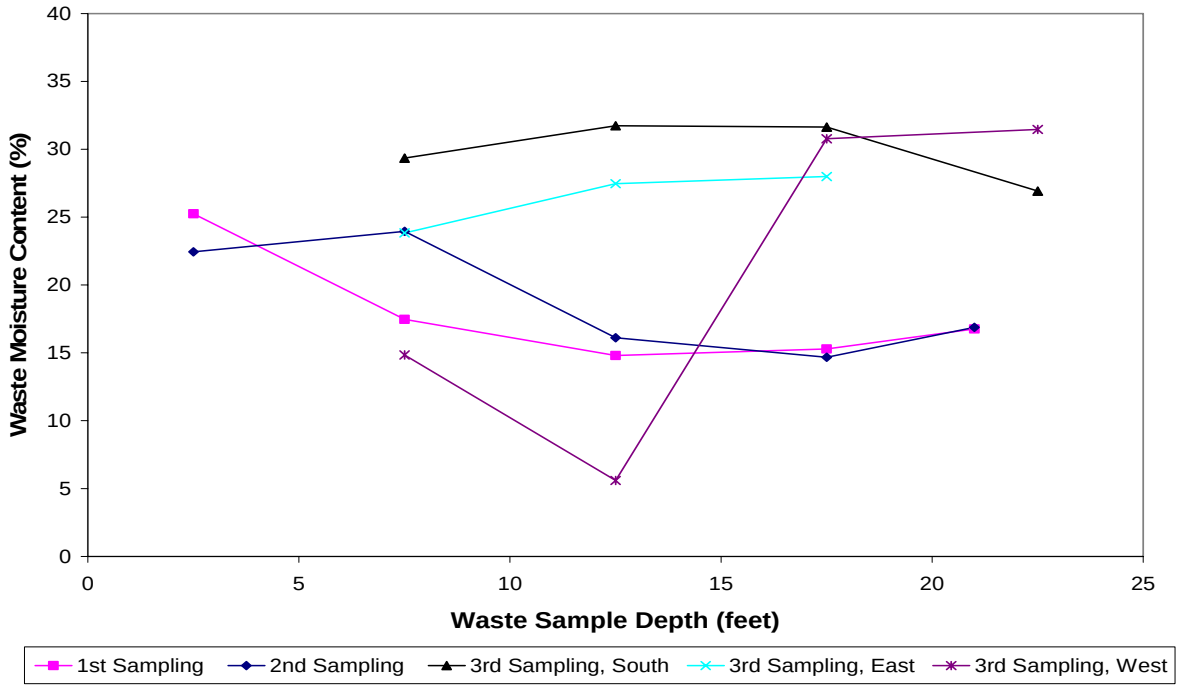


Figure 19. Waste moisture content for the southeast aerobic cell

3.8.2 Discussion of test results on samples

The obvious feature of the sampling results is high variability, i.e. major scatter. The variability is due in part to the heterogeneous nature of the waste itself, likely magnified further by other factors like remnant cover soil as discussed below. The variability in waste has been observed and commented on in other work. For example, large-scale tests were carried out on the <10% fraction of mechanically separated organic residue (MSOR) fraction of European Union Waste not expected to be combusted. Oonk et al. (2000) stated in a presentation summary at a Swedish Landfill Conference that "the measured in situ water content could not be related to areas of leachate injection and it was not possible to determine flow paths of or flow characteristics of the waste." The observed scatter with these samplings was greater than, i.e. drowns out any trends that might exist.

Visual observations confirmed the highly variable analytical results. At Yolo, very pronounced variations in moisture content and decomposition were obvious on inspection during even the most recent sampling. The appearance of waste samples taken from different locations in the same cell differed widely. With given cells, some waste samples appeared dry and printed-paper was entirely legible. In other cases in samples from other areas and other depths of the same cell, the decomposition was far advanced, and waste was blackened and steaming to the point where print was not legible at all. In a modest fraction of cases, "perched" liquid (or liquid trapped and unable to drain quickly through the waste) was indicated as liquid appeared in the bottom of the test sampling borehole on drilling

The main conclusion is that moisture distribution and waste properties have, to date, been heterogeneous in the cells and in waste samples from the cells. It may be possible to reach better conclusions as waste decomposition progress, and more analysis of additional waste samples provides more information. The methane recovery data and moisture balance presented earlier in this report stands as, by far, the best indicators of the decomposition progress.

Regarding these results, some further comment can be offered that might be useful in explaining the results for the Yolo cells, and for future operation of controlled landfill cells.

1. Although results are scattered, the effects of decomposition should become clearer, and scatter less important, over longer terms. At most, the decomposition is under 50% complete. A sampling analysis 5 years from now (for example) should show BMP trends more definitively.

2. Although BMP results are helpful as indicators, they do not, even for the same waste lot and sample, correspond to decomposability and methane yield of the same waste in the landfill. This is because (a) BMP samples are finely ground and (b) their decomposition is carried out for a shorter time in the North Carolina State University lab, a few months. These will have opposing effects: finer particle size will increase decomposition but the shorter retention time will tend to decrease it. Thus, the BMP tests are best regarded as somewhat qualitative indicators.

3. The presently uneven liquid distribution is considered very likely due to remnant daily cover soil. This soil at Yolo is clayey and low permeability. Although diligent attempts were made to remove it, enough evidently remained so that it impeded liquid percolation. Evidence for better

liquid distribution with more permeable cover is found in results from the 9000-ton pilot-scale cell where more liquid permeable greenwaste cover was used rather than soil.

3.9 Waste Settlement and Volume Reduction

3.9.1 Northeast and west-side anaerobic cells

Settlement in the waste cells was monitored on an annual basis through a complete topographic map comparison. In addition to the complete topographic mapping, intermediate surveys were conducted on specific monument points established along the surface of the cells.

The following tables provide a summary of the complete topographic survey events along with the associated volume reduction.

Table 8. Summary of topographic information for the northeast cell

Survey date	Survey description	Total volume, yd^3	Change in volume from initial survey, yd^3	Change in volume from first survey, %
11/15/2002	Initial	132,295	NA	NA
01/16/2003	1st Year	128,613	3,682	2.78
01/28/2004	2nd Year	123,760	8,535	6.45

Table 9. Summary of topographic information for the west-side cell

Survey date	Survey description	Total volume, yd^3	Change in volume from initial survey, yd^3	Change in volume from first survey, %
01/16/2003	Initial	324,209	NA	NA
01/28/2004	1st Year	315,290	8,919	2.75

Settlement was also calculated utilizing a number of benchmarks established on the geomembrane liner. Initial elevations of the survey monuments were conducted during the initial topographic survey of each of the cells. The total depth of waste was then calculated based on the known elevation of the module liner. Subsequent surveys then established the new benchmark elevation, and the percent settlement was calculated relative to the waste depth at each benchmark location. The volume reduction presented in Tables 8 and 9 were consistent with the calculated settlement from the benchmarks (the 2.75% settlement from the 1/28/04 survey of the 6-acre cell compared to 2.57% calculated from the benchmarks). Results from the 3.5-acre cell were similar.

The following graph presents the settlement over time for the northeast 3.5-acre and west 6-acre cells along with the previous pilot-scale enhanced and control cells (Figure 19).

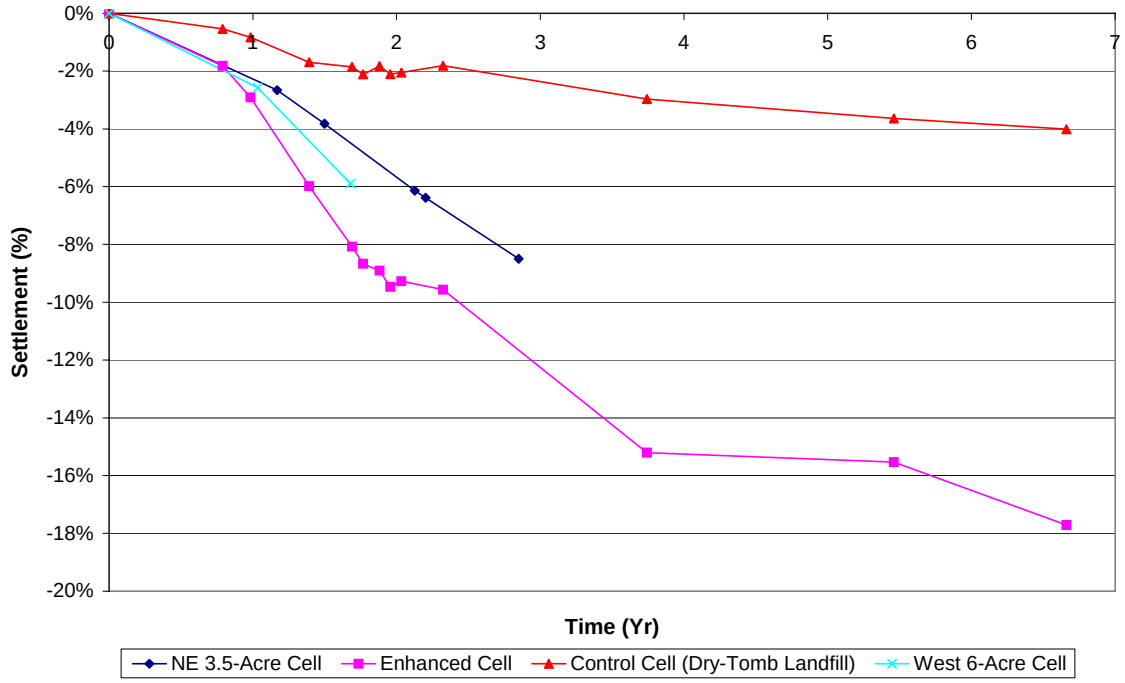


Figure 19. Settlement over time for the northeast and west-side anaerobic cell, along with the previous pilot-scale enhanced and control cells.

To rate the progress of each of the cells, the settlement measured from the cells were compared to the settlement measured from the pilot-scale project. During the first year, settlement in the pilot-scale project was approximately 2.9%, which strongly agrees with the first year results from both the 3.5-acre and 6-acre cells. During the second year of operation of the pilot-scale cell (May 1997 to May 1998) the rate of settlement increased significantly to approximately 1% every 2 months, reaching 9.47% at the end of the second year. In contrast, the northeast 3.5-acre cell has only reached 6.45%. The lesser amount of settlement observed in the northeast 3.5-acre cell is most likely due to the slow rate of liquid addition compared to the pilot-scale cell.

At this point in time, still early in the large-scale cells, it is noted that settlement in both large-scale cells is accelerated by 2 to 3-fold to date, compared to the dry-tomb pilot-scale control cell at the same point in time. As leachate addition and recirculation continues, we expect the overall settlement of each of the two cells to approach that observed in the pilot-scale project.

3.9.2 Southeast aerobic cell

The aerobic cell settlement is shown in Table 10. The measured settlement of 8.24% measured over 2 years appears to translate into an annual rate that is as great as the fastest settling northeast anaerobic cell. Though the aerobic cell certainly experienced oxidative waste breakdown, the cell was much less compacted at the outset than the anaerobic cells. Thus settlement of the aerobic cell could reflect the lesser initial compaction as well.

Table 10. Summary of topographic information for the southeast aerobic cell

Survey date	Survey description	Total volume, yd^3	Change in volume from initial survey, yd^3	Change in volume from first survey, %
11/15/2002	Initial	35,524	NA	NA
01/16/2003	1st Year	33,174	2,350	6.62
01/28/2004	2nd Year	32,597	2,927	8.24

3.10 Methane Production Modeling

A landfill methane generation model is a tool to estimate methane generation over time from a waste mass in landfill. Such a model is used to project or estimate methane generation from a batch of waste that is landfilled at a given point in time. The total methane production at given times, and over the landfill lifetime is obtained by summing the methane from all waste that is placed. Models can assist designers in sizing pipes for the gas collection systems installed for energy recovery, and for purposes including control of migration, odor problems, landfill gas emissions, and connecting the collection system to the energy production facilities.

Other than models, alternative means of estimating landfill methane generation is using landfill gas test wells. Such tests are performed in the field using a series of pump-tests. This is a very costly method and can take weeks or months to yield meaningful results. Another drawback is that pump tests only represent a point in time for the test locations in the landfill rather than a long-term result for the entire landfill. Landfill methane generation models have an advantage of being much less expensive and provide comparable accuracy to extrapolations of pump test results for the entire landfill.

3.10.1 Modeling

Landfill methane generation models are only accurate if sufficient field data are available for calibration. The accuracy of models can only be established over time by calibration against real recovery data measurements. Since numerous variables affect waste decomposition in landfills, the methane production is difficult to predict using the analytical and microbial kinetic models such as the Monod equation that predict the performance and activity of microbial processes for biological conditions that are known. The biological conditions are very difficult to determine for landfills. Another difficulty in modeling methane generation from landfills is that methane recovered from landfill is aggregated from many years of waste placement rather than from an individual batch of waste. The methane generation rate in a landfill is also a function of many site-specific variables such as waste type, waste composition, local climate, available nutrients, moisture content of waste, and waste temperature.

A number of models have been developed to predict landfill methane generation and recovery. The most commonly applied model is the first-order or Scholl Canyon model (EMCON 1981). In this first-order model, a constant fraction of remaining decomposable waste degrades each year. Methane generation is proportional to decomposable waste remaining in the landfill. The result is that methane generation decreases exponentially. This model uses a moderate margin to give the most successful projections (Vogt and Augenstein 1996). In 1996, the U.S. EPA made freely available its version of the first order landfill gas emission model (LandGEM) as a tool for estimating air pollutant emissions from landfills. This first-order model, often referred to now

as the EPA model, uses a first-order decomposition rate equation. The methane generation is a function of two values: k, the methane generation rate constant, and L_0, the methane generation potential. The methane generation rate constant determines the rate of generation of methane of refuse in the landfill. The higher the value of k, the faster the methane recovery occurs and approaches completion over time. The value of k is a function of waste moisture, availability of the nutrients for methanogens, pH, and waste temperature. The k values reported by EPA vary over a wide range, from 0.003 to 0.21. However, the industry generally observes a narrower range of k values from 0.03 to 0.10. The value for the methane generation potential L_0 depends on the type of waste in the landfill. Waste with higher cellulose content would have a higher L_0. EPA has specified the values of theoretical L_0 to be in the range from 6.2 to 270 m^3/Mg waste (0.1 to 4.3 ft^3/lb). However, field observations showed a much smaller range for yield. The typical U.S. MSW compositions result in methane potentials normally ranging from 1.0 to 1.5 ft^3/lb of waste as received.

Despite the numerous variables that could potentially greatly affect generation, and the variance in k values reported by EPA, field data bear out models' utility when models are properly "calibrated". It was found in a major 19-landfill study (Vogt and Augenstein 1997) that most landfill gas generation from typical or conventional landfills can be projected to within –30% to +50% of a median projection using the EPA first-order model. In other words, waste composition and other conditions are such that conventional landfill methane generation can be projected with precision that is very useful for many purposes. Despite remaining uncertainty, modeling is helpful in sizing recovery systems, and also in estimating energy that might be recoverable. Furthermore, the model calibration can be improved by using the data from the landfill being modeled. It should also be remarked that the uncertainty of -30 to + 50% cited above is much better than results of some earlier models (including early versions from EPA) where modeling often gave results that were off by a factor of two or more. However, bioreactor landfills are "atypical" in that decomposition is much faster than conventional, so the question of how to model these is just now being answered by studies at Yolo County as described next.

3.10.2 Methodology

The objective of this report is to estimate the first-order gas generation rate constant for the northeast and west bioreactor cells under test in this project by applying the first-order EPA gas generation model. The methane generation rate constant, k, will be calculated for the northeast 3.5-acre and west 6.0-acres bioreactor cells according to the following methods:

Data for methane generation for the northeast 3.5-acre and west 6.0-acre anaerobic bioreactor cells were plotted as shown in Appendix B, Figures 34 and 35. Methane generation over the first long-term interval of increased methane production was taken from these figures to develop a preliminary model. The first interval of increasing cumulated methane recovery plots for each cell was extrapolated back to an adjusted "zero generation" and also taken up to the most recent time that data was available. A straight-line regression was performed on each curve as shown in Figure 19. This regression line was superimposed on the cumulated methane curve for northeast and west cells in Appendix B, Figures 34 and 35. Using the actual tonnage and initial moisture content of the waste, the data was normalized for calculation of methane generation rate constant as shown in Figure 19.

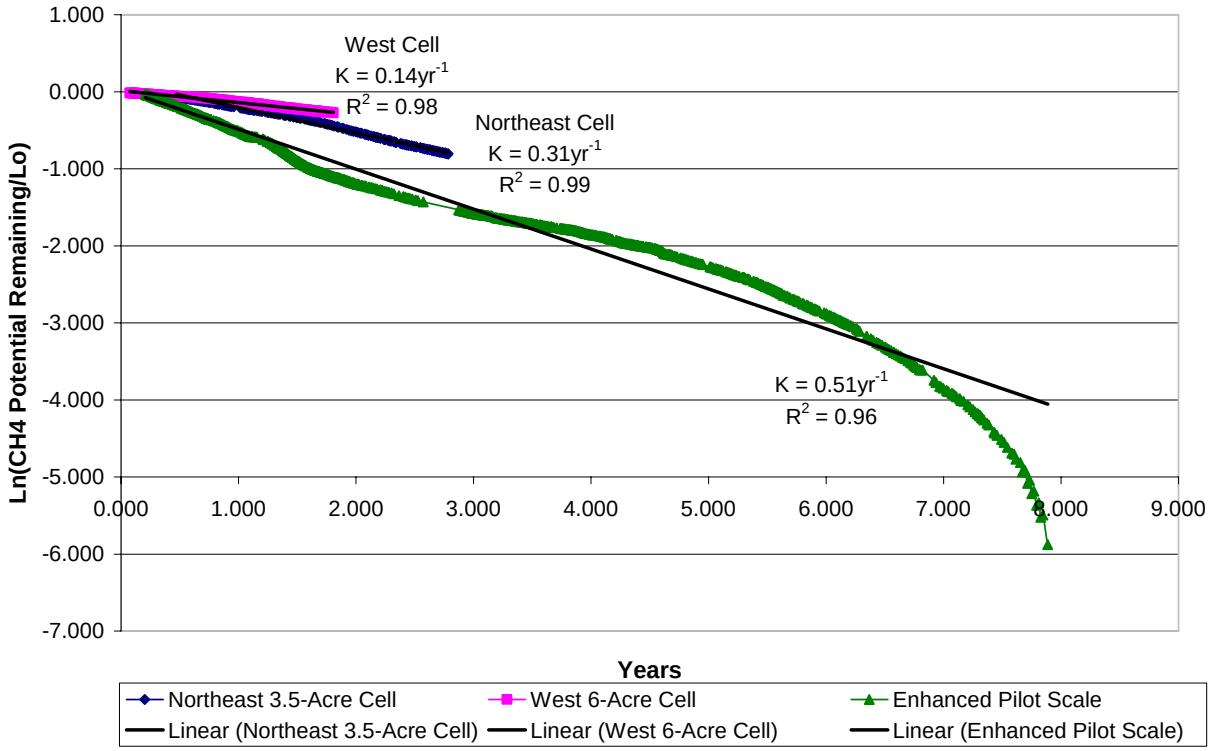


Figure 19. Calculation of k value for all cells, including previous enhanced cell

The best estimate of ultimate methane potential was assumed to be 1.4 ft^3 methane/lb dry waste, or 1.12 ft^3/lb wet waste. This was the best-fit yield result for the previous pilot-scale cells constructed in 1994 and the best information available. The fraction of ultimate methane potential recovered at each time was calculated over time for the northeast and west cells from the normalized methane yield (assuming this ultimate methane potential at L_0 = 1.4 ft^3 methane/lb dry waste). From this, the fraction of remaining methane potential was estimated using standard modeling methods.

Applying this model to the pilot-scale enhanced cell from the previous study at Yolo County Central Landfill resulted in a k value of 0.51 yr^{-1} (Figure 19 Also shown in Figure 11 are the data for the northeast 3.5-acre and west 6-acre cells for comparison. From these data, the preliminary values for k are:

- West 6.0-acre cell - 0.14 yr^{-1}
- Northeast 3.5-acre cell - 0.31 yr^{-1}

Although the scaled up cell k values are below the 0.51 yr^{-1} of the previous pilot-scale cell, the k of 0.31 yr^{-1} for the northeast cell is still very encouraging and over twice the usual dry landfill.

The lower 0.14 yr^{-1} for the west side cell may be due to the fact that only 1/3 of the planned liquid has been added.

These calculated values for the first-order rate constant k, have been determined relatively early in the methane generation cycle of the northeast and west side cells. It is important to note that the first-order model is not perfect, only that it best approximates methane generation. Many factors can affect k, including the further distribution of nutrients and bacteria that occurs within the waste with time as liquid percolates, and self generated temperature. Some degree of change in the best-fit k values are likely and best long-term k values will become known more accurately with time.

3.11 Energy Balance and Parasitic Use

An energy balance, though preliminary at this point, can be projected assuming,

- The gas will be recovered at a yield of 1.4 ft^3/lb dry waste (1.12 ft^3/lb wet waste) as seen in the pilot-scale cell, methane is recovered at 95% efficiency (it could actually be closer to 100%), and moisture content of the waste is about 20%.
- The pumping work on the gas is expended at 1 psi. Measured vacuum in the cell was actually well under 1 psi-- at a maximum of 3 in H_2O, about 0.15 psi. See Figure 31 where surface emissions are plotted as a function of vacuum.
- The liquid is percolated twice through the waste during the term of digestion.
- The head through which the liquid is pumped is 100 ft (it is less, but flow restrictions and inefficiencies make this a reasonable and still conservative assumption.
- The energy for all mechanical work can be accounted for by combustion of methane at 30% thermal (HHV) to mechanical efficiency. At this efficiency, the production of 1 kWh requires 11.4 ft^3 of methane.

It is important to note that the incremental energy associated with all other aspects of bioreactor operation will be (as closely as can be estimated) negligible. This is because all other operations would be required for waste landfilling in any event.

With these stated assumptions, calculations are as follows:

Methane out per ton = 2,240 x 0.95 = 2,128 ft^3 methane

Energy, methane equivalents per ton for gas pumping = 2,128 ft^3/ton x 1/(0.5 = fraction methane in gas) x 144 ft•lb/ft^3 x (1/ 2.6552 x 106 ft•lb/kWh) x 11.4 ft^3 CH4/kWh = 2.63 ft^3 methane equivalent

Energy, methane equivalents for liquid pumping = 30 (estimated) gal/ton x 8.32 lb/gal x 100 ft elevation x 2 cycles percolating through waste x (1/ 2.6552 x 106 ft•lb/kWh) = 0.21 ft^3 methane equivalent

So in summary, an energy balance, stated as cubic feet of methane recovered per ton, is as follows:

Gross methane energy out of bioreactor = + 2,128 ft^3 methane equivalent

Minus energy for gas pumping= - 2.63 ft^3 methane equivalent

Minus energy for liquid pumping = - 0.40 ft^3 methane equivalent

Net energy output = + 2,125 ft^3/ton methane equivalents

In any case, it now seems clear that with a range of energetic accounting approaches and assumptions, that the incremental parasitic energy requirement will be well under 1%. Such low parasitic energy consumption for the controlled landfill bioreactor is obviously desirable.

We would like to note as an aside, another important aspect of municipal waste to methane conversions in bioreactor landfills. A recent review of the compiled waste-to-methane literature (Verma and Shefali 2002) has compiled yields per unit waste fed to the European vessel processes. The Yolo pilot-scale bioreactor has actually produced significantly more methane per unit waste fed, by 20 to 50%, than the methane per unit weight of waste with European approach of carrying out conversion in vessels. This is because only about 60-75% of organics' methane potential can be realized in economically allowable vessel detention times (2 weeks to 2 months), and extended residence times of a year or more appear required for full conversion. The bioreactors greater energy yield is also obtained despite use of landfilled waste that was not ground or reduced in size (this is also a very important finding because size reduction at $10-$30/ton would translate to prohibitive expense, adding over $5/mmBtu to gas cost). The vessel-based process also consumes about 35% of the produced energy in the best of cases (De Baere 2004) and up to all energy in the worst of cases that have been compiled by Dr. Wellinger (1995) and others in Europe. Thus, the bioreactor is estimated to produce about twice the net energy of the vessel based digestion processes. The better net energy performance comprises yet another argument for the bioreactor landfills.

3.12 Carbon Monoxide and Suspected Thermal Decomposition in Aerobic Cell

Aerobic bioreactors, or alternatively aerobically composting landfills are relatively new. One of the possible dangers of operating an aerobic bioreactor, supported by anecdotal reports, is that of fire or thermal decomposition within the landfilled waste mass. If fires are encountered frequently, they could be a serious impediment. In any case, the detection and suppression of thermal decomposition in aerobic landfills is of high interest. Thermal decomposition detection and suppression was part of the Yolo County contingency planning before CO was detected.

The best indicator of fire or thermal decomposition is considered to be elevated concentrations of CO, which would result from oxygen-limited fire within the waste. The limits are not well established, since small amounts of CO (a few ppm) can be naturally present in gas from landfills. However, a sudden rise from less than 5 ppm to 50 ppm or more would be a cause for investigation. The gas from the total exiting the header can be routinely checked for CO. If elevated concentration of CO is seen, individual gas exit lines serving portions of the landfill can be investigated. An elevated CO level in one or a few individual headers, well above that in the mixed exit gas, would indicate thermal decomposition. So would elevated temperatures, if measurable in zones of concern. Conversely, a uniform CO concentration across all headers would tend to suggest that CO could conceivably be arising naturally from non-combustion causes.

Testing of total gas in the main header from the aerobic bioreactor by Draeger carbon monoxide detection tubes began in November 2003. Potential problems were suggested by the detection

of CO levels at 40 ppm in the main header and 600 ppm in a well on November 4, 2003. This was in contrast to negligible levels of CO seen earlier. (The CO levels were less than 5 ppm, or Not Detectable in earlier laboratory gas analyses.) To trace down the source, the exit gas from each individual header was analyzed. A CO level test of the well designated 1-A4 -SE (see Appendix D) showed a reading of 600 ppm, and 45 ppm CO in the lines to either side (west and east) of the line giving 600 ppm. A test of the same line on November 6, 2003 again showed 450 ppm CO (field log).

When these elevated readings were found, a traverse of the headers was carried out to detect any hot spots (i.e. elevated temperature). Although the thermocouple did not traverse the entire gas collection line, temperatures approaching 70°C were seen in the header showing the highest CO concentration. All available information, taken together, suggested that a small area of thermal decomposition had started within the waste. Despite elevated CO, there was no odor of smoke that often accompanies thermal decomposition. However, thermal decomposition was possible even without the characteristic burned or smoky odor.

3.12.1.1 Response to Suspected Thermal Decomposition

Two possible strategies for dealing with thermal decomposition are (a) water addition and (b) use of liquid nitrogen (LN2), a very cold (-300°F) liquefied gas that quenches combustion. LN2 is an industrial product available in bulk at relatively low cost. It was considered superior because nitrogen added as liquid vaporizes quickly and the resultant nitrogen gas would expand to infiltrate to the suspected fire zone faster than water. Discussions among the Yolo County project team suggested LN2 was worth trying. A tanker truckload of 42,000 lb of LN2 was arranged from MG Industrial Gases (Vacaville, CA). The tanker load was injected on November 14, 2003, into the header showing the highest CO concentration in the outlet gas. Appendix C shows steps in the nitrogen injection into the lateral that had the highest CO reading.

3.12.1.2 Results of Liquid Nitrogen Injection

After injection, the gas sampling tubes emplaced in the landfill showed nitrogen to have expanded into a wide zone. Also, temperature, as expected, was considerably depressed in the zone around the line receiving the injection.

Unfortunately, indications of thermal decomposition reappeared after the nitrogen injection. The CO content in the lateral initially showing the highest reading returned to a reading of 280 ppm in the well and 450 ppm in tube 1-12-SE on November 19, 2003. CO was also detected at 40 ppm in the mixed gas in the main header on November 20, 2003.

3.12.1.3 Additional Measures – Water Addition

A second approach was adding water to the suspected area. Water additions to the waste began on November 25, 2003. Additions were to the lateral in layer 1 showing the highest CO concentrations and nearest the suspected thermal decomposition, and those laterals on either side. The total amount of water added from the start of addition on November 25, 2003, to December 17, 2003 was 115,532 gal. Once the water addition was completed, CO levels were less than 5 ppm. Summary of the water additions are shown in Table 11.

Additions were to the lateral 1-L7-SE, which initially showed the highest CO reading Additions were also made to adjacent laterals 1-L9-SE and 1-L5-SE (See Appendix D for details and locations of laterals). Some additions were to the lateral 2-L5-SE, the one above lateral 1-L7-SE. Only the total daily additions are shown below.

Table 11. Summary of liquid addition to the southeast aerobic cell

Date	*Water added, gal*
11/25/2003	13,913
11/26/2003	7,502
12/10/2003	11,332
12/02/2003	11,670
12/03/2003	2,705
12/04/2003	4,578
12/08/2003	14,777
12/09/2003	6,775
12/10/2003	5,875
12/11/2003	6,532
12/12/2003	6,111
12/15/2003	8,587
12/16/2003	9176
12/17/2003	5,859
TOTAL	115,232

Calculated waste decomposition. If it is assumed that CO indicates slow thermal decomposition or fire, the amount of waste involved in the decomposition can be roughly estimated based on collected CO. It is assumed that 20% of the decomposed waste may go to CO based on experience with gasification and pyrolysis (this estimated value is likely only accurate to within a factor of perhaps 3, but it is interesting to know the magnitude, even if not approximate, of the waste involved in any problem). At an extraction rate of 10 CFM and average CO concentration in the exit gas stream of 50 ppm for a month, it can be calculated that 36 lb of waste were consumed over the month. This may actually mean that an amount of waste likely between 10 to 100 lb of waste was consumed. The fire or thermal decomposition was likely limited by oxygen access. However, this would not always be the case if air were drawn through the waste mass at projected rates in the future. The principal value of this experience was to show the value of early CO detection and suppression of undesired reactions or fire, especially before water addition has started.

4 PROJECT OPERATIONS, CONTROL AND PREVENTATIVE MAINTENANCE

The following section is divided into 3 subsections associated with the major systems for the bioreactor cells. Each subsection discusses the operation and maintenance activities for each of the cells.

4.1 Leachate Pumping and Injection System

The leachate pumping and injection system includes the main injection header and laterals for each of the cells. Also included are the leachate recirculation pumps located in the leachate collection sumps of each cell and the liquid addition pumps located in the adjacent leachate ponds.

Initially, a fully automated liquid addition and recirculation system was envisioned for this project. In practice though, a predominantly manual system has evolved. Injection is controlled to each lateral by a manual valve and injection is cycled through banks of valves periodically. Liquid addition from the leachate ponds was controlled manually and typically involved pumping for a 24-hour cycle, and with a down period to allow the liquid to infiltrate. Leachate recirculation, on the other hand, was automated. When leachate levels reached a certain level in the sumps, pumps were automatically cycled and the liquid was removed from the sump and recirculated to the cell (to whichever bank of laterals was open).

4.1.1 Maintenance

Prior to beginning injection in the northeast 3.5-acre cell, each injection lateral was tested and calibrated to determine the flow potential of each lateral. During this testing, several leaks in the system were discovered and repaired. The leaks discovered during testing were the result of an incorrect gasket installed for the saddle and injection header pipe during initial construction of the system. To repair the leaks, each saddle was removed and reinstalled with the correct gasket.

In June 2002, minor leaks in the threaded fittings located at the leachate injection lateral valve assembly were discovered, thus each fitting was tightened.

In August 2002 a major leak was discovered in the leachate injection header line. The leak developed at a butt fusion weld joint and was the result of a faulty fusion weld at the time of initial construction. The construction contractor was notified and performed the repair under warrantee. To ensure no contamination occurred in the area of the leak, all of the standing water was removed and any wet soil was excavated and buried at the active face of the landfill.

Over the course of several months, the flow rate for each injection lateral was observed to be decreasing slowly over time. An investigation revealed that calcium precipitate was forming on the inside of the injection piping. The source of this precipitation was the leachate that was being injected into the cell, which chemical analysis revealed to have extremely high amounts of dissolved solids and a pH of over 9. On September 11, 2002, approximately 3000 gallons of citric acid (pH approximately 4) was added to the injection laterals on the northeast 3.5-acre cell to dissolve scale buildup. The citric acid was added to the injection laterals and allowed to set for approximately 14 hours. Groundwater was then flushed through the injection lines to remove the citric acid and scaling residue. Once the scale buildup was removed from the injection laterals, the flow rates for each lateral returned to its pre-clogged condition. To prevent future clogging, only groundwater (with lower total dissolved solids and pH) has been added to the bioreactor since.

During the month of May 2003, a valve was installed on the main leachate injection header line that fed both cells, allowing the majority of the header line to be drained back into the cells leachate collection and removal system in the event maintenance to the line was necessary.

A pressure relief valve was installed on the main leachate injection header line at the on-site leachate storage pond to prevent over pressurization of the leachate injection systems. In the event an over pressurization occurred (if for instance a main valve was accidentally closed while a pump was running), the pressure relief valve would open and allow liquid to flow back into the on-site storage pond.

Prior to beginning injection in the west 6-acre area, each injection lateral was flushed with clean water to remove any debris that may have deposited during construction activities. Each lateral was then pressure tested to ensure that there were no leaks in the system.

In July 2003, leachate addition in the west 6-acre area was temporarily halted due to liquid buildup under the surface liner at the toe of the slope on the west side of the cell. An investigation determined that liquid most likely injected into layer 4 had migrated laterally until it reached the surface liner, where it then traveled down between the surface liner and soil cover until it accumulated at the toe of the slope. To mitigate this situation, County personnel cut a small hole in the surface liner and pumped approximately 110 gallons of accumulated liquid. To prevent this situation from reoccurring, a portion of the surface liner was temporarily removed so that a subsurface drainage layer could be installed to allow any future liquid to drain into the Module 6D leachate collection and removal system. The liner was then replaced and repaired. Liquid addition in the west 6-acre cell resumed in August 2003.

In September 2003, a volumetric analog flow meter was installed on the main leachate injection line for the northeast 3.5-acre cell. This flow meter was used as a backup meter and for verifying readings from the previously installed digital flow meter.

In March 2004, leachate was again found to have built up under the toe of the west-side surface liner. In this instance, the liquid build up occurred near the southwest side of the module. In response, the County installed additional tire and gravel drainage trenches in the areas of liquid buildup. As a preventative measure, the County also completed a drainage trench along the remaining portions of the west side of the cell. In total, approximately 600 ft of drainage trench was installed along the west side of the cell. It appears that the cause of this problem was a layer of soil that was placed during the filling phase of the cell (6 inches of daily cover is regulatory), but was not completely removed prior to the next lift of waste being placed. These problems that Yolo County have encountered underscores the need to tightly control the amount of soil placed in bioreactor cells, because it can severely impede downward percolation of liquid.

During the installation of these drainage trenches, 3 moisture sensors were installed to monitor the performance of the trenches. If moisture readings were to increase, it would be an indication that the trench may not be draining as intended. To date, 2 of the moisture sensors are reading dry conditions and one is indicating liquid buildup.

The sensors will continue to be monitored to assess the effectiveness of the trenches. Elevated sensor readings might indicate limited liquid intrusion that could be of minor importance. But if any additional sensor registers increased liquid additional steps may be taken. The nature of these steps would be decided by the project team.

4.2 Gas Collection System

The gas collection system for the northeast and west-side anaerobic cells and the southeast aerobic cell consists of the main collection header, the horizontal collection lines connected to a main collection header. The main headers on the anaerobic cells were connected to an on-site LFG-to-energy facility, and the header on the southeast aerobic cell was connected to a biofilter and on-site blower station.

The gas collection systems were operated manually. The main collection header valve was opened such that enough suction was available for collection of gas across the entire cell. Adjustments to the wellheads at each LFG collection line were performed manually during the weekly field readings, and were based on the gas composition. High methane contents above 50% meant an increase in flow was desired for that particular collection line, whereas concentrations below 45% meant a reduction in flow.

4.2.1 Maintenance

In order for a landfill gas extraction system to maintain operation, it is necessary for the piping to be graded such that condensate cannot collect in low spots and block the flow of landfill gas. In the fall of 2004, it was necessary to adjust the grade of the header lines for both cells due to waste settlement. As the waste continues to decompose and settle, re-leveling of the header to eliminate any low points will continue to be necessary.

Though PVC pipes had the advantage of being inexpensive and easy to assemble, they also had the disadvantage of being susceptible to damage by UV radiation. To prevent this, all of the exposed piping were painted with exterior grade latex paint, and repainted as needed. In addition, flexible couplings also needed replacement due to UV degradation.

A gas collection lateral carrying sensor lines was found to be leaking gas condensate where the sensor lines exited the piping. Previously, the sensor lines exited the pipe through a hole that was sealed with silicone, however this proved ineffective. To correct the leaks, special watertight fittings were installed on each sensor line.

Prior to completion of the biofilter and blower station, the southeast aerobic collection header was connected to the gas-to-energy facility. This was done to prevent surface emissions. On July 31, 2003, the gas collection header line was disconnected from the gas-to-energy facility and connected to the biofilter system in preparation for operation. Due to delays in construction, operation did not commence in the following months and the piping was reconnected to the gas-to-energy facility on September 30, 2003.

On August 25, 2003, the landfill gas flow meter for the west 6-acre cell was found not operating. The flow meter was sent for servicing and a back-up flow meter was temporarily installed. On September 26, 2003, the permanent landfill gas flow meter for the west 6-acre cell was received from servicing and reinstalled.

During September 2003, the LFG-to-energy facility partially shut down for several weeks due to a mechanical failure of a compressor unit used to feed landfill gas to the engines. The shut down resulted in low landfill gas flow rates and consequently a build-up of positive pressure under the surface liners. To reduce pressure and increase gas flow rates, perforated piping was installed directly under the surface liner at one location on both the northeast 3.5-acre cell and the west 6-acre cell. The piping was then connected to an existing gas well. The installation of

the piping reduced the pressure under the surface liner and enabled landfill gas flow rates to increase by approximately 30 scfm from each 2-inch well.

Over the course of the project, numerous landfill gas collection lines have become temporarily blocked with liquid as a result of leachate injection activities in both the northeast and west cell. As leachate is injected into the cells, liquid levels build up to such a level inside the shredded tires layer (that comprises the gas collection line) that the gas collection piping becomes blocked. This phenomenon was expected during the design phase of the project, and as a result, significantly more landfill gas collection lines were installed (so that several could be blocked at any one time) than would typically be required. As a way of compensating for the reduced horizontal collection lines in the west 6-acre cell, four vertical collection lines were installed in the bores used for waste sampling.

With so many horizontal collection lines being blocked, the County wanted to try to better understand the gas permeability of the waste. Pressure sensing tubes were installed in each of the west 6-acre cell gas lines. The County will continue to monitor the clogging and unclogging of the gas collection lines to better understand the relationship with leachate injection in hopes of reducing the duration and frequency of this phenomenon. During the installation of the pressure sensing tubes in the gas collection lines, significant leachate buildup was discovered in 4 gas collection lines (2-G3, 2-G4, 2-G6, and 2-G7). Previously, leachate buildup had been suspected but not confirmed, because it had not been possible to collect landfill gas out of these lines. By utilizing the recently installed pressure sensing tubes, it was possible to drain leachate out of these lines with 2-G2, 2-G4, and 2-G6 draining for approximately 10 days and 2-G7 draining for nearly 7 weeks. Even though significant leachate was drained out of these lines, they remained blocked, most likely due to liquid buildup deeper in the cell.

On February 13, 2004, the aerobic cell off-gas was temporarily sent to the biofilter for treatment. This was the first of several tests that lasted a few hours and were intended to test the operation of the blower station and biofilter. Full-scale operation was anticipated to begin in August 2004, but was further postponed due to unresolved problems discussed in Section 3.12, however collection of landfill gas was reinitialized in December 2004. Once operation of the aerobic cell commences, all the off-gas will be collected and sent to the biofilter for treatment.

4.3 SCADA and Instrumentation System

The SCADA system is responsible for most of the data collection associated with the bioreactor project. The various sensors hooked up to the system include temperature sensors, moisture sensors, pressure transducers, and flow meters.

The SCADA system incorporates two main components. An Allen-Bradley small logic controller (SLC), which is essentially a small computer, controls the data collection from all the various sensors. A personnel computer is linked to the SLC and makes up the second half of the SCADA system. A program called Wonderware InTouch® is then used to display the data graphically.

4.3.1 Maintenance

To-date, essentially no maintenance of the SCADA system has been necessary. During the initial development stage of the system, it was necessary to perform program revisions to

correct several bugs, but over the course of the last year, the system has performed extremely well.

Pressure transducers used to measure head over the liner have been removed several times to test their operation and recalibrate as necessary. During the most recent removal process, the cable that is used to remove pressure transducers 4 through 6 (which are under the northeast 3.5-acre cell) broke and we were unable to remove them. The inability to remove these sensors was compounded by the fact that pressure transducers 4 and 5 were reading significant leachate levels, but these readings were not supported by the pressure sensing tubes. The County plans to perform a video inspection of the pipe that the transducers are installed in the spring in hopes of determining the cause of the cable break (we suspect a crushed pipe) and confirm the lack of liquid buildup on the liner.

A number of temperature sensors have failed and were removed from the SCADA system. Moisture was speculated as the cause for failure of the sensors, but has not been confirmed. To date, the number of failed sensors in the northeast, west-side, and southeast aerobic cells are 13, 18, and 6, respectively. A total of 9 temperature sensors in the baseliner have failed. Attempts to revive the failed sensors by inducing a current through the wire proved unsuccessful.

4.4 Surface Liner Cover System

A geomembrane cover was installed over both of the bioreactor cells. A 36-mil RPP was used on the northeast 3.5-acre cell and a 40-mil LLDPE was used on the west 6-acre cell.

4.4.1 Maintenance

As part of a preventative measure for excess uplifting or ballooning of the geomembrane cover, a rope and sandbag ballast system was installed on the northeast 3.5-acre cell. Special UV resistant sandbags that have a life expectancy between 3 and 5 years were used, however, almost immediately following installation of the sandbags, damage began to occur. This damage was not the result of UV radiation, but the result of seagulls pecking holes in the bags. To prevent further damage, each sandbag was covered by a tire and piece of geomembrane. To prevent water being trapped in the tire and a subsequent mosquito problem, the bottom sidewall on each of the tires was removed.

In contrast to the sandbags used to secure the surface liner of the northeast 3.5-acre cell, tires were utilized on the west 6-acre cell because of their durability. Rather than place a complete rope and tire grid over the entire surface cover, the County opted to only place tires in areas that were susceptible to wind uplift. Throughout the course of the project, tires were placed in areas of localized wind uplift. The result of this change was positive in that the surface liner remained intact and the County saved significant time and money as compared to the northeast 3.5-acre cell, without sacrificing liner performance.

At the end of 2003, the surface liner ballast system (either tires or sandbags) required further maintenance. For the west 6-acre cell, additional tires were placed on the liner in areas where they had not previously been installed. During this phase, the County experimented with the use of solid "forklift" tires rather than the previously used passenger car tires with rims. The advantage of the forklift tires was two-fold. First, they were significantly heavier than the passenger car tires, and second, because they were solid, it was not possible for them to trap rainwater in the tire. To reduce the costs associated with this work, labor from the County

probation department was utilized. In the northeast 3.5-acre cell, some of the sandbags had become damaged and were replaced with forklift tires.

During the original installation of the surface liner over the west 6-acre cell, the County elected to not install geomembrane boots at each of the liner pipe penetrations. This was done as an experiment to see if surface emissions could be controlled and with the benefit being significantly reduced cost for liner installation. Unfortunately, surface emissions were detected. The initial effort to reduce surface emissions involved using waterproof and airtight expansion foam to seal the surface liner at the pipe penetrations. Surface emissions persisted so permanent geomembrane boots were installed in January 2004. Even following the permanent boot installation, some moderate emissions were still detected. As a result, additional gas extraction wells were installed under the surface liner, which we believe will eliminate any residual emissions.

5 PROJECTS ECONOMICS

In this chapter, sections 5.1 and 5.2 first present costs actually experienced at the YCCL for the scaled up northeast and west anaerobic bioreactor cells. Following these, in sections 6.3 and 6.4 are the projections for a commercial operation.

5.1 Capital Costs

The total capital costs for the Full-Scale Bioreactor Landfill at YCCL during the contract interval are shown in Table 12 below. An explanation of the derivation of each capital cost item is presented in this section.

Table 12. Summary of capital costs for Yolo County Central Landfill's Full-Scale Bioreactor Project during the contract interval

Item	Description	Capital cost
5.1.1	Base Liner Costs	$ 3,364.67
5.1.2	Surface liner Costs	$ 454,923.72
5.1.3	Liquid Addition and Pumping	$ 193,606.85
5.1.4	Landfill Gas Recovery	$ 102,855.39
5.1.5	Instrumentation	$ 126,203.14
5.1.6	SCADA	$ 137,429.80
5.1.7	Total "other" design, administrative	$ 82,843.30
	Total capital costs	$ 1,101,226.87

5.1.1 Base Liner Costs

The marginal cost of the base liner attributable to the bioreactor has been minimal, at $3,364.67. This is because the base liner and its experienced costs would be required in any event.

5.1.2 Surface Liner Costs

The surface liner cost is high, at $454,923.72 for 9.5 acres, or over 400,000 ft^2 with effect of side slopes. Note here that similarly high cost for surface liner is unlikely to be experienced again if total capture of gas is not desired. Because of the nature of this research project, Yolo County wanted to install a cover system to control and measure all of the gases produced.

If a surface liner is used, the cost per acre would be comparable to other such liner installations, estimated at under $1/$ft^2$, and possibly much lower. This reflects the fact that the purchased cost of the liner material (without installation) generally runs under $0.25/$ft^2$. And given the welding requirements and accessibility of surface liner, if used, certain components such as Construction Quality Assurance (CQA) would be less demanding than with base lining.

5.1.3 Liquid Addition and Pumping Costs

Liquid addition and pumping costs were $193,606.85. This included the cost of design and construction for liquid injection and pumping capital cost.

5.1.4 Landfill Gas Recovery and Utilization Costs

Landfill gas recovery capital costs were $102,855.39, covering the horizontal gas collectors placed in trenches in the waste as landfilling proceeded, and the associated piping system.

5.1.5 Instrumentation Capital Costs

Instrumentation capital costs were $126,203.14. This includes the design and material costs for installation of instruments.

5.1.6 Supervisory Control and Data Acquisition System (SCADA)

The Supervisory Collection and Data Acquisition System capital cost totaled $137,429.80.

5.1.7 Other Capital Costs

Other capital costs include other more general components. These are allocable among several categories, partly to capital. In detail, these costs are assumed at 100% of Project Startup at $926.38, half of Project Management and Data Analysis, $57,202.02 and $24,714.90 for a total "other" of $82,843.30.

5.2 Operation and Maintenance Costs

Costs in the section below were in some cases aggregated rather than broken down in detail for the project. For example, maintenance of the cover (repairing leaks) and of the landfill gas and leachate collection systems is all contained (aggregated) in other categories, such as instrumentation and equipment maintenance. However, costs listed give a good overall picture of the maintenance cost.

Note that the testing costs have major experimental components and purposes. It is estimated by the project team that most of the costs below would be at least considerably reduced in a commercial operation.

The total operating costs are summarized as follows in Table 13.

Table 13. Summary of total operating costs for Yolo Field Experiment

Item	Description	Capital cost
5.2.1	Waste sampling and analysis	$ 41,354.05
5.2.2	Field testing and monitoring of Landfill gas	$ 127,208.40
5.2.3	Leachate Sampling and Testing	$ 61,694.96
5.2.4	Methane emission monitoring	$ 34,516.90
5.2.5	Landfill Settlement Surveys	$ 35,629.09
5.2.6	Methane Production Modeling	$ 7,770.59
5.2.7	Instrumentation and Equipment Maintenance	$ 62,938.29
5.2.8	Project Management and Data Analysis	$ 114,404.13
	Total Operating Cost	$485,516.41

5.2.1 Waste, Leachate, and Gas Sampling and Testing

The waste sampling and analysis costs were incurred during sampling and characterizing of waste from the landfill. Moisture content indicates the degree to which moisture has distributed in the landfill and the biochemical methane potential tests give a check of the methane potential of the waste. The total costs were $41,354.05.

Leachate sampling and testing costs were for the purpose of determining leachate pollutant loads. This in turn, is related to the reduction of risk for groundwater contamination as discussed elsewhere in this report. Total cost was $61,694.96.

Costs experienced for field testing and monitoring of landfill gas totaled $127,208.40. These were for purposes of characterizing landfill gas methane content, VOC content, and generally assessing the quality of gas recovered from the Full-Scale Bioreactor project.

The amount of testing and monitoring was largely for experimental objectives specific to the project, and less testing would normally be required in a large landfill running at steady state.

5.2.2 Instrumentation and Equipment Maintenance

Instrumentation and equipment maintenance include a number of necessary items not broken down or appearing elsewhere. Examples of these include gas flow meter repairs, repairs of cover leaks, and a wide variety of operational activities. The total cost for these in the contract interval has been $ 62,938.29.

5.2.3 Methane emission monitoring

Methane emission monitoring is a standard requirement to determine landfill emission compliance under EPA and California rules. As an experimental program, frequent emission testing was, among other things, a condition of Full-Scale Bioreactor project under EPA's Project XL. In the Project XL circumstances, emission monitoring was several fold (about 3 times) more frequent than would be required in a commercial operation. The total cost was $34,516.90.

5.2.4 Landfill Settlement Surveys

Landfill settlement, item 5.2.5 in Table 13, is an important measurement parameter, indicating how much additional space may be made available as placed waste decomposes and loses volume. The total cost for landfill settlement surveys was $35,629.09.

5.2.5 Methane Production Modeling

Methane production modeling was conducted to determine the kinetic coefficients for waste decomposition. Decomposition rates and kinetic parameters are extremely important as indicators of the efficacy of bioreactor operation. The total charge for modeling work during the contract interval was $7,770.59.

5.2.6 Project Management and Data Analysis

Project management and data analysis costs were $ 114,404.13. This project management and data analysis category is self-explanatory and includes the management activities and data interpretation needed for the project activities in the contract interval.

5.3 Cost for a Full-Scale Commercial System

5.3.1 Summary of Costs for a Commercial System

5.3.1.1 Electricity-only case

The costing in the simplest electricity-only case for a commercial system reduces to a very straightforward situation. The basic assumption is that a waste stream must be managed through landfilling. Governing factors in the "simplest" case are,

- The benefits of bioreactor operation, independently of energy recovery, justify implementing a bioreactor by themselves.
- For most landfills where a bioreactor would be implemented, gas must be recovered using best available control technology.
- Availability of recovered gas at effectively very low or no marginal cost is a "given".
- The cost of electric power is that of the genset running on "free" fuel.

In contrast to previous reports in earlier years on the Yolo project, we do not attempt to cost out in detail the operational costs of engine-generator sets. The project team's expertise is less than other organizations more experienced in landfill gas conversion to energy. We use the costs reported by Waste Management, Incorporated (WMI). WMI generates over 600 MWe of its own electricity from solid waste sites and fuels in including over 200 MWe powered by internal combustion (spark-ignited) engines on landfill gas. The presentation we cite here is that of Paul Pabor, vice president, renewable energy, Waste Management, Inc., "The Energy Value of Landfill Gas". This talk was presented at various symposia including the RecycleMinnesota Symposium in October 2002 and can be found at:

http://www.recycleminnesota.org/2002_conference.htm

For discussion purposes, Mr. Pabor of Waste Management, Inc. notes the following parameters for the average landfill gas to energy (LFGTE) Project:

- 1,600 CFM of landfill gas,
- 400,000 mmBTU/yr,
- 4000 kWe,
- About 32,000,000 kWh/yr.

For this size plant the capital cost is $3.2 to $5 million ($800 to $1250/kWe) and would be comprised of:

- Site Work,
- Building,
- Gas conditioning,
- Equipment (electricity generation) price,

- Interconnect and other miscellaneous.

With this cost picture, the total cost to generate power is generally in the range of 2.5 to 3.5 cents/kWh consisting of these general elements:

- Capital costs,
- Financing costs,
- Depreciation period,
- O&M contract
- Taxes, administration, permitting.

The sole adjustment to power costs would be the application of fairly standard scale factors to account for larger or smaller scales. Otherwise, although the cost picture could be broken out in more detail, the summary of cost by Waste Management is based on the largest experience base in the world, and estimates of more cost detail by us would not, in our view, add significantly to precision.

5.3.1.2 Landfill Gas Price

Electricity cost in following sections does not include any LFG purchase price. Although the landfill gas is a necessary byproduct of bioreactor operation, thus at no net cost to produce, it is often necessary to assign a transaction value, essentially a purchase price for tax purposes (usually only a few percent of the energy worth), because of the intricate IRS tax code section 29. However, this is a minor internal transaction and mostly "out of one pocket and into the other". An energy system must simply be self-justifying on its own merits, i.e. the cost is that of an engine or turbine that is supplied with fuel in the form of landfill gas at what is effectively no marginal cost. As will be seen later, the long-term economic picture is good but there are non-technical barriers of other sorts, permitting requirements, and risks that remain as barriers so the picture is not nearly so simple as this might imply.

The electricity generation cost has been calculated for a 500 TPD and 1000 TPD (365 day/year time average) landfill operation as follows in Table 14.

Table 14. Summary of example electrical generation scenarios

Waste inflow, TPD (time average 365 day/yr)	Power output time average, MWe	Power output, MWh/ yr	Approx. capital Cost, $/kW capacity	Total Plant capital cost, Million $	Cost of generation, Cents/kWh ($/MWh)	Net revenue or profit with sale at 50/MWh, $/yr
500	4.65	40,548	$1200	$5.6	3.5 (35)	$608,000
1000	9.30	81,096	$900	$8.4	3.0 (50)	$1,621,000

This summary represents only two examples distilled or culled from the wide range of power generation scenarios that are actually very complex. The detailed calculations and determinations of performance and power revenue/cost data are presented in subsequent sections 5.3.2 to 5.3.5. The bioreactor can potentially be self-financing based on benefits that are independent of power generation. The benefit/cost ratio calculations for a bioreactor are discussed later in section 6.4.

5.3.1.3 Comment on costs: Incremental costing

The costs presented in this section, whether for power generation or bioreactor operation, are only those incremental costs that would be incurred as the result of operating the landfill as a bioreactor. For example, (a) leachate, the liquid that percolates from the base of the waste, will be present in any case. It must be addressed by an adequate leachate handling/recovery system needed and in fact mandated in all landfills to prevent groundwater contamination. (b) Waste surface coverage will be required in any event to standards that assure continuing coverage with time, as well as assuring rodent, bird exclusion, etc. (c) All normal maintenance and operation work will be required in any case. Cost assumptions are based on the professional judgment of the project team, and experience, and the assumptions used are listed with each cost component developed. Note that in this simplified analysis, the stated installed costs incorporate engineering and design.

5.3.2 Kinetics of gas generation and capture

It is necessary for calculations to follow to assume methane generation kinetics and yield coefficients.

A methane generation yield of 3000 ft^3 (3 million Btu's or mmBtu hereafter) per ton is assumed. Before enhancement, gas is generated with a first-order kinetic rate constant of 0.04 yr^{-1}. Gas generation is assumed to occur with a rate constant of 0.20 yr^{-1} after enhancement begins. These yields and coefficients are from sources including results with the Yolo County Demonstration cell, and the report. This parameter is important, not so much as a cost factor, but in extrapolating the time course of gas recovery and electricity production.

5.3.3 Assumptions about modules

A number of design features must be assumed in order to conduct an economic and performance analysis, and the design must be one that can be straightforwardly implemented at typical U.S. sites.

The landfilling occurs in modules, (also commonly referred to interchangeably with cells, although a module can contain more than one cell or "subcell"). Assumptions about module size are important in the analysis, as they refer to filling time and fugitive emissions during filling. A module can be any size, from 5 to 30 acres but for bioreactor operation a module should be of a size that can be filled quickly, in three years or less to limit early emissions during filling. Subunits of the module, about 10 acre cells, can be completed relatively quickly. Another assumption is that filling results in net density of placed gate waste of 50 lb/ft^3 or 1,350 lb/yd^3 for the total landfill volume. At this density, an acre-foot of waste weighs 1,089 tons. An acre of waste 50 ft deep will contain 54,450 tons, and 100 ft, 108,900 tons. These assumptions will be used below.

5.3.4 Startup And Management Of Landfilling And Gas Recovery Operation

5.3.4.1 Time To Fill Module

At a module size of 10 acres, depth 50 ft and a waste inflow of 500 tons/day, the time requirement to fill a 10-acre module is 3 (actually 2.98) years. Some details of the rather intricate startup sequence are shown for reference in the next subsection. These startup and management parameters will be generally applicable to bioreactors, and independent of whether power is generated or not.

5.3.4.2 Startup Sequence And Timing

The time from initiation of filling to completion of coverage and initiation of full enhancement is assumed to be 3.5 years. During the time to full enhancement, the waste stream entering up to year 3.5 generates about 7% of the methane potential of a year's entering waste (average of 1.75 years' waste x kinetic coefficient of 0.04 yr^{-1}). This gas is captured with 80% efficiency but may be flared as the most convenient early option. After start of enhancement, starting at year 3.5 once the gas capturing cover is in place, the modeled generation rises to 70% of full potential in 5 years and 90% of full potential within 10 years. It is assumed that infrastructure for the electrical generating equipment, such as lines, site preparation and interconnects, can be installed initially at year 3.5 in one operation to achieve economies of scale. The necessary generation equipment can be brought up to full capacity as justified by gas availability, in stages in years thereafter. A heat rate of 12,000 Btu/kWh is assumed, based on higher heating value (HHV) of the methane. At a 500 tons per day time average fill rate, the full capacity, at 95% recovery of the steady state recovery of 1,500 mmBtu/day, is 1,425 mmBtu/day. Accounting for a 95% gas capture, and 1% gas loss at the beginning and end of the landfill methane generation cycle, the recovered gas will also fuel 4.30 MWe. At 1,000 tons/day, recoveries double.

5.3.5 Scenarios For Calculating Methane Recovery And Power Generation

A 25-yr continuous filling operation is considered. From assumptions above, and using estimates based on accepted kinetic models (parameters given above), about 7% of one year's LFG generation is lost to energy use at the start of filling. To use remaining LFG recovered after

closure, it is also assumed that the generating equipment will keep operating (part load of some engines as necessary) down to the point where the "last engine" or 17% of a 6-engine combination becomes fuel limited. At the assumed kinetic rate constant of 0.2 yr^{-1}, this occurs 9 years after closure. In this "optimistic" scenario, the total LFG energy forfeit because of unusable gas at the beginning and end of filling is small, amounting to less than 25% of the methane potential (gas) that could be generated from one years' waste, or 1% of the total gas over the landfill's gas generation cycle. An assumed loss of 5% of gas due to inefficient recovery adds to this 1% for a total loss of methane potential of 6%--perhaps optimistic, but appearing attainable. In other words it is assumed that a 94% fraction of generated gas is recovered.

The calculation of both methane and its cost will assume the following two scenarios. These are:

Scenario 1:

"Small" landfill, time averaged (365 days/year) inflow of 500 tons MSW/day.

Waste per acre=	54,450 tons
Methane Generation per acre=	163,350 mmBtu
Methane recovery efficiency=	94%
Methane recovery per acre over life of landfill=	153,549 mmBtu HHV
Engine online factor=	95%
Engine heat rate=	12,000 Btu/kWh
Calculated total MWh per acre=	12,795
Time averaged power production=	4.65 MWe (365 days/year)
Power production per year=	40,734 MWh

Scenario 2:

Same as scenario 1 except time averaged inflow of 1000 tons MSW/day.

Waste per acre=	108,900 tons
Methane generated per acre =	326,700 mmBtu
Fractional methane recovery=	94%
Calculated total MWh per acre =	25,590 MWh
Time averaged power production=	9.30 MWe
Power production per year =	81,468 MWh

In assigning costs to power generation later, the time between expenditures and revenue deriving from these expenditures is under 4 years and averaging 2 (given a 3-yr module life). In all financial calculations, particularly the low discount rate of 4% used in previous reports to California Energy Commission (June 1997) on this project, the time value of money is "in the noise" making a limited difference to cost estimates as will be seen below. The time value of money also largely cancels if discount rates will be close to the rate of escalation in costs and electricity or energy value. Within the precision of this type of analysis, the application of any discount factor or required interest can be easily treated in other ways. For example, it can be embedded in installed capital cost or in the capital recovery factor. On this basis, elaborate accounting that breaks out discount factors, etc., has been omitted.

5.3.6 Engine Economics Alternative

When engine economics or capital costs are necessary for purposes of incorporating more detail on engine or prime mover costs in cost evaluations such as this, it can be assumed that the landfill gas fueled engines have a capital cost component of 1.8 to 2.5 cents/kWh (capital recovery factor of 14% to 18% per annum on $1,000/kWe and 8,000 hrs/yr as reported in industry experience) and 1.0 to 1.2 cents/kWh variable costs that occur per unit power generation.

Summarizing, the genset related cost of landfill gas fueled generation is taken from this and Waste Management data as 2.5 to 3.5 cents/kWh. To be conservative, we use 3 to 3.5 cents/kWh at various points below.

5.3.7 Caution on regulatory issues and risks "outside the box"

Both risks and regulatory issues remain for the power generation that may occur from bioreactors. Although the picture developing is positive, large-scale performance must be confirmed. An example of risks and barriers is the imposition of extra lining requirements on bioreactors. However, such lining system may also be required for all landfills constructed in California, regardless of the operation as a bioreactor. This issue is currently under discussion at the California State Water Resources control Board and Central Valley Regional Water Quality Control Board. The issue is not yet resolved, but parties intending to implement bioreactors may need to play it safe and spend considerable (to them) "up front" money to install base lining.

One other issue of extreme importance that remains to be resolved for electricity generation is that of exhaust emissions. Present lean-burn engine emissions are falling as engines improve, but are still above allowable limits. As increasingly large sections of California come under increasingly tight emission constraints, NOx offsets must be available, which they are often not. And when available, they must be purchased. These emissions issues are considered solvable by the project team, but their solution would entail more development work. There are two avenues recommended by authors to abate emissions:

- Biofiltration of engine exhaust in large masses of solid waste, already showing practicality in a research project at UC Davis.

- Chemical and mechanical treatment of engine and turbine exhaust followed by standard catalytic removal of contaminants. This is a moderate extension of standard technology.

5.3.8 California Regulations

State regulations, until recently, adversely affected the prospects and costs for bioreactors. However, the Federal regulatory situation has become more favorable. And the regulatory situation in California is resolving in large part favorably as California is moving toward adopting the new federal standards. More discussion is presented in the discussions of cost to benefit ratios risks, and regulatory factors affecting bioreactor implementation at the end of this chapter.

5.4 Estimated Benefits

5.4.1 Airspace Recovery

The results from the Yolo County enhanced cells thus far suggest that airspace of at least 20% of the originally placed waste volume can be gained back within a reasonable time (under 10 years) from the time of placement of waste. All other things being equal, this airspace can be used over time to allow greater waste acceptance, and extend life of the landfill. The value to the landfill over time is judged to be equivalent to adding 20% to existing gate revenue. After adjusting for added (variable) operating expenses, the additional value to the landfill of additional air space created can be about 15% more. The revenue can be seen in alternative terms, as added net revenue per ton of waste received with bioreactor operation compared to no bioreactor operation. This value for the Yolo situation is calculated at about $4.80 more per ton of waste. Although the value will depend on the site, it will be similar for other landfills.

This valuation may be on the low side. Several aspects of it can be noted: (a) The Yolo volume reduction is by no means complete. Furthermore, (b) additional steps—particularly slow aerobic treatment of the bioreactor remnant after methane production is essentially complete—can give further volume reduction to destroy at least 5-10% more of the original gate waste. Aerobic landfill operation is already permitted and encouraged at some sites. (c) The cost of additional landfill sites has been increased, if anything, at greater than the cost of inflation, as landfills become progressively more difficult to site near populated areas in California and in the U.S. For these reasons, a volume reduction of 25% seems quite likely and with landfill cost escalation equaling the compound interest rate, a "high end" valuation for volume reduction calculated on the same basis as above would be $9/ton waste. Thus, value of volume reduction for this analysis is between $ 4.80 and $9/ton of waste.

Table 15. Summary of the benefits

Fill Rate	Low end benefit at $4.80/ton	High end benefit at $9.00/ton
500 TPD	$ 876,000	$1,642,500
1,000 TPD	$1,752,000	$3,285,000

5.4.2 Leachate Treatment

The experience with projects that use permeable layers beneath conventional clay cap for gas recovery suggests that for new projects using this approach, leachate production would not be much altered. In essence, rain will enter and leachate will drain through a conventional cover

with conventional practice at rates and costs rather similar to the bioreactor. This in turn would imply little savings in terms of leachate disposal. However, leachate will be cleaner with somewhat lower BOD. Also, in intermediate stages, any leachate from earlier operations can be directed to fulfill liquid needs of later stages. Given all factors for now, there will be no credit or debit assumed in the economic evaluation for leachate associated costs, compared to conventional practice.

The benefit-to-cost ratio of cover membrane is affected by many factors and a multitude of associated design options. Newer cover approaches could easily have net cost close to zero compared to a conventional design. In fact, recent modeling has suggested that gas capture can be extremely high without cover membrane, providing that there is judicious use of near-surface high permeability layers (such as shredded tires) and low permeability cover. This is being found in modeling work by both D. Augenstein (unpublished) and the University of Delaware working in cooperation with Yolo County. And, when surface geomembrane cover is used, its cost can be offset by further benefits such as prevention of precipitation infiltration, reduction in leachate generation and volume through post-closure. The value of this leachate prevention is very roughly estimated here at $50,000/acre (for example, avoiding the cost of treating 20 to 40 gal/ton of waste of leachate at 2.5 to 5 cents/gal and about 50,000 to 100,000 tons MSW/acre). This value for leachate abatement justifies surface liner, and once waste is stabilized, surface membrane can ensure reduction of long-term risk.

Thus, in the simplest case, geomembrane cover may not be needed and if cover should be used, the leachate reduction noted above lower or "zero out" net cost of surface geomembrane cover. This is a complex situation that needs more study than is possible here. Given the possibilities for limiting leachate management cost, and likely positive benefit-to-cost ratio of surface lining if used, neither surface lining nor leachate credits or benefits' costing are attempted in the analyses below.

5.4.3 Gas Recovery

In this analysis, any gas value is normally embedded in the electricity output, whose value is already counted. When there is electrical generation, there will normally be no other sale of gas energy. This ignores the internal transaction valuations that may exist. Internal transactions may occur when the energy developer finances some gas collection for the bioreactor, and values this gas, but this is associated with tax credits to the developer so that the net result is very small or negligible addition to the gas cost that fuels generation.

Thermal uses. A moderate but significant fraction of LFG projects, about 20%, sell the LFG for thermal energy. The fraction of 20% results from the percentage of nearby thermal use opportunities at particular sites. When gas is sold, the value will be tied to the avoided cost of fossil fuel otherwise necessary. With existing prices of fossil fuel around $6/million Btu under long-term contracts, but depending on the situation, sellers have to now netted about 50% of the raw energy's market price. The lower revenue than pipeline gas comes from cleanup needs and needs for equipment adjustment, for example to run on gases with widely varying energy content. The value of gas derived above multiplied by a presumed value of $3/million Btu would result in revenue of $8/ton of waste. These revenues can clearly vary and are becoming more variable and nearly always higher in the rapidly changing U.S. energy situation.

Thus, revenue from landfill gas, other than the electric revenue, may range all the way from zero to $8.00+ per ton of waste. Realization of $8/ton has been a high end that is relatively uncommon because of the need to clean contaminants, and cost to modify energy equipment. The purpose of the Yolo bioreactor program is, however, to generate electricity. Thermal energy sales are presently not possible at Yolo and thermal uses will not be discussed further.

5.4.4 Greenhouse Gas Emissions

The present status of greenhouse gas abatement credits is not only uncertain but also poor.

The party desiring credits must demonstrate that it can sell a greenhouse emission that can be abated. Greenhouse credits were discussed at symposia sponsored by LMOP in the talk by Michael Carolan and can be found at:

http://www.epa.gov/lmop/conf/01_greenpower/carolan.pdf.

A greenhouse gas (GHG) reduction program involves various constraints: (a) the emission cannot be one that would have been reduced anyhow, by regulations; (b) the emission reduction must be rigorously quantifiable and verifiable; (c) no other entity than the seller of credits (in this case the party collecting landfill gas) is likely to sell the same credit; (d) there must be a willing buyer.

The constraints reduce the projects eligible for credits to a small fraction of landfill gas energy sites and prospects. And without U.S. participation in the Kyoto accord, the market valuation for U.S. sale of "carbon credits" is very poor. Therefore, few landfill gas energy projects seek, let alone, have revenue from greenhouse credits, although some projects are "banking" them. Those that do quantify GHG credits find that the market price is very variable, but in the best of cases where there is a willing buyer of credits, the sale of credits can gain over $1/ton of waste. One such case, documented by Michael Carolan in the reference above, involved a sale of credits to Ontario Hydro Corporation of Canada. However, the anecdotal information available now is that the credits are rare as well as minor.

A carbon credit of even $1/ton of CO_2 and acceptance of abatement of methane with a global warming potential (GWP) weight ratio of 21-to-1 over CO_2, as accepted by the Intergovernmental Panel on Climate Change (IPCC), would lead to a credit for capture of methane of 1.6 cents/kWh, or about $5/ton of MSW landfilled. (This is using the above per ton methane yield calculations as a basis.) Since the CO_2 abatement credits of several dollars per ton have been under consideration in the past, the greenhouse credit could be extremely high, over $10/ton. However, the political situation and other constraints are such that such a credit is not near-term.

Likely range of still-speculative greenhouse credit in the next few years: Zero to about $1/ton of MSW landfilled. This amounts to:

- 500 TPD = zero to $182,500 per year
- 1000 TPD = zero to $ 365,000 per year

5.4.5 Closure and Post-Closure Maintenance

The effort now required under state and federal rules for necessary landfill maintenance after landfill cells are closed, is considerable. Among other reasons, major effort is necessary to

maintain gas and liquid emission control once the landfill is closed. A major uncertainty is what post-closure care may be required, in terms of components of, and length of, post-closure care. This uncertainty and the possibility of more than 30-yr ongoing care causes concern, even if projected post-closure costs may appear reasonable at some discount factor.

After closure, conventional landfills' gas control requirements continue, depending on gas generation. Typical gas systems require continuing adjustments of gas extraction so that gas is captured with reasonable efficiency while air entrainment is avoided. Gas system adjustment is labor-intensive, and maintenance of the gas system (which may involve maintaining pipes and blowers) is likewise costly. Pipes and blowers must be repaired. Costs can be estimated to be between $ 0.01 and $0.10 per annum per ton of waste in place, but are quite site specific. The cost for other waste decomposition related maintenance—such as cover subsidence—is about equal to this. All of the costs associated with the gas system monitoring and maintenance would be expected to cease if gas production were to end (i.e. be 95 + % complete) earlier than the mandated 30 years post-closure. In a simplified (long-term steady state) analysis of a bioreactor the assumption that gas generation and recovery effort could end in 15 years rather than 30 years leads to an estimated savings, at $ 0.10/ton/year of about $1.50/ton. The value of minimizing post-closure care may be at least as high from a liability standpoint for "responsible parties" as it is from a monetary standpoint. Large mandatory "up-front" financial assurance deposits to assure post-closure care are required under law and these could potentially be reduced.

Considering everything, including the industry's strong weighting of and concerns about post-closure liabilities even at long-term, this analysis assumes that bioreactor benefits to post-closure care is $1.50/ton, and at 500 TPD, $274,000/yr and at 1,000 TPD, $ 548,000/yr. It is emphasized that these values though used below, could vary substantially.

5.4.6 Tax Credits

Tax credits, or other regulated incentives may also be possible. Presently applicable IRS (Section 29) code relating to tax credits has been changing with many constraints and valuations on credits, but tax credits of over $1.00 per million Btu (mmBtu) of landfill gas can accrue to qualifying recipients of recent IRS "Section 29" tax credits. The landfill operator typically arranges by one mechanism or another to receive all or a portion of the credit value. Where the gas recovered from one ton of waste is 2.6 mmBtu, the tax credit would also be $2.60/ton MSW (about) or 1 cent/kWh. Purely hypothetical tax credits (based on $2/ton waste) are as follows:

- 500 TPD = zero to $ 336,000,
- 1000 TPD = zero to $ 672,000.

5.5 Economic Analysis of Full-Scale Project with Energy Generation

5.5.1 Benefit to Cost Comparison for Bioreactor Operation

In this section, costs were calculated for the bioreactor independently of electricity generation for fill rates of 500 TPD and 1,000 TPD (time average). The resulting costs and resulting benefits are expressed on an annual basis.

5.5.1.1 Assumptions

See the previous section 5.3 for the assumed filling sequence and kinetics assumptions. Other assumptions are outlined below. However, the site-specific and design aspects of bioreactors can range very widely.

In projecting results of bioreactor cells to a commercial operation, adjusting benefits to later commercial operations from both a learning curve and economies of scale, it was assumed that savings would be between 25% and 50% less for similar installations of similar equipment.

The initial cost projections below are for the bioreactor operation, which is the critical unknown area, and the area where the project team has greatest experience.

The incremental costs for all power-related and bioreactor related items below are assumed over the 25-yr period of filling. Items that might plausibly be included as capital costs such as various lining, instrumentation, gas conveyance pipe, and other items are treated as operating costs because of their recurring nature.

Another basic assumption for projections below is that landfill cell filling and operation follows approaches that are largely conventional, unless otherwise specified. The key assumptions and differences from conventional landfill practice were described in the above sections 6.4.3 to 6.4.5.

The landfill is filled using conventional operations. The specifications of a conventional LCRS, highly permeable and requiring accommodation for a 100-yr rain event, with associated pumping are also more than sufficient. This allows a large safety factor to accommodate the leachate expected from a bioreactor.

Note that infiltration rates, shown highly effective, are equivalent to below 1 in/day precipitation. The recirculation rate in the pilot experiment at Yolo County was equivalent to below 30 in/yr of liquid infiltration, far under the drainage capacity of a large-pore drainage layer. All required liquid management is well within the capacities of present drainage layer design. Note that the possibility of precipitation clogging must be forestalled by use of large pore drainage material such as shredded tires or gravel.

These same constraints exist for conventional landfills, and no incremental cost was assumed for the LCRS.

Waste is filled as with conventional practice. However, alternative daily cover is used, that will allow later liquid infiltration, rather than conventional cover soil. This porous daily cover may be greenwaste, tarp, or alternately, fully decomposed waste from a cell filled earlier, or water based foam of some type that collapses within a few days. Such porous daily cover actually offers considerable savings and has regulatory acceptance. Thus, no incremental cost is assumed.

Instrumentation is required, as moisture and temperature sensors and hydraulic transducers are embedded in the waste as the filling proceeds. However, the sensors' spacing will be much lower than that of earlier demonstrations. It is assumed that 50 moisture and 50 temperature sensors per 10 acre module will be adequate to indicate temperature profiles and the degree of moisture penetration. Projecting from the large-scale demonstration program a cost of $2,000

per temperature/moisture sensor, or $ 10,000/acre is assumed. This cost is incurred for bioreactor operation, regardless of power generation.

From fill rate and other statistics, the time to fill a 10-acre module is the same for 500 tons/day (50-ft depth) and 1,000 tons/day (100-ft depth). This time is 2.98 years. Correspondingly, 3.36 acres are filled per year. The annual cost for instrumentation at the $10,000/acre cost is $ 33,600/yr.

Provision for liquid addition is made by installing piping with appropriate perforation in layers. For the 50-ft deep cell, the layers are midway up and at the top of the cell. Liquid addition occurs at 25, 50, and 75 ft up and at the top of the 100-ft deep cell. The cost of liquid lines for the demonstration cells was $160,000 per 9.5 acres, or about $4,000/acre per level of 25-ft spaced injection lines. The cost is assumed to be $2500/acre per level of injection lines for a commercial operation. This cost is incurred for bioreactor operation, regardless of power generation. For the 500-ton/day fill rate, annual cost experienced for the liquid addition system is estimated at $16,800/annum and for the 1,000 tons/day operation, $33,600/annum.

A surface membrane cover is not used but instead the default assumption is that a near-surface conductive layer is used, beneath final and conventional clay or other low permeability cover. As noted above, flow modeling of gas recovery with this design is expected to be over 95% of the generated gas. As what is basically a modest variation of permeable daily cover, the extra cost for compost, wood chips, or tires layer would be expected to be minimal. A minimal incremental (added) cost of $3,000/acre is assumed for this cover.

On this basis, annual cost experienced for gas capture is $10,000/annum (rounded from $10,080). At a roughly $1/ft^2 cost, a surface geomembrane, if needed, would add a further $146,000/yr in incremental cost. The cost components, if surface geomembrane are used, are listed in Table 13 at $3.58/MWh for 500 tons/day, or 0.36 cents/kWh. At the 1000 ton/day fill rate, the cost would be 0.18 cents/kWh.

Costs associated with conveyance of landfill gas from the bioreactor will increase. Compared to conventional gas recovery from the same mass of waste, the bioreactor's flow of gas may easily reach four times as much at peak generation as with a conventional landfill design.

This does not, however, translate to proportional increase in piping cost. A 4-fold increase in flow leads to a 65% increase in required diameter. And much of the piping cost is installation, which is not flow dependent. The landfill gas conveyance cost will increase by not more than 50%. This is based on industry figures of $8,000 to $20,000/acre (Waste Management, Inc.) and a 50% increase would result in added incremental cost of landfill gas conveyance due to bioreactor operation between about $5,000 (500 TPD) and $10,000 (1000 TPD).

On this basis, the cost of piping is conservatively estimated by the authors' professional judgment at $20,000 for the 500 tons/day and $ 35,000/annum for the 1000-tons/day cases. This value, used as a "proxy" cost in Table 16 below should be recognized as potentially quite variable by landfill site.

Because of potentially differing stability of wastes in bioreactors, initial geotechnical analyses of stability are likely to be required. However, once the first few generalized analyses are completed, it is expected that the stability issues will be satisfactorily resolved and guidelines developed. The long-term incremental cost is assumed to be zero. Permitting is also likely to be

more intricate and costly. The extra cost is again a difficult call, but we estimate a cost of $3,000/acre for the other costs. This cost is incurred for bioreactor operation, regardless of power generation.

Permitting and geotechnical analyses as needed for 500 tons/day and 1,000 tons/day is $10,000/annum.

All of the cost calculations above assumed that the costs of base lining would be the same whether a landfill is conventional or a bioreactor. However, extra base lining costs may be incurred if the landfill must, for example, have double membrane base lining as opposed to a conventional landfill's single liner. In California, the double membrane requirement may become the standard design for all landfills in the future. This awaits resolution by regional water boards.

The base per-acre cost of base layers for a single lined landfill is shown in Table 16 below and will be approximately $100,000. (This cost, required in any event, is presented for reference.) Though the first liner cost is not attributable to the bioreactor, the costs of the single liner serve as a good guide to the costs of the second liner if a double liner is required. If a double liner is required, the incremental cost attributable to a bioreactor is the cost of the second liner.

Table 16. Typical costs of landfill base layers

Base Layers (listed from the bottom up)	Cost per acre
Purchase soil	$ 19,000
Compacted clay liner	$ 12,000
60 mil HDPE liner	$ 15,000
HDPE geonet (drainage layer)	$ 8,000
Geotextile	$ 8,000
Operations layer	$ 6,000
HDPE pipes, 4-in diameter	$4,000
Subtotal liner cost	$ 72,000
Other associated costs:	
Engineering and Design	$ 5,800
Quality assurance & quality control	$ 12,000
Contingencies @ 10%	$ 7,200
Subtotal other costs	$ 25,000
TOTAL COSTS	**$ 97,000**

Cell depths of 50 ft and 100 ft are again assumed and, other assumptions and particularly gas recovery are identical to that derived above.

Although need for a surface liner appears uncertain, the surface liner could turn out to be a valuable adjunct to (possibly) maximize gas recovery efficiency. The type of liner integrity required of a base liner is not necessary and imperfect coverage could still substantially limit fugitive emissions. The surface liner would have obvious value when installed at closure (after 25 years) to prevent precipitation infiltration and bring the stabilized waste to a "drier", i.e. more leachate drainage-free condition. The estimated cost of surface lining, estimated at roughly $1/ft² earlier or 43,560/acre) would work out to $ 146,000/yr and could be another cost factor. However, long term the surface lining value is probably offset by the value of leachate mitigation that would otherwise occur without it. Because of this, and as noted earlier, surface lining is not included as a net cost.

The most significant additional operating cost for a bioreactor, versus conventional operation, is labor. Extra labor requirement is another factor that is difficult to estimate precisely, but it might be judged that the extra monitoring and other operations of a bioreactor would require the presence of one additional employee. At a fully burdened operating cost of $60,000/yr, the assignment of this employee cost to the recovered electricity adds $60,000/yr to both the 500 and 1,000 TPD case.

The accounting of the bioreactor cost components is inherently complex with several options. For example, expenses might be assigned against: (a) the electricity, or (b) waste management benefits like volume reduction and the other landfill benefits. Although much uncertainty remains about exact magnitudes of costs and benefits, the benefit-to-cost ratio is positive even with all likely uncertainties, and however the accounting is done. Next is a list of some estimated annual expense and benefit components for the 500 and 1000 ton/day fill rate.

Table 17. Annual dollar expense of cost items specific to bioreactor
(Representative but approximate values, vary by site. See text for discussions.)

Cost Factor	500 TPD		1,000 TPD	
	High End	Low End	High End	Low End
Sensors	29,800	29,800	29,800	29,800
Leachate Injection Lines	16,800	16,800	33,400	33,400
Surface Membrane	146,000	0	146,000	0
Extra Cost for Gas Conveyance	20,000	20,000	35,000	35,000
Permitting	10,000	10,000	10,000	10,000
Extra Base Lining	289,000	0	289,000	0
Totals	511,660	76,600	542,300	108,200
Cost/MWh (see below)	12.56	1.88	6.66	1.33

Table 18. Annual Value Of Bioreactor Waste Management Economic Credits
(Exclusive of electricity: All figures approximate. See text for discussions.)

Credit Valued	500 TPD		1,000 TPD	
	High End	Low End	High End	Low End
Landfill Gas Gain	$1,642,000	$876,000	$3,284,000	$1,752,000
Greenhouse Credit	$182,000	$0	$365,000	$0
Post-closure Care at $1.50/ton	$274,000	$274,000	$548,000	$548,000
Tax and Similar Incentives	$336,000	$0	$672,000	$0
Total Benefits Estimated	$2,434,000	$1,150,000	$4,869,000	$2,300,000

The MWh per year estimated for the 500 and 1000-ton cases are as follows (repeated from 5.3.5 Scenarios 1 and 2):

- 40,734 MWh/yr for 500 TPD cost factor.
- 81,468 MWh/yr for 1,000 TPD cost factor.

Even if all costs were assigned to the gas used to fuel power generation, the estimated costs would clearly be acceptably low, ranging from $1.33 to $12.56/MWh (0.132 to 1.26 cents/kWh). These costs appear quite tolerable despite attendant uncertainties. It is also clear from the above that the value of prospective benefits exclusive of energy outweighs the costs by several-fold. This basically justifies the assumptions of "free" gas as was used in the cost analysis for electricity generation above.

This benefit-to-cost ratio is, however, a preliminary estimate. Operational experience is as yet limited. What must also be considered is public perception of bioreactors, and perceived or real environmental impact. Any serious environmental mishap would set back bioreactors' implementation, and it must be shown that bioreactors can be operated with confidence by typical landfill operators without creating environmental problems. In a heavily regulated situation such as waste landfilling where control is as tight as it is, the benefits must be well-established with extensive operating experience. All RD&D operations must be cautious and carefully thought out and run

5.6 Effect of New Regulations

The recently implemented U.S. EPA Bioreactor Landfill Research, Development and Demonstration (RD & D) rule allows and facilitates large-scale landfill testing of bioreactors for energy production and their other benefits noted above. This testing will occur under auspices and regulations of individual U.S. states. U.S. EPA rules permitting bioreactors are in the

process of adoption by California (after nearly a decade of bioreactor related discussions by Yolo Staff with the California Integrated Waste Management Board, CIWMB, and the help to the Yolo team of Waste Board staff). The Yolo County findings and the long trail of ongoing negotiations and discussions by Yolo team members with waste board members are proving extremely valuable to the advancement of bioreactors in California.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

With the initial construction phase of the project completed for the northeast and west side anaerobic cells, Yolo County has gained valuable knowledge about the design and operation of bioreactor landfills. The following sections provide major conclusions and a summary of recommendations for future bioreactor operation and areas that require additional research.

The 9,000-ton pilot-scale cell continues to show that bioreactors can provide projected energy, environmental (greenhouse gas reduction) benefits, and waste management benefits. Methane enhancement has proven to be manageable and highly controllable in the demonstration. The full-scale cells are confirming the same benefits on larger scale.

The objectives were stated on pages 20 and 21 of this report as:

1. Acceleration of waste decomposition and leachate treatment, via liquid amendments and recirculation of leachate via a pipe network serving the waste mass. This was to be done while showing that recirculation could be accomplished without excessive leachate head build-up over the base liner. The ultimate objective was to accomplish rapid completion of composting, stabilization and generation of methane to the maximum practical yield.

2. Efficient capture of nearly all generated methane, by withdrawing at slight vacuum from a freely gas-permeable shredded tires collection layer beneath low-permeability cover. The withdrawal was to be accomplished with negligible impact to the local air quality.

3. Document the capital and operations cost of a full-scale bioreactor and determine the economic viability of its commercialization.

4. Establish these environmental and renewable energy benefits to facilitate regulatory acceptance.

The results of the objectives were:

1. The acceleration of decomposition was shown in Figure 16 in Section 3.6.2. There has been, at minimum, a 4-fold increase in the methane recovery rate, with increases up to 7-fold, depending on the time from filling/startup at which recovery was compared with conventional operation.

2. The efficient capture was documented by surface scanning as seen in Table 5, Section 3.7.1, Table 6, Section 3.7.2 and Table 7, Section 3.7.3. The data of these tables are supported by Figures 43 through 45 of Appendix B. This showed averaged surface emissions to be under 1/50 of the allowable standard of 500 ppm. In many cases, surface emissions were undetectable.

3. The capital and operating costs were documented in section 6 above. From a purely economic standpoint, commercialization is attractive. Public acceptance is developing and long-term performance remains to be established.

6.2 Conclusions on Other Issues

6.2.1 Stability Analysis

Based on the stability analysis performed for the YCCL, it is likely that other landfills could construct and operate a bioreactor module with an acceptable factor of safety. We would recommend any landfill operator perform a site-specific slope stability analysis prior to considering bioreactor operation.

Early recovery of the landfill gas being generated by the northeast cell was possible because the landfill gas collection system (horizontal gas collection lines) were installed during waste placement and subsequently connected to the site gas collection system shortly after completion of waste placement. In addition, the placement of the synthetic surface liner has ensured near complete capture of the landfill gas that was being generated.

6.2.2 Staging And Sequencing Of Controlled Landfill Operations

Early installation of a landfill gas collection system and subsequent gas collection could significantly reduce fugitive emissions in addition to increasing the opportunity for power generation.

6.2.3 Exploration Of Alternative Cover And Surface Biofilter

Because the early installation of a membrane cover represented a significant capital outlay, an area for future research should involve the trial operation of a bioreactor module that is without a synthetic cover. The purpose of this research would be to determine if surface emissions could be controlled with an active gas collection system without the presence of a synthetic cover. A possible alternative that would require demonstration would be the inclusion of a relatively thick layer of greenwaste or compost over the entire module that could act as a natural biofilter for possible fugitive emissions.

Based on the findings of this project, it is recommended that research on both of these areas, alternate covers that allow high control of gas emissions, and use of a biocover to further mitigate emissions be continued.

6.2.4 Further Options: Landfill Mining

One option that requires further study would be mining and sorting of the waste following aerobic and/or anaerobic decomposition. One attractive option for appropriately reclaimed waste that adds no net volume to the landfill would be used in place of other cover that does occupy volume. Such use of reclaimed waste can further reduce use and extend life of landfills. The further benefit from use of reclaimed waste is in facilitating moisture addition. The moisture addition necessary to enhance methane generation can be relatively slow. Care and slow addition are required to avoid seeps, and in general moisture addition to enhance methane remains incompletely understood. The full-scale test results so far suggest that deeper, better compacted cells may require less liquid per ton of filled waste, because of lower void (i.e. pore

volume) fraction and other factors. It appears likely that standard, low permeability daily cover soils should be avoided because they may impede liquid addition and cause side seeps. Instead, if possible, porous greenwaste, removable tarps, or the mined and separated residual waste fines from old cells could be used for daily cover instead.

6.2.5 Moisture Addition

Moisture addition is manageable with a degree of care that should be possible at most landfills. Work associated with moisture addition was fairly straightforward whether moisture was added to the top of landfilled waste or at multiple levels in the full-scale cells.

6.2.6 Energy Balance

Energy balance of a full-scale bioreactor showed that the extra energy required to operate the bioreactor amounted to less than 1% of the incremental added methane energy obtained. The bioreactor was better than any alternative waste-to-energy technology in terms of minimal parasitic energy.

6.2.7 Sensors and SCADA

Yolo's network of moisture, temperature, pressure and other key sensors were linked to commercially available data acquisition and logging equipment and software. This linkage has been highly successful. Yolo's unique and advanced system was custom constructed, but Yolo's experience showed that this type of sensor and datalogging arrangement can be set up where bioreactors are implemented elsewhere. Such a system greatly eases the tasks of both tracking and controlling the bioreactor's operation.

6.3 Commercialization Potential

The controlled landfill or accelerated anaerobic composting, as conducted at Yolo, should have excellent commercialization potential. At the same time it needs to be appreciated that there are several necessary steps along the way. The following is a general overview of factors affecting commercialization, and activities to date on behalf of commercialization.

6.3.1 Yolo Team Efforts Toward Commercialization

Over the past decade, Yolo County project team members have had central roles, carrying out several activities aside from the experimental work to help advance and realize the potential of the bioreactor. These activities include:

1. Working through SWANA to develop a white paper on bioreactor benefits.

2. Cooperating with regulatory agencies to modify rules to allow bioreactors. Ramin Yazdani, Don Augenstein and John Pacey and other Yolo staff have all promoted the cause of bioreactors via U.S. EPA's Project XL and other avenues. This has resulted via an involved, and several steps process, in the issuance of EPA draft and final rules (RD&D rules) in the United States' Federal Register allowing bioreactor implementation across the U.S. Similar rules have been issued for California and will be finalized this year.

3. Presenting papers at major conferences, particularly the Solid Waste Association of North America (SWANA) and also worldwide (U.S. EPA and Department of Energy climate and renewable conferences in China and Russia) for the recent years. It should be of interest

that these international conferences were cosponsored by the U.S. Department of Energy and U.S. EPA, with Russia and Chinese counterparts. These have increased appreciation of the bioreactor's possible benefits.

4. Sharing project data and providing information on environmental benefits, and on how environmental risks may be mitigated by approaches that are being demonstrated.

5. Assisting California Energy Commission in the review of other projects in California.

6.3.2 Yolo Team Collaborations

In short, the project team members have been doing a range of necessary things, although not direct marketing. In some ways the bioreactor is self-selling to most landfill operators provided volume reduction can be realized. The use of membrane cover for gas capture, and the minimization of greenhouse emissions is self-selling based on value added from energy capture. The use of cover for better gas capture becomes increasingly attractive as energy prices rise. The fact that Waste Management is pursuing bioreactor technology is other evidence of this. Yet other evidence is provided by the support of bioreactor advancement by the Solid Waste Association of North America, the U.S.'s largest professional association dealing with solid waste issues. Provided a reasonable design basis is available, the expertise is available do design and construct bioreactors.

In terms of coalitions to advance commercialization, IEM and other team members have proposed liaisons with other active entities such as Hydro Geo Chem. These and other entities can move the technology forward. However, realizing maximum energy potential from bioreactors involves intricacies that may not be obvious to outside observers. Aside from the scientific advancement, facilitation requires that regulatory and political hurdles continue to be addressed and the bioreactor merits be emphasized in terms of environmental and energy benefits to California. Such benefits must continue to be emphasized. Bioreactor technology needs help from all involved stakeholders, and not just landfill operators.

6.3.3 Facilitating Interagency Collaboration On Bioreactors

Interagency cooperation can help advance bioreactor energy technology. It would be helpful to use an "environmental balance sheet" to weigh benefits and debts across different agencies' jurisdictions, globally as well as locally, and over the full life cycle of landfilled waste. A particular concern and present barrier appears to be fear of groundwater contamination if liquid is added to landfills. Where liquid and wastewater additions may be desirable, base lining systems may be mandated whose incremental costs to operators may preclude controlled landfilling and its benefits. This will depend on the location of the landfill and the State Water Control Board and Regional Water Quality Control Boards requirement for liner system for all Class III landfills in California. In the recent years there has been discussion about requiring double liner system for all Class III landfills in California. Yet, reduced pollutant loads in conjunction with hydraulic analyses show risks might well be reduced with bioreactors. It seems likely that conventional dry tomb landfills could pose greater threats, particularly over the longer term.

6.3.4 Facilitating Intercomparison Of Waste Management And Waste To Electricity/ Fuels Options For Waste Management Jurisdictions

Another issue is comparison of the controlled landfill with other waste management to energy alternatives that might ultimately be permitted in California. For example other MSW to methane conversion approaches are often claimed to be superior to variants of the bioreactor landfill. However careful analysis of the dominant alternative, MSW to methane in vessels, shows a host of barriers, including kinetic limitations to conversion in the allowable vessel retention times, high parasitic energy use, economics, and (even) very serious but little recognized environmental impacts that are not present with bioreactors. The same kinds of limitations also occur with other waste-to-energy conversion processes including (for examples) MSW to alcohol conversions and gasification. Aerobic composting is widely favored by a number of entities in California. Yet aerobic composting lacks necessary markets and incentives for the compost, particularly compost from dirty mixed wastes, and has much less renewable energy and greenhouse benefit. The only realistic alternative that is widely proven is MSW combustion. The near term prospects for implementation of combustion technology in California are non-existent.

6.3.5 Describing Advantages Of Waste To Electricity/Fuels Options For Waste Management Jurisdictions And Advantages In Light Of California's Needs

Aerobic composting is widely favored by a number of entities and environmental groups in California. Yet, aerobic composting lacks necessary markets and incentives for the compost, particularly compost from "dirty" mixed wastes, and has much less renewable energy and greenhouse benefits. The only realistic alternative that is widely proven is MSW combustion. The near term prospects for implementation of combustion technology in California are non-existent. Thus, the advantages to the controlled landfill or accelerated anaerobic composting bioreactor must continue to be pointed out to the range of stakeholders.

6.3.6 Addressing Remaining Barriers--Emissions Associated With Electric Generation

Other barriers exist for electric fueling uses of landfill gas. Various prime movers that might be fueled by landfill gas encounter somewhat differing barriers. For many otherwise attractive prime movers, particularly internal combustion engines, the barriers are posed by nitrogen oxide emissions that may be above statutory limits. At least so far, catalytic converters do not have sufficient life in the presence of exhaust from engines run on LFG. This is because of attack by hydrogen chloride from halocarbons. Though very low in quantity, any hydrogen chloride in exhaust gas attacks the catalysts that are satisfactory with most stationary or vehicle piston engines. For gas turbines and microturbines, silica from combustion of siloxanes also plates out on catalysts, and fouls turbines. Solutions can be identified in principle, and these barriers can be overcome. In fact aside from the emission problems, the history of LFG fueled piston engines has been excellent at landfills. The emissions issues are considered by the project team to be solvable, and university work has been progressing on exhaust gas remediation, but the necessary research, though underway, is incomplete.

6.3.7 Emphasizing Bioreactor's Other Benefits

Some other drivers strongly favoring bioreactors are California's newly active climate change mitigation initiative that favors Yolo's approach that maximizes mitigation of landfills' greenhouse gases. There are also looming long-term limitations that may constrain California's

natural gas supply that fuels the majority of its "swing" electricity (the "swing" electricity is the extra over "must run" nuclear, hydro wind, and geothermal, etc.) that is all natural gas fueled. It includes a high fraction of peaking electricity.

Fortunately, the State of California is now recognizing greenhouse benefits, both from abating methane emission, and also the landfill gas use offsets of fossil fuel combustion that would otherwise occur. Further information on California's climate change advisory committee can be found at http://www.energy.ca.gov/global_climate_change/.

Given that about 70% of California's electricity is fueled by natural gas, the derivation of an estimated 1% or more added power from landfill gas would be welcome. Thus, the critical engineering, technical and reliability issues are being addressed by Yolo's work. It is felt by the project team that the engineering of bioreactors is part of a bigger picture containing the ancillary issues such as regulatory facilitation and defining what is adequate emissions compliance.

These are but a few of the considerations aside from technical feasibility and economics that will determine progress toward future wide commercialization. The sorts of regulatory issues mentioned cannot be addressed from narrow perspectives. Rather, they must be addressed by carefully evaluating and summing the widest possible range of impacts from environmental and other standpoints, over the full and post-closure "life cycle" of landfills.

6.4 Benefits to California

A large number of benefits are possible from bioreactors, for the State of California. The benefits lie in such areas as the betterment of waste management and landfilling, reduction of environmental impacts, economics, and yet other areas. The following summarizes some of the energy, environmental benefits and benefits to the state's economy.

6.4.1 Energy Benefits

The potential added renewable energy benefits to California depend on assumptions but are in any case, quite significant. We can make some estimates based on the following assumptions:

California waste pro-rated on population = 22.5 million tons/year (based on CIWMB statistics, 45 million tons, less 50% diversion).

Controlled landfilling applied to 70% of waste in California or to 15.75 million tons/year.

Methane yield = 3000 ft^3/ton of waste (Vogt and Augenstein, 19-landfill survey, 1997 as well as Yolo results). With predictable availability, 90% of methane converted to electricity at 11 ft^3 CH_4/kWh to give time-average power generation of about 500 MWe. Present California Generation is about 75% of a nameplate 240 MWe, or 180 MWe.

Thus, the additional power made available is about 300 MWe. Although this is only around 1% of California electricity generation, this is enough power for 250,000-300,000 Californians.

6.4.2 Greeenhouse Emission Abatement

We assume that the control of California generated methane from 22.5 million tons of waste increases from 70% to 95%. At the accepted Intergovernmental Panel on Climate Change (IPCC), 20-fold equivalence of methane to carbon dioxide, reduction of methane emissions by

2400 ft^3 equates to a reduction of CO_2 emissions by 1 ton. The decreased CO_2 equivalent emission by this example would be 7 million tons/year.

More greenhouse benefit comes from the CO_2 equivalent emission reduction; in other terms the fossil CO_2 offset of the methane fueled electricity. Here we note an aspect of energy that does not seem well recognized. In electricity generation, certain power sources including hydro, wind, and nuclear are must run, fixed at the maximum level afforded by the source. Consequently, the "swing fuel" for extra power generated "at the margin" is all fossil. Depending on the mix of displaced fossil oil or gas, the CO_2 abated by renewable methane is about 0.75 tons/MWh generated. Assuming the 300 MWe time-average above for a year, another 2 million tons of fossil CO_2 emission would be prevented.

6.4.3 Air Pollution Emission Abatement

Landfill gas contains roughly 1000 ppm of volatile organic compounds (using the EPA convention of expression as hexane) in addition to CO_2 and CH_4. This is about 0.7 grams of local air pollutant or volatile organic compounds (VOCs) per cubic foot. It is assumed, as above, that there is the abatement of an additional 1.68 x 1010 ft^3 of methane, or 3.36 x 1010 ft^3 of 50% methane landfill gas. At this loading of VOCs, the VOC (local air pollutant) abatement for California would be slightly in excess of 10,000 tons. Reduction of VOCs by this amount would provide a significant improvement in local air quality in the vicinity of landfills.

6.4.4 Employment and Economic Benefits

Just as do nations, states including California run a "balance of payments". The balance of payment is important in various ways to the state economy. The realization of 300 MWe time average of extra power, annually, at 10,000 Btu saved per renewably fueled kWh, would reduce the need for about 30 trillion Btu's or 30 million million Btu's (in common U.S. energy usage). At a rather conservative cost these days for the swing fuel energy of $5/million Btu's, this amount of extra power and associated fuel savings would keep an extra $150 million a year in the state's economy. Still more benefit not quantified here, comes from the fact that associated payroll and employment for the power generation is kept within the state.

An accepted economic correlation for money brought into an economy in the form of payrolls, or kept in the economy via savings on payment out of state for energy, is that each $1 in income/savings translates to $3 in personal income. Thus, the retention of energy dollars in the state's economy should mean the addition of over $400 million in personal income annually in California. Though this analysis is rather simplified, bioreactors can help increase personal income in the state by several hundred million dollars annually. In the most basic terms, bioreactor operation in California can help promote economic activity in California.

6.4.5 Landfill Life Extension

A rough estimate of landfill life extension is possible by assuming that about 15% more waste can be filled because of the now well-established waste "shrinkage". This means that given landfills can operate 15% longer. An alternative way of looking at the benefit is that five landfills of a particular size would be needed, whereas six such landfills would be needed with conventional operation.

6.5 Recommendations

The following are some recommendations considered important by the project team:

1. Continue monitoring full-scale operations to give the type of long-term performance information that is desirable to advance the technology. Bioreactor landfill operational assessments require extremely long times, beyond the typical time span of contracts issued by sponsoring agencies. A typical contract period is of the order of 3 years. Several promising projects elsewhere have been halted when funding ran out. However, information of great value will come at long terms, and continues to come from the initial Yolo pilot-scale cell as its operation continues in its eighth year.

2. Full-scale bioreactor operation and monitoring for long terms will give necessary information on reliability, long-term management requirements and key performance parameters that are not obtainable in any other way. Performance parameters include (but are not limited to) normalized methane energy recovery, emissions reductions (as determined by surface scans and other means) volume reduction, moisture management parameters and head over liner, the ultimate time required and other performance parameters as amply documented above. One very important long-term determination will be finding out the long-term stabilization performance-what to expect once the landfilled waste has produced most of its methane.

3. Gain experience in dealing with problems. To date, the problems (which are considered solvable) relate to leachate seeps, better controlling gas recovery, and maintenance of containment. Other problems relate to equipment fouling by precipitates.

4. Continue to demonstrate the reliability and predictability necessary to provide confidence in benefits to future users of the controlled landfill energy technology.

5. In future projects, explore alternative gas collection methods that do not require expensive geomembrane.

6. In future projects explore the use of more permeable alternative daily cover (ADC) that would allow easier liquid infiltration and lessen events such as side seeps.

7. Conduct additional gas tracer tests to determine the moisture content of the waste over time.

8. In combination of computer modeling and field tests determine the best strategy for air and leachate injection in the aerobic landfill.

9. Operate the aerobic landfill and conduct additional emissions testing on the biofilter to determine the best operational strategies for reduction of methane emissions.

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APPENDIX A - TABLES

Table 1. Sonoma county project design

Cell	Initial Water Addition	Continuing WaterAddition (gal/d)	Leachate Recirculation (gal/d)
A	None, Project Control	none	none
B	Brought to Field capacity, with 41,000 gallons of water	none	none
C	none	200-1000	none
D	none	none	500-1000
E	Brought to Field capacity, with 27,200 gallons of septic tank pumpings	none	none

Table 2. Mountain view project design

Cell	Water	Sludge	Buffer	Leachate Recirculation
A	Field capacity Added 458,000 gallons	X	X	X
B	none	X	X	no
C	Field capacity Added 451,110 gallons	X	X	no
D	Below field capacity Added 69,640 gallons		X	no
E	Below field capacity Added 63,100 gallons	X	X	no
F	None, project control	no	no	no

Table 3. Summary of Mountain View project results

Cell[1]	Moisture Content (%)	Landfill Gas Volume at day 1597 (100,000 ft^3)	Volitile Solids Content (%)	Biochemical Methane Potential (scf CH_4/lb dry refuse)	Cellulose (%)	Lignin (%)	Carbon to Nitrogen Ratio	Carbon to Phosphorus Ratio
A	69	111	32	0.35	16	13	13:1	6593:1
B	54	97	43	1.57	26	14	20:1	945:1
D	33	264	51	1.93	33	14	26:1	1345:1
F (control)	40	223	44	1.48	27	14	27:1	1169:1

Table adopted from Reinhart

1. Cells C and E were not analyzed for Biochemical Methane Potential, therefore they are not presented in this table.

Table 4. Summary of Brogborough project results

Cell	Enhancement Technique	Refuse (ton)	Volume Landfill Gas (m^3/t/d)
1	Project Control	15,130	0.0159
2	Low density waste placement	13,980	0.0132
3	Water addition and leachate recycling	14,270	0.0118
4	Air injection system in place	14,400	0.0184
5	Sewage sludge addition plus supply of water	16,870	0.0192
6	Commercial and industrial waste addition	14,980	0.0205

Table 5. Waste Management operations at Louisville, Kentucky Outer Loop site

Cell Description	Tonnage or Cubic yards	Liquids and aeration	Overall Procedure
5.1A FLB	Appx 484,000 tons	Liquid: with NO2/NO3 (nitrified) leachate	Enhancement by nitrified leachate (no aeration)
5-2B FLB (5-1A duplicate	Appx 484,000 tons	Liquid: with NO2/NO3 (nitrified) leachate	Enhancement by nitrified leachate (no aeration
5-1B FLB	Appx 484,000 tons	Liquid: with NO2/NO3 (nitrified) leachate	Enhancement by nitrified leachate (no aeration
5-2A (5-1B duplicate)	Appx 484,000 tons	Liquid: with NO2/NO3 (nitrified) leachate	Enhancement by nitrified leachate (no aeration
7-3A (control)	822,000 cubic yards 6/03	None: No liquid No aeration	"conventional" operation to serve as control
7-3B	692,000 cubic yards 6/03	None: No liquid No aeration	"conventional" operation to serve as control
7-4-A	Being filled Over 500,000 tons	Intermittent aeration 6/18/02 to 3/27/03	Aeration through 3/27/03 then liquid
7-4B (7-4A duplicate)	Being filled Over 500,000 tons	Intermittent aeration 6/18/02 to 3/27/03	Aeration through 3/27/03 then liquid

Table 6. Summary of sensors for the anaerobic bioreactor cells

Type of Instrumentation	FPA Proposed Location/Quantity/Spacing	Northeast Anaerobic Cell Actual Location/Quantity/Spacing	West-Side Anaerobic Cell Actual Location/Quantity/Spacing
Bubbler Gage for Liquid/Gas Pressure Measurement and Liquid/Gas Sampling	1. Top of the first lift of waste- 55 gages 2. Top of the second lift of waste-40 gages 3. Top of the third lift of waste-30 gages 4. Top of the final lift of waste-20 gages TOTAL= 145 gages	1. Top of the first lift of waste- 15 gages at 75 ft spacing 2. Top of the second lift of waste-13 gages at 75 ft spacing 3. Top of the third lift of waste- 13 gages at 75 ft spacing 4. Top of the final lift of waste- no gages TOTAL= 41 gages	1. Top of the first lift of waste- 6 gages at various spacing 2. Top of the second lift of waste-7 gages at various spacings 3. Top of the third lift of waste- no gages 4. Top of the final lift of waste- no gages TOTAL= 13
Moisture and Temperature Sensors	1. Top of the first lift of waste-55 temperature and moisture sensors 2. Top of the second lift of waste-40 temperature and moisture sensors 3. Top of the third lift of waste-30 temperature and moisture sensors 4. Top of the final lift of waste-20 temperature sensors TOTAL= 145 temperature sensors and 125 moisture sensors	1. Top of the first lift of waste-18 temperature and 18 moisture sensors at 75 ft spacing 2. Top of the second lift of waste-16 temperature and 39 moisture sensors at 75 ft spacing 3. Top of the third lift of waste-13 temperature and 13 moisture sensors at 75 ft spacing 4. Top of the final lift of waste- no sensors TOTAL= 47 temperature sensors and 70 moisture sensors	1. Top of the first lift of waste-6 temperature and 6 moisture sensors at various spacings 2. Top of the second lift of waste-43 temperature and 43 moisture sensors at various spacings 3. Top of the third lift of waste-14 temperature and 14 moisture sensors at various spacings 4. Top of the final lift of waste- no sensors TOTAL= 63 temperature sensors and 63 moisture sensors

Because the original project was altered from constructing one 9.5-acre anaerobic cell to constructing two anaerobic cells, one occupying 6-acres and one occupying 3.5-acres, waste placement area was lost in the valley separating the two anaerobic cells. This resulted in the installation of fewer sensors over the 9.5-acre area than initially proposed.

Table 7. Summary of sensors for the southeast bioreactor cell

Type of Instrumentation	FPA Proposed Location/Quantity/Spacing	Aerobic Cell Actual Location/Quantity/Spacing
Pressure Transducers	1. Two over the primary liner at 200 ft spacing 2. One within the leachate collection sump	1. Two over the primary liner at 200 ft spacing 2. One within the leachate collection sump
Bubbler Gage for Liquid/Gas Pressure Measurement and Liquid/Gas Sampling	1. Top of the aerobic bottom liner-48 gages at 50 ft spacing 2. Top of the first lift of waste- 24 gages 3. Top of the second lift of waste-20 gages 4. Top of the final lift of waste-20 gages TOTAL= 112 gages	1. Top of the aerobic bottom liner-12 gages at 75 ft spacing 2. Top of the first lift of waste- 26 gages 3. Top of the second lift of waste- 16 gages 4. Top of the final lift of waste- no gages TOTAL= 54 gages
Moisture and Temperature Sensors	1. Top of the aerobic bottom liner-48 temperature and 12 moisture sensors 2. Between bottom liner and the top of the first lift of waste- no sensors 3. Top of the first lift of waste- 24 temperature and moisture sensors 4. Top of the second lift of waste-20 temperature and moisture sensors 5. Top of the final lift of waste-20 temperature and moisture sensors	1. Top of the aerobic bottom liner-12 temperature and 2 moisture sensors at 75 ft spacing 2. Between bottom liner and the top of the first lift of waste- 3 temperature sensors and 3 moisture sensors at various spacings. 3. Top of the first lift of waste- 26 temperature and 26 moisture sensors at various spacings 4. Top of the second lift of waste-18 temperature and 21 moisture sensors at various spacings 5. Top of the final lift of waste-no temperature or moisture sensors
	TOTAL= 112 temperature sensors and 76 moisture sensors	TOTAL= 59 temperature sensors and 52 moisture sensors

Table 8. Summary of sensors for Module 6D base liner

Type of Instrumentation	FPA Proposed Location/Quantity/Spacing	Module 6D Base Liner Actual Location/Quantity/Spacing
Pressure Transducer	1. Eight over the primary liner near the LCRS trench at 200 ft spacing 2. Two over the primary liner within the leachate collection sumps	1. Six over the primary liner at 200 ft spacing (three near the west LCRS and three near the east LCRS) 2. Four over the primary liner within the leachate collection sumps
Bubbler Gage for Liquid/Gas Pressure Measurement and Liquid/Gas Sampling	Top of primary bottom liner-66 gages at 75 ft spacing	Top of primary bottom liner-66 gages at 75 ft spacing
Moisture and Temperature Sensors	Top of primary bottom liner-66 temperature sensors at 75 ft spacing and 12 moisture sensors	Top of primary bottom liner-66 temperature sensors at 75 ft spacing and 12 moisture sensors

Table 9. Summary of gas collection lines for the northeast cell

Gas Collection Line[1]	Description	Spacing
1-G1	Alternating 4 and 6-inch schedule 80 PVC[2].	50′ from west toe
1-G2	Shredded tires with pipe at ends. The north end is 40 ft of schedule 40 PVC with a 10-ft section of 3-inch perforated schedule 80 PVC. The south end is 40 ft of 4-inch schedule 80 PVC, 5 ft of 3-inch schedule 80 PVC, and 10 ft of perforated HDPE.	40′ from 1-G1-NE
1-G3	Alternating 4 and 6-inch schedule 80 PVC.	40′ from 1-G2-NE
1-G4	Shredded tires with PVC pipe at ends. The south end is 40 ft of 4-inch schedule 80 PVC and 10 ft of 6-inch schedule 80 PVC. The north end is 40 ft of 4-inch schedule 40 PVC.	40′ from 1-G3-NE
1-G5	Shredded tires with PVC pipes at ends. The south end is 40 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, 20 ft of 4-inch schedule 80 PVC, and 5 ft of 24 inch corrugated HDPE. The north end is 40 ft of 4-inch schedule 40 PVC.	40′ from 1-G4-NE
1-G6	Shredded tires with PVC pipes at ends. The south end is 40 ft of 4-inch schedule 80 PVC, 20 ft of 3-inch perforated schedule 80 PVC, 10 ft of 6-inch schedule 80, and 20 ft of 3-inch perforated schedule 80 PVC. The north end is 40 ft of 4-inch schedule 40 PVC.	40′ from 1-G5-NE
2-G1	Shredded tires with PVC pipes at ends. The south end is 40 ft of 4-inch schedule 80, 10 ft of 6-inch schedule 80, and 10 ft of 4-inch schedule 80 PVC. The north end is 40 ft of 4-inch schedule 40 PVC.	30′ from West toe
2-G2	Alternating 4 and 6-inch schedule 80 PVC pipe for the entire length with 40 ft of 4-inch at the north and south end.	40′ from 2-G1-NE
2-G3	Shredded tires with PVC pipe at the ends. The north end is 40 ft of 4-inch schedule 40 PVC. The south end 40 ft of 4- inch schedule 80 PVC, 20 ft of 3-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, and 20 ft 3-inch perforated schedule 80 PVC.	40′ from 2-G2-NE
2-G4	Alternating 6 and 3-inch schedule 80 PVC pipe. The south end is 4-inch schedule 80 PVC and the north end is 4-inch schedule 40 PVC.	40′ from 2-G3-NE
2-G5	Shredded tires with pipe at the ends. The north end is 40 ft of 4-inch schedule 40 PVC. The south end is 40 ft of 4-inch schedule 80 PVC, 20 ft of 3-inch schedule 80 PVC, 20 ft of 4-inch schedule 80 PVC, and 10 ft of 12-inch corrugated HDPE[3].	40′ from 2-G4-NE
3-G1	Shredded tires with PVC pipe at the ends. The north end is 40 ft of 4-inch schedule 40 PVC. The south end is 40 ft 4- inch schedule 80 and 20 ft of 8-inch schedule 40.	45′ from west toe
3-G2	Shredded tires with PVC pipe at the ends. The north end is 40 ft of 4-inch schedule 40 VC. The south end is 40 ft of 4-inch schedule 80 PVC, 20 ft of 8-inch HDPE, and 40 ft of 6-inch HDPE.	45′ from 3-G1-NE
3-G3	Shredded tires with PVC pipe at the ends. The north end is 40 ft of 4-inch schedule 40 PVC. The south end is 40 ft of 4-inch schedule 80 PVC, 20 ft of 6-inch schedule 40 PVC, and 10 ft of 12-inch corrugated HDPE.	35′ from 3-G2-NE

[1]Gas Collection Line Nomenclature: Layer # - G (for gas) and gas line #
[2]Polyvinyl chloride, PVC
[3]High Density Polyethylene, HDPE

Table 10. Summary of gas collection lines for the west-side cell

Gas Collection Line[1]	Description	Spacing
2-G1	Shredded tires with pipe at ends. The east end is 45 ft of 4-inch schedule 80 PVC[2], 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC. The west end is 50 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC.	80′ from 2-G2
2-G2	Shredded tires with pipe at ends. The east end is 40 ft of 4-inch schedule 40 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC. The west end is 40 ft of 4-inch schedule 40 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC.	80′from 2-G3
2-G3	Shredded tires with pipe on ends. The east and west ends are 40 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, 10 ft of 4 inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC.	80′ from 2-G4
2-G4	Shredded tires with pipe on ends. The east end is 20 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, 10 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC. The west end is 20 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, 10 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, 10 ft of 4-inch schedule 80 PVC, and 20 ft of 24-inch corrugated metal pipe.	80′ from 2-G5
2-G5	Alternating 10-ft lengths of 4 inch schedule 40 electrical conduit and 6 inch corrugated metal. The east end is 40 ft of 4-inch schedule 40 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC. The west end is 40 ft of schedule 80 PVC and 10 ft of 6-inch schedule 40 electrical conduit.	80′from 2-G6
2-G6	Shredded tires with pipe at ends. The east end is 40 ft of 4-inch schedule 40 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC. The west end is 40 ft of 4-inch schedule 40 PVC, 10 ft of 12-inch schedule 40 PVC, 10 ft of 4-inch schedule 80 PVC, 10 ft of 12-inch schedule 40 PVC, and 10 ft of 4-inch schedule 80 PVC.	80′ from 2-G7
2-G7	Shredded tires with pipe on ends. The east end is 40 ft of 4-inch schedule 40 PVC, 10 ft of 6-inch schedule 80 PVC, and 10 ft of 4-inch schedule 80 PVC. The west end is 40 ft of 4-inch schedule 80 PVC, 10 ft of 6-inch schedule 80 PVC, and six sets of alternating 10-ft lengths of 4-inch schedule 80 PVC telescoped with 12-inch schedule 40 PVC.	80′from 2-G8
2-G8	Same as 2-G2	80′ from 2-G9
2-G9	Same as 2-G2	40′from south toe
3-G1	Shredded tires with pipe on west end. No pipe on east end. The west end is 40 ft of 4-inch schedule 80 PVC, and three sets of alternating 10-ft lengths of 6-inch schedule 80 PVC telescoped with 4-inch schedule 80 PVC.	80′ from 3-G2
3-G2	Same as 3-G1	80′ from 3-G3
3-G3	Same as 3-G1	80′ from 3-G4
3-G4	Same as 3-G1	80′ from 3-G5
3-G5	Same as 3-G1	80′ from 3-G6
3-G6	Shredded tires with pipe on west end. No pipe on east end. The west end is 50 ft of 4-inch schedule 80 PVC, and 60 ft of alternating 10-ft lengths of 6-inch and 4-inch schedule 80 PVC.	80′ from 3-G7
3-G7	Same as 3-G1	40′ from south toe
4-G1	Shredded tires with pipe on ends. The north and south ends are 3 sets of alternating 10-ft lengths of 6-inch schedule 80 PVC and 6-inch schedule 40 PVC, and one additional 10-ft length of 6-inch schedule 80 PVC.	40′ from south toe
4-G2	Same as 4-G1	50′ from 4-G1

[1]Gas Collection Line Nomenclature: Layer #-G (for gas) and line #

[2]Polyvinyl

Table 11. Summary of Air Collection Lines for the Southeast Aerobic Cell

Air Collection Line[1]	Description	Spacing
1-A1	Alternating 10 ft lengths of 4 and 6 inch schedule 80 CPVC[2].	30’ from west toe
1-A2	Alternating 10 ft lengths of 6 and 8 inch corrugated metal pipe.	40’ from 1-A1-SE
1-A3	Alternating 10 ft lengths of 6 and 8 inch corrugated metal pipe.	40’ from 1-A2-SE
1-A4	Alternating 10 ft lengths of 4 and 6 inch schedule 80 CPVC.	40’ from 1-A3-SE
1-A5	Alternating 10 ft lengths of 6 and 8 inch corrugated metal pipe.	40’ from 1-A4-SE
1-A6	Alternating 10 ft lengths of 4 and 6 inch schedule 80 CPVC.	40’ from 1-A5-SE
2-A1	Alternating 10 ft lengths of 6 and 8 inch corrugated metal pipe.	25’ from west toe
2-A2	Alternating 10 ft lengths of 4 and 6 inch schedule 80 CPVC.	40’ from 2-A1-SE
2-A3	Alternating 10 ft lengths of 6 and 8 inch corrugated metal pipe.	40’ from 2-A2-SE
2-A4	Alternating 10 ft lengths of 4 and 6 inch schedule 80 CPVC.	40’ from 2-A3-SE
2-A5	Alternating 10 ft lengths of 6 and 8 inch corrugated metal pipe.	40’ from 2-A4-SE

Table 12. Itemized list of waste composition

YOLO COUNTY CENTRAL LANDFILL FULL-SCALE BIOREACTOR PROJECT WASTE PLACEMENT SUMMARY			
MATERIAL DESIGNATION	DESCRIPTION	NORTHEAST 3.5 ACRE CELL TONS	WEST 6 ACRE CELL TONS
Bulky Waste	furniture	41.96	122.09
Asphalt Clean	Generally used to construct roads or tipping pads	0.00	261.07
AC Grindings	Generally used to construct roads or tipping pads	0.00	7.72
Bulky Waste Other	stumps, large pieces of concrete, hard to handle items	413.91	1,106.39
Bulky Waste Special	Styrofoam	49.27	237.19
Construction and Demolition	Wood, metal, gypsum wallboard, other construction related material	6,317.56	19,702.68
Concrete Clean	Generally used to construct roads or tipping pads	12.21	166.93
Charitable	Loads received from thrift stores and other charitable organizations - no charge	4.00	13.03
Commercial Load	mainly residential waste from homes and apartments	54,949.88	117,705.18
Clarksburg Load	material from the Clarksburg transfer station	1.03	0.00
Concrete Tile	Generally used to construct roads or tipping pads	10.40	1,921.43
Dirt Clean	Used for intermediate daily cover or roads and tipping pads	1,262.91	15,447.21
Dewatered Sewage	material from waste water treatment plants	0.00	9.93
Esparto Convenience Center	material form the Esparto transfer station	346.14	995.07
Grits & Rags	material from waste water treatment plants	55.25	337.78
Greenwaste	when possible, used as alternative daily cover	0.00	12.27
Inerts Mixed	Generally used to construct roads or tipping pads	111.52	757.83
Metals Trash	non-recyclable material from our metals recycling area	6.58	0.00
Newspaper	Only non-recyclable loads	5.06	6.85
Road Side Trash	Material from roadside litter removal activities	13.34	42.69
Christmas Trees	self explanatory	0.00	17.94
Waste Management Contract Exclusions	non-recyclable material from the greenwaste recycling area	32.11	90.75
Auto	Loads received in automobiles	152.85	228.75
Full Pick-Up	loads received in full-size pick-ups	488.56	4,346.20
Garbage Can	loads received in garbage cans	39.45	115.39
Household	Furniture such as couches, chairs, tables	43.35	212.85
Household	Mattresses and box springs	54.15	239.45
Mini pick-up	Loads received in small pick-ups	692.34	2,189.22
Greenwaste alternative Daily Cover	ground or screened greenwaste used as daily cover	11,059.75	27,557.69
TOTAL WASTE AND GREENWASTE ALTERNATIVE DAILY COVER PLACED IN EACH CELL =		76,163.58	193,851.58

Table 13. Field chemistry and analytical results for leachate sampled from the northeast anaerobic cell

TIME PERIOD		Surface cover installed, prior to leachate injection	Begin limited leachate addition for testing		Full-scale leachate addition and recirculation																
PARAMETER	**Date:**	**2/14/2002**	**3/27/2002**	**5/14/2002**	**6/20/2002**	**7/23/2002**	**8/13/2002**	**9/26/2002**	**10/17/2002**	**2/26/2003**	**5/27/2003**	**8/21/2003**	**9/30/2003**	**1/8/2004**	**2/23/2004**	**3/24/2004**	**5/26/2004**	**6/28/2004**	**7/26/2004**	**9/27/2004**	**11/9/2004**	**3/3/2005**
Field Parameters:	**Units**																				
pH		7.13	7.55	7.40	7.60	7.44	7.48	7.47	7.35	8.16	7.02	7.55	7.58	7.56	7.35	7.41	7.53	7.33	7.39	7.31	7.98	7.78
Electrical Conductivity	µS	6583	6173	6095	4054	11510	15860	12440	10230	9351	11990	10650	13710	12120	13180	13400	14460	14660	14850	14840	14110	9924
Oxidation Reduction Potential	mV	-119	-12	80	94	-7	43	-35	-25	160	17	34	75	-28	-79	-531	68	18	11	70	125	-22
Temperature	C	19.9	21.5	25.9	26.5	30.5	30.5	28.4	26.0	23.5	33.3	33.3	34.4	35.5	32.9	34.6	35.0	35.5	36.8	38.3	31.1	28.5
Dissolved Oxygen	mg/L	0.65	2.13	1.4	2.04	0.33	1.31	3.66	2.96	5.56	2.80	3.00	2.94	0.34	0.31	0.28	1.30	0.51	0.18	0.69	1.87	5.59
Total Dissolved Solids	ppm	5244	4860	4059	3062	9740	14050	10770	8640	7850	9978	8673	11440	9946	10950	11280	12280	12470	12660	12580	11880	8062
General Chemistry:																						
Bicarbonate Alkalinity	mg/L	1740	1550	1760	1110	3740	5150	3960	4010	2680	3280	3220	4330	3640	4400	4600	4600	4600	4500	4800	4200	3100
Carbonate Alkalinity	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<10	<10	<5.0	<5.0	<5.0	<5.0	<5.0
Total Alkalinity as CO_3	mg/L	1740	1550	1760	1110	3740	5150	3960	4010	2680	3280	3220	4330	3640	4400	4600	4600	4600	4500	4800	4200	3100
BOD	mg O/L	20	34	19	10	200	490	1400	3000	44	85	66	140	120	150	100	130	150	130	110	<44	770
Chemical Oxygen Demand	mg O/L	633	488	791	196	1620	2820	2830	1810	120	1590	1010	4450*	1710	2200	2000	2700	2800	2700	2900	2600	970
Chloride	mg/L	1070	1100	1030	617	1950	2830	1870	1380	1470	1670	1650	1850	1760	2100	1800	2400	2500	2500	2700	2500	770
Hydroxide	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<10	<10	<5.0	<5.0	<5.0	<5.0	<5.0
Ammonia as N	mg/L	30	24.4	26.3	13.5	131	264	255	289	132	207	158	398	558	280	510	436	618	1420	550	480	140
Nitrate-Nitrite as N	mg/L	<0.03	0.43	<1.5	<0.015	0.061	0.22 (tr)	1.4	<0.009	17.3	13	7.6	0.22(tr)	5	<0.045	<0.045	<0.088	<0.088	<0.088	0.55	2.4 (tr)	1.6 (tr)
Total Kjeldahl Nitrogen	mg/L	53.1	71	40	21.8	201	354	326	358	222	320	271	573	423	320	260	650	560	830	800	460	130
Sulfate	mg/L	322	210	94.3(tr)	256	5.3	8.2(tr)	155	7	315	45.3	243	20.4	169	25	4.0	0.91(tr)	1.8 (tr)	2	68	560	60
Total Dissolved Solids @ 180 C	mg/L	4440	3960	3700	2500	7800	9860	8000	6680	5720	7700	6430	7820	6600	7400	7500	8300	8300	8200	8200	8000	4200
Total (Non-Volatile) Organic Carbon	mg/L	202	147	123	68.8	544	713	943	588	325	490	286	630	473	690	640	760	740	760	890	800	540
Total Phosphorus	mg/L	1.9	1.3	1.1	1.6	1.9	2.7	3.7	3.4	1.8	3.3	1	4.6	4.5	3.7	4.3	6.3	5.3	5.5	5.5	4.8	2.8
Total Sulfide	mg/L	1.3	0.18	1.3	0.74	1.2	2.5	1.1	1.4	0.034 (tr)	0.020 (tr)	<0.0093	<0.046	<0.0093	21	78 (tr)	0.20 (tr)	0.34 (tr)	0.16	0.18 (tr)	0.056 (tr)	0.044 (tr)
BOD/COD	unitless	0.032	0.070	0.024	0.051	0.123	0.174	0.495	1.657	0.367	0.053	0.065	0.031	0.070	0.068	0.050	0.048	0.054	0.048	0.038	0.008	0.794
BOD/TOC	unitless	0.099	0.231	0.154	0.145	0.368	0.687	1.485	5.102	0.135	0.173	0.231	0.222	0.254	0.217	0.156	0.171	0.203	0.171	0.124	0.028	1.426
Carbon/Nitrogen Ratio	unitless	3.804	2.070	3.075	3.156	2.706	2.014	2.893	1.642	1.464	1.531	1.055	1.099	1.118	2.156	2.462	1.169	1.321	0.916	1.113	1.739	4.154
Metals:																						
Dissolved Aluminum	mg/L	0.14 (tr)	<0.043	0.10(tr)	<0.043	0.097(tr)	0.11(tr)	0.058(tr)	0.096 (tr)	0.063 (tr)	0.099 (tr)	0.098 (tr)	0.12 (tr)	0.11 (tr)	<0.40	<0.40	<0.40	<3.0	<0.4	<0.4	<1.0	0.0968 (tr)
Dissolved Antimony	mg/L	0.0022	0.0015(tr)	0.0012(tr)	0.0008(tr)	0.012	<0.031	0.0089	0.0072	0.0072	0.0057	<0.031	0.0055	0.004	0.0054 (tr)	0.0028 (tr)	0.0045 (tr)	0.0046 (tr)	0.0052 (tr)	0.0120 (tr)	0.00636 (tr)	0.00262 (tr)
Dissolved Arsenic	mg/L	0.029	0.026	0.028	0.037	0.054	0.062	0.058	0.062	0.043	0.06	0.046	0.1*	0.049	0.088	0.078	0.095	0.095	0.12	0.0953	0.0884	0.0515
Dissolved Barium	mg/L	0.84	0.56	0.92	0.39	1.6	1.6	2.5	1.7	0.88	1.2	1.1	1.5	1.400	1.300	1.3	1.2	1.4	1.5	1.4	1	0.874
Dissolved Beryllium	mg/L	<0.000078	<0.000078	<0.00078	<0.000078	<0.000078	<0.00009	<0.000078	<0.000078	<0.000078	<0.00039	<0.000090	<0.000078	<0.000078	<0.04	<0.040	<0.040	<0.016	<0.040	<0.040	<0.1	<0.00015
Dissolved Boron	mg/L	7.9	7.1	7.4	NA	12.8	20.1	15.7	11.6	11.1	10.9	NA	13.7	13.7	12	12	11	12	14	14	13	8.11
Dissolved Cadmium	mg/L	<0.000074	<0.000074	<0.000074	<0.000074	<0.000074	<0.0031	<0.000074	<0.000074	0.00018 (tr)	0.00015 (tr)	<0.0031	<0.000074	<0.000074	0.0018 (tr)	0.00094 (tr)	0.00057 (tr)	0.0029	<0.00021	<0.001	<0.0001	<0.0001
Dissolvd Calcium	mg/L	183	137	158	NA	175	92	174	221	114	89.8	126	125*	112	140	130	100	120	120	110	89	94.8
Dissolved Chromium	mg/L	0.036	0.024	0.025	0.0099	0.086	0.075	0.074	0.073	0.071	0.14	0.07	0.11	0.094	0.072	0.084	0.086	<0.27	0.17	0.11	0.1	0.0622
Dissolved Cobalt	mg/L	0.007	0.0058	0.0049	0.0034	0.011	0.014(tr)	0.018	0.016	0.037	0.048	0.028 (tr)	0.041	0.038	0.031	0.028	0.039	0.037	0.047	0.0479 (tr)	0.0447	0.0268
Dissolved Copper	mg/L	0.0054	0.004	0.002	0.0024	0.0052*	0.0043 (tr)	0.0044*	0.0044	0.03*	0.016	0.0053 (tr)	0.0083*	0.0077	0.0058 (tr)	0.0029 (tr)	0.0065 (tr)	0.0076 (tr)	<0.0032	0.0141 (tr)	0.029	0.00382
Dissolved Iron	mg/L	1.1	0.44	0.39	0.19	2.9*	1.8	3.9	4	2.5	2.8	2	2.9	2	0.98	1.4	1.7	<5.1	2	2.9	4.5	2.05
Dissolved Lead	mg/L	0.00046(tr)	0.00016(tr)	0.00020(tr)	<0.000066	0.001	0.0016	0.0011	0.00078 (tr)	0.0014	0.004	0.0015	0.003	0.0021	0.0022 (tr)	<0.00069	0.0031	0.0017 (tr)	0.0051 (tr)	0.00480 (tr)	0.0043 (tr)	0.00081 (tr)
Dissolved Magnesium	mg/L	323	248	262	NA	535	655	480	437	359	265	365	317	294	280	260	230	260	280	250	240	205
Dissolved Manganese	mg/L	4.1	3.2	4.5	2.9	2	0.33	3	0.94	0.68	1.1	0.98	1	1.2	1.2	1.1	0.94	1.1	1.1	0.97	0.75	1.62
Dissolved Mercury	mg/L	<0.000049	<0.000049	<0.000049	<0.000049	<0.000049	0.000081(tr)*	<0.000049	<0.000049	<0.000064	<0.000064	<0.000064	0.000078(tr)*	<0.000064	<0.000025	<0.000025	<0.000025	<0.000025	0.00005 (tr)	<0.000025	<0.000025	0.000157 (tr)
Dissolved Molybdenum	mg/L	0.012(tr)	<0.0046	<0.0046	0.0048(tr)	0.0048 (tr)	<0.0046	<0.0046	<0.0046	0.013 (tr)	0.015 (tr)	NA	0.0094 (tr)	0.011 (tr)	<0.16	<0.16	<0.16	<0.78	<0.16	<0.16	<0.4	<0.003
Dissolved Nickel	mg/L	0.13	0.14	0.13	0.08	0.26	0.3	0.23	0.2	0.38	0.4	0.26	0.29	0.24	0.22	0.19	0.25	0.23	0.29	0.334	0.337	0.183
Dissolved Potassium	mg/L	152	124	133	NA	215	336	319	348	371	372	307	395	405	360	380	410	480	550	560	500	278
Dissolved Phosphorus	mg/L	1.9	0.96	1.9	NA	1.6	2	3.6	2.6	2.1	3.3	NA	4.8	4.5	NA	4.3	4.8	4.7	4.6	4.1	0.072	1.8
Dissolved Selenium	mg/L	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0077	<0.0017	0.002	<0.0017	<0.0017	<0.0085	0.0017 (tr)	0.033	0.036	0.045	0.055	0.07	0.0370 (tr)	0.0256	0.016
Dissolved Silver	mg/L	0.000083 (tr)	0.000031(tr)	<0.00003	<0.00003	0.0002(tr)	<0.0032	0.0001(tr)	0.000061 (tr)	0.000084 (tr)	0.00018 (tr)	<0.0032	0.000086 (tr)	0.000082 (tr)	0.00015 (tr)*	<0.000067	0.00012 (tr)	0.00024	<0.00013	0.00820 (tr)	<0.00008	0.0001 (tr)
Dissolved Sodium	mg/L	875	774	759	NA	1370	2340	1820	1330	1440*	1410	1470	<0.036	1550	1500	1500	1400	1800	1900	1700	1800	1100
Dissolved Thallium	mg/L	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.0034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.000034	<0.000017	<0.000017	<0.000017	0.00089 (tr)	<0.0008	<0.00008	<0.00008
Dissolved Tin	mg/L	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	0.0062 (tr)	0.058 (tr)	0.032 (tr)	0.034 (tr)	0.025 (tr)	<0.066	<0.033	<0.033	0.047 (tr)	<0.033	<0.0120	<0.012	<0.012
Dissolved Vanadium	mg/L	0.059	0.03(tr)	0.031(tr)	0.013(tr)	0.21	0.1	0.071	0.054	0.061	0.093	0.072	0.086	0.051	<0.16	<0.16	<0.16	<0.18	<0.16	<0.16	<0.4	0.0489
Dissolved Zinc	mg/L	0.032	0.034	0.035	0.015	0.13(tr)	0.13	0.17	0.13	0.15	0.14	0.038	0.11	0.11	<0.04	<0.040	<0.040	1 (tr)	0.063	0.058	<0.1	<0.0016
Volatile Organic Compounds:																						
Acetone	µg/L	16	10	6.4	6.9	170*	1500 (tr)	2300	650	49	39	33 (tr)	<1.0	23	10	26	23	39	36 (tr)	44 (tr)	25	< 120
Acrylonitrile	µg/L	<10	<10	<10	<10	<50	<100	<1000	<200	<20	<20	<32	<10	<10	NA	<1.3	<1.3	1.1 (tr)	<1.3	<1.3	<0.26	< 0.26
Benzene	µg/L	<0.13	0.28 (tr)*	0.22(tr)	<0.13	<0.65	<1.3	<13	<2.6	0.36 (tr)	1.1 (tr)	<2.2	1.2	0.59 (tr)	2.8	2.2 (tr)	3.1	3.2	<1.4	2.8 (tr)	0.48 (tr)	0.39 (tr)
Bromobenzene	µg/L	<0.18	<0.18	<0.18	<0.18	<0.90	NA	<18	<3.6	<0.36	<0.36	NA	<0.18	<0.18	<0.39	<2.0	<2.0	<0.39	<2.0	<2.0	<0.39	< 0.39
Bromochloromethane	µg/L	<0.31	<0.31	<0.31	<0.31	<1.6	<3.1	<31	<6.2	<0.62	<0.62	<2.0	<0.31	<0.31	<0.42	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
Bromodichloromethane	µg/L	<0.14	<0.14	<0.14	<0.14	<0.70	<1.4	<14	<2.8	<0.28	<0.28	<2.2	<0.14	<0.14	<0.25	<1.3	<1.3	<0.25	<1.3	<1.3	<0.25	< 0.25
Bromoform	µg/L	<0.10	<0.10	<0.10	<0.10	<0.50	<1.0	<10	<2.0	<0.20	<0.20	<3.6	<0.10	<0.10	<0.18	<0.91	<0.91	<0.18	<0.91	<0.91	<0.18	< 0.18
Bromomethane (Methly bromide)	µg/L	<0.08	<0.08	0.68(tr)	<0.08	6.2*	<0.80	37(tr)*	<1.6	0.96 (tr)	<0.16	<1.8	<0.080	0.14 (tr)	<0.61	<3.0	<3.0	<0.61	<3.0	<3.0	<0.61	< 0.18
2-Butanone (MEK)	µg/L	<1.0	<1.0	<1.0	1.1(tr)	240	2200	4300	1400	3.8 (tr)	<2.0	14 (tr)	<1.0	<1.0	2 (tr)	<0.70	1.4 (tr)	6.8	<0.7	3.4 (tr)	<0.14	< 110
n-Butylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<0.60	NA	<12	<2.4	<0.24	<0.24	NA	<0.12	<0.12	<0.38	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.38
sec-Butylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<0.60	NA	<12	<2.4	<0.24	<0.24	NA	<0.12	<0.12	<0.36	<1.8	<1.8	<0.36	<1.8	<1.8	<0.36	< 0.36
tert-Butylbenzene	µg/L	<0.14	<0.14	<0.14	<0.14	<0.70	NA	<14	<2.8	<0.28	<0.28	NA	<0.14	<0.14	<0.35	<1.7	<1.7	<0.35	<1.7	<1.7	<0.35	< 0.35
Carbon Disulfide	µg/L	<1.0	<1.0	1.1(tr)	<1.0	<5.0	<10	<100	<20	<2.0	<2.0	<2.3	<1.0	2.4	2.1	<1.4	1.8 (tr)	0.71	1.6 (tr)	1.4 (tr)	<0.29	0.56 (tr)
Carbon Tetrachloride	µg/L	<0.15	<0.15	<0.15	<0.15	<0.75	<1.5	<15	<3.0	<0.30	<0.30	<2.0	<0.15	<0.15	<0.37	<1.9	<1.9	<0.37	<1.9	<1.9	<0.37	< 0.37
Chlorobenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<0.60	<1.2	<12	<2.4	0.67 (tr)	1.1 (tr)	<1.8	0.13 (tr)	<0.12	<0.32	<1.6	<1.6	<0.32	<1.6	<1.6	<0.32	< 0.32
Chloroethane	µg/L	<0.34	<0.34	<0.34	<0.34	<1.7	<3.4	<34	<6.8	<0.68	26	<2.4	<0.34	<0.34	<0.31	<1.6	<1.6	<0.31	<1.6	1.8 (tr)	<0.31	< 0.31
Chloroform	µg/L	<0.12	<0.12	<0.12	<0.12	<0.60	<1.2	<12	7.5 (tr)	<0.24	<0.24	<2.3	<0.12	<0.12	0.78	2 (tr)	<1.8	<0.37	<1.8	1.8 (tr)	2.8	1 (tr)
Chloromethane (Methyl chloride)	µg/L	<0.25	<0.25	<0.25	<0.25	<1.2	<2.5	<25	<5.0	1.6 (tr)	<0.50	<2.9	<0.25	<0.25	<0.18	<0.88	<0.88	<0.18	<0.88	2.2 (tr)	<0.18	< 0.18
2-Chlorotoluene	µg/L	<0.26	<0.26	<0.26	<0.26	<1.3	NA	<26	<5.2	<0.52	0.62 (tr)	NA	<0.26	<0.26	<0.33	<1.7	<1.7	<0.33	<1.7	<1.7	<0.33	< 0.33
4-Chlorotoluene	µg/L	<0.10	<0.10	<0.10	<0.10	<0.50	NA	<10	<2.0	<0.20	<0.20	NA	<0.10	<0.10	<0.42	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
Dibromochloromethane	µg/L	<0.40	<0.40	<0.40	<0.40	<2.0	<4.0	<40	<8.0	<0.80	<0.80	<2.8	<0.40	<0.40	<0.47	<2.3	<2.3	<0.47	<2.3	<2.3	<0.47	< 0.47
1,2-Dibromo-3-chloropropane (DBCP)	µg/L	<0.22	<0.95	<0.95	<0.95	<4.8	<9.5	<95	<19	<1.9	<1.9	<5.9	<0.95	<0.95	<0.64	<3.2	<3.2	<0.64	<3.2	<3.2	<0.64	< 0.64
1,2-Dibromoethane (EDB)	µg/L	<0.22	<0.21	<0.22	<0.22	<1.1	<2.2	<22	<4.4	<0.44	<0.44	<2.4	<0.22	<0.22	<0.43	<2.2	<2.2	<0.43	<2.2	<2.2	<0.43	< 0.43

Table 13. Field chemistry and analytical results for leachate sampled from the northeast anaerobic cell

TIME PERIOD		Surface cover installed, prior to leachate injection	Begin limited leachate addition for testing		Full-scale leachate addition and recirculation																
PARAMETER	Date:	2/14/2002	3/27/2002	5/14/2002	6/20/2002	7/23/2002	8/13/2002	9/26/2002	10/17/2002	2/26/2003	5/27/2003	8/21/2003	9/30/2003	1/8/2004	2/23/2004	3/24/2004	5/26/2004	6/28/2004	7/26/2004	9/27/2004	11/9/2004	3/3/2005
Dibromomethane (Methly bromide)	µg/L	<0.21	<0.21	<0.21	<0.21	<1.0	<2.1	<21	<4.2	<0.42	<0.42	<2.4	<0.21	<0.21	<0.38	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.38
1,2-Dichlorobenzene	µg/L	<0.14	<0.14	<0.14	<0.14	<0.70	<1.4	<14	<2.8	<0.28	<0.28	<1.7	<0.14	<0.14	<0.31	<1.5	<1.5	<0.31	<1.5	<1.5	<0.31	< 0.31
1,3-Dichlorobenzene	µg/L	<0.11	<0.11	<0.11	<0.11	<0.55	NA	<11	<2.2	<0.22	<0.22	<2.2	<0.11	<0.11	<0.34	<1.7	<1.7	<0.34	<1.7	<1.7	<0.34	< 0.34
1,4-Dichlorobenzene	µg/L	<0.13	<0.13	<0.13	<0.13	<0.65	<1.3	<13	<2.6	<0.26	<0.26	<1.8	<0.13	0.16 (tr)	<0.46	<2.3	<2.3	<0.46	<2.3	<2.3	<0.46	< 0.46
trans-1,4-Dichloro-2-butene	µg/L	<1.0	<1.0	<1.0	<1.0	<5.0	<10	<100	<20	<2.0	<2.0	<7.0	<1.0	<1.0	NA	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
Dichlorodifluoromethane (Freon 12)	µg/L	<0.16	0.17(tr)	0.24(tr)	<0.16	<0.80	NA	<16	<3.2	<0.32	<0.32	<2.6	<0.16	<0.16	<0.31	<1.5	<1.5	<0.31	<1.5	<1.5	<0.31	< 0.31
1,1-Dichloroethane (1,1-DCA)	µg/L	0.77(tr)	0.50(tr)	0.77(tr)	0.54(tr)	<0.50	<1.0	<10	<2.0	0.36 (tr)	0.55 (tr)	<2.9	<0.10	2.4	2.5	<1.1	1.7 (tr)	1.9	1.8 (tr)	2.9 (tr)	0.75 (tr)	0.69 (tr)
1,2-Dichloroethane (1,2-DCA)	µg/L	<0.22	<0.22	<0.22	<0.22	<1.1	<2.2	<22	<4.4	<0.44	<0.44	<2.4	<0.22	<0.22	<0.42	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
1,1-Dichloroethene (1,1-DCE)	µg/L	<0.36	<0.36	<0.36	<0.36	<1.8	<3.6	<36	<7.2	<0.72	<0.72	<2.4	<0.36	<0.36	<0.24	<1.2	<1.2	<0.24	<1.2	1.4 (tr)	<0.24	< 0.24
cis-1,2-Dichloroethene (cis-1,2-DCE)	µg/L	0.58(tr)	1.2	1.8	1.5	2.3(tr)	1.8(tr)	<10	<2.0	<0.20	0.85 (tr)	<2.8	0.84 (tr)	0.83 (tr)	5.2	<1.5	<1.5	1.9	<1.5	4.2 (tr)	<0.31	< 0.31
trans-1,2-Dichloroethene (trans-1,2-DCE)	µg/L	<0.11	<0.11	<0.11	<0.11	<0.55	<1.1	<11	<2.2	<0.22	<0.22	<2.7	<0.11	<0.11	<0.26	<1.3	<1.3	<0.26	<1.3	<1.3	0.77 (tr)	< 0.26
1,2-Dichloropropane	µg/L	<0.15	<0.15	<0.15	<0.15	<0.75	<1.5	<15	<3.0	<0.30	<0.30	<2.0	<0.15	<0.15	<0.32	<1.6	<1.6	<0.32	<1.6	<1.6	<0.32	< 0.32
1,3-Dichloropropane	µg/L	<0.20	<0.20	<0.20	<0.20	<1.0	NA	<20	<4.0	<0.40	<0.40	<2.6	<0.20	<0.20	<0.40	<2.0	<2.0	<0.40	<2.0	<2.0	<0.4	< 0.4
2,2 Dichloropropane	µg/L	<0.13	<0.13	<0.13	<0.13	<0.65	NA	<13	<2.6	<0.26	<0.26	<2.1	<0.13	<0.13	<0.38	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.38
1,1-Dichloropropene	µg/L	<0.14	<0.14	<0.14	<0.14	<0.70	NA	<14	<2.8	<0.28	<0.28	<2.0	<0.14	<0.14	<0.38	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.38
cis-1,3-Dichloropropene	µg/L	<0.22	<0.22	<0.22	<0.22	<1.1	<2.2	<22	<4.4	<0.44	<0.44	<1.7	<0.22	<0.22	NA	<0.55	<0.55	<0.11	<0.55	<0.55	<0.11	< 0.11
trans-1,3-Dichloropropene	µg/L	<0.30	<0.30	<0.30	<0.30	<1.5	<3.0	<30	<6.0	<0.60	<0.60	<1.9	<0.30	<0.30	NA	<0.50	<0.50	<0.1	<0.5	<0.5	<0.1	< 0.1
Ethylbenzene	µg/L	<0.27	<0.27	<0.27	<0.27	<1.4	<2.7	<27	<5.4	<0.54	<0.54	<2.1	1.7	0.83 (tr)	5.3	2.7	2.6	4.2	3.2	2.0 (tr)	0.57	< 0.64
Hexachlorobutadiene	µg/L	<0.22	<0.22	<0.22	<0.22	<1.1	NA	<22	<4.4	<0.44	<0.44	<2.8	<0.22	<0.22	<0.50	<2.5	<2.5	<0.5	<2.5	<2.5	<0.5	< 0.5
2-Hexanone (Methyl butyl ketone)	µg/L	<1.0	<1.0	<1.0	<1.0	<5.0	26	<100	<20	<2.0	<2.0	<3.4	<1.0	<1.0	<0.017	<1.3	<1.3	<0.26	<1.3	<1.3	<0.26	< 0.26
Iodomethane (Methyl iodide)	µg/L	<1.0	<1.0	<1.0	<1.0	<5.0	<10	<100	<20	<2.0	<2.0	<1.9	<1.0	<1.0	NA	<0.18	<0.18	<0.036	<0.18	<0.18	<0.036	< 0.036
Isopropylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<0.60	NA	<12	<2.4	0.43 (tr)	1.0 (tr)	NA	0.24 (tr)	0.23 (tr)	0.3 (tr)	<1.4	<1.4	<0.28	<1.4	<1.4	0.73 (tr)	< 0.28
p-Isopropyltoluene	µg/L	<0.13	<0.13	0.13(tr)	<0.13	<0.65	NA	<13	<2.6	<0.26	0.88 (tr)	NA	<0.13	0.96 (tr)	1.6	<2.0	<2.0	1.4	<2.0	<2.0	2.5	< 1.7
Methyl-tert-butyl ether (MTBE)	µg/L	14	10	16	6.3	44	76	150(tr)	110	8.7	10	37	11	24	32	26	20	21	18	15	9.3	< 6.5
4-Methyl-2-pentanone (MIBK)	µg/L	2	<1.0	<1.0	<1.0	100	520	1000	700	<2.0	<2.0	6.4 (tr)	<1.0	7.1	5.5	<0.85	<0.85	3.7	1.9 (tr)	13	4.2	< 5
Methylene Chloride	µg/L	1.5	<0.35	0.46(tr)	<0.35	<1.8	<3.5	<35	<7.0	<0.70	<0.70	<3.1	<0.35	<0.35	0.52 (tr)	4.0 (tr)	<1.1	0.36 (tr)	<1.1	10	0.29 (tr)	1 (tr)
Naphthalene	µg/L	<0.15	0.45(tr)*	<0.15	<0.15	<0.75	NA	<15	<3.0	<0.30	0.77 (tr)	<1.8	0.85 (tr)	0.16 (tr)	<0.93	<4.6	<4.6	<0.93	<4.6	<4.6	<0.93	< 0.93
n-Propylbenzene	µg/L	<0.15	<0.15	<0.15	<0.15	<0.75	NA	<15	<3.0	<0.30	<0.30	NA	<0.15	<0.15	<0.37	<1.9	<1.9	<0.37	<1.9	<1.9	<0.37	< 0.37
Styrene	µg/L	<0.15	<0.15	<0.15	<0.15	<0.75	<30	<15	<3.0	<0.30	<0.30	<1.8	1.2	0.33 (tr)	3.3	<1.7	<1.7	2	<1.7	<1.7	<0.33	< 0.33
1,1,1,2-Tetrachloroethane	µg/L	<0.10	<0.10	<0.10	<0.10	<0.50	<20	<10	<2.0	<0.20	<0.20	<2.2	<0.10	<0.10	<0.34	<1.7	<1.7	<0.34	<1.7	<1.7	<0.34	< 0.34
1,1,2,2-Tetrachloroethane	µg/L	<0.37	<0.37	<0.37	<0.37	<1.8	<74	<37	<7.4	<0.74	<0.74	<2.6	<0.37	<0.37	<0.59	<3.0	<3.0	<0.59	<3.0	<3.0	<0.59	< 0.59
Tetrachloroethene (PCE)	µg/L	<0.38	0.84(tr)	<0.38	<0.38	<1.9	<76	<38	<7.6	<0.76	<0.76	<1.3	<0.38	<0.38	<0.44	<2.2	<2.2	<0.44	<2.2	<2.2	<0.44	< 0.44
Toluene	µg/L	1.3*	0.98(tr)	2.9	0.44(tr)	8.3	<50	<25	24	<0.50	1.0 (tr)	9.1 (tr)	14	3.8	23	10	18	22	14	13	2.4	< 3.3
1,2,3-Trichlorobenzene	µg/L	<0.14	<0.14	<0.14	<0.14	<0.70	NA	<14	<2.8	<0.28	<0.28	NA	<0.14	<0.14	<0.46	<2.3	<2.3	<0.46	<2.3	<2.3	<0.46	< 0.46
1,2,4-Trichlorobenzene	µg/L	<0.23	<0.23	<0.23	<0.23	<1.2	NA	<23	<4.6	<0.46	<0.46	NA	<0.23	<0.23	<0.41	<2.0	<2.0	<0.41	<2.0	<2.0	<0.41	< 0.41
1,1,1-Trichloroethane (1,1,1-TCA)	µg/L	<0.41	<0.41	<0.41	<0.41	<2.0	<82	<41	<8.2	<0.82	<0.82	<2.0	<0.41	<0.41	<0.19	<0.94	<0.94	<0.19	<0.94	<0.94	<0.19	< 0.19
1,1,2-Trichloroethane (1,1,2-TCA)	µg/L	<0.31	<0.31	<0.31	<0.31	<1.6	<62	<31	<6.2	<0.62	<0.62	<2.3	<0.31	<0.31	<0.43	<2.2	<2.2	<0.43	<2.2	<2.2	<0.43	< 0.43
Trichloroethene (TCE)	µg/L	0.33(tr)	0.77(tr)	<0.31	0.46(tr)	<1.6	<62	<31	<6.2	<0.62	<0.62	<2.4	<0.31	0.36 (tr)	<0.36	<1.8	<1.8	<0.36	<1.8	<1.8	<0.36	< 0.36
Trichlorofluoromethane (Freon 11)	µg/L	<0.23	<0.23	<0.23	<0.23	<1.2	<46	<23	<4.6	<0.46	<0.46	<2.8	<0.23	<0.23	<0.42	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
1,2,3-Trichloropropane	µg/L	<0.30	<0.30	<0.30	<0.30	<1.5	<60	<30	<6.0	<0.60	<0.60	<3.4	<0.30	<0.30	<0.55	<2.8	<2.8	<0.55	<2.8	<2.8	<0.55	< 0.55
1,2,4-Trimethylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<0.60	NA	<12	<2.4	<0.24	<0.24	<1.6	0.24 (tr)	<0.12	<0.18	<0.92	<0.92	0.51	<0.92	<0.92	<0.18	< 0.18
1,3,5-Trimethylbenzene	µg/L	<0.14	0.27(tr)	<0.14	<0.14	<0.70	NA	<14	<2.8	<0.28	<0.28	NA	<0.14	<0.14	<0.28	<1.4	<1.4	<0.28	<1.4	<1.4	<0.28	< 0.28
Vinyl Acetate	µg/L	<1.0	<1.0	<1.0	<1.0	<5.0	<200	<100	<20	<2.0	<2.0	<2.2	<1.0	<1.0	<0.21	<4.7	<4.7	<0.94	<4.7	<4.7	<0.94	< 0.94
Vinyl Chloride	µg/L	<0.12	<0.12	0.30(tr)	<0.12	<0.60	<24	<12	<2.4	<0.24	<0.24	<2.9	<0.12	2.2	6.7	3.3	<0.80	4.8	3.4 (tr)	2.2 (tr)	<0.16	< 0.16
Total Xylenes	µg/L	<0.10	0.13 (tr)	0.30(tr)	<0.10	<0.50	<20	<10	2.5 (tr)	<0.20	0.46 (tr)	<5.0	4	2.9	15	5.7	<2.4	10	5.4	3.2 (tr)	1.5	< 1.8

Footnotes:
NA=Not Analyzed
MDL=Method Detection Limit
PQL=Practical Quantification Limit
<=Less than the MDL
tr=trace: the amount detected was above the MDL but below the PQL
* = this parameter was alo detected in the method blank

Table 14. Analytical results for leachate sampled from the west-side anaerobic cell

TIME PERIOD		Waste actively being placed in cell						Surface liner installed, prior to liquid addition		Full-scale leachate addition and recirculation													
PARAMETER	**DATE:**	**2/14/2002**	**3/27/2002**	**5/14/2002**	**6/20/2002**	**7/23/2002**	**8/13/2002**	**2/26/2003**	**5/29/2003**	**6/26/2003**	**7/30/2003**	**8/20/2003**	**9/30/2003**	**1/8/2004**	**2/23/2004**	**03/24/04**	**04/19/04**	**5/26/2004**	**06/28/04**	**07/26/04**	**09/27/04**	**11/09/04**	**03/03/05**
Field Parameters:	**Units**																						
pH		6.74	6.76	6.8	6.72	6.85	6.71	6.87	6.72	6.66	6.63	6.63	6.74	6.5	7.2	7.02	7.07	7.05	7.23	7.04	7.08	7.16	7.04
Electrical Conductivity	µS	3530	3868	3851	3944	3899	3810	2320	2687	3056	3265	3245	3621	1950	10880	11190	12030	11310	12680	12450	14290	11690	9816
Oxidation Reduction Potential	mV	-62	-59	-46	-19	-38	-36	-56	-33	-75	-55	-53	-48	-11	-60	-37	-15	-3	56	-23	83	141	-156
Temperature	C	24.9	25.9	26.2	25.2	25.7	26.9	22.1	29.3	30.4	28.5	30.7	29.0	24.4	24.9	26.7	25.5	28.6	29.5	31.7	28.1	27.1	25.8
Dissolved Oxygen	mg/L	3.15	1.09	1.54	1.31	3.62	2.6	3.18	1.06	1.55	1.61	1.91	0.99	1.27	0.6	0.5	0.83	0.27	0.69	0.28	1.55	2.09	0.79
Total Dissolved Solids	ppm	2617	2886	2871	2960	2965	2908	1703	1933	2227	2398	NA	2670	1360	9075	9330	7100	10370	10740	10500	12210	9666	8001
General Chemistry:																							
Bicarbonate Alkalinity	mg/L	1700	1790	1780	1730	1710	1680	1000	1070	1210	1260	NA	NA	852	4300	4200	4300	4500	4400	4400	4900	3700	3200
Carbonate Alkalinity	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA	NA	<5.0	<10	<10	<10	<10	<5.0	<5.0	<5.0	<5.0	<5.0
Total Alkalinity as CO_3	mg/L	1700	1790	1780	1730	1710	1680	1000	1070	1210	1260	NA	NA	852	4300	4200	4300	4500	4400	4400	4900	3700	3200
BOD	mg O/L	28	18	12	12	7.9	12	16	11	<6.0	10	NA	NA	ND	570	160	<30	200	190	190	120	88	230
Chemical Oxygen Demand	mg O/L	350	317	300	274	270	262	98.1	82.5	102	105	NA	NA	104	2300	1600	1900	2100	2200	2300	2800	1600	1900
Chloride	mg/L	187	323	333	358	341	366	196	263	345	335	NA	NA	135	1700	2500	2000	1900	2100	2200	2500	2200	1400
Hydroxide	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA	NA	<5.0	<10	<10	<10	<10	<5.0	<5.0	<5.0	<5.0	<5.0
Ammonia as N	mg/L	20.3	20	23.5	21.2	23.8	25	9.5	10.3	13.7	12.4	NA	NA	31.2	445	300	307	44.4	395	850	430	430	240
Nitrate-Nitrite as N	mg/L	0.016(tr)	<0.015	<1.5	<0.03	<0.015	<0.015	0.022 (tr)	<0.18	<0.09	<0.25	NA	NA	<0.5	<0.045	<0.045	<0.088	<0.088	<0.088	<0.088	<0.088	<0.88	<1.5
Total Kjeldahl Nitrogen	mg/L	32.6	68.9	31.1	31.5	31.4	31	13.8	15.7	19.1	15.7*	NA	NA	40.2	630	410	260	190	230	460	630	210	78
Sulfate	mg/L	1.7(tr)	1.5(tr)	<10	0.80(tr)	2.2	0.75(tr)	<0.70	3.4 (tr)	<0.28	1.2 (tr)	NA	NA	9.5	1.4 (tr)	120	1 (tr)	5.6	25	1.2 (tr)	1.8	15	110
Total Dissolved Solids @ 180 C	mg/L	2220	2380	2320	2410	2310	2280	1320	1480	1700	1840	NA	NA	993	7000	6800	7100	7500	7800	7700	8100	7200	5700
Total (Non-Volatile) Organic Carbon	mg/L	112	95.7	85.2	86.5	82.7	78.1	28.3	25.5	37.9	34.4	NA	NA	30.6	620	490	560	570	580	670	800	510	470
Total Phosphorus	mg/L	0.13	1.6*	1.1	0.6	0.057	0.049(tr)	<0.12	<0.12	<0.12	0.38	NA	NA	0.62	5	3.8	4.1	5.9	4.8	5.4	5.5	2.6	4
Total Sulfide	mg/L	0.033(tr)	0.015(tr)	<0.014	<0.014	0.023 (tr)	<0.014	<0.0093	<0.0093	<0.0093	<0.0093	NA	NA	<0.0093	34	38 (tr)	0.24	0.8	0.34 (tr)	0.69	0.3 (tr)	0.057 (tr)	0.31
BOD/COD	unitless	0.080	0.057	0.040	0.044	0.029	0.046	0.163	0.133	NA	0.095	NA	NA	NA	0.248	0.100	NA	0.095	0.086	0.083	0.043	0.055	0.121
BOD/TOC	unitless	0.250	0.188	0.141	0.139	0.096	0.154	0.565	0.431	NA	0.291	NA	NA	NA	0.919	0.327	NA	0.351	0.328	0.284	0.150	0.173	0.489
Carbon/Nitrogen Ratio	unitless	3.436	1.389	2.740	2.746	2.634	2.519	2.051	1.624	1.984	2.191	NA	NA	1.949	39.490	31.210	35.669	36.306	36.943	42.675	50.955	32.484	29.936
Metals:												NA	NA										
Dissolved Aluminum	mg/L	0.13(tr)	<0.043	0.053(tr)*	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	NA	NA	0.022 (tr)	<0.40	<0.40	<0.4	<0.40	<3.0	<0.4	<0.4	<1.0	0.153
Dissolved Antimony	mg/L	0.0013(tr)	0.00091(tr)	0.00065(tr)	0.0006 (tr)	0.0008(tr)	<0.031	0.00090 (tr)	0.00074 (tr)	0.00036 (tr)	0.00029 (tr)	NA	NA	0.00044 (tr)	0.0067 (tr)	0.0025 (tr)	0.0045 (tr)	0.0051	0.0065	0.008 (tr)	0.00670 (tr)	0.000392 (tr)	0.00542
Dissolved Arsenic	mg/L	0.27	0.02	0.018	0.019	0.017	0.01	0.012	0.012	0.0028	0.013	NA	NA	0.013	0.14	0.10	0.1	0.11	0.11	0.15	0.107	0.0506	0.0542
Dissolved Barium	mg/L	1.8	1.8	0.45	1.8	1.6	1.4	1.1	1	1.3	1.3	NA	NA	0.95	4.3	3.5	3.6	2.6	3	2.6	3.2	2.2	1.58
Dissolved Beryllium	mg/L	<0.000078	<0.000078	<0.000078	<0.000078	<0.000078	<0.00009	<0.000078	<0.00039	<0.000078	<0.000078	NA	NA	<0.000078	<0.04	<0.040	<0.04	<0.040	<0.016	<0.04	<0.04	<0.1	< 0.000150
Dissolved Boron	mg/L	3.2	3.5	18.9	NA	3.7	3.2	<0.000078	3.6	4.2	4.2	NA	NA	2.1	8.9	11	10	9.8	11	14	13	13	8.1
Dissolved Cadmium	mg/L	<0.000074	<0.000074	<0.000074	<0.000074	<0.000074	<0.0031	<0.000074	<0.000074	<0.000074	0.0011	NA	NA	<0.000074	0.0024	0.0010	0.00092 (tr)	0.00052 (tr)	0.0024	0.00041 (tr)	<0.0010	0.0012 (tr)	< 0.000100
Dissolvd Calcium	mg/L	241	234	58.2	NA	231	193	108	115	131	132	NA	NA	73.9	270	230	230	180	210	280	190	170	148
Dissolved Chromium	mg/L	0.0088	0.0069	0.0064	0.0059	0.0054	0.0035(tr)	0.0019 (tr)	0.0033	0.0021	0.0023	NA	NA	0.0031	0.089	0.092	0.12	0.098	<0.27	0.15	0.16	<1.0	0.0687
Dissolved Cobalt	mg/L	0.0038	0.0043	0.003	0.0025	0.0025	<0.0074	0.0015	0.0039 (tr)	0.0021	0.0026	NA	NA	0.002	0.016	0.015	0.019	0.024	0.025	0.03	0.0347 (tr)	0.0244	0.0215
Dissolved Copper	mg/L	0.0018(tr)	0.0022	0.0011(tr)*	0.002	0.0023	0.0035(tr)	0.002*	0.0018 (tr)	0.0035	0.0062*	NA	NA	0.0027	0.0082 (tr)	0.0054 (tr)	0.011	0.0078 (tr)	0.013	0.0089 (tr)	0.0108 (tr)	0.0064 (tr)	0.00278
Dissolved Iron	mg/L	0.4	1.2	0.035(tr)*	1.9	0.59	0.11	0.15	0.11	0.064 (tr)	0.077 (tr)	NA	NA	4.6	4.6	5.3	6.3	1.9	7.9 (tr)	1.9	11	5.5	0.896
Dissolved Lead	mg/L	0.00024 (tr)	0.000066(tr)	0.000078(tr)*	<0.000066	<0.000066	<0.000066	<0.000066	0.00026 (tr)	<0.000066	0.0019	NA	NA	0.00071 (tr)	0.0023 (tr)	<0.0069	0.0021 (tr)	0.0015 (tr)	0.0027 (tr)	0.0084	0.00840 (tr)	0.0034 (tr)	0.000470 (tr)
Dissolved Magnesium	mg/L	198	211	343	NA	217	185	123	143	162	173	NA	NA	112	360	370	410	300	400	370	410	530	266
Dissolved Manganese	mg/L	24.6	22.9	0.0062(tr)	21.4	19.3	15.9	10.9	9.8	11.3	10.6	NA	NA	7.3	5.9	5.2	5.1	2.7	3.9	3.4	3.7	2.8	2.37
Dissolved Mercury	mg/L	<0.000049	<0.000049	<0.000049	<0.000049	<0.000049	0.000078(tr)*	<0.000064	0.000083 (tr)	<0.000064	<0.000064	NA	NA	<0.000064	<0.000025	<0.000025	<0.000025	<0.000025	<0.000025	0.00023	<0.000025	<0.000025	0.000178 (tr)
Dissolved Molybdenum	mg/L	<0.0046	<0.0046	0.044	<0.0046	<0.0046	<0.0046	<0.0046	0.0084 (tr)	<0.0046	<0.0046	NA	NA	0.0061 (tr)	<0.16	<0.16	<0.16	<0.16	<0.78	<0.16	<0.16	<0.4	< 0.00300
Dissolved Nickel	mg/L	0.042	0.053	0.052	0.047	0.046	0.041	0.018	0.026	0.027	0.026	NA	NA	0.021	0.19	0.16	0.2	0.23	0.24	0.28	0.334	0.234	0.167
Dissolved Potassium	mg/L	55.2	48.3	58.6	NA	37.8	32.5	23.7	20.1	23.8	22.8	NA	NA	28.6	250	270	350	320	380	390	490	220	234
Dissolved Phosphorus	mg/L	0.28(tr)	0.14(tr)	1	NA	<0.12	<0.12	0.38	<0.12	<0.12	<0.12	NA	NA	0.62		2.8	3.3	4.3	3.3	3.8	3.8	0.022	2.7
Dissolved Selenium	mg/L	<0.0017	<0.0017	<0.0017	<0.0017	0.002	<0.0017	<0.0017	<0.0017	<0.0017	0.0023	NA	NA	<0.0017	0.024	0.029	0.022	0.035	0.043	0.054	0.0291 (tr)	0.0163	0.0156
Dissolved Silver	mg/L	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.0032	<0.000030	<0.000030	<0.000030	<0.000030	NA	NA	<0.000030	0.00021(tr)*	<0.000067	0.00048 (tr)	0.00010 (tr)	0.00029 (tr)	<0.00013	<0.0008	<0.00008	0.000220 (tr)
Dissolved Sodium	mg/L	260	281	1500*	NA	268	234	226	266	282	309	NA	NA	156	1100	1200	1300	1200	1500	1500	1600	1400	1010
Dissolved Thallium	mg/L	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	<0.00034	NA	NA	<0.00034	<0.000034	0.000017 (tr)	<0.000017	<0.000017	<0.000017	0.0022 (tr)	<0.0008	<0.00008	< 0.0000800
Dissolved Tin	mg/L	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.0014	0.048 (tr)	0.023 (tr)	<0.0014	NA	NA	0.0093 (tr)	<0.066	0.035 (tr)	<0.033	0.033 (tr)	0.034 (tr)	<0.033	<0.0120	<0.012	< 0.0120
Dissolved Vanadium	mg/L	0.0056(tr)	0.0038(tr)	0.017(tr)	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	NA	NA	<0.00089	<0.16	<0.16	<0.16	<0.16	0.32 (tr)	0.17	0.19	<0.4	0.0646
Dissolved Zinc	mg/L	0.068	0.07	0.039	0.037	0.05	0.006(tr)	0.042	0.042	0.043	0.042	NA	NA	0.039	0.08	<0.040	0.048	<0.040	2.4	0.23	0.19	<0.1	0.0287

Table 14. Analytical results for leachate sampled from the west-side anaerobic cell

TIME PERIOD		Waste activly being placed in cell						Surface liner installed, prior to liquid additior		Full-scale leachate addition and recirculation													
PARAMETER	**DATE:**	**2/14/2002**	**3/27/2002**	**5/14/2002**	**6/20/2002**	**7/23/2002**	**8/13/2002**	**2/26/2003**	**5/29/2003**	**6/26/2003**	**7/30/2003**	**8/20/2003**	**9/30/2003**	**1/8/2004**	**2/23/2004**	**03/24/04**	**04/19/04**	**5/26/2004**	**06/28/04**	**07/26/04**	**09/27/04**	**11/09/04**	**03/03/05**
Volatile Organic Compounds:												NA	NA										
Acetone	µg/L	<50	28	22	22	14(tr)*	33 (tr)	13 (tr)	33 (tr)	15 (tr)	21 (tr)	NA	NA	33 (tr)	<72	25	29	8.4 (tr)	18	45 (tr)	42 (tr)	25	140
Acrylonitrile	µg/L	<500	<100	<100	<100	<50	<100	<50	<50	<50	<50	NA	NA	<100		<1.3	<1.3	<1.3	<0.26	<1.3	<1.3	<0.26	< 0.26
Benzene	µg/L	<6.5	3.3(tr)*	2.3(tr)	<1.3	3.5(tr)	3.6(tr)	2.6 (tr)	2.4 (tr)	3.2 (tr)	3.3 (tr)	NA	NA	3.9 (tr)	<56	4.7	4.6	7.4	7.5	5.6	5.6	3.2	4.6
Bromobenzene	µg/L	<9.0	<1.8	<1.8	<1.8	<0.90	NA	<0.90	<0.90	<0.90	<0.90	NA	NA	<1.8	<78	<2.0	<2.0	<2.0	<0.39	<2.0	<2.0	<0.39	< 0.39
Bromochloromethane	µg/L	<16	<3.1	<3.1	<3.1	<1.6	<3.1	<1.6	<1.6	<1.6	<1.6	NA	NA	<3.1	<84	<2.1	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
Bromodichloromethane	µg/L	<7.0	<1.4	<1.4	<1.4	<0.70	<1.4	<0.70	<0.70	<0.70	<0.70	NA	NA	<1.4	<51	<1.3	<1.3	<1.3	<0.25	<1.3	<1.3	<0.25	< 0.25
Bromoform	µg/L	<5.0	<1.0	<1.0	<1.0	<0.50	<1.0	<0.50	<0.50	<0.50	<0.50	NA	NA	<1.0	<36	<0.91	<0.91	<0.91	<0.18	<0.91	<0.91	<0.18	< 0.18
Bromomethane (Methly bromide)	µg/L	<4.0	<0.80	<0.80	<0.80	4.6(tr)*	<0.80	<0.40	<0.40	<0.40	<0.40	NA	NA	<0.80	<120	<3.0	<3.0	<3.0	<0.61	<3.0	<3.0	<0.61	< 0.61
2-Butanone (MEK)	µg/L	<50	<10	<10	<10	<5.0	<10	<5.0	<5.0	<5.0	<5.0	NA	NA	<10	280 (tr)	<0.70	4.7 (tr)	<0.70	3.3	8.3 (tr)	<0.7	<0.14	75
n-Butylbenzene	µg/L	<6.0	<1.2	<1.2	<1.2	<0.60	NA	<0.60	<0.60	<0.60	<0.60	NA	NA	<1.2	<76	<1.9	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.38
sec-Butylbenzene	µg/L	<6.0	<1.2	<1.2	<1.2	<0.60	NA	<0.60	<0.60	<0.60	<0.60	NA	NA	<1.2	<73	<1.8	<1.8	<1.8	<0.36	<1.8	<1.8	<0.36	< 0.36
tert-Butylbenzene	µg/L	<7.0	<1.4	<1.4	<1.4	<0.70	NA	<0.70	<0.70	<0.70	<0.70	NA	NA	<1.4	<69	<1.7	<1.7	<1.7	<0.35	<1.7	<1.7	<0.35	< 0.35
Carbon Disulfide	µg/L	<50	<10	<10	<10	<5.0	<10	<5.0	<5.0	<5.0	<5.0	NA	NA	<10	<14	<1.4	<1.4	2.3 (tr)	0.61	1.6 (tr)	<1.4	<0.29	5.8
Carbon Tetrachloride	µg/L	<7.5	<1.5	<1.5	<1.5	<0.75	<1.5	<0.75	<0.75	<0.75	<0.75	NA	NA	<1.5	<75	<1.9	<1.9	<1.9	<0.37	<1.9	<1.9	<0.37	< 0.37
Chlorobenzene	µg/L	<6.0	<1.2	<1.2	<1.2	<0.60	<1.2	<0.60	<0.60	<0.60	<0.60	NA	NA	<1.2	<65	<1.6	<1.6	<1.6	<0.32	<1.6	<1.6	<0.32	< 0.32
Chloroethane	µg/L	<17	<3.4	<3.4	<3.4	<1.7	<3.4	3.1 (tr)	<1.7	2.8 (tr)	5.6	NA	NA	<3.4	<62	<1.6	<1.6	<1.6	<0.31	<1.6	<1.6	<0.31	1.6
Chloroform	µg/L	<6.0	<1.2	<1.2	<1.2	<0.60	<1.2	<0.60	<0.60	<0.60	<0.60	NA	NA	<1.2	<73	<1.8	<1.8	<1.8	<0.37	<1.8	<1.8	1	1 (tr)
Chloromethane (Methyl chloride)	µg/L	<12	<2.5	<2.5	<2.5	<1.2	<2.5	<1.2	<1.2	<1.2	<1.2	NA	NA	<2.5	<35	<0.88	<0.88	1.6 (tr)	<0.18	<0.88	<0.88	<0.18	< 0.18
2-Chlorotoluene	µg/L	<13	<2.6	<2.6	<2.6	<1.3	NA	<1.3	<1.3	<1.3	<1.3	NA	NA	<2.6	<66	<1.7	<1.7	<1.7	<0.33	<1.7	<1.7	<0.33	< 0.33
4-Chlorotoluene	µg/L	<5.0	<1.0	<1.0	<1.0	<0.50	NA	<0.50	<0.50	<0.50	<0.50	NA	NA	<1.0	<85	<2.1	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
Dibromochloromethane	µg/L	<20	<4.0	<4.0	<4.0	<2.0	<4.0	<2.0	<2.0	<2.0	<2.0	NA	NA	<4.0	<93	<2.3	<2.3	<2.3	<0.47	<2.3	<2.3	<0.47	< 0.47
1,2-Dibromo-3-chloropropane (DBCP)	µg/L	<48	<9.5	<9.5	<9.5	<4.8	<9.5	<4.8	<4.8	<4.8	<4.8	NA	NA	<9.5	<130	<3.2	<3.2	<3.2	<0.64	<3.2	<3.2	<0.64	< 0.64
1,2-Dibromoethane (EDB)	µg/L	<11	<2.2	<2.2	<2.2	<1.1	<2.2	<1.1	<1.1	<1.1	<1.1	NA	NA	<2.2	<86	<2.2	<2.2	<2.2	<0.43	<2.2	<2.2	<0.43	< 0.43
Dibromomethane (Methly bromide)	µg/L	<10	<2.1	<2.1	<2.1	<1.0	<2.1	<1.0	<1.0	<1.0	<1.0	NA	NA	<2.1	<76	<1.9	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.38
1,2-Dichlorobenzene	µg/L	<7.0	<1.4	<1.4	<1.4	<0.70	<1.4	<0.70	<0.70	<0.70	<0.70	NA	NA	<1.4	<61	<1.5	<1.5	<1.5	<0.31	<1.5	<1.5	<0.31	< 0.31
1,3-Dichlorobenzene	µg/L	<5.5	<1.1	<1.1	<1.1	<0.55	NA	<0.55	<0.55	<0.55	<0.55	NA	NA	<1.1	<67	<1.7	<1.7	<1.7	<0.34	<1.7	<1.7	<0.34	< 0.34
1,4-Dichlorobenzene	µg/L	<6.5	<1.3	<1.3	<1.3	<0.65	<1.3	<0.65	<0.65	<0.65	<0.65	NA	NA	<1.3	<91	<2.3	<2.3	<2.3	<0.46	<2.3	<2.3	<0.46	< 0.46
trans-1,4-Dichloro-2-butene	µg/L	<50	<10	<10	<10	<5.0	<10	<5.0	<5.0	<5.0	<5.0	NA	NA	<10	NA	<2.1	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
Dichlorodifluoromethane (Freon 12)	µg/L	<8.0	2.4(tr)	4.2(tr)	<1.6	16	NA	<0.80	<0.80	<0.80	<0.80	NA	NA	<1.6	<61	<1.5	<1.5	<1.5	<0.31	<1.5	<1.5	<0.31	< 0.31
1,1-Dichloroethane (1,1-DCA)	µg/L	<5.0	4.6(tr)	7.4(tr)	9.5(tr)	12	13	1.5 (tr)	2.9 (tr)	3.0 (tr)	9.0	NA	NA	4.9 (tr)	<45	2.7	1.8 (tr)	1.8 (tr)	1	2.2 (tr)	1.4 (tr)	0.76 (tr)	2
1,2-Dichloroethane (1,2-DCA)	µg/L	<11	2.5(tr)	3.5(tr)	4.0 (tr)	4.8(tr)	5.8(tr)	4.0 (tr)	5.5	5.9	5.4	NA	NA	7.2 (tr)	<84	<2.1	9.0	8.4	8.8	8.9	8.7	4.5	4.2
1,1-Dichloroethene (1,1-DCE)	ug/L	<18	<3.6	<3.6	<3.6	<1.8	<3.6	<1.8	<1.8	<1.8	<1.8	NA	NA	<3.6	<47	<1.2	<1.2	<1.2	<0.24	<1.2	<1.2	<0.24	< 0.24
cis-1,2-Dichloroethene (cis 1,2-DCE)	µg/L	<5.0	2.3(tr)	1.9(tr)	<1.0	3.3(tr)	3.5(tr)	3.7 (tr)	2.5 (tr)	2.6 (tr)	1.9 (tr)	NA	NA	<1.0	<62	<1.5	<1.5	<1.5	<0.31	1.9 (tr)	<1.5	0.55 (tr)	1.3
trans-1,2-Dichloroethene (trans-1,2-DCE)	µg/L	<5.5	<1.1	<1.1	<1.1	<0.55	<1.1	<0.55	<0.55	<0.55	<0.55	NA	NA	<1.1	<52	<1.3	<1.3	<1.3	<0.26	<1.3	<1.3	<0.26	< 0.26
1,2-Dichloropropane	µg/L	<7.5	<1.5	<1.5	<1.5	<0.75	<1.5	<0.75	<0.75	<0.75	<0.75	NA	NA	<1.5	<63	<1.6	<1.6	<1.6	<0.32	<1.6	<1.6	<0.32	< 0.32
1,3-Dichloropropane	µg/L	<10	<2.0	<2.0	<2.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	NA	<2.0	<80	<2.0	<2.0	<2.0	<0.40	<2.0	<2.0	<0.4	< 0.4
2,2 Dichloropropane	µg/L	<6.5	<1.3	<1.3	<1.3	<0.65	NA	<0.65	<0.65	<0.65	<0.65	NA	NA	<1.3	<76	<1.9	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.46
1,1-Dichloropropene	µg/L	<7.0	<1.4	<1.4	<1.4	<0.70	NA	<0.70	<0.70	<0.70	<0.70	NA	NA	<1.4	<75	<1.9	<1.9	<1.9	<0.38	<1.9	<1.9	<0.38	< 0.38
cis-1,3-Dichloropropene	µg/L	<11	<2.2	<2.2	<2.2	<1.1	<2.2	<1.1	<1.1	<1.1	<1.1	NA	NA	<2.2	NA	<0.55	<0.55	<0.55	<0.11	<0.55	<0.55	<0.11	< 0.11
trans-1,3-Dichloropropene	µg/L	<15	<3.0	<3.0	<3.0	<1.5	<3.0	<1.5	<1.5	<1.5	<1.5	NA	NA	<3.0	NA	<0.5	<0.50	<0.50	<0.1	<0.5	<0.5	<0.1	< 0.1
Ethylbenzene	µg/L	<14	<2.7	<2.7	<2.7	<1.4	<2.7	1.4 (tr)	1.4 (tr)	1.5 (tr)	2.2 (tr)	NA	NA	3.1 (tr)	<47	2.6	3.2	4.0	4.4	3.5	4.6	2.3	5.4
Hexachlorobutadiene	µg/L	<11	<2.2	<2.2	<2.2	<1.1	NA	<1.1	<1.1	<1.1	<1.1	NA	NA	<2.2	<100	<2.5	<2.5	<2.5	<0.5	<2.5	<2.5	<0.5	< 0.5
2-Hexanone (Methyl butyl ketone)	µg/L	<50	<10	<10	<10	<5.0	<10	<5.0	<5.0	<5.0	<5.0	NA	NA	<10	<3.4	<1.3	<1.3	<1.3	<0.26	<1.3	<1.3	<0.26	< 0.26
Iodomethane (Methyl iodide)	µg/L	<50	<10	<10	<10	<5.0	<10	<5.0	<5.0	<5.0	<5.0	NA	NA	<10	NA	<0.18	<0.18	<0.18	<0.036	<0.18	<0.18	<0.036	< 0.036
Isopropylbenzene	µg/L	<6.0	<1.2	<1.2	<1.2	<0.60	NA	<0.60	<0.60	<0.60	<0.60	NA	NA	<1.2	<55	3.0	6.1	3.2	4.6	<1.4	<1.4	0.84 (tr)	< 0.56
p-Isopropyltoluene	µg/L	<6.5	<1.3	<1.3	<1.3	<0.65	NA	<0.65	<0.65	<0.65	<0.65	NA	NA	<1.3	<80	<2.0	<2.0	<2.0	1.4	<2.0	<2.0	2.9	< 0.4
Methyl-tert-butyl ether (MTBE)	µg/L	210	190	160	160	180	170	110	90	130	120	NA	NA	99	120	110	120	79	87	42	55	37	< 0.23
4-Methyl-2-pentanone (MIBK)	µg/L	1200	19(tr)	52	<10	<5.0	26	7.1 (tr)	7.7 (tr)	<5.0	<5.0	NA	NA	<10	350 (tr)	9.3 (tr)	6.1 (tr)	7.2 (tr)	2.1	50	<0.85	1.7 (tr)	59

Table 14. Analytical results for leachate sampled from the west-side anaerobic cell

TIME PERIOD		Waste activly being placed in cell						Surface liner installed, prior to liquid additior		Full-scale leachate addition and recirculation												
PARAMETER	DATE:	2/14/2002	3/27/2002	5/14/2002	6/20/2002	7/23/2002	8/13/2002	2/26/2003	5/29/2003	6/26/2003	7/30/2003	8/20/2003	9/30/2003	1/8/2004	2/23/2004	03/24/04	04/19/04	5/26/2004	06/28/04	07/26/04	09/27/04	11/09/04	03/03/05
Methylene Chloride	µg/L	<18	<3.5	<3.5	<3.5	2.1(tr)	<3.5	<1.8	<1.8	2.3 (tr)	<1.8	NA	NA	<3.5	<45	<1.1	2.2 (tr)	2.2 (tr)	<0.23	5.8	<1.1	<0.23	< 0.23
Naphthalene	µg/L	<7.5	<1.5	<1.5	<1.5	<0.75	NA	<0.75	<0.75	<0.75	<0.75	NA	NA	<1.5	<190	<4.6	<4.6	<4.6	<0.93	<4.6	<4.6	<0.93	2.8
n-Propylbenzene	µg/L	<7.5	<1.5	<1.5	<1.5	<0.75	NA	<0.75	<0.75	<0.75	<0.75	NA	NA	<1.5	<74	<1.9	<1.9	<1.9	<0.37	<1.9	<1.9	<0.37	< 0.37
Styrene	µg/L	<7.5	<1.5	<1.5	<1.5	<0.75	<1.5	<0.75	<0.75	<0.75	<0.75	NA	NA	<1.5	<67	<1.7	<1.7	<1.7	0.98	<1.7	<1.7	<0.33	1.3
1,1,1,2-Tetrachloroethane	µg/L	<5.0	<1.0	<1.0	<1.0	<0.50	<1.0	<0.50	<0.50	<0.50	<0.50	NA	NA	<1.0	<67	<1.7	<1.7	<1.7	<0.34	<1.7	<1.7	<0.34	< 0.34
1,1,2,2-Tetrachloroethane	µg/L	<18	<3.7	<3.7	<3.7	<1.8	<3.7	<1.8	<1.8	<1.8	<1.8	NA	NA	<3.7	<120	<3.0	<3.0	<3.0	<0.59	<3.0	<3.0	<0.59	< 0.59
Tetrachloroethene (PCE)	µg/L	<19	<3.8	<3.8	<3.8	<1.9	NA	<1.9	<1.9	<1.9	<1.9	NA	NA	<3.8	<89	<2.2	6.2	<2.2	<0.44	<2.2	<2.2	<0.44	< 0.44
Toluene	µg/L	150*	42	20	22	22	20	14	7.6	6.6	7.1	NA	NA	9.5 (tr)	<65	20	15	28	7.5	56	15	2.2	38
1,2,3-Trichlorobenzene	µg/L	<7.0	<1.4	<1.4	<1.4	<0.70	NA	<0.70	<0.70	<0.70	<0.70	NA	NA	<1.4	<92	<2.3	<2.3	<2.3	<0.46	<2.3	<2.3	<0.46	< 0.46
1,2,4-Trichlorobenzene	µg/L	<12	<2.3	<2.3	<2.3	<1.2	NA	<1.2	<1.2	<1.2	<1.2	NA	NA	<2.3	<82	<2.0	<2.0	<2.0	<0.41	<2.0	<2.0	<0.41	< 0.41
1,1,1-Trichloroethane (1,1,1-TCA)	µg/L	<20	<4.1	<4.1	<4.1	<2.0	<4.1	<2.0	<2.0	<2.0	<2.0	NA	NA	<4.1	<38	<0.94	<0.94	<0.94	<0.19	<0.94	<0.94	<0.19	< 0.19
1,1,2-Trichloroethane (1,1,2-TCA)	µg/L	<16	<3.1	<3.1	<3.1	<1.6	<3.1	<1.6	<1.6	<1.6	<1.6	NA	NA	<3.1	<87	<2.2	<2.2	<2.2	<0.43	<2.2	<2.2	<0.43	< 0.43
Trichloroethene (TCE)	µg/L	<16	<3.1	<3.1	<3.1	<1.6	<3.1	<1.6	<1.6	<1.6	<1.6	NA	NA	<3.1	<72	<1.8	<1.8	<1.8	<0.36	<1.8	<1.8	<0.36	< 0.36
Trichlorofluoromethane (Freon 11)	µg/L	<12	<2.3	2.7(tr)	<2.3	<1.2	<2.3	<1.2	<1.2	<1.2	<1.2	NA	NA	<2.3	<83	<2.1	<2.1	<2.1	<0.42	<2.1	<2.1	<0.42	< 0.42
1,2,3-Trichloropropane	µg/L	<15	<3.0	<3.0	<3.0	<1.5	<3.0	<1.5	<1.5	<1.5	<1.5	NA	NA	<3.0	<110	<2.8	<2.8	<2.8	<0.55	<2.8	<2.8	<0.55	< 0.55
1,2,4-Trimethylbenzene	µg/L	<6.0	<1.2	<1.2	<1.2	<0.60	NA	<0.60	<0.60	<0.60	<0.60	NA	NA	<1.2	<37	<0.92	<0.92	<0.92	0.34 (tr)	<0.92	<0.92	0.52 (tr)	< 0.79
1,3,5-Trimethylbenzene	µg/L	<7.0	<1.4	<1.4	<1.4	<0.70	NA	<0.70	<0.70	<0.70	<0.70	NA	NA	<1.4	<57	<1.4	<1.4	<1.4	<0.28	<1.4	<1.4	<0.28	< 0.28
Vinyl Acetate	µg/L	<50	<10	<10	<10	<5.0	<10	<5.0	<5.0	<5.0	<5.0	NA	NA	<10	<43	<4.7	<4.7	<4.7	<0.94	<4.7	<4.7	<0.94	< 0.94
Vinyl Chloride	µg/L	<6.0	<1.2	<1.2	<1.2	<0.60	<1.2	2.3 (tr)	<0.60	3.3 (tr)	10	NA	NA	<1.2	<32	5.2	<0.8	4.6	4.5	4.6 (tr)	<0.8	2.8	4.7
Total Xylenes	µg/L	<5.0	4.0(tr)	3.8(tr)	<1.0	3.4(tr)	4.0(tr)	2.8 (tr)	2.1 (tr)	2.4 (tr)	4.8 (tr)	NA	NA	6.2 (tr)	<97	3.6	6.1	2.4 (tr)	9.7	7.1	7.9	5.8	17

Footnotes:

NA=Not Analyzed

tr=trace: the amount detected was above the MDL but below the PQL

* = this parameter was alo detected in the method blank

[A] = None of the sample dilutions selected met the criteria of at least 2 mg/l dissolved oxygen depletion. The reported result was from the least diluted sample. Due to holding time constraints, reanalysis was not possible.

Table 15. Analytical Results for Leachate Sampled from the Southeast Aerobic Cell

		No Liquid Addition or Recirculation				Full-scale leachate Addition and Recirculation								
PARAMETER	**DATE:**	**2/26/2002**	**3/27/2002**	**5/14/2002**	**5/29/2003**	**12/3/2003**	**1/8/2004**	**2/23/2004**	**5/26/2004**	**6/28/2004**	**7/26/2004**	**9/27/2004**	**11/9/2004**	**3/3/2005**
Field Parameters:	**Units**													
pH		7.75	8.17	8.48	8.48	6.21	7.86	7.63	7.45	7.28	7.56	7.57	7.52	7.35
Electrical Conductivity	µS	7026	7705	9048	9426	23730	19110	16990	16720	17020	17140	16020	15400	14580
Oxidation Reduction Potential	mV	195	195	127	201	-67	-128	-148	-54	-75	-68	-44	-131	-171
Temperature	C	15.1	15.2	21.1	27.9	50.0	33.6	44.5	37.7	38.0	37.7	37.8	40.8	39.5
Dissolved Oxygen	mg/L	5.45	5.73	6.8	1.67	0.2	0.17	0.17	0.18	0.18	0.16	0.11	0.16	0.48
Total Dissolved Solids	ppm	5673	NA	7448	7686	21100	16780	14320	14410	14530	14740	13690	13150	12220
General Chemistry:														
Bicarbonate Alkalinity	mg/L	1120	935	1020	1480	5240	5990	4900	4700	4400	4600	4200	4000	2400
Carbonate Alkalinity	mg/L	NA	<5.0	24.8	34.6	<5.0	<5.0	<10	<10	<5.0	<5.0	<5.0	<5	<5
Total Alkalinity as CO_3	mg/L	1120	935	1050	1510	5240	5990	4900	4700	4400	4600	4200	4000	2400
BOD	mg O/L	3.3	5	89	35	5000	2000	2400	750	200	150	140	160	160
Chemical Oxygen Demand	mg O/L	595	563	602	818	25900	7300	7500	4900	5000	4600	4100	4000	2900
Chloride	mg/L	1610	1800	2290	1740	3370	3620	2500	3300	3500	3700	3200	3300	2900
Hydroxide	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<10	<5.0	<5.0	<5.0	ND	<5.0
Ammonia as N	mg/L	2.8	1.1	0.60(tr)	36	313	861	500	560	478	994	350	390	1000
Nitrate-Nitrite as N	mg/L	0.16	0.22	4.8(tr)	4.8	<0.90	0.17	<0.045	<0.088	<0.088	<0.088	<0.088	<0.088	<1.5
Total Kjeldahl Nitrogen	mg/L	19.9	19.2	11.1	69.1	518	689	550	440	360	600	170	190	310
Sulfate	mg/L	290	478	526	544	1870	8	8.5	4.1	130	5.4	230	180	4400
Total Dissolved Solids @ 180 C	mg/L	4810	5200	5640	6330	58100	13900	13000	11000	12000	11000	10000	7000	0.060 (tr)
Total (Non-Volatile) Organic Carbon	mg/L	766	149	168	215	11100	1950	2600	1500	1300	1500	1400	1500	1000
Total Phosphorus	mg/L	0.51	0.19	0.85*	1.2	2	4.7	5.9	7.2	4.4	5.3	5.9	6.4	6.6
Total Sulfide	mg/L	<0.014	0.015(tr)	<0.014	<0.0093	1.2	<0.0093	76	0.97	0.35 (tr)	0.19	1.8	0.69	0.060 (tr)
BOD/COD	unitless	0.006	0.009	0.148	0.043	0.193	0.274	0.320	0.153	0.040	0.033	0.034	0.040	0.055
BOD/TOC	unitless	0.004	0.034	0.530	0.163	0.450	1.026	0.923	0.500	0.154	0.100	0.100	0.107	0.160
Carbon/Nitrogen ratio	unitless	38.492	7.760	15.135	3.111	21.429	2.830	4.727	3.409	3.611	2.500	8.235	7.895	3.226
Metals:														
Dissolved Aluminum	mg/L	<0.043	<0.043	0.082(tr)*	<0.043	4.9	1.4	1.3	0.55	<3.0	0.43	<0.4	<1.0	0.533
Dissolved Antimony	mg/L	0.002	0.0016(tr)	0.002	0.0037	0.016	0.016	0.013	0.010	0.0083	0.0093 (tr)	0.00440 (tr)	0.00436 (tr)	0.005
Dissolved Arsenic	mg/L	0.012	0.015	0.017	0.027	0.039	0.063	0.15	0.074	0.1	0.12	0.0765	0.0834	0.0796
Dissolved Barium	mg/L	0.43	0.54	1.9	0.54	1.8	0.2	0.43	0.41	0.57 (tr)	0.86	0.76	<1.0	0.551
Dissolved Beryllium	mg/L	<0.000078	<0.000078	<0.000078	<0.00039	0.00045 (tr)	0.000095 (tr)	<0.04	<0.040	<0.016	<0.04	<0.040	<0.1	<0.00015
Dissolved Boron	mg/L	NA	12.2	3.8	14.3	22	14	13	13	13	16	15	15	11.2
Dissolved Cadmium	mg/L	0.00013(tr)	0.00016(tr)	0.0062	0.00017 (tr)	0.0011 (tr)	0.0022	0.0023	0.0073	0.011	0.04	0.00520 (tr)	0.0011 (tr)	0.00034 (tr)
Dissolvd Calcium	mg/L	NA	57	257	46	1340	40.3	130	65	69 (tr)	64	100	150	134
Dissolved Chromium	mg/L	0.01	0.0062	0.0062	0.046	0.83	0.4	0.24	0.27	<0.27	0.33	0.22	0.23	0.148
Dissolved Cobalt	mg/L	0.0095	0.0073	0.004	0.014	0.21	0.025	0.014	0.027	0.031	0.038	0.0377 (tr)	0.0326	0.0262
Dissolved Copper	mg/L	0.016	0.014	0.019	0.0090 (tr)	0.02	0.038	0.012 (tr)	0.014	0.015	0.018	0.00910 (tr)	0.0051 (tr)	0.00789
Dissolved Iron	mg/L	0.32	0.084(tr)	0.34	0.81	92.7	6.1	4.1	3.3	18 (tr)	4.2	2	1.7	1.78
Dissolved Lead	mg/L	0.00026(tr)	<0.000066	0.00061(tr)	0.0017	0.0025 (tr)	0.017	0.0034 (tr)	0.0084	0.0064	0.012	0.00730 (tr)	0.0038 (tr)	0.00635
Dissolved Magnesium	mg/L	273	260	220	401	1350	666	590	390	460	490	390	330	258
Dissolved Manganese	mg/L	1.1	0.77	23.9	0.29	71.1	0.23	1.1	0.21	0.11 (tr)	0.24	0.23	0.31	0.463
Dissolved Mercury	mg/L	<0.000049	0.000059	0.000074(tr)	<0.000064	0.00018 (tr)	<0.000064	<0.000025	<0.000025	<0.000025	0.00008 (tr)	<0.000025	<0.000025	0.000203
Dissolved Molybdenum	mg/L	0.026(tr)	0.033(tr)	<0.0046	0.024 (tr)	0.011 (tr)	0.045	<0.16	<0.16	<0.78	<0.16	<0.16	<0.4	0.0069 (tr)
Dissolved Nickel	mg/L	0.14	0.11	0.11	0.12	1.2	0.32	0.24	0.31	0.32	0.39	0.33	0.282	0.224
Dissolved Potassium	mg/L	NA	66.1	47.8	165	657	940	780	650	700	780	770	740	628
Dissolved Phosphorus	mg/L	NA	0.47	<0.312	1.2	2	4.7	NA	4.3	3.2	3.9	2.9	0.66	4.2
Dissolved Selenium	mg/L	<0.0085	0.0034	0.0053	0.0038	0.02	<0.0034	0.051	0.063	0.077	0.11	0.0471 (tr)	0.0317	0.026
Dissolved Silver	mg/L	<0.00003	<0.00003	<0.00003	0.000043 (tr)	0.00068 (tr)	0.00029 (tr)	0.00034 (tr)*	0.00033 (tr)	0.00027 (tr)	0.0002 (tr)	<0.0008	<0.00008	0.00012 (tr)
Dissolved Sodium	mg/L	NA	1260	284	1430	2420	1880	1800	1700	2200	2200	1900	2000	1960
Dissolved Thallium	mg/L	<0.00034	<0.00034	<0.00034	<0.00034	<0.0017	<0.00034	<0.000034	<0.000017	<0.000017	0.00057 (tr)	<0.0008	<0.00008	<0.00008
Dissolved Tin	mg/L	<0.022	<0.022	<0.022	0.042 (tr)	0.15 (tr)	0.019 (tr)	<0.066	0.065 (tr)	0.035 (tr)	<0.033	<0.0120	<0.012	<0.012
Dissolved Vanadium	mg/L	0.023(tr)	0.018(tr)	<0.0032	0.033 (tr)	0.3	0.16	<0.16	0.16	0.25 (tr)	0.24	0.18	<0.4	0.0517
Dissolved Zinc	mg/L	0.027*	0.032	0.018	0.057	0.22	0.69	0.32	0.18	1.1	0.38	0.24	<0.1	0.0795

Table 15. Analytical Results for Leachate Sampled from the Southeast Aerobic Cell

		No Liquid Addition or Recirculation				Full-scale leachate Addition and Recirculation								
PARAMETER	**DATE:**	**2/26/2002**	**3/27/2002**	**5/14/2002**	**5/29/2003**	**12/3/2003**	**1/8/2004**	**2/23/2004**	**5/26/2004**	**6/28/2004**	**7/26/2004**	**9/27/2004**	**11/9/2004**	**3/3/2005**
Volatile Organic Compounds:														
Acetone	µg/L	12	23	8.8	59	2300	3900	1900	32	50	58	55	48	45
Acrylonitrile	µg/L	<10	<10	<10	<10	<400	<50	NA	<2.6	<0.26	<1.3	<1.3	<0.26	<0.26
Benzene	µg/L	0.43(tr)*	0.27(tr)*	0.17(tr)	0.88 (tr)	<5.2	<13	<56	2.9 (tr)	0.85	<1.4	<1.4	1.2	2.1
Bromobenzene	µg/L	<0.18	<0.18	<0.18	<0.18	<7.2	<18	<78	<3.9	<0.39	<2.0	<2.0	<0.39	<0.39
Bromochloromethane	µg/L	<0.31	<0.31	<0.31	<0.31	<12	<31	<84	<4.2	<0.42	<2.1	<2.1	<0.42	<0.42
Bromodichloromethane	µg/L	<0.14	<0.14	<0.14	<0.14	<5.6	<14	<51	<2.5	<0.25	<1.3	<1.3	<0.25	<0.25
Bromoform	µg/L	<0.10	<0.10	<0.10	<0.10	<4.0	<10	<36	<1.8	<0.18	<0.91	<0.91	<0.18	<0.18
Bromomethane (Methly bromide)	µg/L	<0.08	<0.08	0.23(tr)	0.72 (tr)	<3.2	<8.0	<120	<6.1	<0.61	<3.0	<3.0	<0.61	<0.61
2-Butanone (MEK)	µg/L	2.5	<1.0	<0.12	5	630	850	870 (tr)	<1.4	10	3.2 (tr)	<0.7	1.6 (tr)	2.1
n-Butylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<4.8	<12	<76	<3.8	<0.38	<1.9	<1.9	<0.38	<0.38
sec-Butylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<4.8	<12	<73	<3.6	<0.36	<1.8	<1.8	<0.36	<0.36
tert-Butylbenzene	µg/L	<0.14	<0.14	<0.14	<0.14	<5.6	<14	<69	<3.5	<0.35	<1.7	<1.7	<0.35	<0.35
Carbon Disulfide	µg/L	<1.0	<1.0	<1.0	<1.0	<40	24	<14	<2.9	0.61	<1.4	5.2 (tr)	3.5	2
Carbon Tetrachloride	µg/L	<0.15	<0.15	<0.15	<0.15	<6.0	<15	<75	<3.7	<0.37	<1.9	<1.9	<0.37	<0.37
Chlorobenzene	µg/L	2	2.8	0.23(tr)	4.8	<4.8	<12	<65	<3.2	<0.32	<1.6	<1.6	<0.32	<0.32
Chloroethane	µg/L	<0.34	<0.34	<0.34	<0.34	<14	<34	<62	5.0 (tr)	<0.31	<1.6	<1.6	<0.31	<0.31
Chloroform	µg/L	<0.12	<0.12	<0.12	<0.12	<4.8	<12	<73	<3.7	<0.37	<1.8	<1.8	3.8	1 (tr)
Chloromethane (Methyl chloride)	µg/L	<0.25	0.46(tr)	0.33(tr)	3.9	<10	<25	<35	2.7 (tr)	<0.18	<0.88	<0.88	<0.18	<0.18
2-Chlorotoluene	µg/L	<0.26	0.31(tr)	<0.26	<0.26	<10	<26	<66	<3.3	<0.33	<1.7	<1.7	<0.33	<0.33
4-Chlorotoluene	µg/L	<0.10	<0.10	<0.10	<0.10	<4.0	<10	<85	<4.2	<0.42	<2.1	<2.1	<0.42	<0.42
Dibromochloromethane	µg/L	<0.40	<0.40	<0.40	<0.40	<16	<40	<93	<4.7	<0.47	<2.3	<2.3	<0.47	<0.47
1,2-Dibromo-3-chloropropane (DBCP)	µg/L	<0.95	<0.95	<0.95	<0.95	<38	<95	<130	<6.4	<0.64	<3.2	<3.2	<0.64	8.8
1,2-Dibromoethane (EDB)	µg/L	<0.22	<0.22	<0.22	<0.22	<8.8	<22	<86	<4.3	<0.43	<2.2	<2.2	<0.43	<0.43
Dibromomethane (Methly bromide)	µg/L	<0.21	<0.21	<0.21	<0.21	<8.4	<21	<76	<3.8	<0.38	<1.9	<1.9	<0.38	<0.38
1,2-Dichlorobenzene	µg/L	<0.14	<0.14	<0.14	<0.14	<5.6	<14	<61	<3.1	<0.31	<1.5	<1.5	<0.31	<0.31
1,3-Dichlorobenzene	µg/L	<0.11	<0.11	<0.11	<0.11	<4.4	<11	<67	<3.4	<0.34	<1.7	<1.7	<0.34	<0.34
1,4-Dichlorobenzene	µg/L	<0.13	<0.13	<0.13	<0.13	<5.2	<13	<91	<4.6	<0.46	<2.3	<2.3	<0.46	<0.46
trans-1,4-Dichloro-2-butene	µg/L	<1.0	<1.0	<1.0	<1.0	<40	<5.0	NA	<4.2	<0.42	<2.1	<2.1	<0.42	<0.42
Dichlorodifluoromethane (Freon 12)	µg/L	0.27(tr)	<0.16	<1.0	<0.16	<6.4	<16	<61	<3.1	<0.31	<1.5	<1.5	<0.31	<0.31
1,1-Dichloroethane (1,1-DCA)	µg/L	0.32(tr)	0.16(tr)	<0.10	<0.10	<4.0	<10	<45	<2.2	<0.22	<1.1	<1.1	<0.22	<0.22
1,2-Dichloroethane (1,2-DCA)	µg/L	<0.22	<0.22	<0.22	<0.22	<8.8	<22	<84	<4.2	<0.42	<2.1	<2.1	<0.42	<0.42
1,1-Dichloroethene (1,1-DCE)	µg/L	<0.36	<0.36	<0.36	<0.36	<14	<36	<47	<2.4	<0.24	<1.2	<1.2	<0.24	<0.24
cis-1,2-Dichloroethene (cis-1,2-DCE)	µg/L	0.38(tr)	0.20(tr)	<0.10	<0.10	<4.0	<10	<62	<3.1	0.51	<1.5	<1.5	0.92 (tr)	2.4
trans-1,2-Dichloroethene (trans-1,2-DC	µg/L	<0.11	<0.11	<0.11	<0.11	<4.4	<11	<52	<2.6	<0.26	<1.3	<1.3	<0.26	<0.26
1,2-Dichloropropane	µg/L	<0.15	<0.15	<0.15	<0.15	<6.0	<15	<63	<3.2	<0.32	<1.6	<1.6	<0.32	<0.32
1,3-Dichloropropane	µg/L	<0.20	<0.20	<0.20	<0.20	<8.0	<20	<80	<4.0	<0.4	<2.0	<2.0	<0.4	<0.4
2,2 Dichloropropane	µg/L	<0.13	<0.13	<0.13	<0.13	<5.2	<13	<76	<3.8	<0.38	<1.9	<1.9	<0.38	<0.38
1,1-Dichloropropene	µg/L	<0.14	<0.14	<0.14	<0.14	<5.6	<14	<75	<3.8	<0.38	<1.9	<1.9	<0.38	<0.38
cis-1,3-Dichloropropene	µg/L	0.38(tr)	<0.22	<0.22	<0.22	<8.8	<22	NA	<1.1	<0.11	<0.55	<0.55	<0.11	<0.11
trans-1,3-Dichloropropene	µg/L	<0.30	<0.30	<0.30	<0.30	<12	<30	NA	<1.0	<0.1	<0.5	<0.5	<0.1	<0.1
Ethylbenzene	µg/L	<0.27	<0.27	<0.27	<0.27	<11	<27	<47	<2.4	0.69	<1.2	<1.2	0.78	1.6
Hexachlorobutadiene	µg/L	<0.22	<0.22	<0.22	<0.22	<8.8	<22	<100	<5.0	<0.5	<2.5	<2.5	<0.5	<0.5
2-Hexanone (Methyl butyl ketone)	µg/L	<1.0	<1.0	<1.0	<1.0	<40	<5.0	<3.4	<2.6	<0.26	<1.3	5.4 (tr)	<0.26	<0.26
Iodomethane (Methyl iodide)	µg/L	<1.0	<1.0	<1.0	<1.0	<40	<5.0	NA	<0.36	<0.036	<0.18	<0.18	<0.036	<0.036
Isopropylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<4.8	<12	<55	<2.8	<0.28	<1.4	<1.4	<0.28	<0.28
p-Isopropyltoluene	µg/L	<0.13	<0.13	<0.13	<0.13	<5.2	<13	<80	<4.0	1.3	<2.0	<2.0	0.94 (tr)	2.2
Methyl-tert-butyl ether (MTBE)	µg/L	3	<1.0	1.3(tr)	<1.0	<40	<5.0	<72	<3.6	0.37	<1.8	<1.8	<0.36	0.74 (tr)
4-Methyl-2-pentanone (MIBK)	µg/L	3.8	<1.0	3.3	1.7 (tr)	280	82	380 (tr)	320	30	18	11	40	15
Methylene Chloride	µg/L	0.35(tr)	<0.35	<0.35	<0.35	<14	<35	<45	7.7 (tr)	0.37	<1.1	<1.1	<0.23	<0.23
Naphthalene	µg/L	<0.15	<0.15	<0.15	<0.15	<6.0	<15	<190	<9.3	<0.93	<4.6	<4.6	1.4	2.5
n-Propylbenzene	µg/L	<0.15	<0.15	<0.15	<0.15	<6.0	<15	<74	<3.7	<0.37	<1.9	<1.9	<0.37	<0.37
Styrene	µg/L	<0.15	<0.15	<0.15	<0.15	<6.0	<15	<67	<3.3	<0.33	<1.7	<1.7	<0.33	0.36 (tr)
1,1,1,2-Tetrachloroethane	µg/L	<0.10	<0.10	<0.10	<0.10	<4.0	<10	<67	<3.4	<0.34	<1.7	<1.7	<0.34	<0.34
1,1,2,2-Tetrachloroethane	µg/L	<0.37	<0.37	<0.37	<0.37	<15	<37	<120	<5.9	<0.59	<3.0	<3.0	<0.59	<0.59

Table 15. Analytical Results for Leachate Sampled from the Southeast Aerobic Cell

		No Liquid Addition or Recirculation				Full-scale leachate Addition and Recirculation								
PARAMETER	**DATE:**	**2/26/2002**	**3/27/2002**	**5/14/2002**	**5/29/2003**	**12/3/2003**	**1/8/2004**	**2/23/2004**	**5/26/2004**	**6/28/2004**	**7/26/2004**	**9/27/2004**	**11/9/2004**	**3/3/2005**
Tetrachloroethene (PCE)	µg/L	0.67(tr)	0.60(tr)	0.88(tr)	<0.38	<15	<38	<89	<4.4	<0.44	<2.2	<2.2	<0.44	<0.44
Toluene	µg/L	0.35(tr)	0.27(tr)*	<0.25	<0.25	<10	<25	120	20	3.5	5.2	2.2	4	7.7
1,2,3-Trichlorobenzene	µg/L	<0.14	<0.14	<0.14	<0.14	<5.6	<14	<92	<4.6	<0.46	<2.3	<2.3	<0.46	<0.46
1,2,4-Trichlorobenzene	µg/L	<0.23	<0.23	<0.23	<0.23	<9.2	<23	<82	<4.1	<0.41	<2.0	<2.0	0.59 (tr)	<0.41
1,1,1-Trichloroethane (1,1,1-TCA)	µg/L	<0.41	<0.41	<0.41	<0.41	<16	<41	<38	<1.9	<0.19	<0.94	<0.94	<0.19	<0.19
1,1,2-Trichloroethane (1,1,2-TCA)	µg/L	<0.31	<0.31	<0.31	<0.31	<12	<31	NA	<4.3	<0.43	<2.2	<2.2	<0.43	<0.43
Trichloroethene (TCE)	µg/L	1.6	0.83(tr)	<0.31	<0.31	<12	<31	<72	<3.6	<0.36	<1.8	<1.8	<0.36	<0.36
Trichlorofluoromethane (Freon 11)	µg/L	<0.23	<0.23	<0.23	<0.23	<9.2	<23	<83	<4.2	<0.42	<2.1	<2.1	<0.42	<0.42
1,2,3-Trichloropropane	µg/L	<0.30	<0.30	<0.30	<0.30	<12	<30	<110	<5.5	<0.55	<2.8	<2.8	<0.55	<0.55
1,2,4-Trimethylbenzene	µg/L	<0.12	<0.12	<0.12	<0.12	<4.8	<12	<37	<1.8	0.4	<0.92	<0.92	<0.18	0.88 (tr)
1,3,5-Trimethylbenzene	µg/L	<0.14	<0.14	<0.14	<0.14	<5.6	<14	<57	<2.8	<0.28	<1.4	<1.4	<0.28	<0.28
Vinyl Acetate	µg/L	<1.0	<1.0	<1.0	<1.0	<40	<5.0	<43	<9.4		<4.7	<4.7	<0.94	<0.94
Vinyl Chloride	µg/L	<0.12	<0.12	<0.12	<0.12	<4.8	<12	<32	<1.6	<0.16	<0.8	<0.8	<0.16	<0.16
Total Xylenes	µg/L	0.34(tr)	0.10(tr)	<0.10	1.2	<4.0	<10	160	<4.8	2.5	<2.4	<2.4	2.7	6.1

Footnotes:

NA=Not Analyzed

MDL=Method Detection Limit

PQL=Practical Quantification Limit

<=Less than the MDL

tr=trace: the amount detected was above the MDL but below the PQL

* = this parameter was alo detected in the method blank

Table 16. Analytical Results for Landfill Gas Sampled from the Northeast Anaerobic Cell and Pilot-Scale Enhanced Cell

		Northeast Anaerobic Cell														Pilot Scale Cell
GAS ANALYSIS PARAMETERS	**DATE:**	**3/8/2002**	**5/29/2002**	**8/29/2002**	**12/5/2002**	**3/18/2003**	**5/27/2003**	**8/25/2003**	**11/19/2003**	**3/20/2004**	**8/9/2004**	**10/28/2004**	**3/9/2005**	**6/28/2005**	**10/25/2005**	**Average of 3 samples during 2002**
Method CFR60 EPA 25C Mod:	**Units**															
Methane	ppm	280,000	280,000	460,000	400,000	390,000	450,000	530,000	510,000	NA	NA	NA	NA	NA	NA	466,667
Total Non-Methane Hydocarbons as Methane	ppm	10,000	9,500	6,200	3,000	1,600	1,500	1,400	730	1,700	2,100	894	490	670	460	680
Method CFR60A EPA 15/16:																
Dimethyl Sulfide	ppm	18	12	11	4.5	2.7	ND	0.91	ND	ND	ND	ND	1	ND	ND	ND
Hydrogen Sulfide	ppm	ND	ND	1.8	220	160	230	270	130	110	86	34	36	1.1	66.0	177
Carbonyl Sulfide	ppm	ND	ND	ND	0.47	0.43	ND	0.61	0.57	ND	ND	ND	ND	ND	ND	ND
Methyl Mercaptan	ppm	ND	ND	0.38	0.87	0.44	ND	0.36	0.26	ND	ND	ND	ND	ND	ND	ND
Ethyl Mercaptan	ppm	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND	ND
Carbon Disulfide	ppm	0.64	0.54	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyl Disulfide	ppm	0.52	ND	ND	ND	ND	ND	ND	0.8	ND	ND	ND	ND	ND	ND	ND
Method CFR60 EPA 3C:																
Carbon Dioxide	%	41	41	43	37	40	37	42	37	43	41	33	26	36	38	37
Carbon Monoxide	%	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	ND		ND	ND	ND
Methane	%	28	28	46	40	39	45	53	51	55	53	46	34	46	45	47
Nitrogen	%	26	27	6.9	20	15	13	5.3	8.6	4.5	3.2	22	34	590	28	14
Oxygen	%	0.83	0.21	0.26	1.9	1.5	0.66	0.23	1.5	0.83	0.37	1	6.6	ND	1.8	1
Method EPA-2 TO -15:																
Dichlorodifluormethane	ppb	7,900	6,400	1,400	1,300	1,200	680	410	890	460	400	500	380	260	500	303
Chloromethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloro-1,1,2,2-tetrafluoroethane	ppb	ND	400	320	110	85	68	ND	57	33	53	50	42	24	52	100
Vinyl Chloride	ppb	ND	950	3,600	4,000	1,200	1,200	840	1,100	1,000	700	680	550	330	430	167
Bromomethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ppb	1,100	820	550	360	170	160	ND	ND	79	80	98	98	45	81	41
Trichlorofluoromethane	ppb	620	430	280	130	92	ND	ND	ND	32	44	20	18	17	24	ND
1,1-Dichlorethene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	40
Carbon Disulfide	ppb	ND	ND	ND	ND	ND	ND	ND	280	ND	100 (TR)	190	130	72	51	ND
1,1,2-Trichloro-1,2,2-trifluoroethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	66
Acetone	ppb	54,000	28,000	22,000	10,000	4,300	4,300	4,000	3,400	2,300	3,000	1,100	1,200	1,100	440	195
Methylene Chloride	ppb	14,000	8,200	3,900	1,200	300	160	72	170	66	ND	26	23	24	32	ND
trans-1,2-Dichloroethene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ppb	1,600	1,000	850	340	130	95	72	ND	41	40	38	45	18	26	45
Vinyl Acetate	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	ppb	ND	240	670	760	520	500	380	490	300	260	230	120	71	110	108
2-Butanone (MEK)	ppb	38,000	28,000	29,000	9,500	3,800	3,800	4,100	2,700	2,500	3,000	1,600	1,000	1,100	340	155
Chloroform	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ppb	ND	ND	ND	ND	42	ND	ND	ND	ND	ND	ND	23	ND	ND	ND
Carbon Tetrachloride	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ppb	1,700	1,800	1,500	960	380	450	310	290	260	320	160	150	99	140	89
1,2-Dichloroethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ppb	1,700	1,300	1,200	620	260	240	200	140	260	300	80	61	39	45	39
1,2-Dichloropropane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis-1,3-Dichloropropene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methyl-2-Pentanone (MIBK)	ppb	10,000	9,700	8,100	2,500	760	760	570	540	310	420	340	ND	ND	430	ND
Toluene	ppb	31,000	26,000	25,000	19,000	8,400	8,400	7,000	7,400	5,400	5,500	3,000	2,500	1,300	1,400	1,400
trans-1,3-Dichloropropene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ppb	2,300	2,200	1,600	1,000	480	470	340	300	230	220	140	130	85	89	61
2-Hexanone	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromochloromethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dibromoethane (EDB)	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13	29

		Northeast Anaerobic Cell														Pilot Scale Cell
GAS ANALYSIS PARAMETERS	**DATE:**	**3/8/2002**	**5/29/2002**	**8/29/2002**	**12/5/2002**	**3/18/2003**	**5/27/2003**	**8/25/2003**	**11/19/2003**	**3/20/2004**	**8/9/2004**	**10/28/2004**	**3/9/2005**	**6/28/2005**	**10/25/2005**	**Average of 3 samples during 2002**
Ethylbenzene	ppb	2,800	3,200	3,000	3,100	1,800	1,800	1,800	1,500	1,400	2,500	1,500	1,300	900	1,000	1,633
Total Xylenes	ppb	9,400	11,000	9,700	9,700	5,200	5,600	4,900	3,800	4,050	6,800	3,780	3,650	2,420	2,070	2,933
Styrene	ppb	700	930	950	980	350	250(tr)	250	84(tr)	120	240	980	120	81	79	48
Bromoform	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	150	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzyl Chloride	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Ethyltoluene	ppb	ND	930	710	980	470	600	490	140	240	710	540	460	330	220	315
1,3,5-Trimethylbenzene	ppb	ND	290	260	390	170	210	190	63	72	230	230	180	160	120	203
1,2,4-Trimethylbenzene	ppb	ND	760	640	840	380	480	370	63	ND	580	450	390	270	210	437
1,3-Dichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ppb	ND	270	190	280	66	78	ND	ND	ND	180	170	130	120	140	270
1,2-Dichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND=Not Detected

Table 17. Analytical Results for Landfill Gas Sampled from the West-Side Anaerobic Cell

		West-Side Anaerobic Cell											Pilot Scale Cell
GAS ANALYSIS PARAMETERS	**Units**	**5/29/2002**	**3/18/2003**	**5/27/2003**	**8/25/2003**	**11/19/2003**	**3/30/2004**	**8/9/2004**	**10/28/2004**	**3/9/2005**	**6/28/2005**	**10/25/2005**	**Average of 3 samples during 2002**
Method CFR60 EPA 25C Mod:													
Methane	ppm	230,000	180,000	310,000	460,000	460,000	NA	NA	NA	NA	NA	NA	466,667
Total Non-Methane Hydocarbons as Methane	ppm	5,100	2,200	6,200	3,500	1,400	1,800	2,800	1,180	660	820	620	680
Method CFR60A EPA 15/16:													
Dimethyl Sulfide	ppm	5.2	5	7	4.5	1.4	ND	ND	ND	ND	ND	ND	ND
Hydrogen Sulfide	ppm	ND	66	81	270	340	240	92	8.6	98	37	75	177
Carbonyl Sulfide	ppm	ND	0.91	0.81	1.2	1.4	ND	ND	1.1	ND	ND	ND	ND
Methyl Mercaptan	ppm	ND	1.3	1.5	1.8	1.3	ND	ND	ND	ND	ND	ND	ND
Ethyl Mercaptan	ppm	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND	ND
Carbon Disulfide	ppm	ND	0.89	0.52	0.38	0.24	ND	0.68	ND	ND	ND	ND	ND
Dimethyl Disulfide	ppm	ND	ND	0.22	ND	ND	ND	ND	ND	ND	ND	ND	ND
Method CFR60 EPA 3C:													
Carbon Dioxide	%	68	19	34	39	35	34	42	31	24	34	33	37
Carbon Monoxide	%	ND	ND	ND	ND	ND	NA	NA	ND	NA	ND	ND	ND
Methane	%	23	18	30	46	47	42	53	45	30	43	43	47
Nitrogen	%	11	49	31	14	13	20	2.8	24	39	27	32	14
Oxygen	%	ND	11	1.1	1	3	5.8	0.39	2.1	7.3	ND	ND	1
Method EPA-2 to-15													
Dichlorodifluormethane	ppb	17,000	3,800	2,700	1,300	1,300	940	820	630	680	310	120	303
Chloromethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
1,2-Dichloro-1,1,2,2-tetrafluoroethane	ppb	1,100	340	240	ND	82	99	ND	ND	48	20	37	100
Vinyl Chloride	ppb	1,200	170	180	1,500	1,000	710	920	850	690	320	170	167
Bromomethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Chloroethane	ppb	780	320	380	ND	150	100	130	72	68	26	75	41
Trichlorofluoromethane	ppb	7,900	370	370	ND	270	150	140	81	87	39	83	ND
1,1-Dichlorethane	ppb	880	440	620	250	210	160	ND	ND	ND	ND		40
Carbon Disulfide	ppb	ND	ND	ND	ND	360	ND	170 (tr)	ND	200	ND	160	ND
1,1,2-Trichloro-1,2,2-trifluoroethane	ppb	960	ND	ND	ND	ND	ND	ND	ND	ND	ND		66
Acetone	ppb	13,000	16,000	22,000	12,000	9,700	3,100	6,700	3,000	2,600	770	770	195
Methylene Chloride	ppb	4,800	3,500	3,900	830	430	290	200	210	91	27	84	ND
trans-1,2-Dichloroethene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
1,1-Dichloroethene	ppb	ND	ND	ND	ND	ND	ND	180	130	110	53	82	45
Vinyl Acetate	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
cis-1,2-Dichloroethene	ppb	ND	290	310	530	860	500	560	380	260	110	250	108
2-Butanone (MEK)	ppb	6,000	23,000	23,000	14,000	13,000	4,000	8,900	5,800	3,000	960	1,100	155
Chloroform	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
1,1,1-Trichloroethane	ppb	680	ND	ND	ND	ND	130	60	ND	ND	ND		ND
Carbon Tetrachloride	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Benzene	ppb	490	980	1,300	730	730	500	690	430	310	200	250	89
1,2-Dichloroethane	ppb	120	ND	150	ND	ND	ND	61	ND	ND	ND		ND
Trichloroethene	ppb	220	860	1,000	580	440	350	520	200	150	68	150	39
1,2-Dichloropropane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Bromoodichloromethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
cis-1,3-Dichloropropene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
4-Methyl-2-Pentanone (MIBK)	ppb	5,400	4,500	4,400	1,700	1,900	790	1,300	830	780	350		ND
Toluene	ppb	3,400	21,000	22,000	13,000	15,000	9,700	15,000	7,100	5,100	2,200	3,900	1,400
trans-1,3-Dichloropropene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
1,1,2-Trichloroethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Tetrachloroethene	ppb	350	1,100	1,700	840	630	480	550	290	280	130	250	61
2-Hexanone	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Dibromochloromethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
1,2-Dibromoethane (EDB)	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Chlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	46	29

		West-Side Anaerobic Cell											Pilot Scale Cell
GAS ANALYSIS PARAMETERS	**Units**	**5/29/2002**	**3/18/2003**	**5/27/2003**	**8/25/2003**	**11/19/2003**	**3/30/2004**	**8/9/2004**	**10/28/2004**	**3/9/2005**	**6/28/2005**	**10/25/2005**	**Average of 3 samples during 2002**
Ethylbenzene	ppb	170	5,100	3,600	1,800	1,800	1,800	4,400	2,700	2,100	1,000	2,000	1,633
Total Xylenes	ppb	480	14,000	11,000	5,000	3,900	4,530	11,200	5,600	4,400	2,150	3,760	2,933
Styrene	ppb	ND	890	1400	550	160(tr)	230	730	340	230	550	200	48
Bromoform	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	110		ND
1,1,2,2-Tetrachloroethane	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Benzyl Chloride	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
4-Ethyltoluene	ppb	ND	590	1100	400	140	350	1100	550	590	260	390	315
1,3,5-Trimethylbenzene	ppb	ND	230	350	ND	ND	100	330	210	230	120	190	203
1,2,4-Trimethylbenzene	ppb	ND	370	750	260	ND	ND	860	400	520	220	350	437
1,3-Dichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
1,4-Dichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	290	150	140	78	180	270
1,2-Dichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
1,2,4-Trichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Hexachlorobutadiene	ppb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND

ND=Not Detected

Table 18. Analytical Results for Gas Sampled from the Southeast Aerobic Cell

		Aerobic Cell								Pilot Scale Cell
Gas Analysis Parameters	**Units**	**3/18/2003**	**5/27/2003**	**8/25/2003**	**11/19/2003**	**12/6/2004**	**3/9/2005**	**6/28/2005**	**10/25/2005**	**Average of 3 samples during 2002**
Method CFR60 EPA 25C Mod:										
Methane	ppm	100,000	63,000	65,000	NA	NA	NA	NA	NA	466,667
Total Non-Methane Hydocarbons as Methane	ppm	7,700	8100	7,500	3,700	658	530	670	380	680
Method CFR60A EPA 15/16:										
Dimethyl Sulfide	ppm	10	6.3	8.6	4.1	1.5	ND	ND	ND	ND
Hydrogen Sulfide	ppm	ND	ND	ND	ND	2.4	ND	ND	ND	177
Carbonyl Sulfide	ppm	ND	ND	0.2	ND	ND	ND	ND	ND	ND
Methyl Mercaptan	ppm	1	0.95	0.4	0.32	ND	ND	ND	ND	ND
Ethyl Mercaptan	ppm	ND	ND	ND	ND	ND	NA	ND	ND	ND
Carbon Disulfide	ppm	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyl Disulfide	ppm	0.84	1.1	0.96	0.57	ND	ND	ND	ND	ND
Method CFR60 EPA 3C:										
Carbon Dioxide	%	24	21	22	10	31	29	34	38	37
Carbon Monoxide	%	ND	ND	ND	0.0019	ND		ND	ND	ND
Methane	%	10	6.3	6.5	4.5	35	33	40	50	47
Nitrogen	%	62	68	69	83	28	33	26	12	14
Oxygen	%	1.9	1.3	1.3	0.9	4	5.1	1.9	ND	1
Method EPA-2 to-15										
Dichlorodifluormethane	ppb	1,400	1,300	1,100	310	89	130	500	160	303
Chloromethane	ppb	ND	350	ND	ND	ND	ND	ND		ND
1,2-Dichloro-1,1,2,2-tetrafluoroethane	ppb	ND	ND	ND	ND	ND	ND	ND	15	100
Vinyl Chloride	ppb	ND	120	ND	ND	ND	320	98	43	167
Bromomethane	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Chloroethane	ppb	ND	ND	ND	ND	ND	ND	ND	10	41
Trichlorofluoromethane	ppb	ND	130	ND	110	ND	ND	63		ND
1,1-Dichloroethane	ppb	580	240	240	200	ND	ND	ND		40
Carbon Disulfide	ppb	ND	ND	ND	ND	ND	160	110	72	ND
1,1,2-Trichloro-1,2,2-trifluoroethane	ppb	ND	ND	ND	ND	ND	ND	ND		66
Acetone	ppb	50,000	40,000	42,000	39,000	3,900	2,000	170		195
Methylene Chloride	ppb	1,700	920	760	380	ND	ND	ND		ND
trans-1,2-Dichloroethene	ppb	ND	ND	ND	ND	ND	ND	ND		ND
1,1-Dichloroethene	ppb	ND	ND	ND	ND	ND	ND	ND		45
Vinyl Acetate	ppb	ND	ND	ND	ND	ND	ND	ND		ND
cis-1,2-Dichloroethene	ppb	ND	ND	ND	130	430	ND	100	96	108
2-Butanone (MEK)	ppb	28,000	23,000	20,000	21,000	3600	ND	230	14	155
Chloroform	ppb	ND	ND	ND	ND	ND	1,700	ND		ND
1,1,1-Trichloroethane	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Carbon Tetrachloride	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Benzene	ppb	1,300	850	700	640	260	180	120	98	89
1,2-Dichloroethane	ppb	220	140	ND	ND	ND	ND	ND		ND
Trichloroethene	ppb	620	550	440	400	160	99	44	72	39
1,2-Dichloropropane	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Bromoodichloromethane	ppb	ND	ND	ND	ND	ND	ND	ND		ND
cis-1,3-Dichloropropene	ppb	ND	ND	ND	ND	ND	ND	ND		ND
4-Methyl-2-Pentanone (MIBK)	ppb	14,000	8,700	6,200	7,200	1100	1,100	290		ND
Toluene	ppb	20,000	16,000	11,000	10,000	3100	3,700	1,500	720	1,400
trans-1,3-Dichloropropene	ppb	ND	ND	ND	ND	ND	ND	ND		ND
1,1,2-Trichloroethane	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Tetrachloroethene	ppb	1,500	1,400	1,100	1,000	380	190	72	83	61
2-Hexanone	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Dibromochloromethane	ppb	ND	ND	ND	ND	ND	ND	ND		ND
1,2-Dibromoethane (EDB)	ppb	ND	ND	ND	ND	ND	ND	ND		ND

		Aerobic Cell								Pilot Scale Cell
Gas Analysis Parameters	**Units**	**3/18/2003**	**5/27/2003**	**8/25/2003**	**11/19/2003**	**12/6/2004**	**3/9/2005**	**6/28/2005**	**10/25/2005**	**Average of 3 samples during 2002**
Chlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND	13	29
Ethylbenzene	ppb	2,300	3,000	2,400	2,600	930	1,700	690	380	1,633
Total Xylenes	ppb	6,500	9,500	7,000	7,200	3700	4,500	2,340	1,210	2,933
Styrene	ppb	310	520(tr)	240	150(tr)	ND	600	120		48
Bromoform	ppb	ND	ND	ND	ND	ND	ND	ND		ND
1,1,2,2-Tetrachloroethane	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Benzyl Chloride	ppb	ND	ND	ND	ND	ND	ND	ND		ND
4-Ethyltoluene	ppb	500	1,200	480	190	330	540	380	160	315
1,3,5-Trimethylbenzene	ppb	ND	410	200	ND	140	200	180	120	203
1,2,4-Trimethylbenzene	ppb	370	890	330	ND	270	390	290	89	437
1,3-Dichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND		ND
1,4-Dichlorobenzene	ppb	ND	170	ND	ND	ND	120	96	54	270
1,2-Dichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND		ND
1,2,4-Trichlorobenzene	ppb	ND	ND	ND	ND	ND	ND	ND		ND
Hexachlorobutadiene	ppb	ND	ND	ND	ND	ND	ND	ND		ND

ND=Not Detected

TABLE 19

NORTHEAST ANAEROBIC BIOREREACTOR

Yolo County Full-Scale Anerobic Bioreactor Project

Waste Sampling Results

Sampling Event	Sample Location/ID	Sample Depth (ft)	Sample Depth(ft)	Sample pH	Temp. @ pH, Celcius	% H20	% Cellulose	% Hemicullose	% Lignin	3.5-acre North-East (C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/5/2002	NE-1	0-5 (SS)	2.5	6.16	25.8	13.96	14.68	4.09	13.99	1.34	18.93	27.7	lots of paper
6/5/2002	NE-2	5-10 (SS)	7.5	5.76	24.8	20.29	27.85	8.05	23.68	1.52	51.15	56.45	lots of plastic and wood
6/5/2002	NE-3	10-15	12.5	5.88	24.5	22.34	35.52	9.93	26.92	1.69	56.31	64.35	lots of wood
6/5/2002	NE-4	15-20	17.5	5.58	26.4	16.14	39.48	9.64	16.04	3.06	82.1	70.25	
6/5/2002	NE-5	20-25 (SS)	22.5	6.15	26.1	16.89	30.55	8.62	25.63	1.53	35.3	57.2	
6/5/2002	NE-6	25-30	27.5	5.76	27.6	18.69	35.23	9.40	18.51	2.41	71.56	62	
6/5/2002	NE-7	30-35	32.5	6.03	27.4	20.28	20.28	7.42	16.89	1.64	59.05	58.35	
		1st Sampling Event Averages		**5.90**	26.09	18.37	29.08	8.16	20.24	1.88	53.49	56.61	

Sampling Event	Sample Location/ID	Sample Depth (ft)	Sample Depth(ft)	Sample pH	Temp. @ pH, Celcius	% H20	% Cellulose	% Hemicullose	% Lignin	3.5-acre North-East (C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
7/16/2003	NE-N-1	5-10	7.5	6.18	26.9	18.47	23.55	5.57	17.97	1.62	52.72	44.45	Plastic, paper, p. bd, wood
7/16/2003	NE-N-2	10-15	12.5	6.30	25.35	27.04	20.60	5.21	15.13	1.71	53.07	35.75	dark brown
7/16/2003	NE-N-3	15-20	17.5	6.23	26.65	24.19	21.24	5.84	14.48	1.87	57.9	47	paper, plastic, metal
7/16/2003	NE-N-4	20-25	22.5	5.74	26.95	22.94	28.73	7.88	17.73	2.06	90.78	57.65	paper, plastic
7/16/2003	NE-N-5	25-30	27.5	5.77	28.7	29.50	21.36	4.10	16.01	1.59	68.58	47.75	paper, plastic, dry
7/16/2003	NE-N-6	30-35	32.5	5.86	31.2	16.35	23.18	5.64	15.13	1.90	64.47	42.05	wood, pen, paper, organic matter
		Average for sample N =		**6.01**		**23.08**	**23.11**	**5.71**	**16.07**	**1.79**	**64.59**	**45.78**	
7/16/2003	NE-S-1	5-10	7.5	6.04	33.8	20.42	23.93	5.78	11.65	2.55	82.59	47.75	plastic, cloth, paper, dry
7/16/2003	NE-S-2	10-15	12.5	6.33	33.85	15.33	29.62	8.19	13.86	2.73	90.9	60.55	metal, paper, wood, dry
7/16/2003	NE-S-3	15-20	17.5	6.61	37	41.00	16.96	4.10	11.29	1.87	46.62	35.7	paper, plastic, wet, some metal, dark gray/black
7/16/2003	NE-S-4	20-25	22.5	6.08	36.85	28.23	26.14	9.02	16.11	2.18	79.92	51.6	organic matter, plastic, cloth, newspaper, very wet
		Average for sample S =		**6.15**		**26.25**	**24.16**	**6.77**	**13.23**	**2.33**	**75.01**	**48.90**	
		Overall 2nd Sampling Event Averages =		**6.11**		**24.35**	**23.53**	**6.13**	**14.93**	**2.01**	**68.76**	**47.03**	

Sampling Event	Sample Location/ID	Sample Depth (ft)	Sample Depth(ft)	Sample pH	Temp. @ pH, Celcius	% H20	% Cellulose	% Hemicullose	% Lignin	3.5-acre North-East (C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/3/2004	NE-N-1	5-10	7.5	5.54	30.1	33.15	34.17	8.35	17.14	2.48	87.01	64.7	wood chips, paper, plastic, dry, stinky, piece of video tape
6/3/2004	NE-N-2	10-15	12.5	6.22	28.5	35.98	37.30	7.48	13.60	3.29	102.97	60.45	fabric, paper, yard waste, dry
6/3/2004	NE-N-3	15-20	17.5	6.56	30.4	27.32	46.26	10.36	12.08	4.69	109.20	73.6	paper, plsatic, large piece of wood
6/4/2004	NE-N-4	20-25	22.5	7.89	18.9	57.02	21.92	6.25	17.03	1.65	39.99	46.1	wood, paper, ADC very wet, small oil can
6/4/2004	NE-N-5	25-30	27.5	7.64	18	60.98	17.52	4.83	17.64	1.27	23.90	37.15	very wet, film, plastic, paper, dirt
		Average for sample N =		**6.77**		**42.89**	**31.43**	**7.45**	**15.50**	**2.68**	**72.62**	**56.40**	

TABLE 19

NORTHEAST ANAEROBIC BIOREREACTOR

Yolo County Full-Scale Anerobic Bioreactor Project

Waste Sampling Results

Sampling Event	Sample Location/ID	Sample Depth (ft)	Sample Depth(ft)	Sample pH	Temp. @ pH, Celcius	% H20	% Cellulose	% Hemicullose	% Lignin	3.5-acre North-East (C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/4/2004	NE-S-1	5-10	7.5	8.62	19.2	29.82	10.43	2.99	10.79	1.24	14.17	21.40	wood, dirt, wire, slightly damp paper
6/4/2004	NE-S-2	10-15	12.5	8.36	19.3	36.27	17.08	4.94	14.39	1.53	11.40	40.88	wet, grass, paper
6/4/2004	NE-S-3	15-20	17.5	7.91	20.5	45.42	13.11	4.41	16.18	1.08	12.97	31.55	plastic, dirt, wire, wood, wet
6/4/2004	NE-S-4	20-25	22.5	7.12	20.4	51.33	15.19	3.92	14.42	1.26	21.70	36.85	wood, dirt, plastic, very wet
6/4/2004	NE-S-5	25-30	27.5	6.94	23.9	51.43	13.82	3.57	14.23	1.22	11.86	29.00	wood, very wet, paper, dirt
		Average for sample S =		**7.92**		**37.17**	**13.54**	**4.11**	**13.78**	**1.29**	**12.85**	**31.28**	
Overall 3rd Sampling Event Averages =				**7.34**		**40.75**	**24.72**	**6.20**	**14.86**	**2.15**	**50.20**	**46.98**	

Using a clean 5 gallon bucket and a clean PVC pipe as a stirrer, combine and mix for approx. 30 to 60 seconds.

Waste used for each sample (by weight): 1 - 2 pounds

SS - Split sample: made into two samples

DI water used for each sample (by volume): 1/2 to 1 gallon

TABLE 20

WEST-SIDE ANAEROBIC BIOREACTOR

Yolo County Full-Scale Bioreactor Project

Waste Sampling Results

Date	Sample Location/ID	Sample Depth	Sample Depth(ft)	Sample pH	% H20	Temp. @ pH, Celcius	% Cellulose	% Hemicullose	% Lignin	6-acre West Anaerobic(C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/4/2002	W-2	5-10	7.5	5.44	24.45	24.7	36.78	11.01	22.59	2.12	42.01	63.7	
6/4/2002	W-4	15-20	17.5	6.18	21.08	23.6	32.76	11.57	26.52	1.67	15.57	51.95	
6/4/2002	W-6	25-30	22.5	6.91	17.59	24.4	14.35	4.28	10.51	1.77	21.77	25	
6/4/2002	W-7	30-33	31.5	6.61	27.03	24.6	34.42	9.05	17.7	2.46	47.94	51.85	changed to using Ultrameter for pH readings due to YSI not working properly
	1st Sampling Event Averages			**6.285**	22.54	24.33	29.58	8.98	19.33	2.00	31.82	48.13	

Date	Sample Location/ID	Sample Depth	Sample Depth(ft)	Sample pH	% H20	Temp. @ pH, Celcius	% Cellulose	% Hemicullose	% Lignin	6-acre West Anaerobic(C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
7/15/2003	W-N-1	5-10	7.5	6.42	15.19	34.35	31.54	6.685	12.32	3.10	77.89	48.85	wood, paper, plastic, cloth, dry
7/15/2003	W-N-2	10-15	12.5	6.31	20.70	35.00	5.045	2.065	7.39	0.96	13.5	16.2	wood, paper, dry
7/15/2003	W-N-3	15-20	17.5	6.55	27.51	33.4	43.245	10.66	10.885	4.95	120.78	63.8	wood, plastic, dry
7/15/2003	W-N-4	20-25	22.5	6.69	25.96	34.8	30.56	7.54	18.7	2.04	88.03	61.65	wood, plastic, dry
7/15/2003	W-N-5	25-30	27.5	6.23	32.92	33.25	39.855	9.37	14.27	3.45	122.16	77.35	twine, plastic, paper
7/15/2003	W-N-6	30-35	32.5	5.95	30.49	35.45	37.905	7.62	13.115	3.47	118.41	62.35	paper, plastic, wood, diaper, dry
7/15/2003	W-N-7	35-40	37.5	6.55	20.11	40.9	28.56	7.29	17.96	2.00	61.21	46.95	plastic
	Average of	**sample N**		**6.38**	**24.70**		**30.96**	**7.32**	**13.52**	**2.85**	**86.00**	**53.88**	
7/15/2003	W-S-1	5-10	7.5	7.55	13.85	25.9	19.68	6.17	17.98	1.44	28.41	34.25	
7/15/2003	W-S-2	10-15	12.5	6.72	26.75	26.7	20.335	5.92	13.135	2.00	30.43	33.3	a lot of wood, 1 piece of metal
7/15/2003	W-S-3	15-20	17.5	7.55	40.98	28.55	12.71	4.07	17.41	0.96	15.77	54.95	black, wet, paper, plastic, appears saturated
7/15/2003	W-S-4	20-25	22.5	7.69	44.42	30.55	23.48	5.7	12.455	2.34	35.19	35.95	wet, but not saturated, plastic, paper, nondescript waste
7/15/2003	W-S-5	25-30	27.5	7.37	43.16	33.3	26.18	7.045	15.22	2.18	59.82	44.05	wood, paper, plastics, moist (not as wet as 20-25 ft sample)
7/15/2003	W-S-6	30-35	32.5	7.46	27.53	33.8	13.6	4.09	11.12	1.59	13.4	28.5	cloth, wood, paper, dark brown/gray
7/15/2003	W-S-7	35-40	37.5	7.12	28.31	33.15	24.255	8.36	19.505	1.67	20.64	39.9	a lot of soil, greenwaste, plastic, wood, paper, dry
	Average of	**sample S**		**7.35**	**32.14**		**20.03**	**5.91**	**15.26**	**1.74**	**29.09**	**38.70**	
	Overall 2nd Sampling Event Averages =			**6.87**	**28.42**	**32.79**	**25.50**	**6.61**	**14.39**	**2.30**	**57.55**	**46.29**	

Date	Sample Location/ID	Sample Depth	Sample Depth(ft)	Sample pH	% H20	Temp. @ pH, Celcius	% Cellulose	% Hemicullose	% Lignin	6-acre West Anaerobic(C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/4/2004	W-S-1	5-10	7.5	8.17	35.85	26	17.55	5.925	17.155	1.37	44.28898	42.9	paper, dry, some wood chips, yard waste
6/4/2004	W-S-2	10-15	12.5	8.44	3.06	21.6	28.1	6.63	11.3	3.07	40.9486	46.65	plastic, wood, dirt, damp
6/4/2004	W-S-3	15-20	17.5	8.32	19.74	24.3	15.94	4.735	17.275	1.20	14.5947	30.55	food, plastic, wood, damp
6/4/2004	W-S-4	20-25	22.5	8.36	33.82	23.7	19.805	5.575	15.64	1.62	33.6071	38.25	cardboard, plastic, wood, food waste, very damp
6/4/2004	W-S-5	25-30	27.5	8.57	13.20	25.4	17.3625	4.4925	16.325	1.34	26.4215	37.25	plastic, wood, damp

WEST-SIDE ANAEROBIC BIOREACTOR

Yolo County Full-Scale Bioreactor Project

Waste Sampling Results

Date	Sample Location/ID	Sample Depth	Sample Depth(ft)	Sample pH	% H20	Temp. @ pH, Celcius	% Cellulose	% Hemicullose	% Lignin	6-acre West Anaerobic(C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/4/2004	W-S-6	30-35	32.5	7.08	10.28	23.7	30.37	7.185	13.88	2.71	49.4801	50.2	lots of plastic, cardboard, slightly damp
6/4/2004	W-S-7	35-40	37.5	7.12	8.56	22.2	24.465	7.115	10.945	2.89	61.5819	47.95	wood, plastic, paper, dry
6/4/2004	W-S-8	40-45	42.5	7.09	21.80	23	24.94	5.5	12.93	2.35	61.5819	47.95	lots of plastic, dirt, dry
	Average of	**sample S**		**8.01**	**17.79**		**21.94**	**5.95**	**14.65**	**2.03**	**38.70**	**41.96**	
6/4/2004	W-N-1	5-10	7.5	8.52	27.52	25.4	4.11	1.455	7.3	0.76	19.03	16.45	wood, food waste, plastic, damp
6/4/2004	W-N-2	10-15	12.5	7.98	35.03	24.9	14.425	4.52	11.39	1.66	38.7041	30.8	wood, paper, very damp recording tape
6/4/2004	W-N-3	15-20	17.5	7.79	42.14	26.6	12.37	3.59	11.97	1.33	17.7523	22.15	very wet, smelly, wood, paper
6/4/2004	W-N-4	20-25	22.5	7.70	35.72	25.5	26.99	5.04	14.825	2.16	47.3175	43.65	wet, paper, plstic bottle, film, plastic, wood
6/4/2004	W-N-5	25-30	27.5	7.37	43.11	33.4	17.3675	4.9525	12.2925	1.82	32.178	28.25	very wet, paper, plastic, wood, cloth
6/4/2004	W-N-6	30-35	32.5	7.08	53.64	31.3	18.28	4.31	11.635	1.94	37.7571	33.2	damp, dirt, plastic, paper, wood
6/4/2004	W-N-7	35-40	37.5	7.05	21.40	30.2	15.77	4.49	11.20	1.79	36.14	28.30	dirt, paper, wood, dry
	Average of	**sample N**		**7.64**	**36.94**		**15.62**	**4.05**	**11.52**	**1.64**	**32.70**	**28.97**	
	Overall 3rd Sampling Event Averages =			**7.83**	**27.36**	**26.01**	**18.78**	**5.00**	**13.08**	**1.83**	**35.70**	**35.47**	

Using a clean 5 gallon bucket and a clean PVC pipe as a stirrer, combine and mix for approx. 30 to 60 seconds.

SS - Split sample: made into two samples

Waste used for each sample (by weight): 1 - 2 pounds

DI water used for each sample (by volume): 1/2 to 1 gallon

TABLE 21

SOUTHEAST AEROBIC BIOREACTOR

Yolo County Full-Scale Bioreactor Project

6/5/2002	Time	Sample Location/ID	Sample Depth (ft)	Sample Depth (ft)	Sample pH	Temp. @ pH, Celcius	% H20	% Cellulose	% Hemicullose	% Lignin	Aerobic Bioreactor (C+H)/L	BMP (ml CH_4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/5/2002	8:10	SE-1	0-5	2.5	6.93	24.3	25.25	16.3	5.12	20.34	1.05	24.08	38.7	
6/5/2002	8:16	SE-2	5-10	7.5	6.88	24.4	17.47	27.1	8.27	21.54	1.64	38.44	55.5	
6/5/2002	8:21	SE-3	10-15	12.5	6.50	24.7	14.80	19.58	6.32	18.77	1.38	30.89	41.05	lots of wood
6/5/2002	8:24	SE-4	15-20	17.5	6.34	23.8	15.28	24.06	6.05	14.66	2.05	44.43	43.6	typical with a large piece of cloth
6/5/2002	8:38	SE-5	20-22 (SS)	21	6.42	22.7	16.77	22.03	5.69	18.13	1.53	44.7	43.3	
6/5/2002	8:44	SE-5	20-22 (SS)		6.50	23.4								
			1st Sampling Event Averages =		**6.60**	**23.88**	**17.91**	**21.81**	**6.29**	**18.69**	**1.53**	**36.51**	**44.43**	

Using a clean 5 gallon bucket and a clean PVC pipe as a stirrer, combine and mix for approx. 30 to 60 seconds.
Waste used for each sample (by weight): 1 - 2 pounds

7/16/2003	Time	Sample Location/ID	Sample Depth (ft)	Sample Depth(ft)	Sample pH	Temp. @ pH, Celcius	% H20	% Cellulose	% Hemicullose	% Lignin	Aerobic Bioreactor (C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
7/16/2003	7:55	SE-1	0-5 A	2.5	6.41	25.8	22.45	15.72	3.55	10.64	1.3842593	35.38	21.60	shoe insert, paper, plastic, moist, cardboard, nails, wood
7/16/2003	8:04	SE-2	5-10 A	7.5	6.54	23.7	23.96	24.42	7.00	19.89	1.1753723	39.04	43.65	cardboard, wood, paper, dry
7/16/2003	8:15	SE-3	10-15 A	12.5	6.76	22.7	16.12	11.29	3.62	11.74	0.8393701	33.13	31.75	plastic, wood, paper, cloth, particle board, dry
7/16/2003	8:35	SE-4	15-20 A	17.5	6.64	23.3	14.67	27.06	7.55	14.21	0.8723861	54.97	55.95	paper, metal, plastic, wood
7/16/2003	9:11	SE-5	20-25 A	21	6.17	22.7	16.88	20.73	4.56	21.62	0.9398798	44.99	49.90	cloth, metal, wood, plastic, paper
			2nd Sampling Event Averages =		**6.50**	**23.62**	**18.82**	**19.84**	**5.25**	**15.62**	**1.04**	**41.50**	**40.57**	

6/4/2004	Time	Sample Location/ID	Sample Depth (ft)	Sample Depth(ft)	Sample pH	Temp. @ pH, Celcius	% H20	% Cellulose	% Hemicullose	% Lignin	Aerobic Bioreactor (C+H)/L	BMP (ml CH4/gram)	% Volatile Solids	Notes @ Sample (identifable objects, color, etc.)
6/4/2004	11:30	SE-S-1	5-10	7.5	6.34	24.6	29.36	18.11	3.76	10.09	2.17	41.96	29.65	wood, plastic, rocks, dirt, damp, cardboard
6/4/2004	11:50	SE-S-2	10-15	12.5	7.31	24.9	31.73	10.75	2.68	9.08	1.48	18.74	22.60	damp, wood, plastic, paper, dirt
6/4/2004	13:00	SE-S-3	15-20	17.5	7.28	27.8	31.63	30.54	7.56	16.35	2.33	51.10	50.78	wood, wire, paper, dirt, dry, piece of tire
6/4/2004	13:30	SE-S-4	20-25	22.5	7.52	23.8	26.93	35.04	6.43	16.68	2.49	50.33	49.80	wire, plastic, foil, wood, damp
			3rd Sampling Event Averages =		**7.11**	**25.28**	**29.91**	**23.61**	**5.11**	**13.05**	**2.12**	**40.54**	**38.21**	
6/4/2004	13:35	SE-E-1	5-10	7.5	7.81	29.6	23.84	2.94	1.18	6.31	0.65	5.96	12.25	lots of dirt, styrofoam, wet and dry mix
6/4/2004	13:40	SE-E-2	10-15	12.5	7.72	29.5	27.47	27.69	6.51	11.71	3.07	46.77	43.85	wood, plastic, dirt, slightly damp
6/4/2004	13:50	SE-E-3	15-20	17.5	6.63	27.6	27.99	13.63	3.71	11.30	1.53	35.41	28.50	plastic, paper, dirt, slightly damp
			3rd Sampling Event Averages =		**7.39**	**28.90**	**26.44**	**14.75**	**3.80**	**9.77**	**1.75**	**29.38**	**28.20**	
6/4/2004	14:20	SE-W-1	5-10	7.5	6.53	33.0	14.84	9.53	2.86	10.91	1.14	28.40	26.18	dirt, paper, plastic, damp
6/4/2004	15:43	SE-W-2	10-15	12.5	6.52	29.4	5.59	11.21	3.27	9.70	1.49	23.44	23.25	lots of paper, wood, very dry
6/4/2004	15:53	SE-W-3	15-20	17.5	6.76	30.7	30.78	21.24	5.69	14.73	1.83	39.57	43.05	plastic, rubber, wood, film plastic
6/4/2004	16:05	SE-W-4	20-25	22.5	7.48	30.7	31.47	25.84	6.63	15.89	2.04	47.62	39.30	wood, paper, plastic, dirt, stamp
			3rd Sampling Event Averages =		**6.82**	**30.95**	**20.67**	**16.95**	**4.61**	**12.81**	**1.63**	**34.76**	**32.94**	

APPENDIX B - GRAPHS

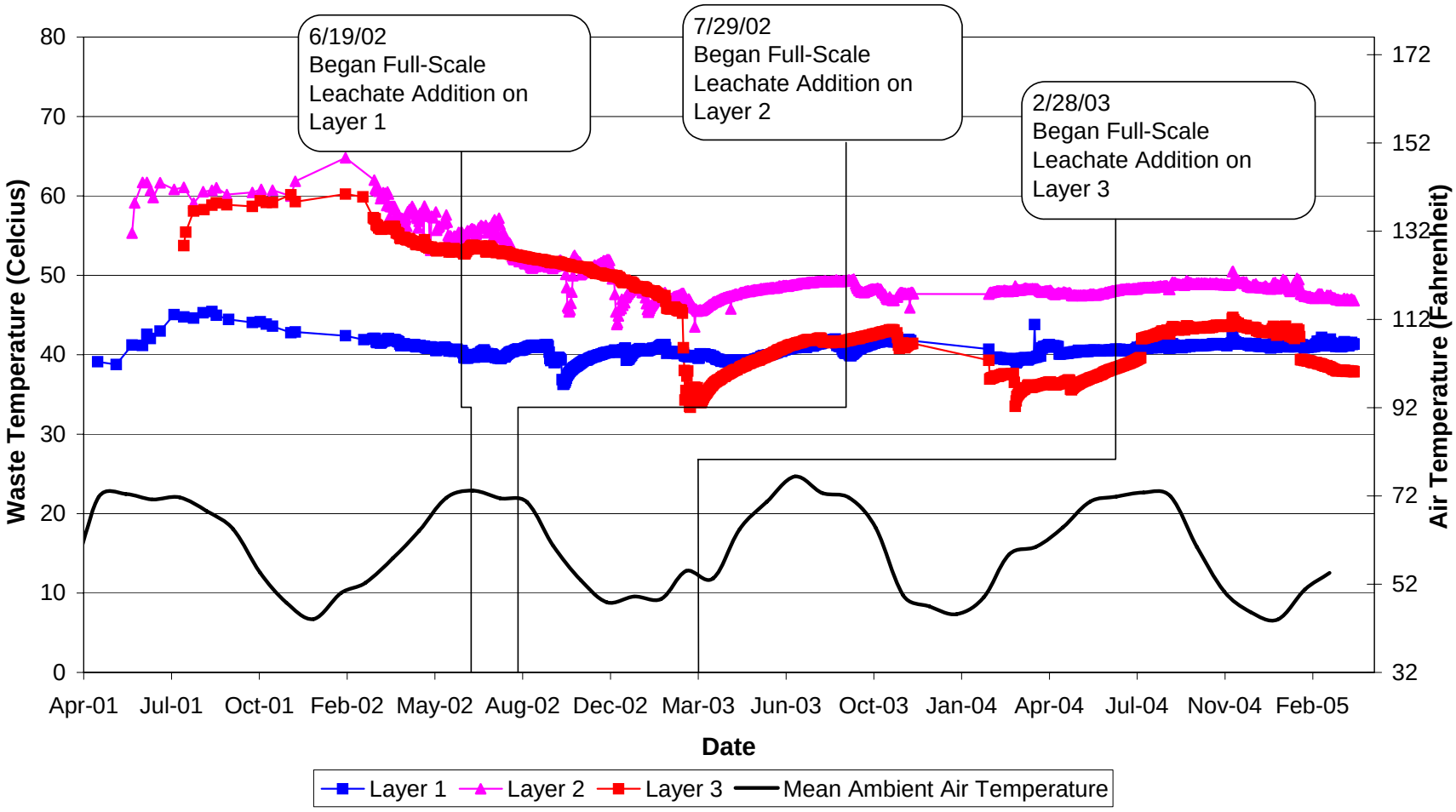


Figure 1. Average temperatures for the northeast cell

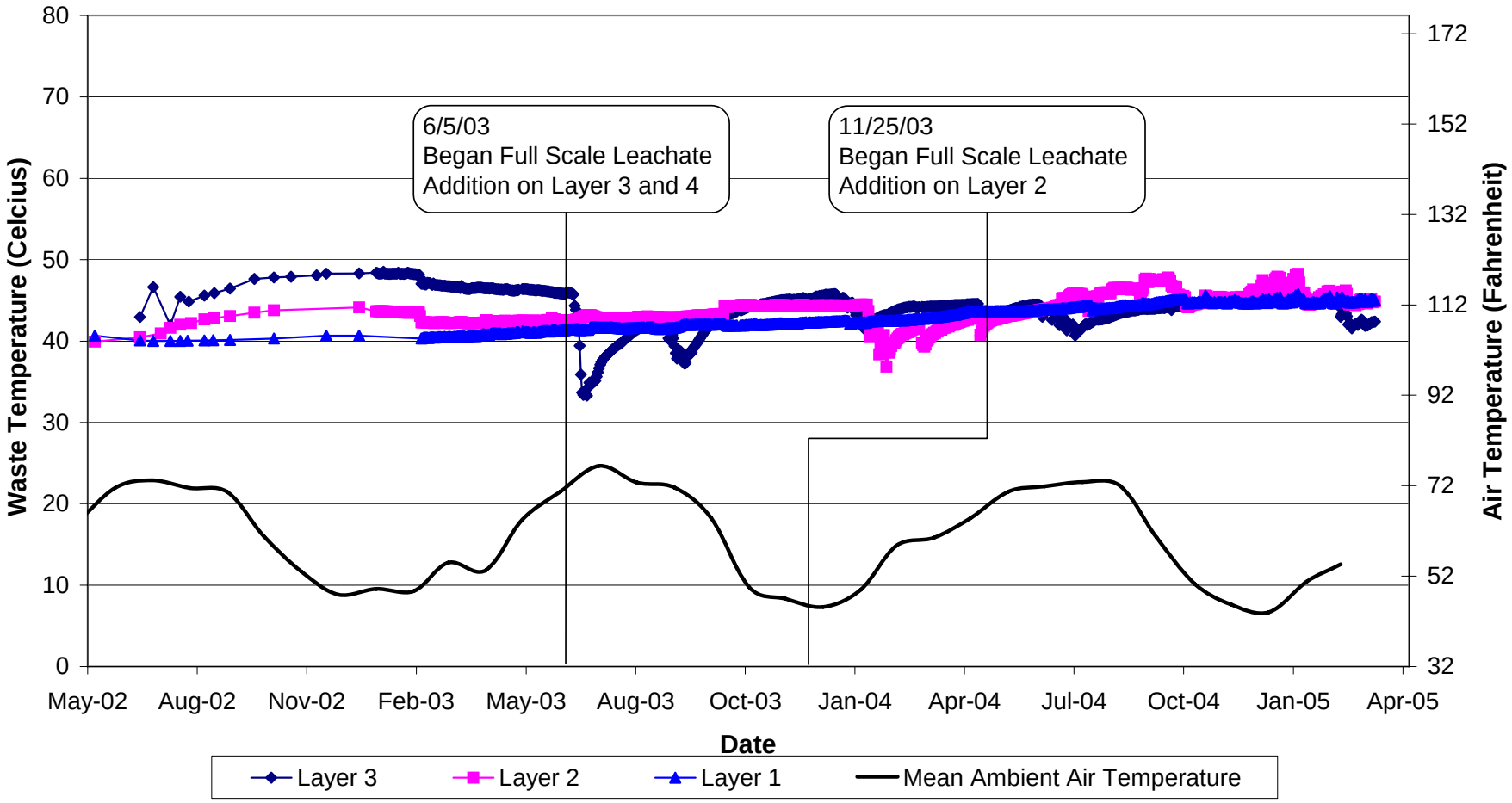


Figure 2. Average temperatures for the west-side cell

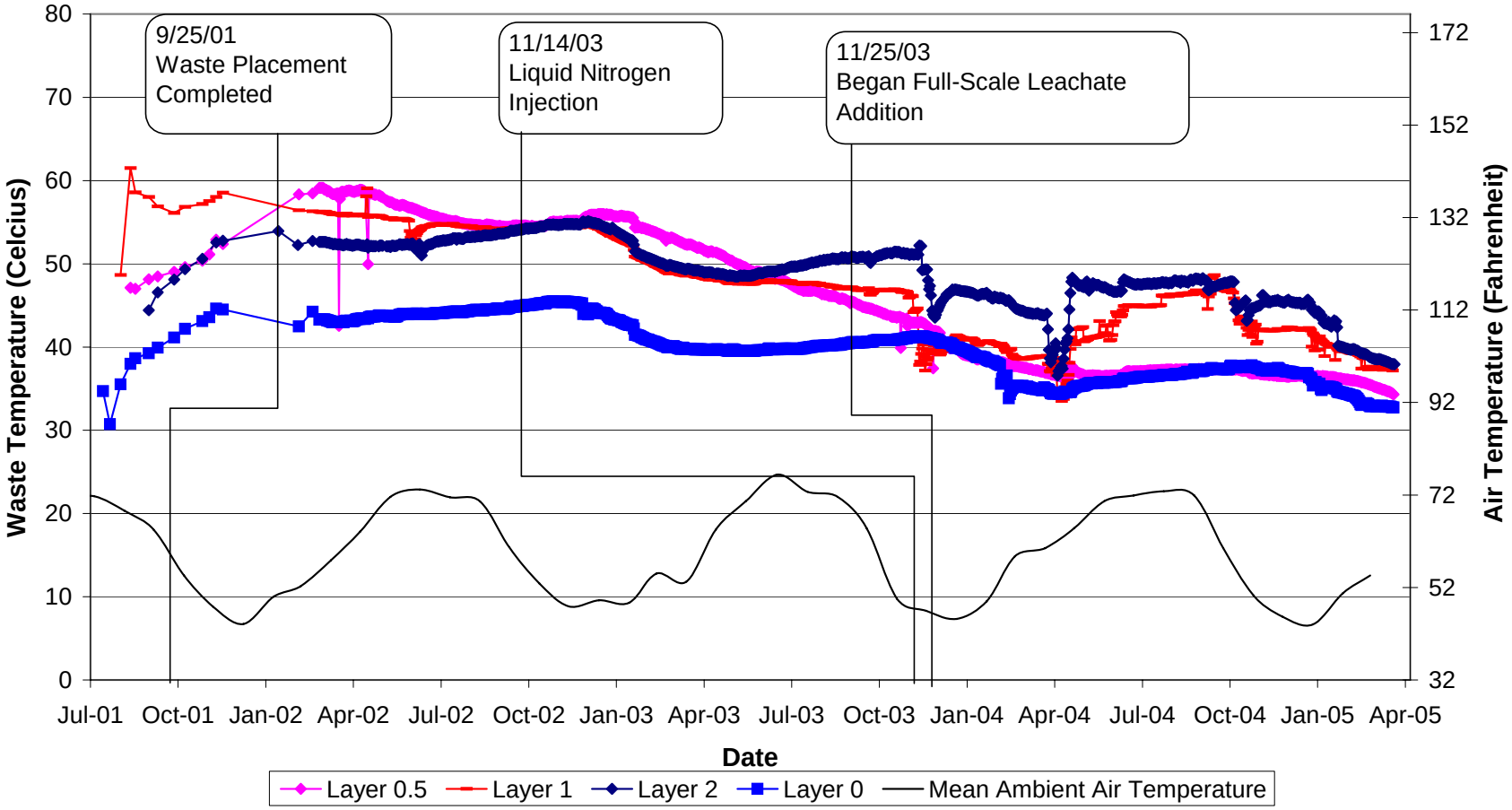


Figure 3. Average temperatures for the southeast aerobic cell

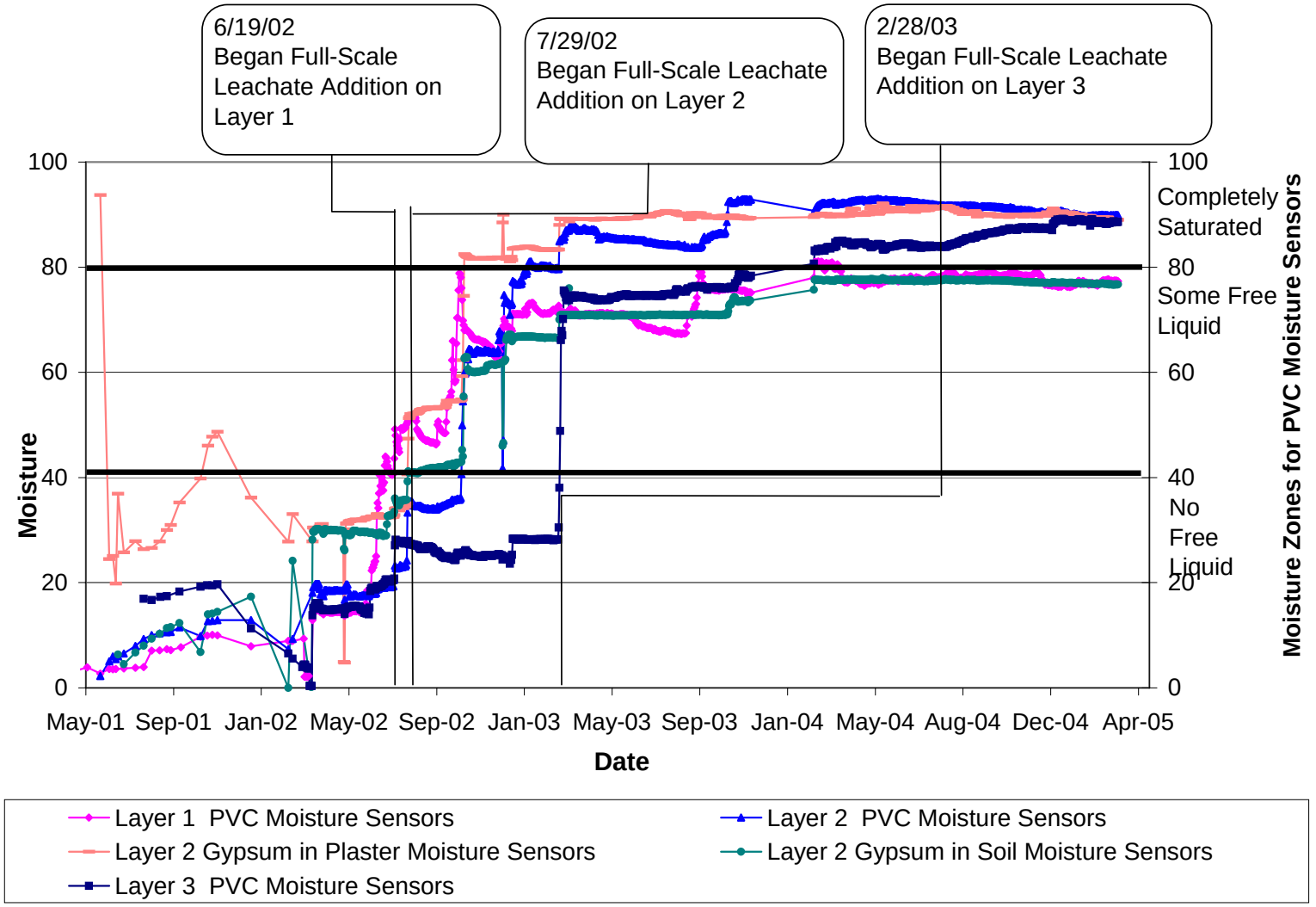


Figure 4. Average moisture for each layer on the northeast cell

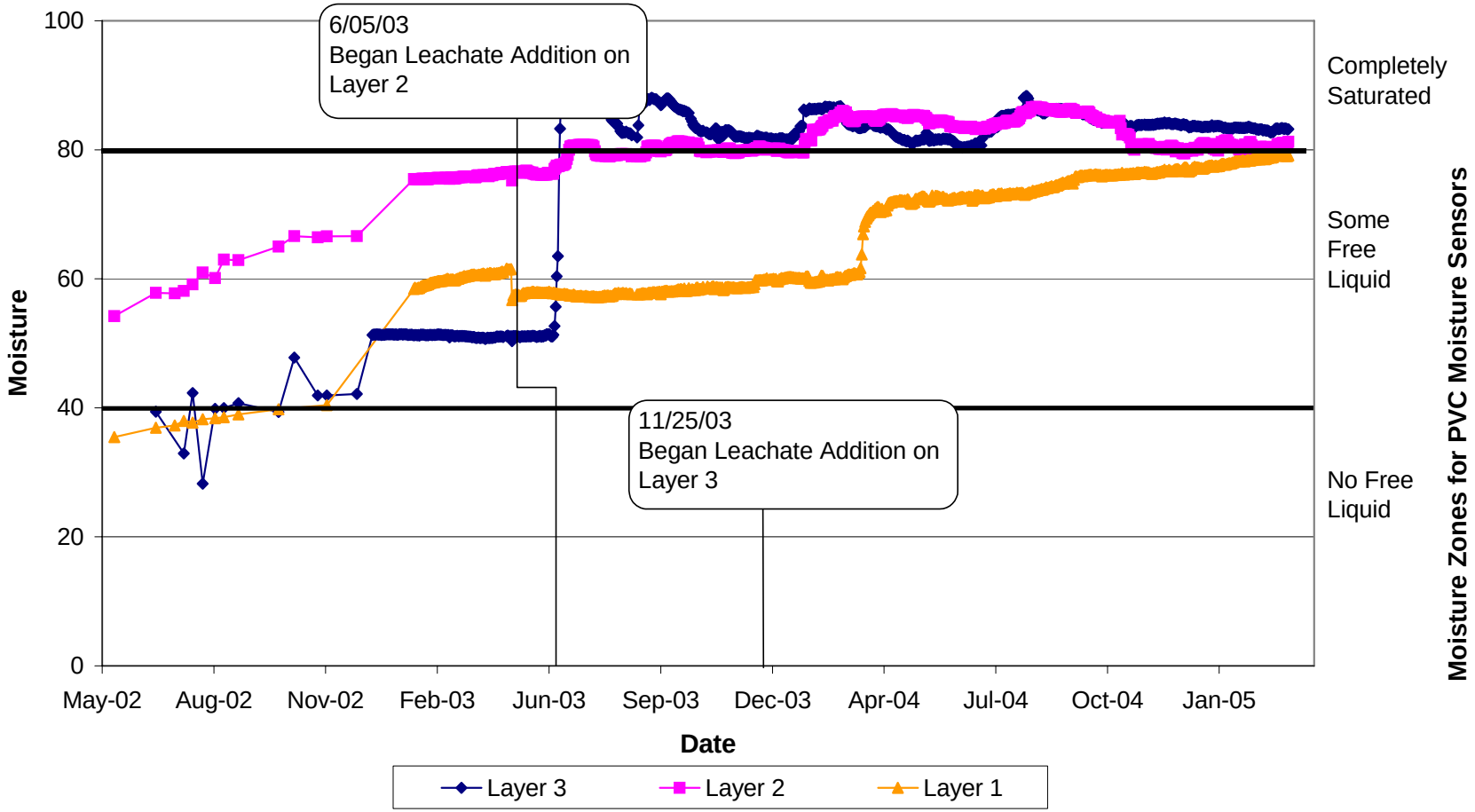


Figure 5. Average moisture for each layer on the west-side cell

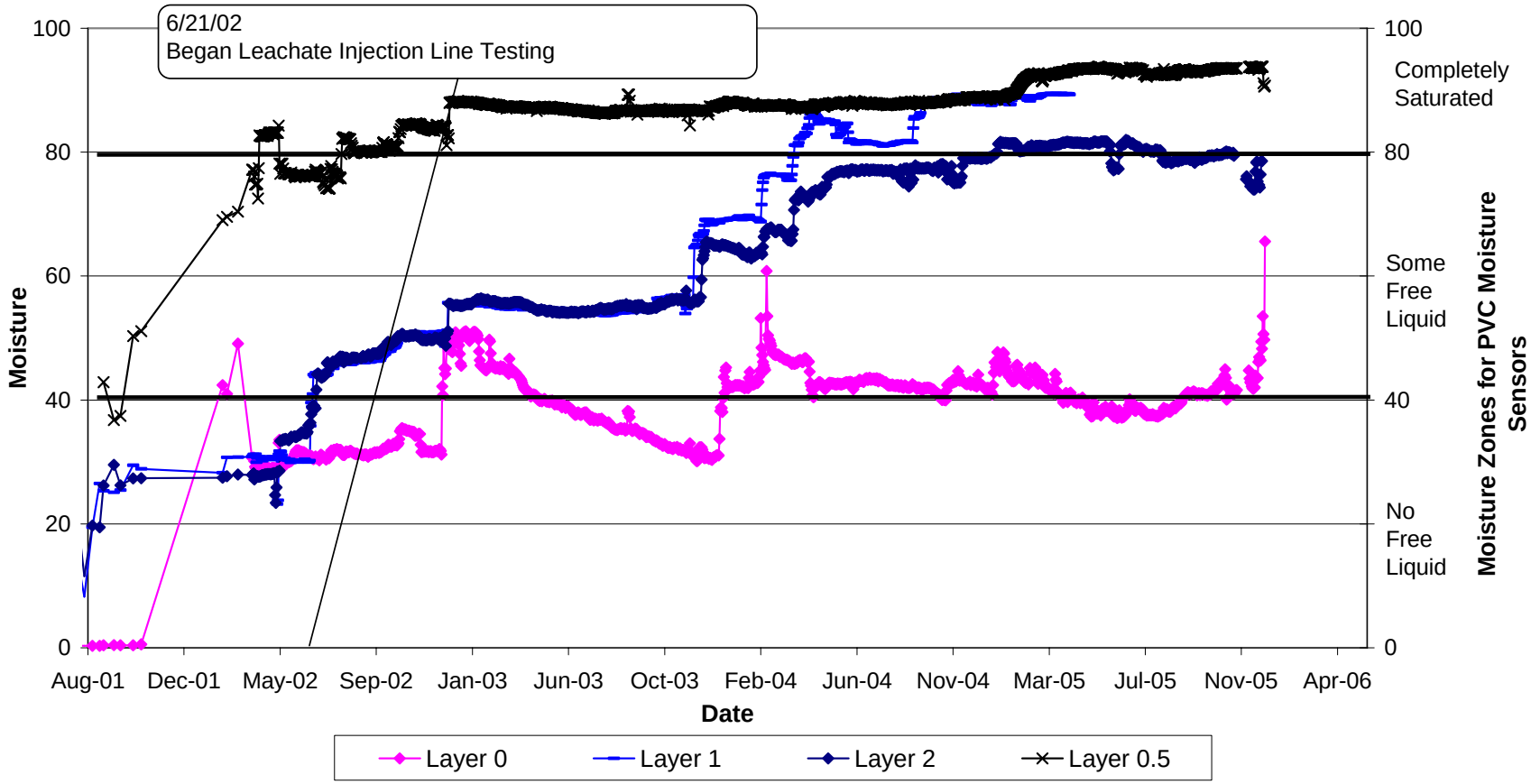


Figure 6. Average moisture for each layer on the southeast aerobic cell

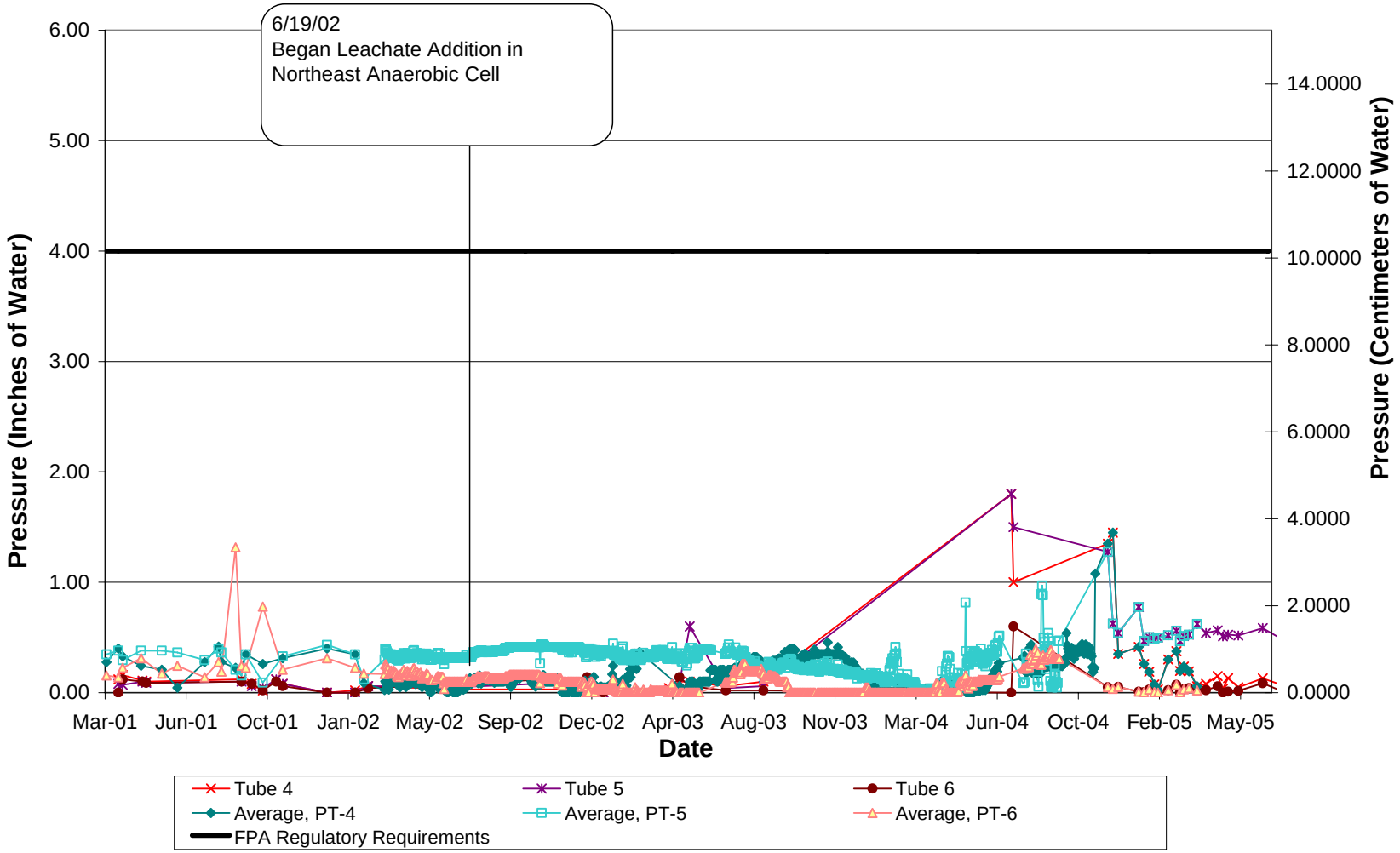


Figure 7. Liquid head on base liner for northeast cell

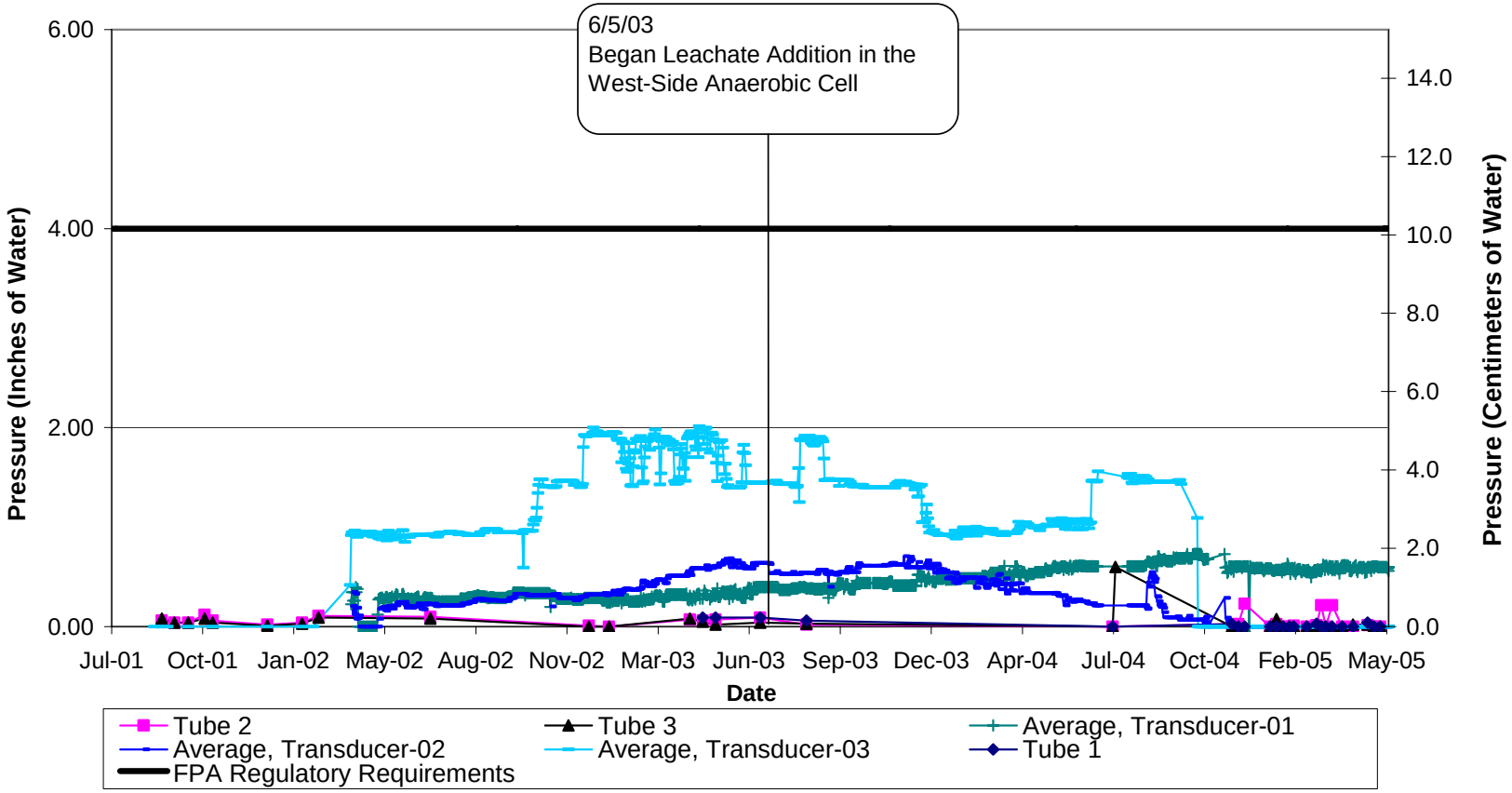


Figure 8. Liquid head on base liner for west-side cell

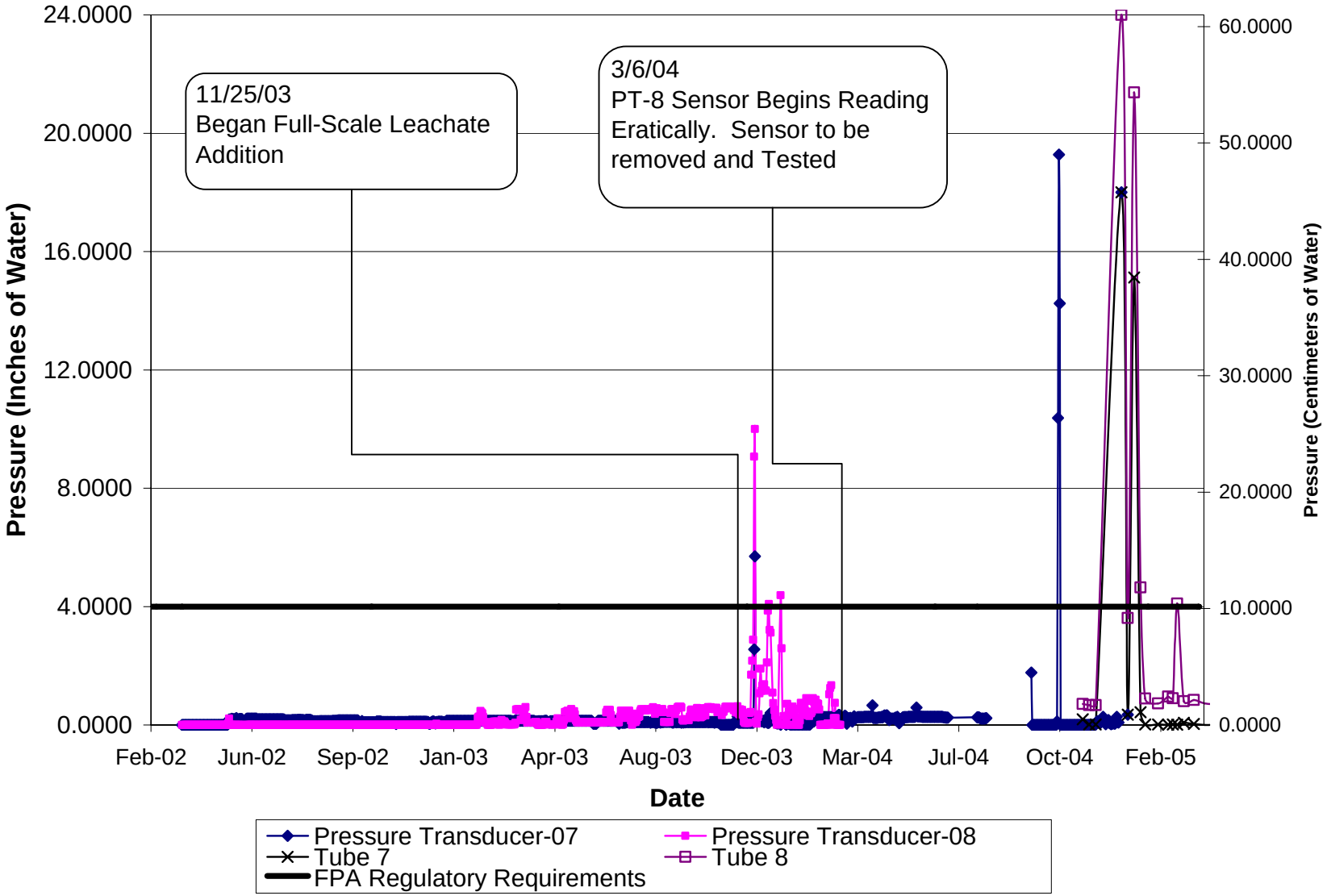


Figure 9. Liquid head on southeast aerobic liner

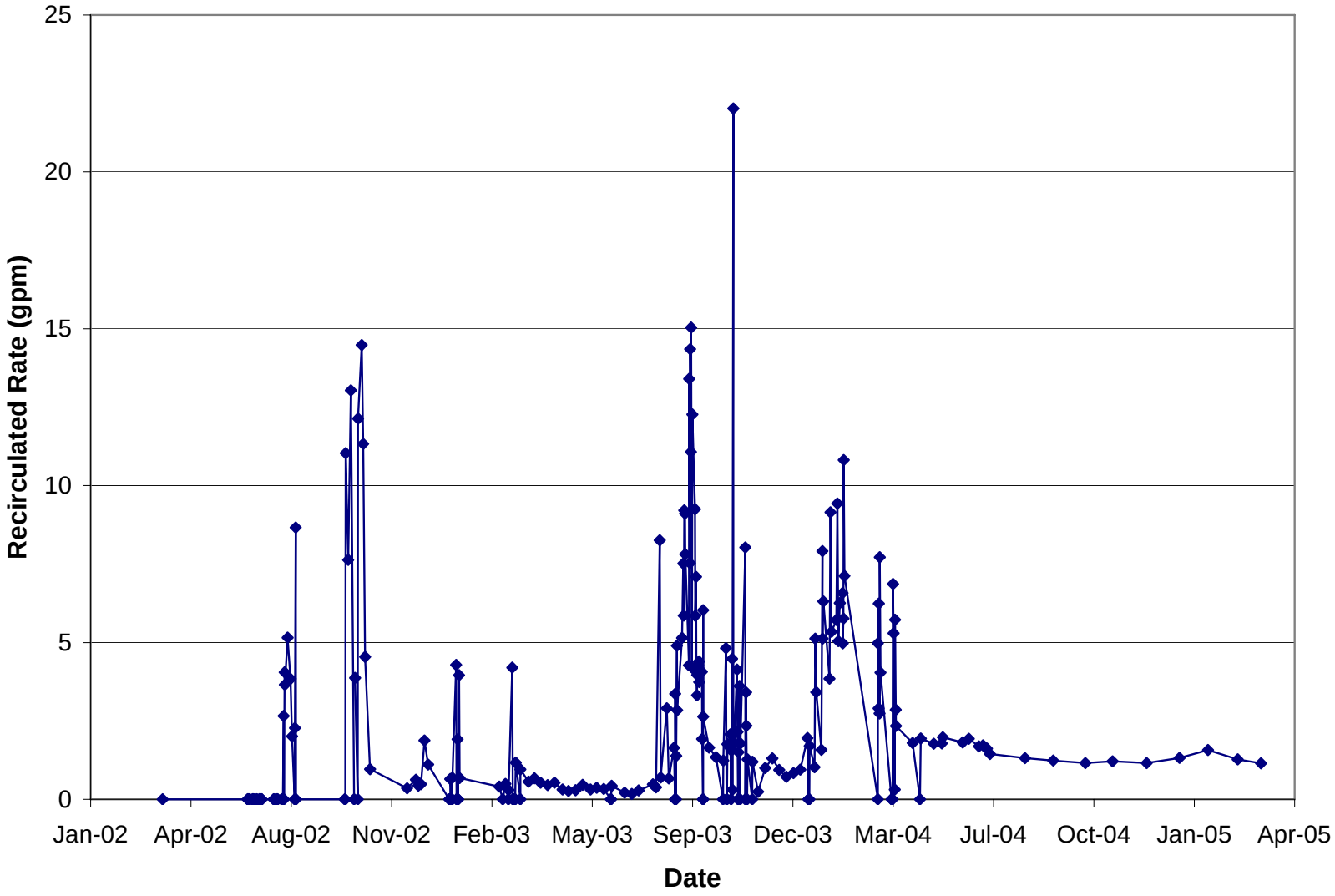


Figure 10. Average daily leachate recirculated rate for northeast cell

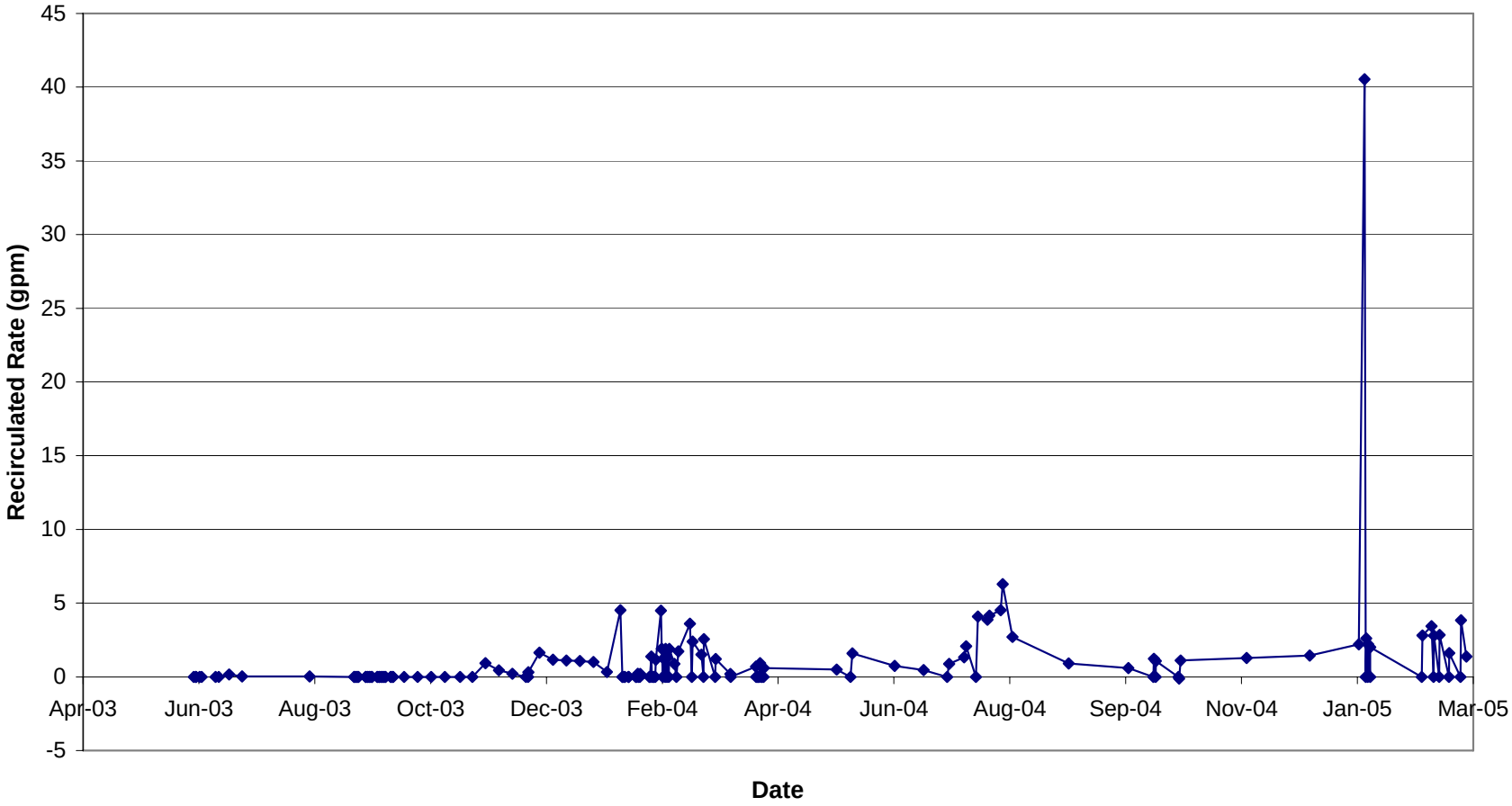


Figure 11. Average daily leachate recirculated rate for west-side cell

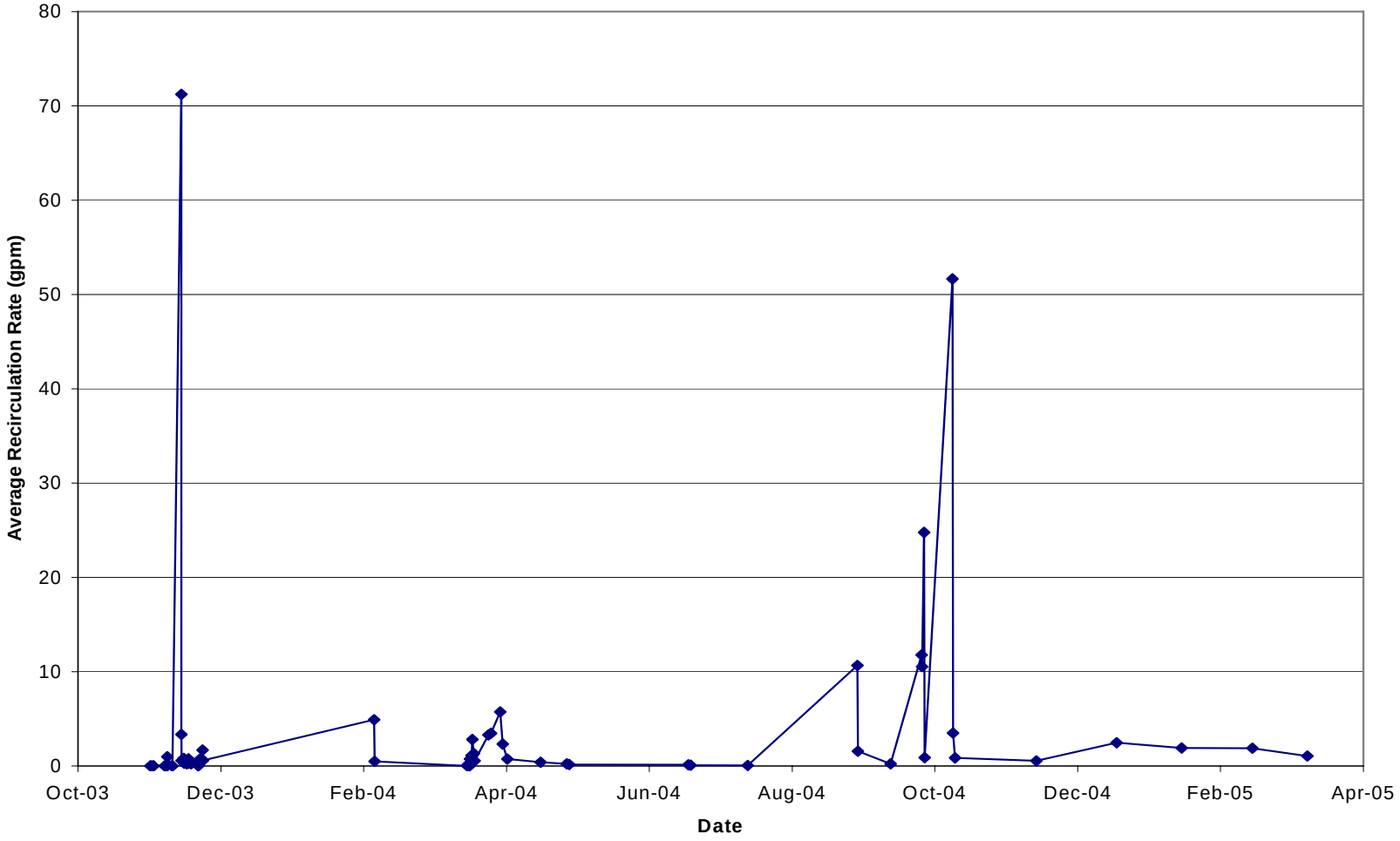


Figure 12. Average daily leachate recirculated rate for southeast aerobic cell

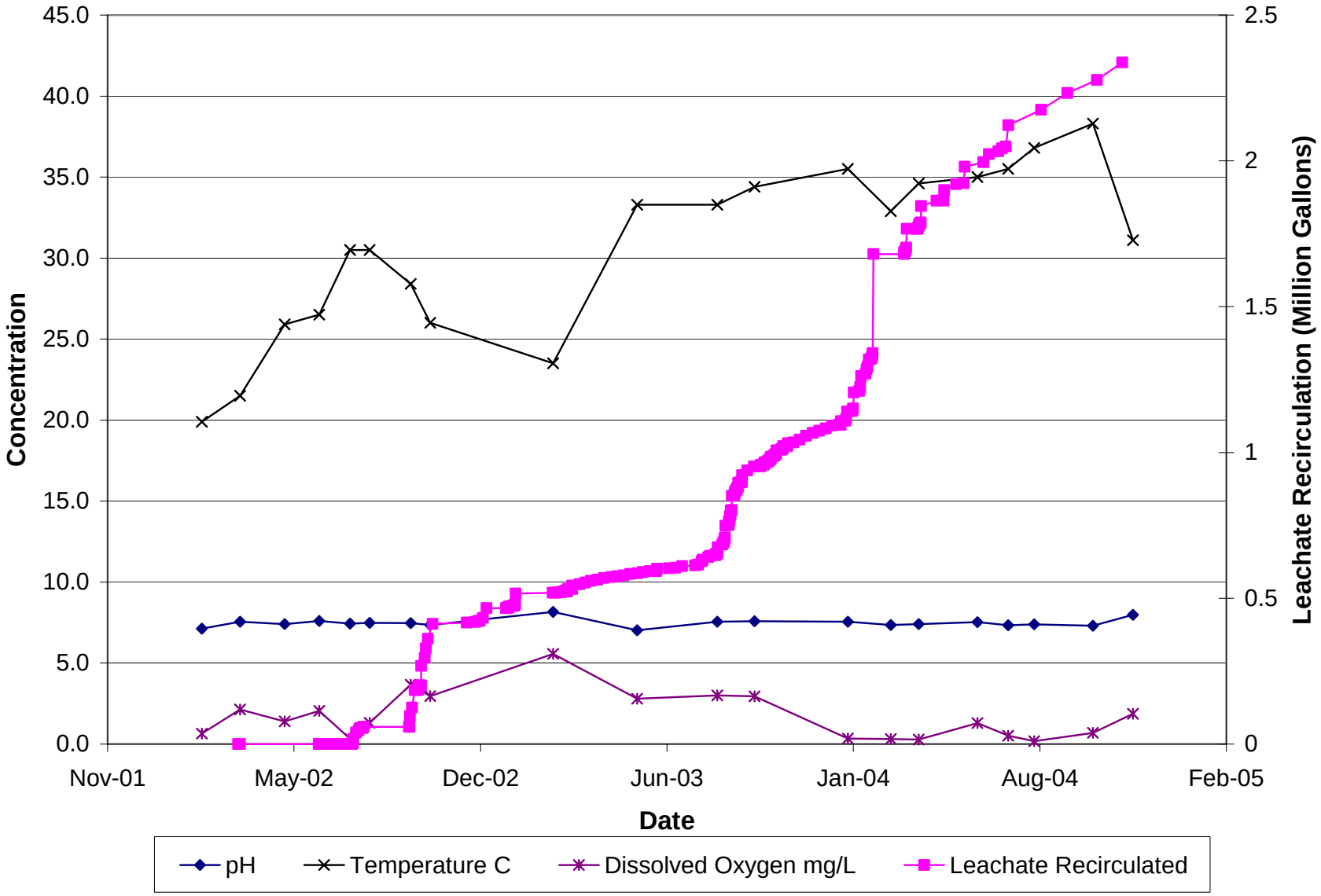


Figure 13a. Leachate field parameters for the northeast cell

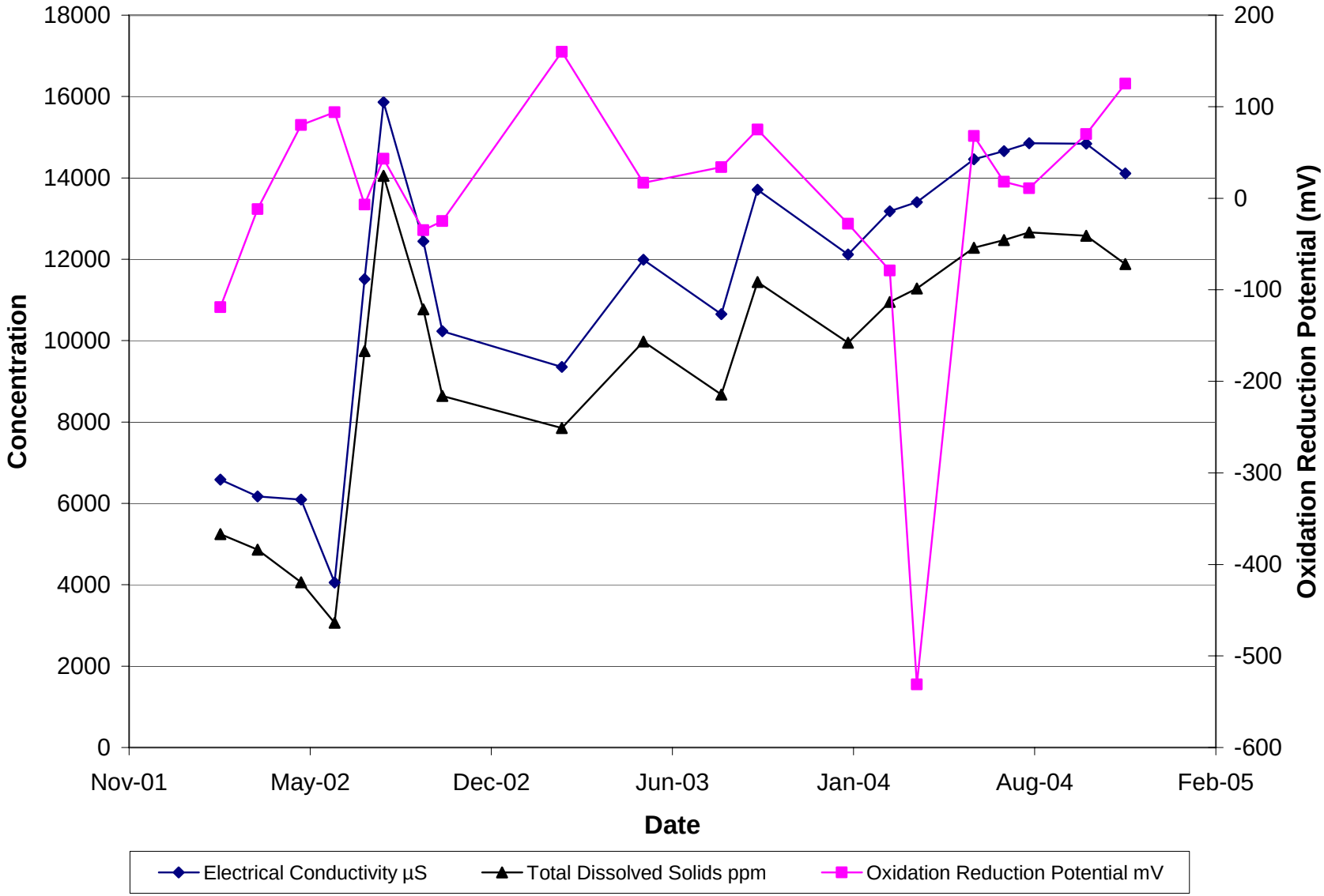


Figure 13b. Leachate field parameters for the northeast cell

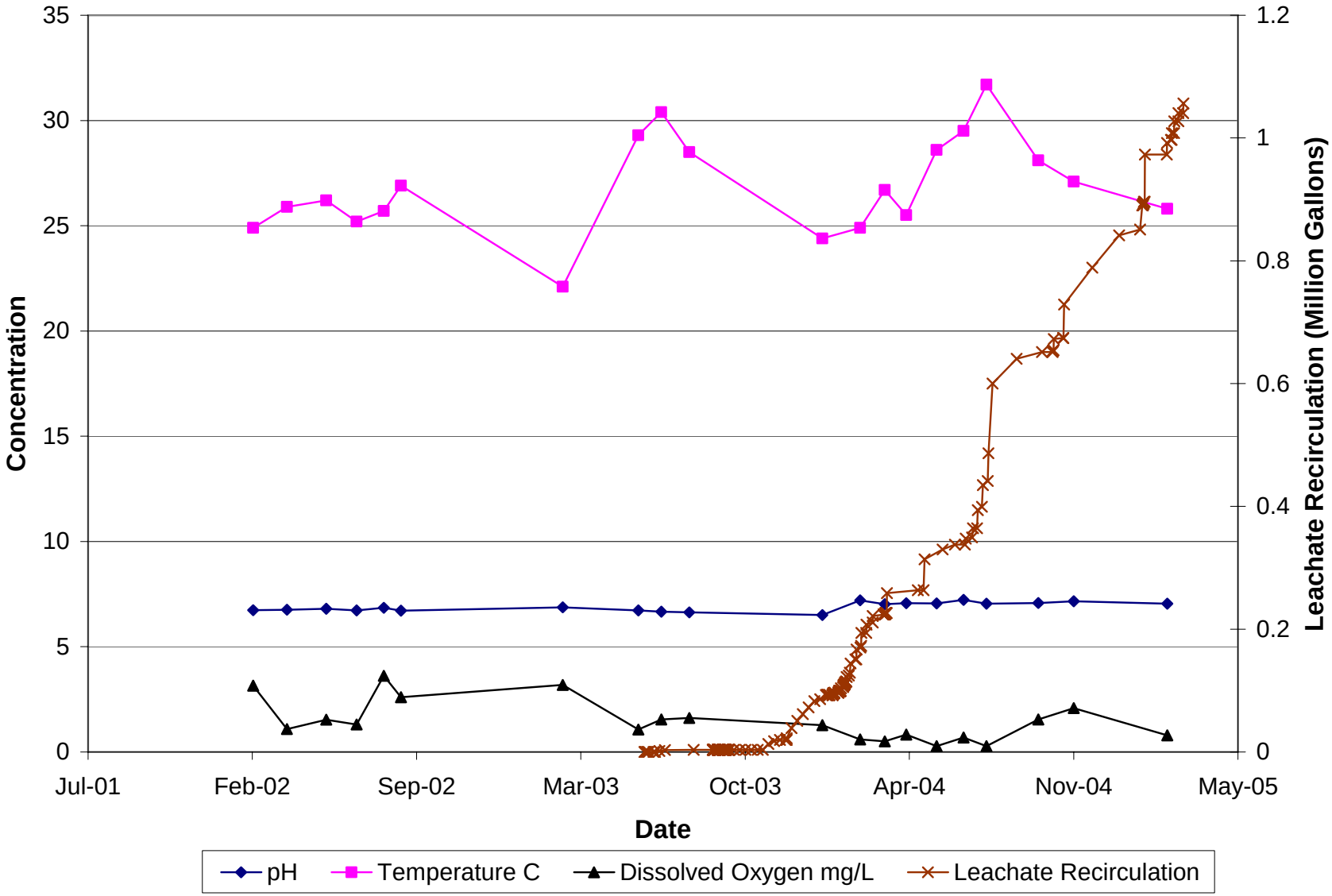


Figure 14a. Leachate field parameters for the west-side cell

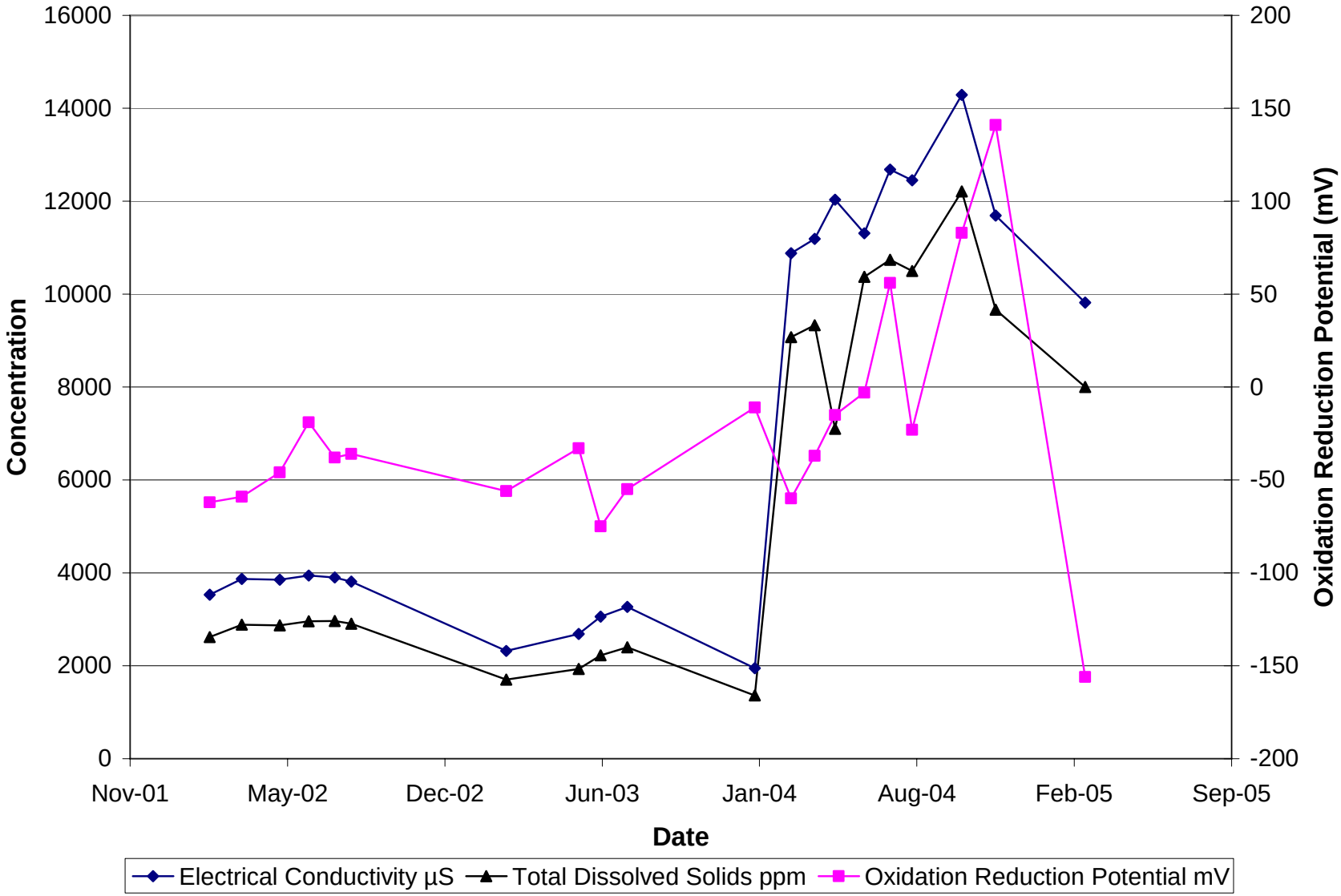


Figure 14b. Leachate field parameters for the west-side cell

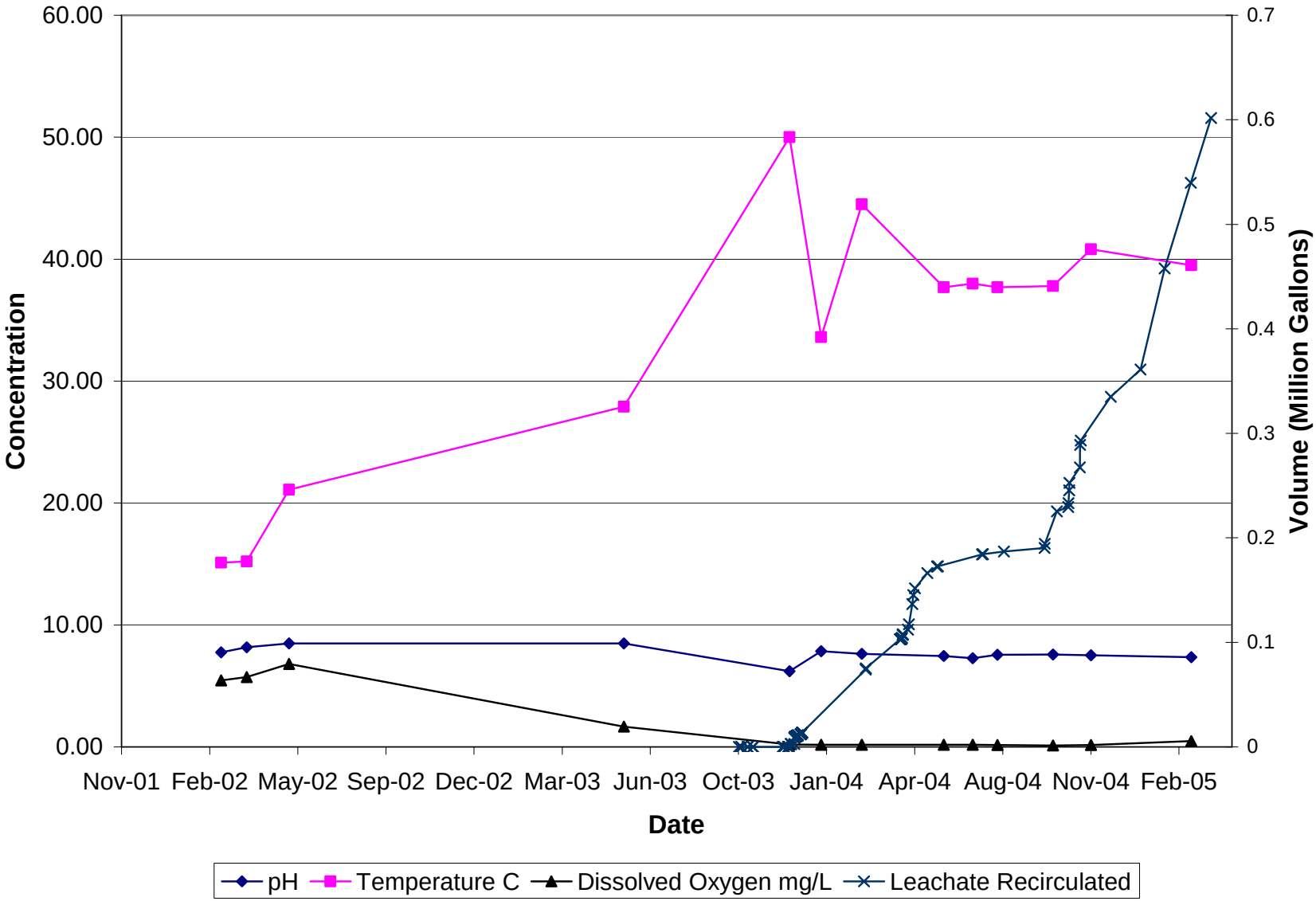


Figure 15a. Leachate field parameters for the southeast aerobic cell

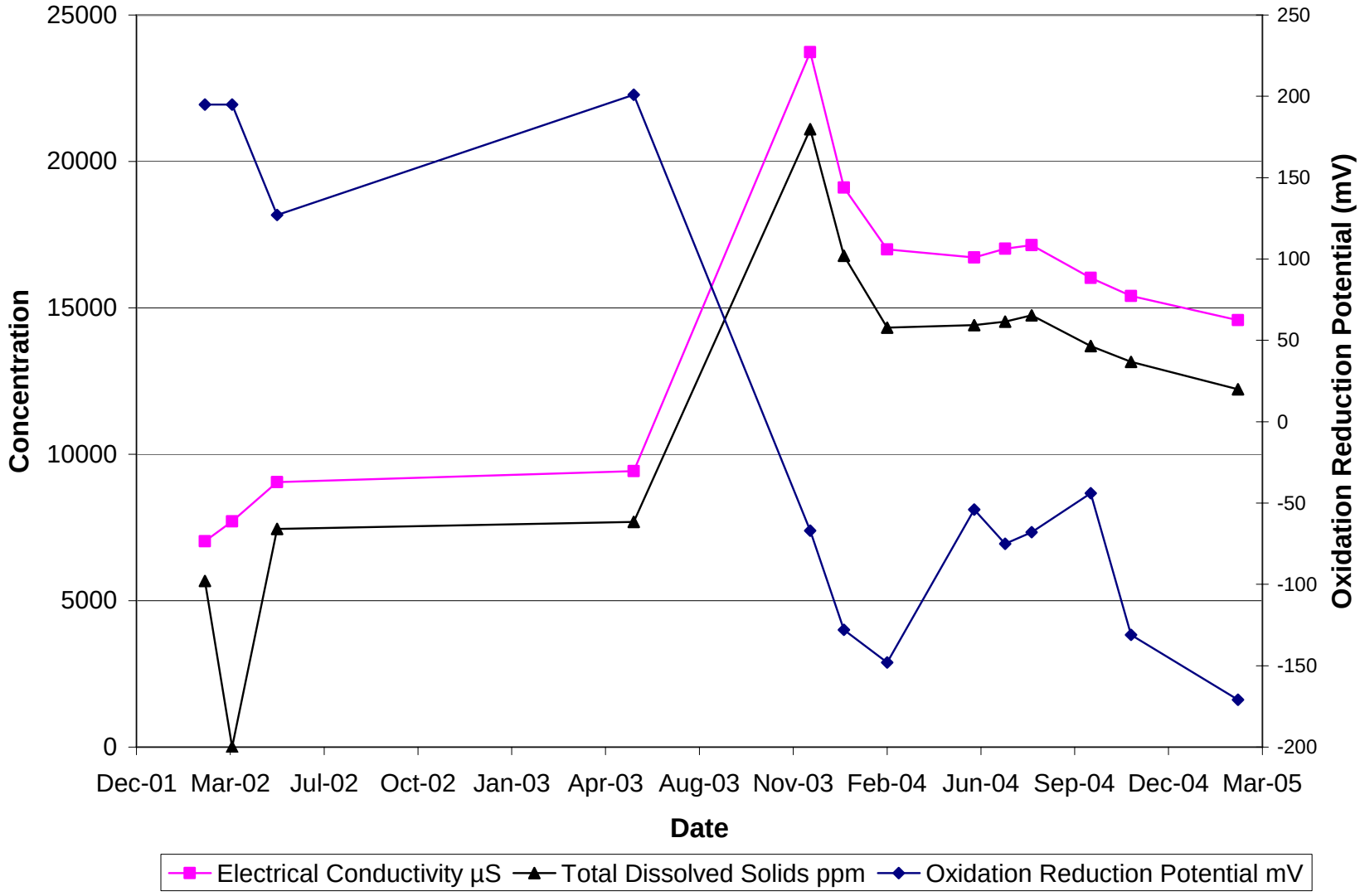


Figure 15b. Leachate field parameters for the southeast aerobic cell

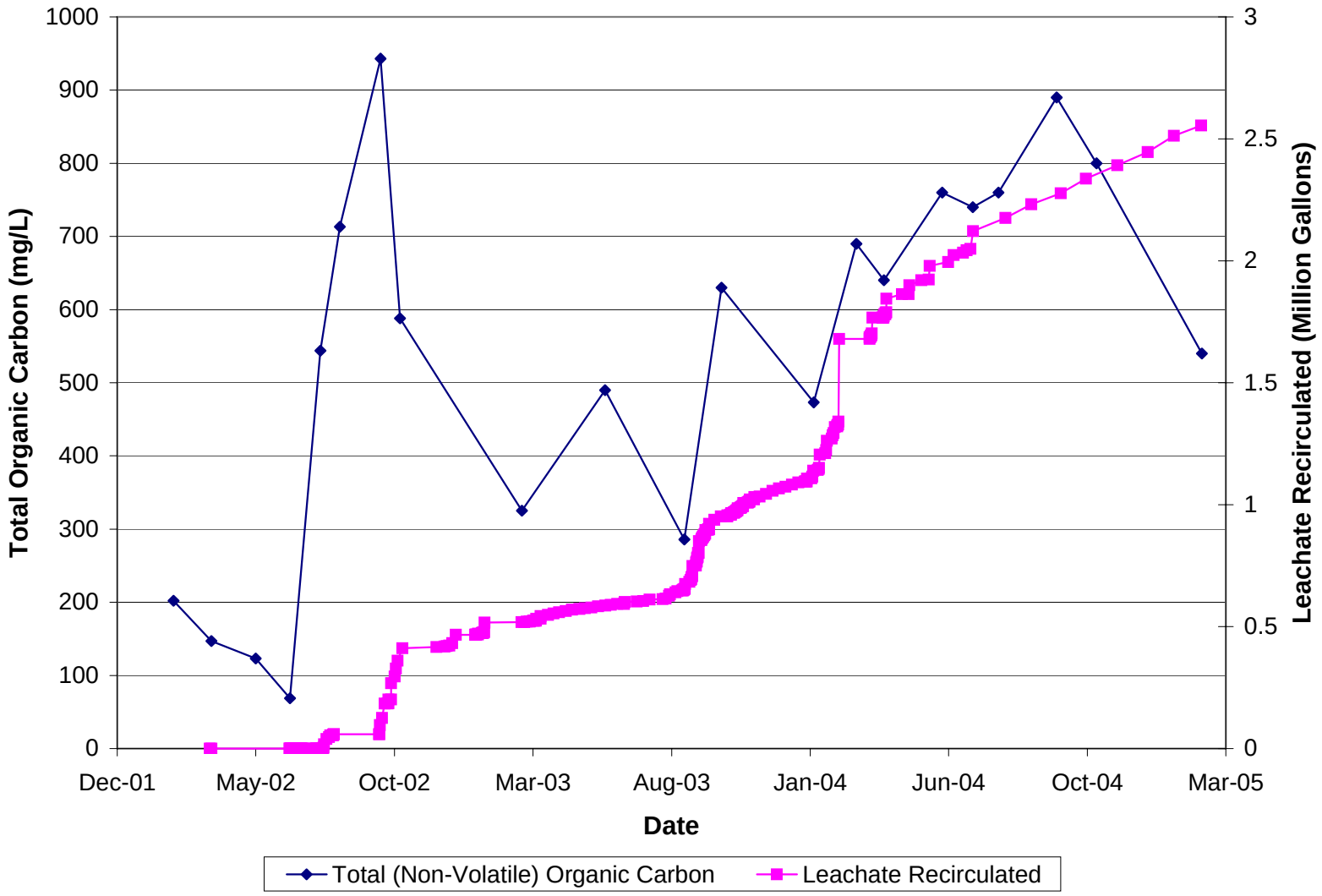


Figure 16. Profile of leachate total (nonvolatile) organic carbon for the northeast cell

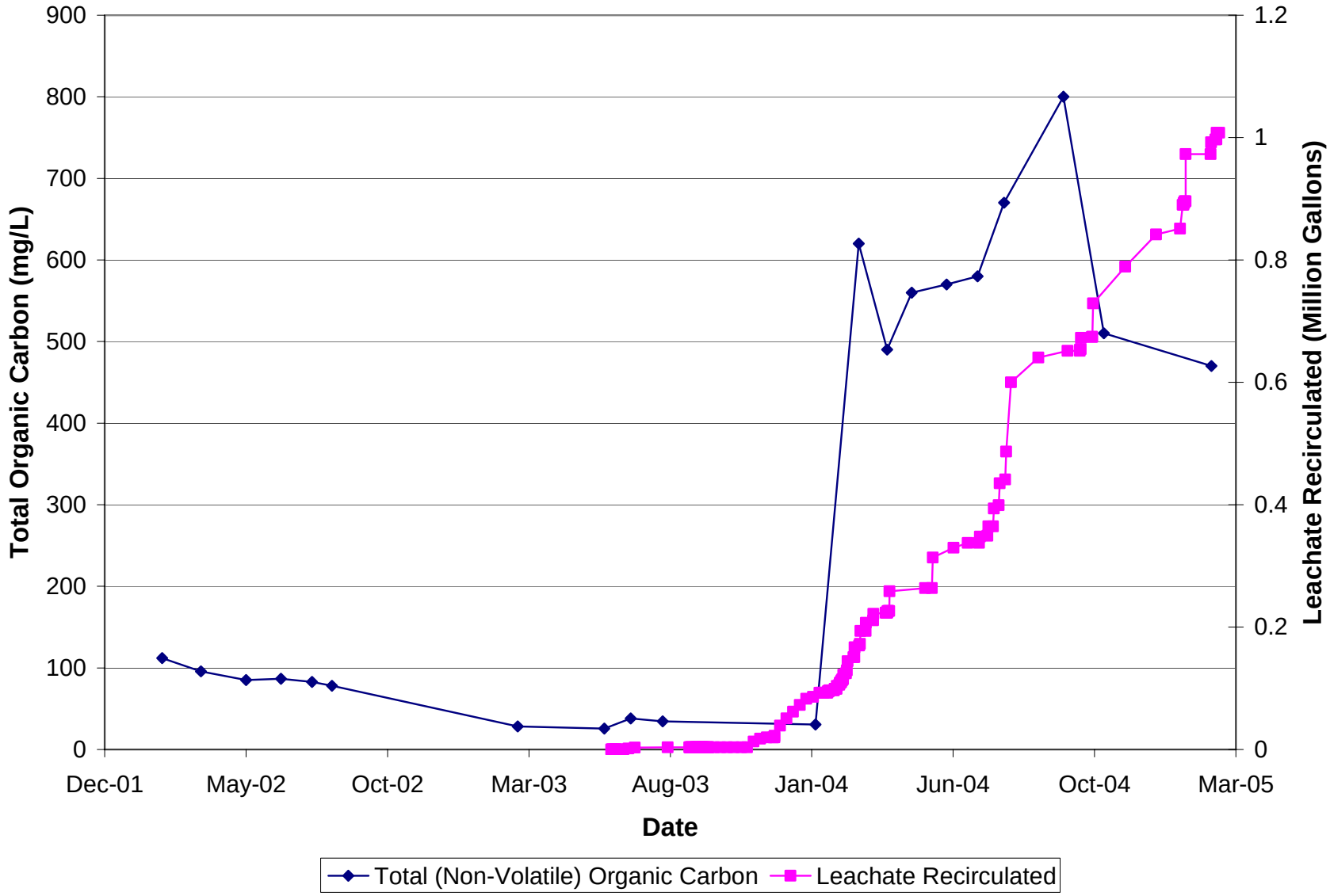


Figure 17. Profile of leachate total (nonvolatile) organic carbon for the west-side cell

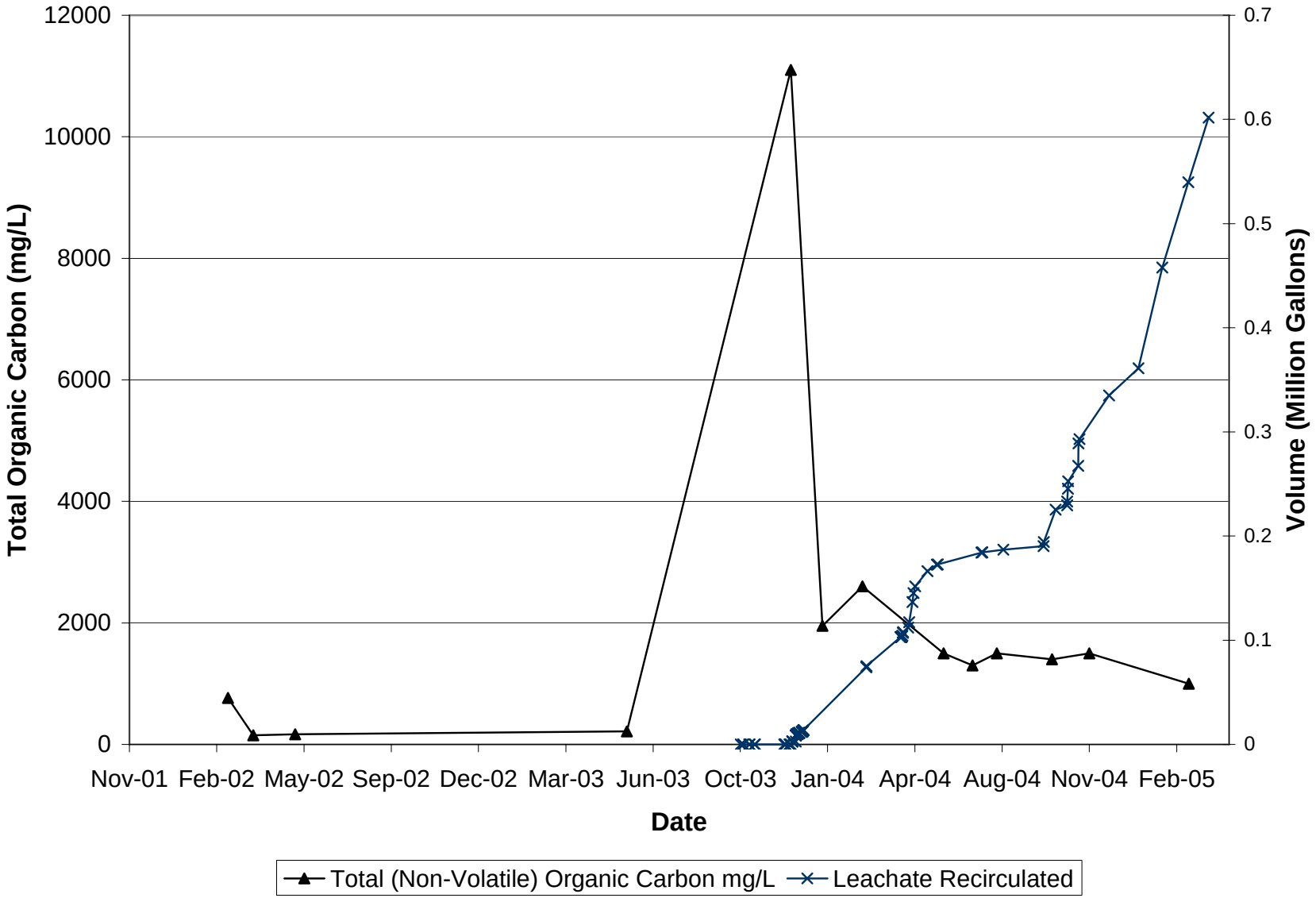


Figure 18. Profile of leachate total (nonvolatile) organic carbon for the southeast aerobic cell

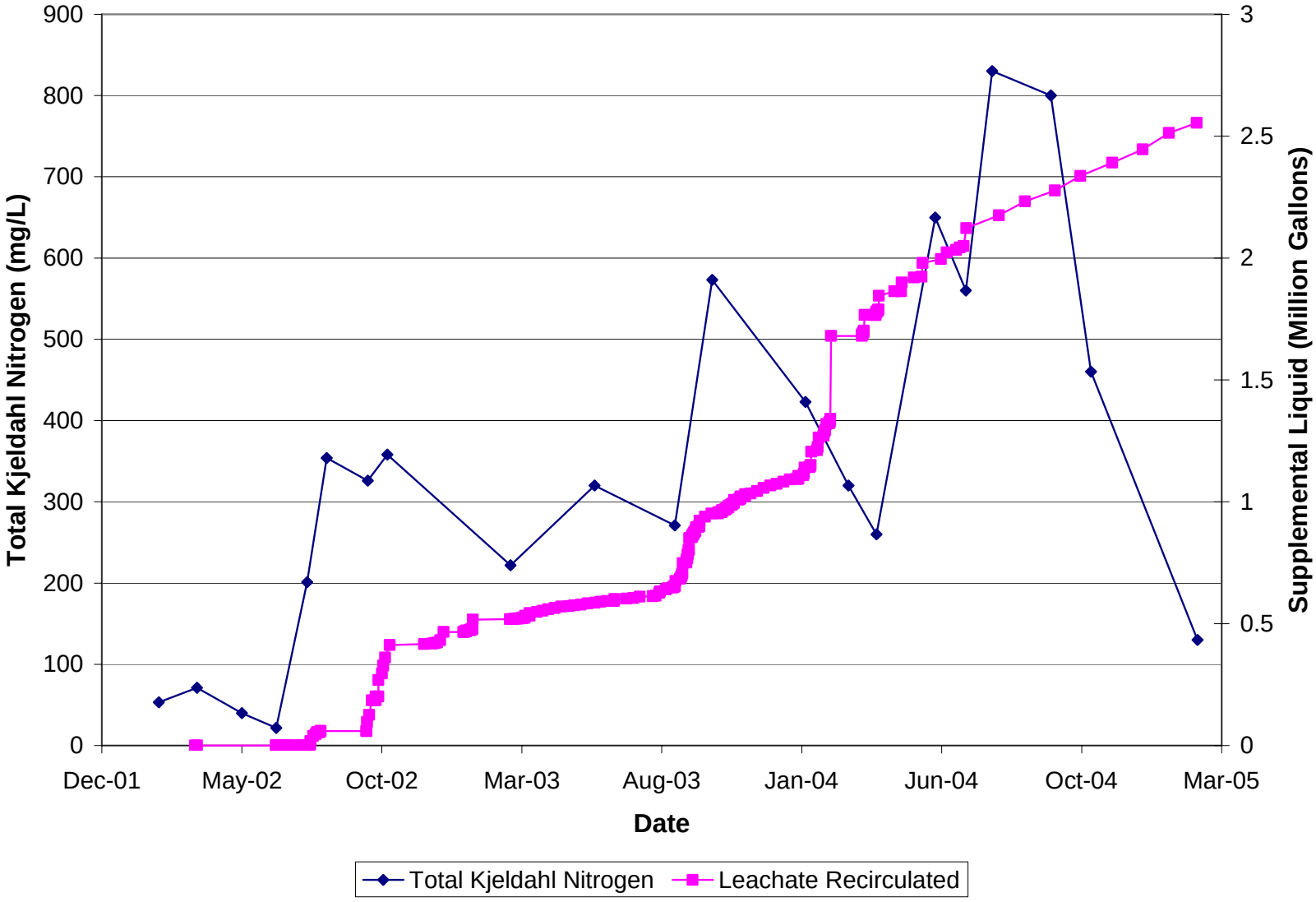


Figure 19. Leachate nitrogen profile for the northeast cell

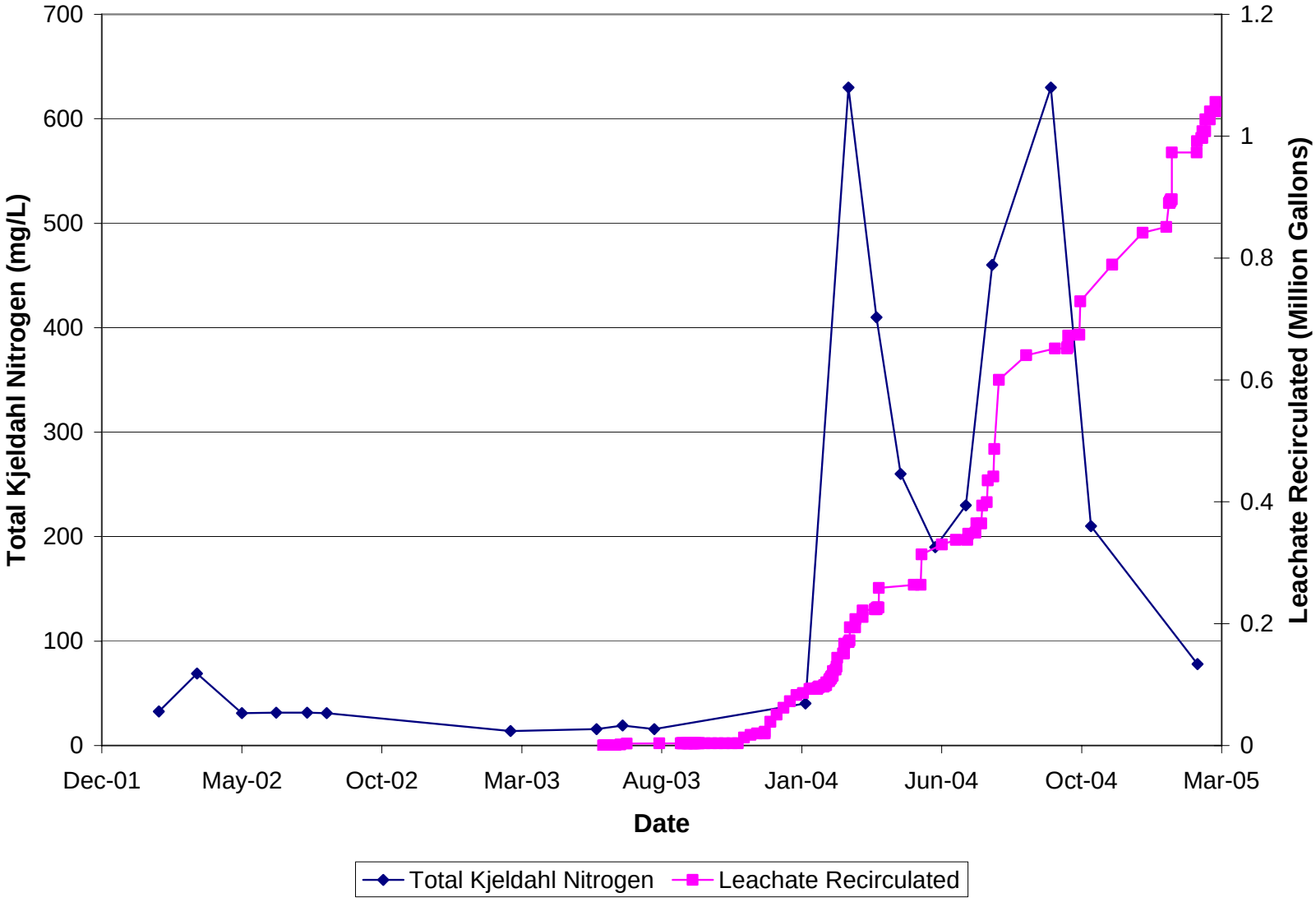


Figure 20. Leachate nitrogen profile for the west-side cell

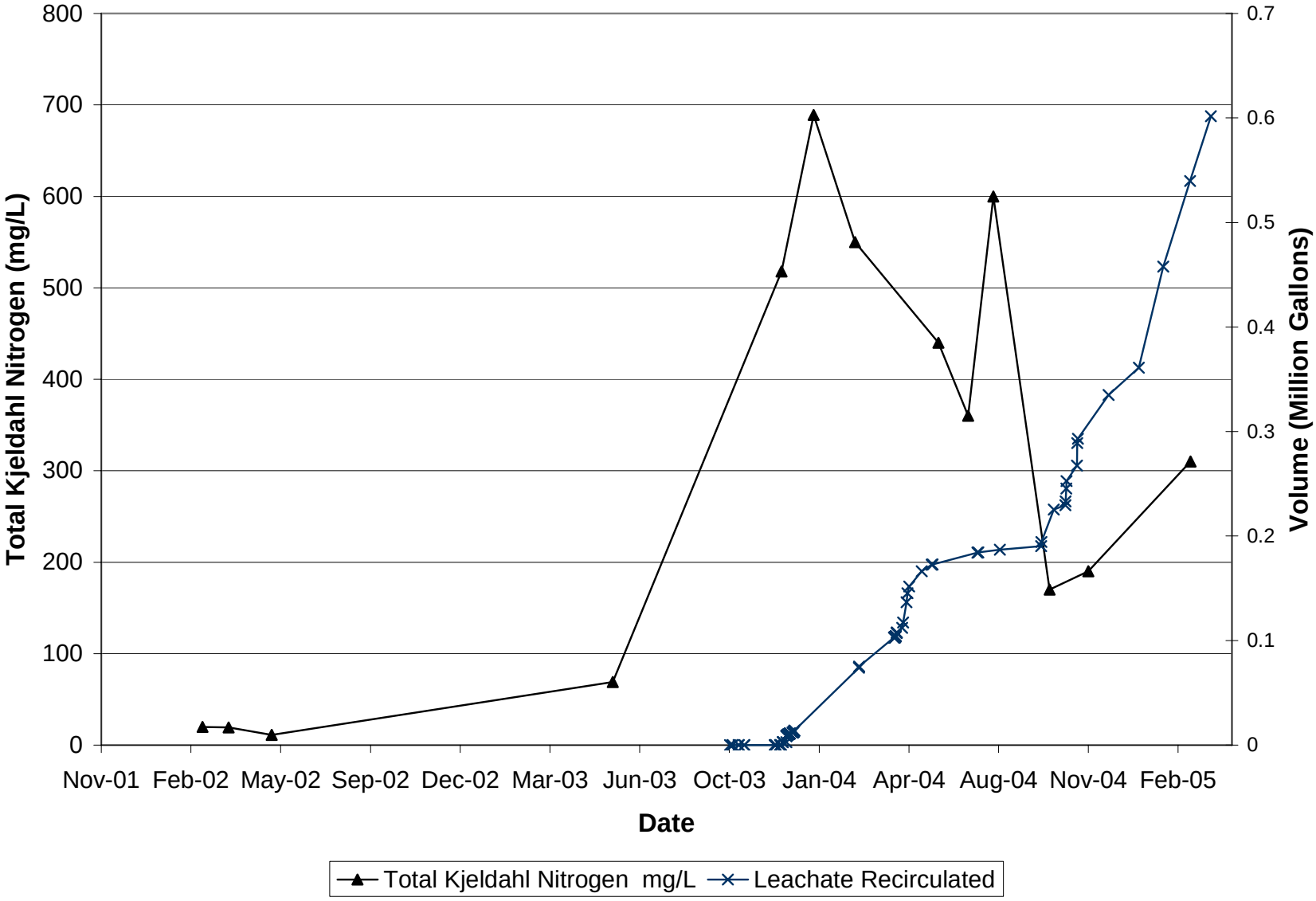


Figure 21. Leachate nitrogen profile for the southeast aerobic cell

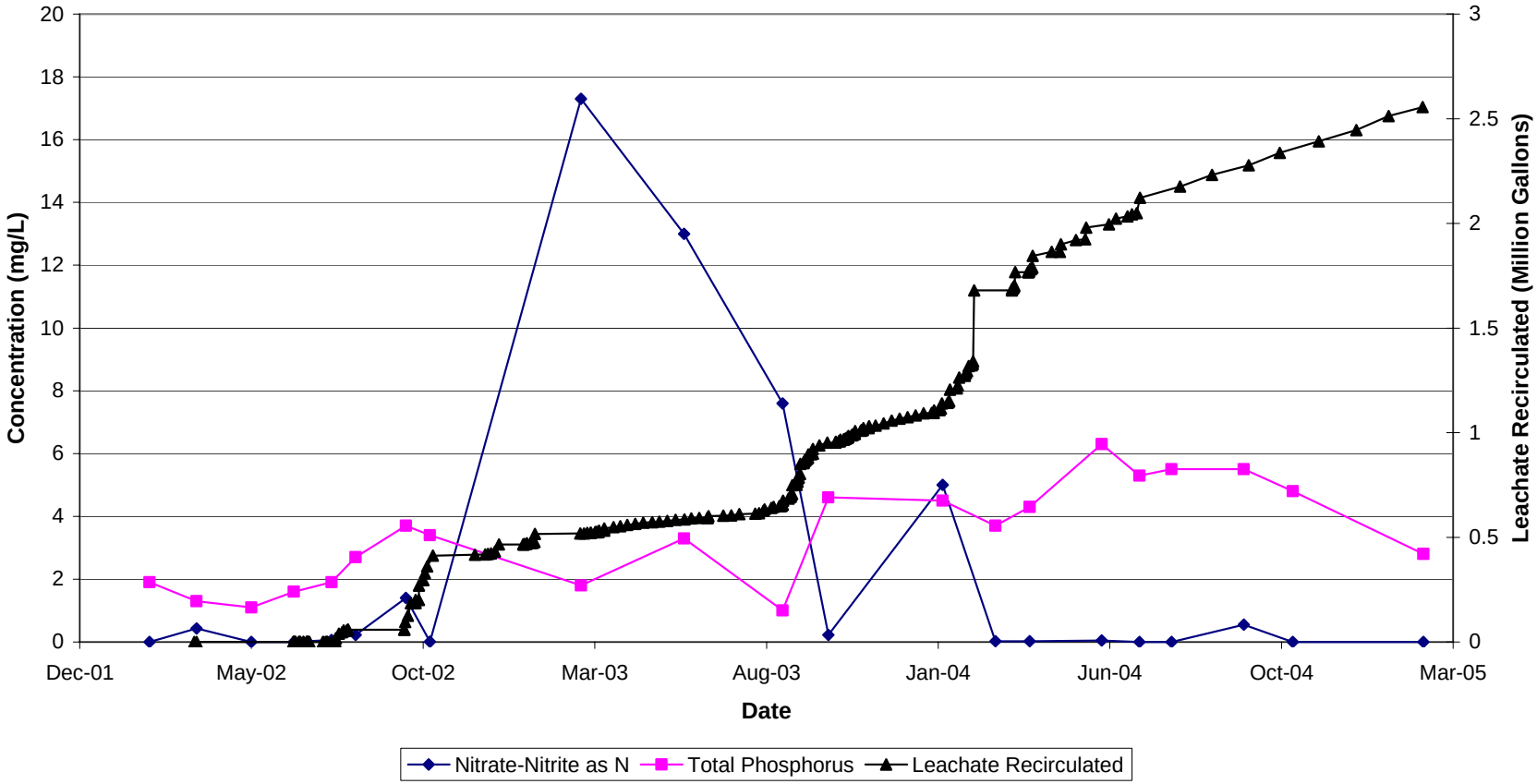


Figure 22. Profile of leachate nutrients for the northeast cell

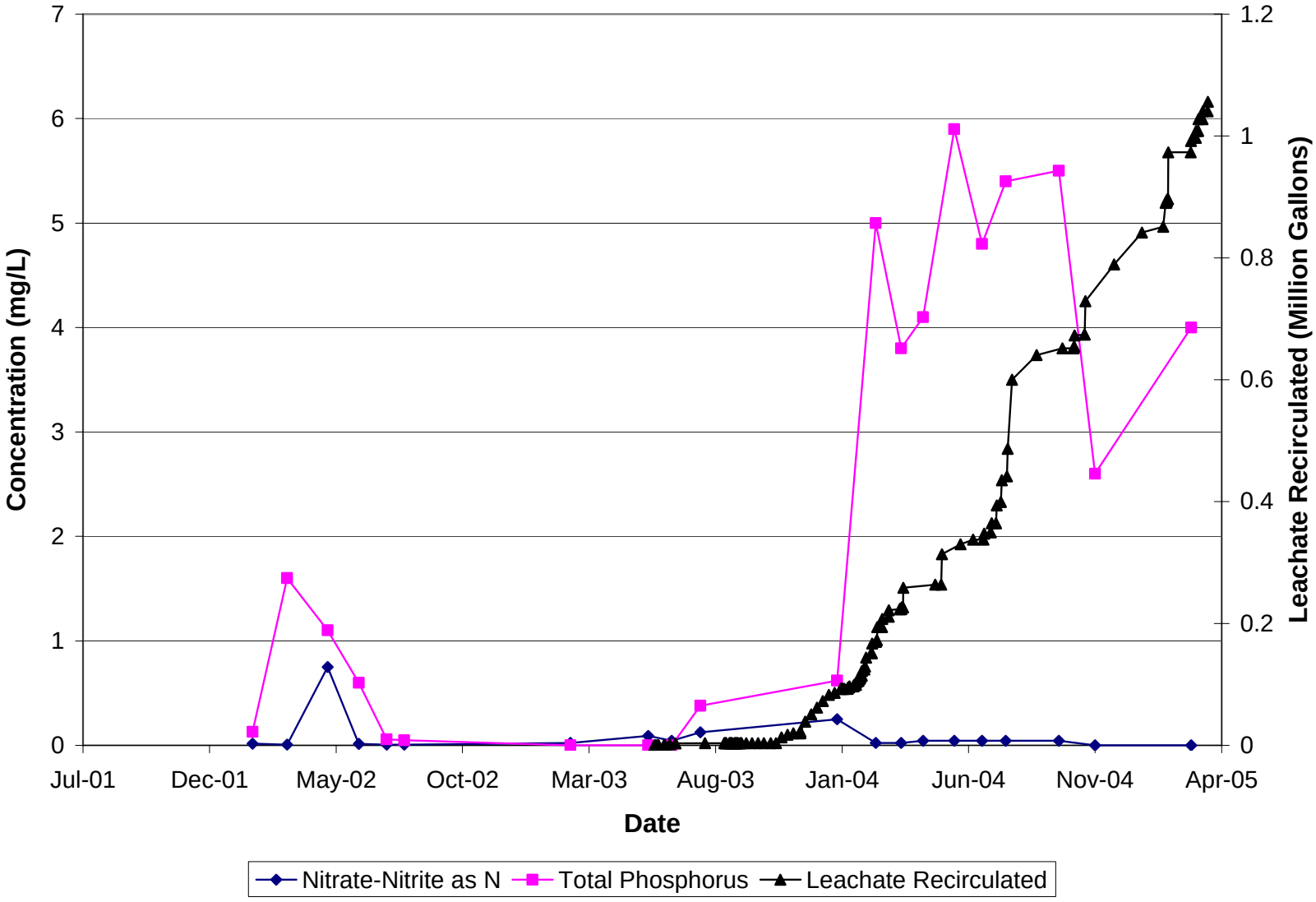


Figure 23. Profile of leachate nutrients for the west-side cell

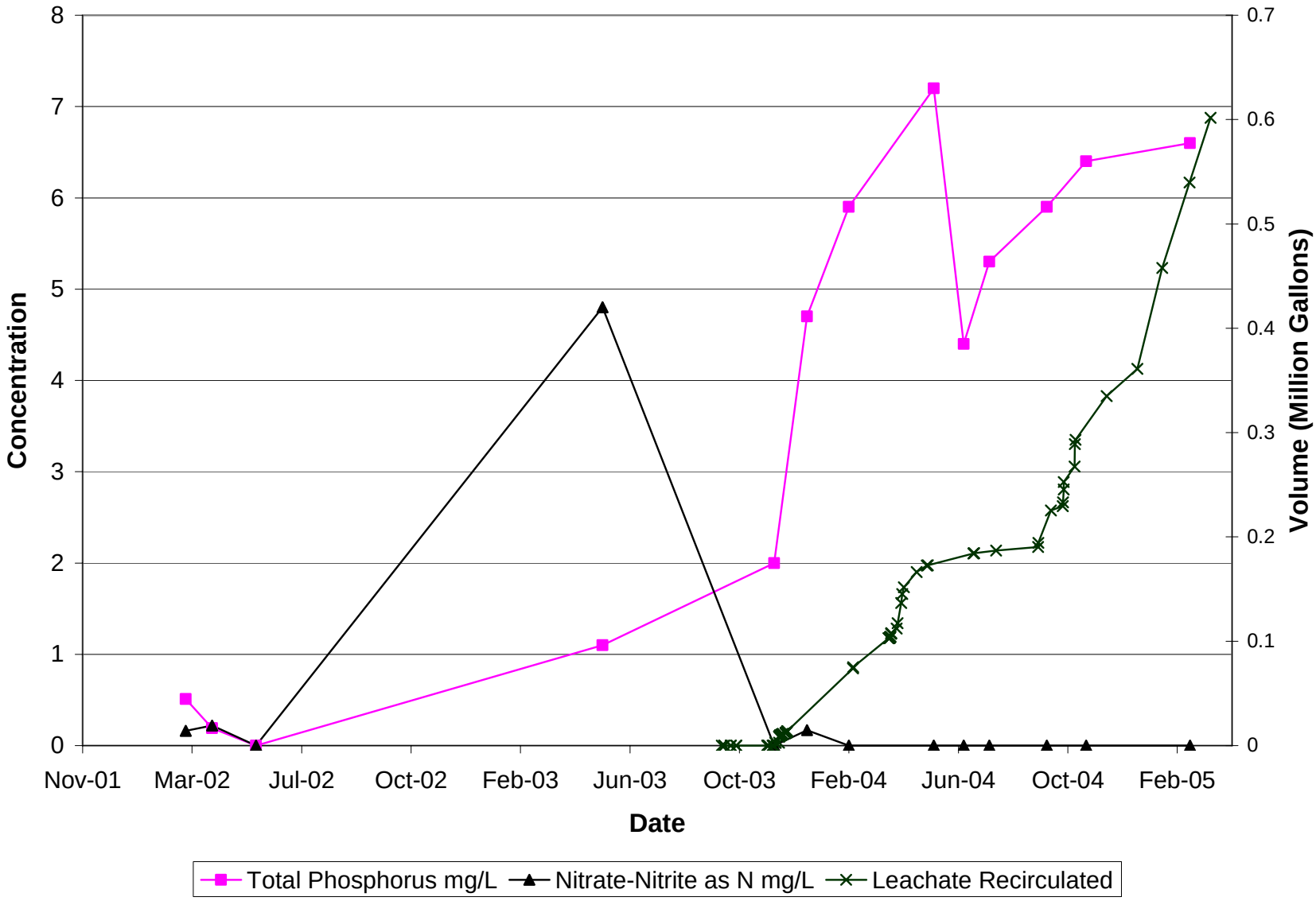


Figure 24. Profile of leachate nutrients for the southeast aerobic cell

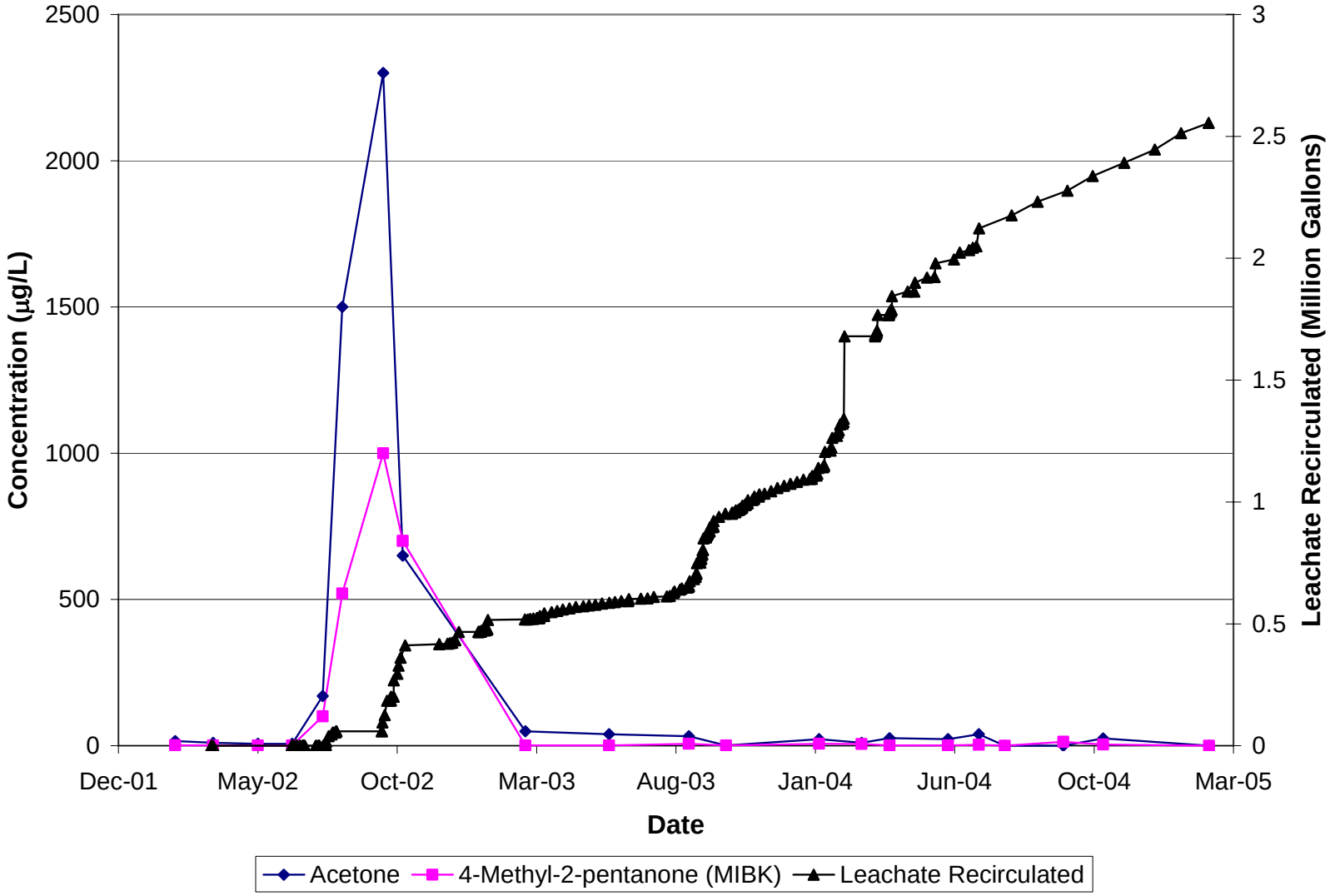


Figure 25a. Northeast cell - Concentration of various VOC's over time

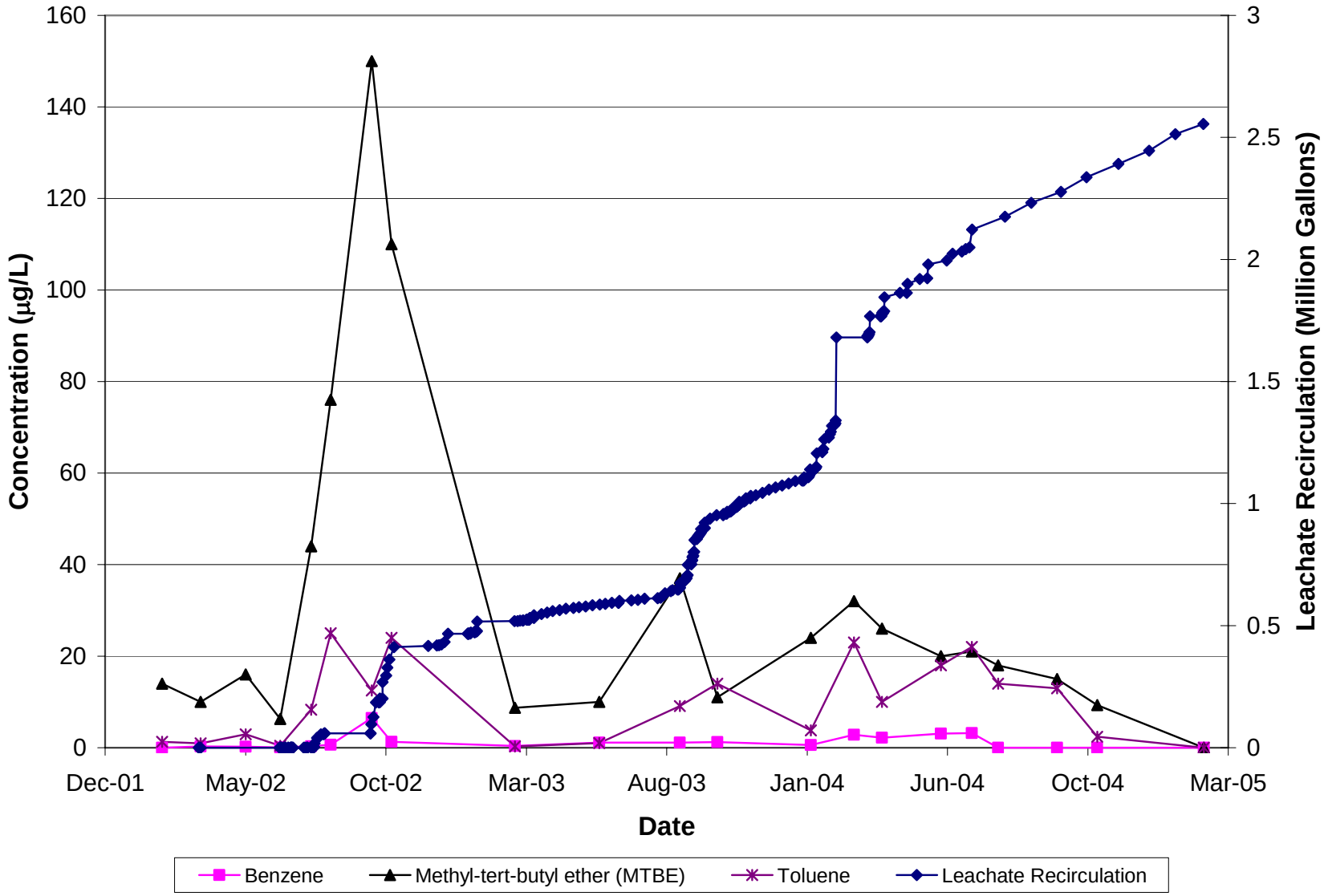


Figure 25b. Northeast cell - Concentration of various VOC's over time

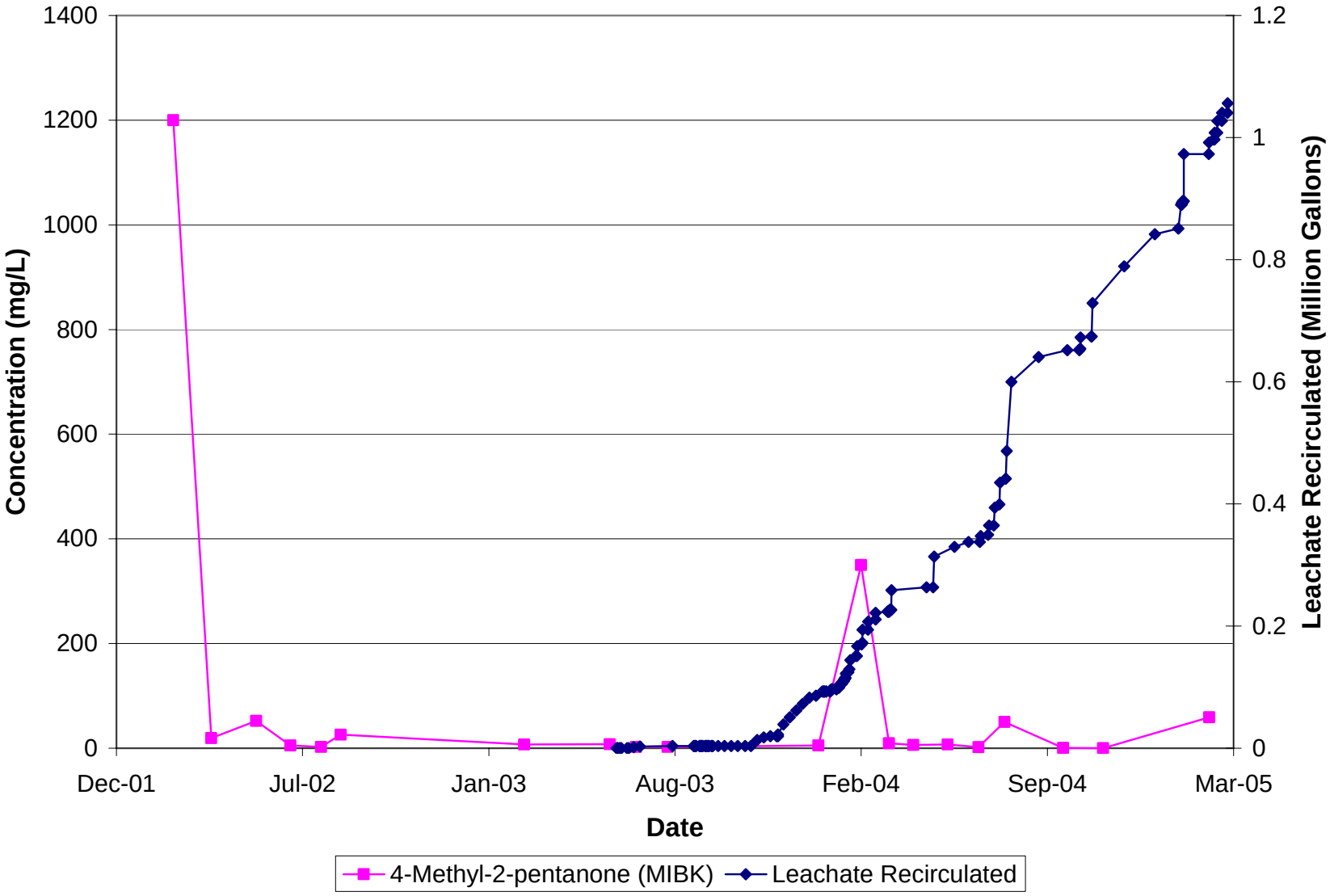


Figure 26a. West-side cell - Concentration of various VOC's over time

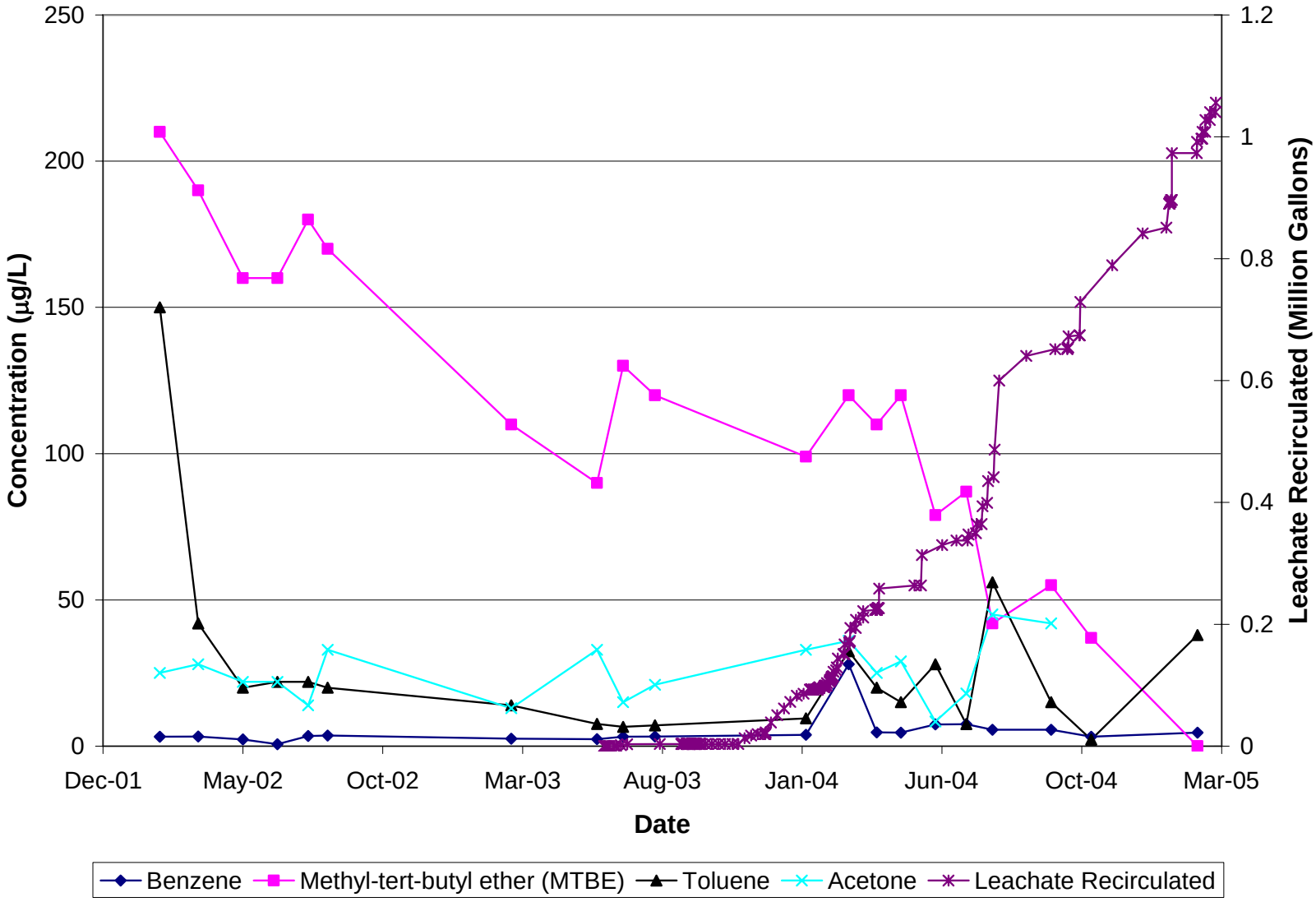


Figure 26b. West-side cell - Concentration of various VOC's over time

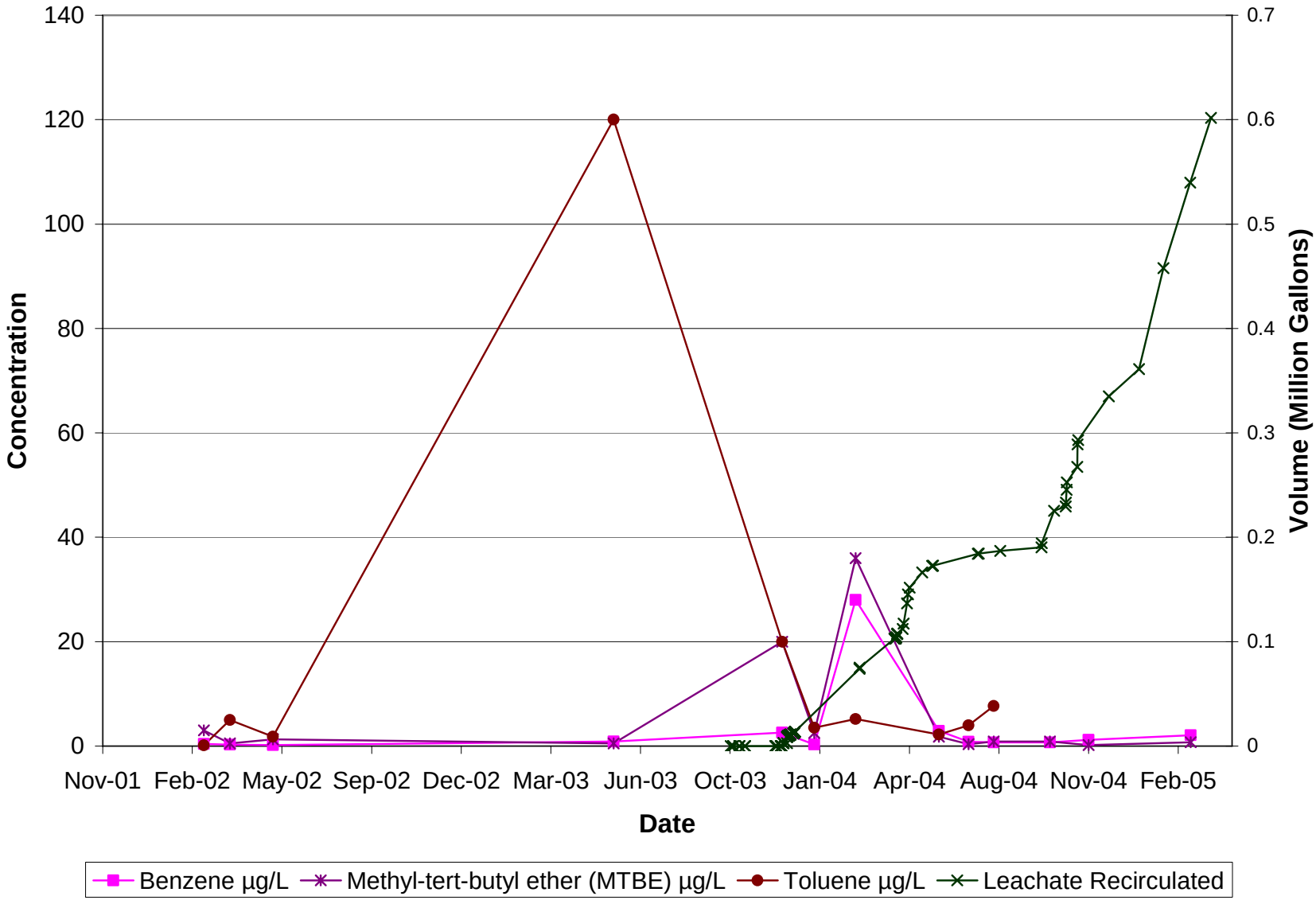


Figure 27a. Southeast aerobic cell - Concentration of various VOC's over time

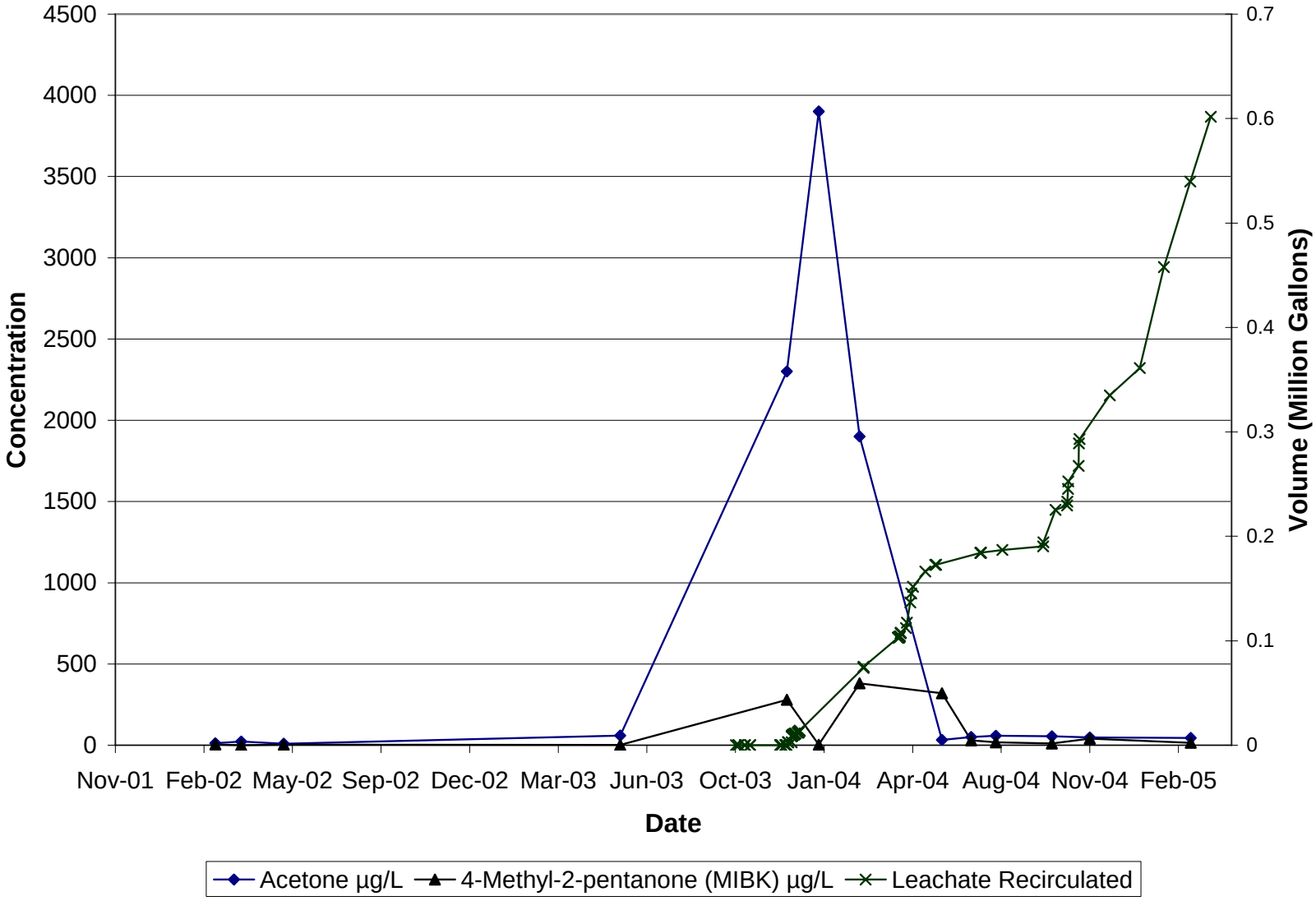


Figure 27b. Southeast aerobic cell - Concentration of various VOC's over time

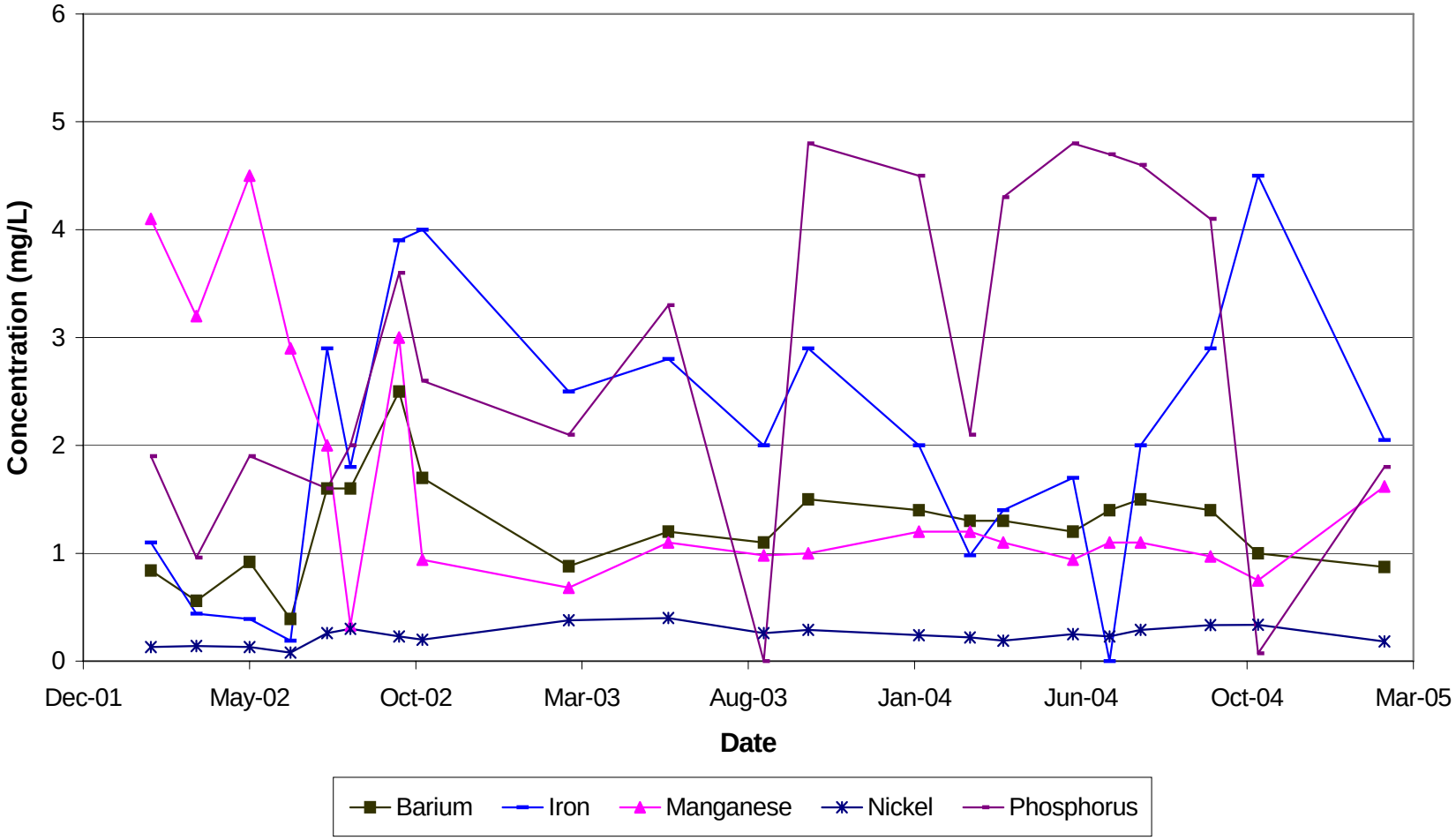
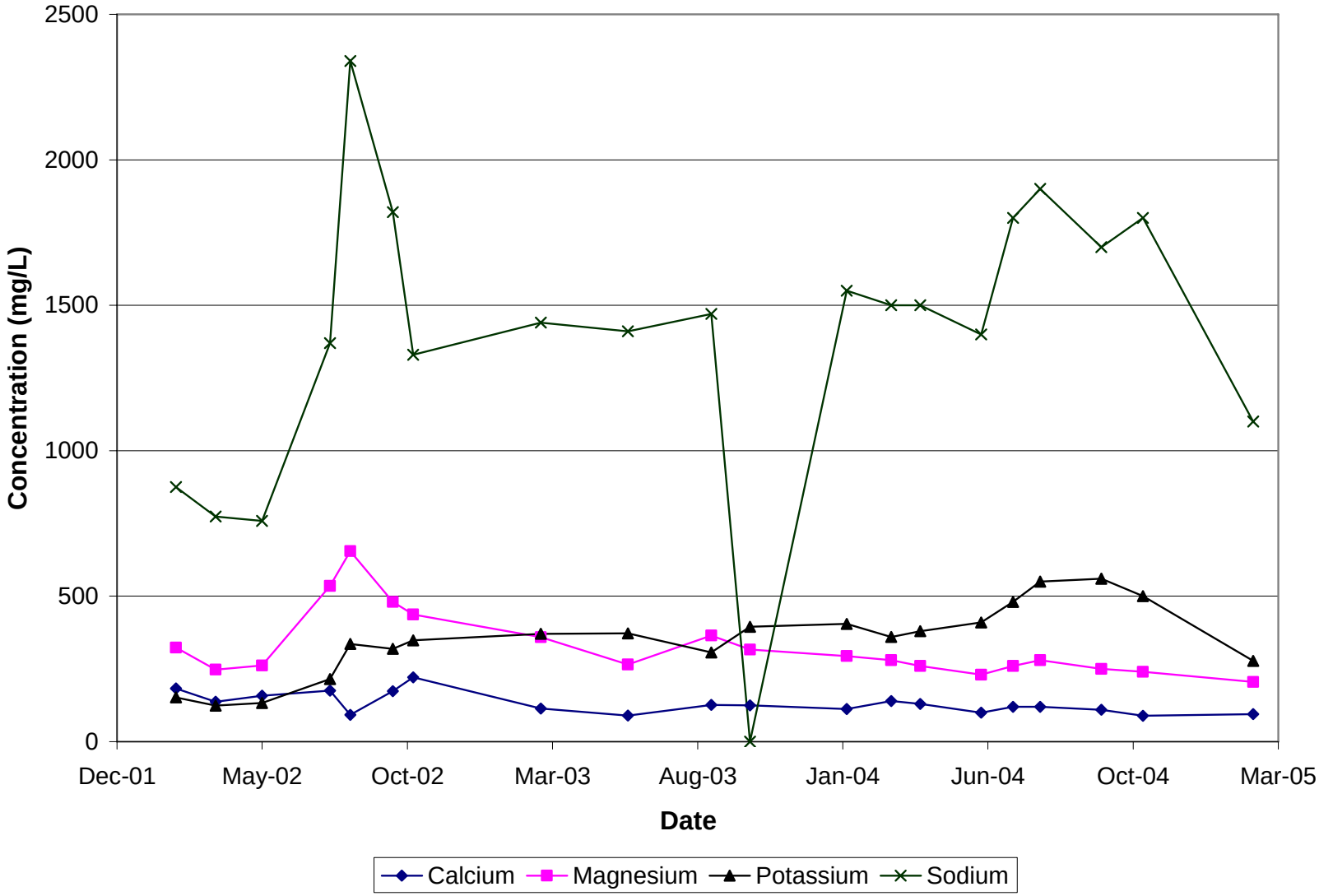


Figure 28a. Profile of leachate dissolved metals for the northeast cell



Note: The low sodium point was an ND, but there were no reported errors from the lab.

Figure 28b. Profile of leachate dissolved metals for the northeast cell

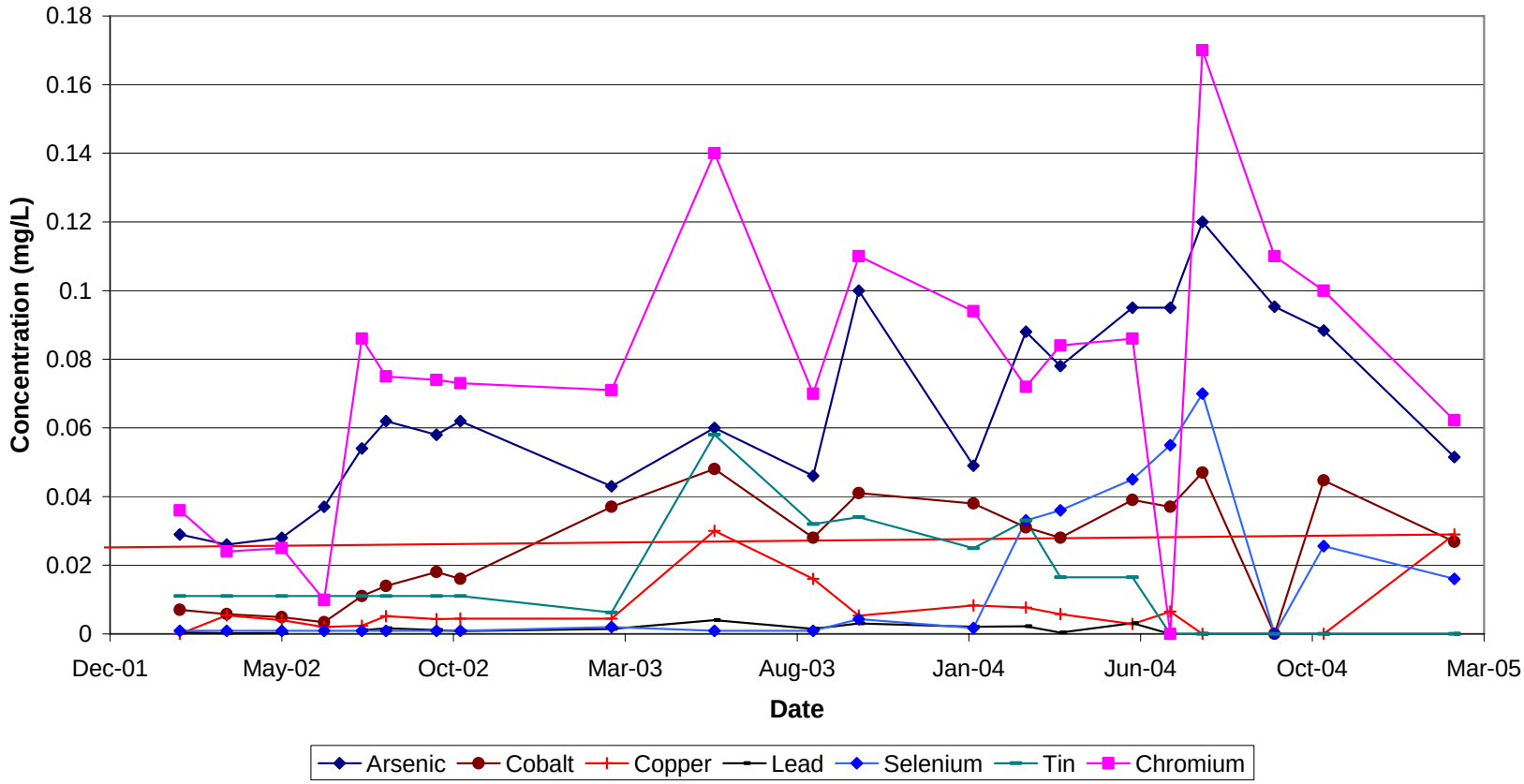


Figure 28c. Profile of leachate dissolved metals for the northeast cell

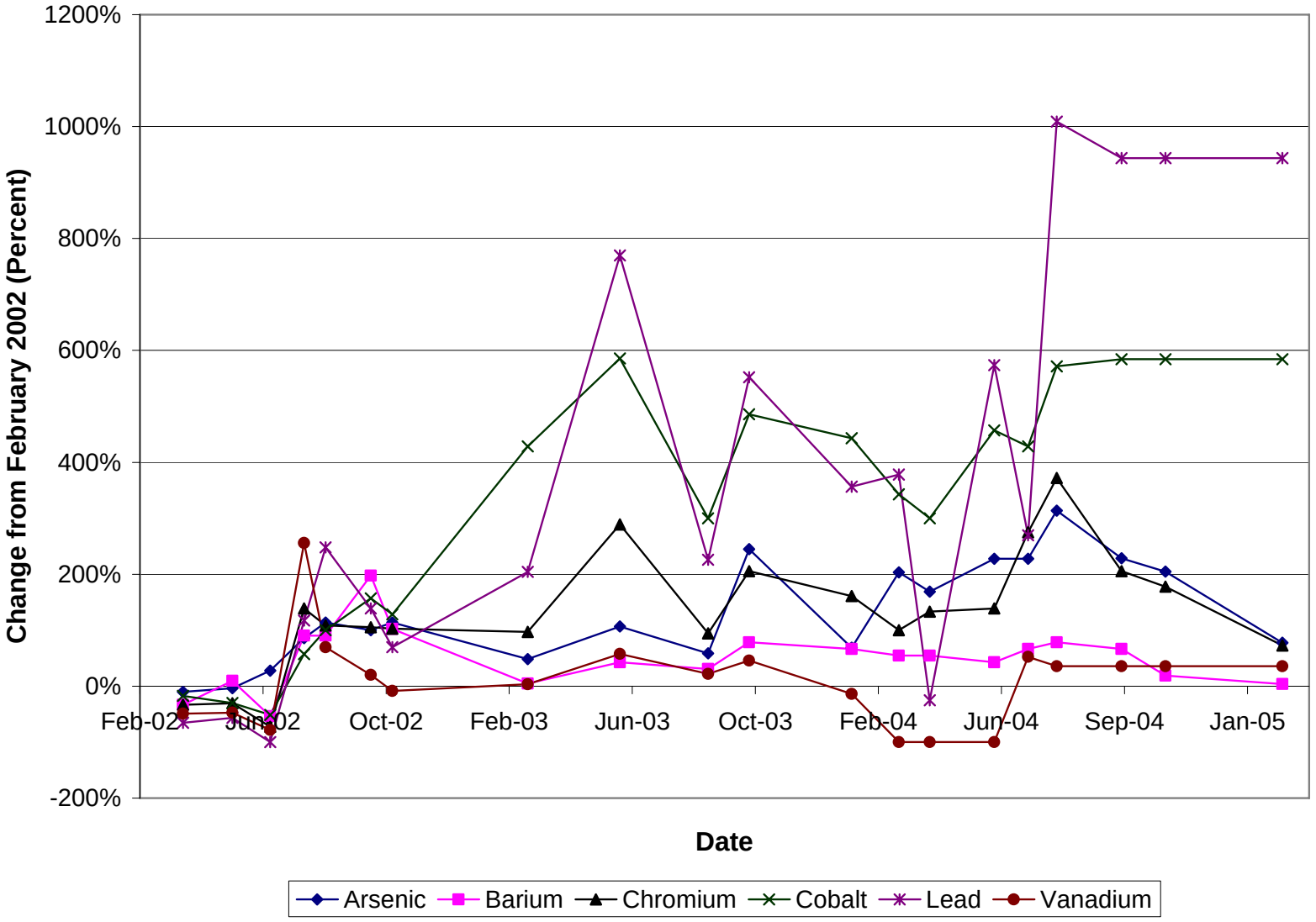


Figure 29. Change in dissolved metals concentration relative to initial concentration measured in February 2002 for the northeast cell

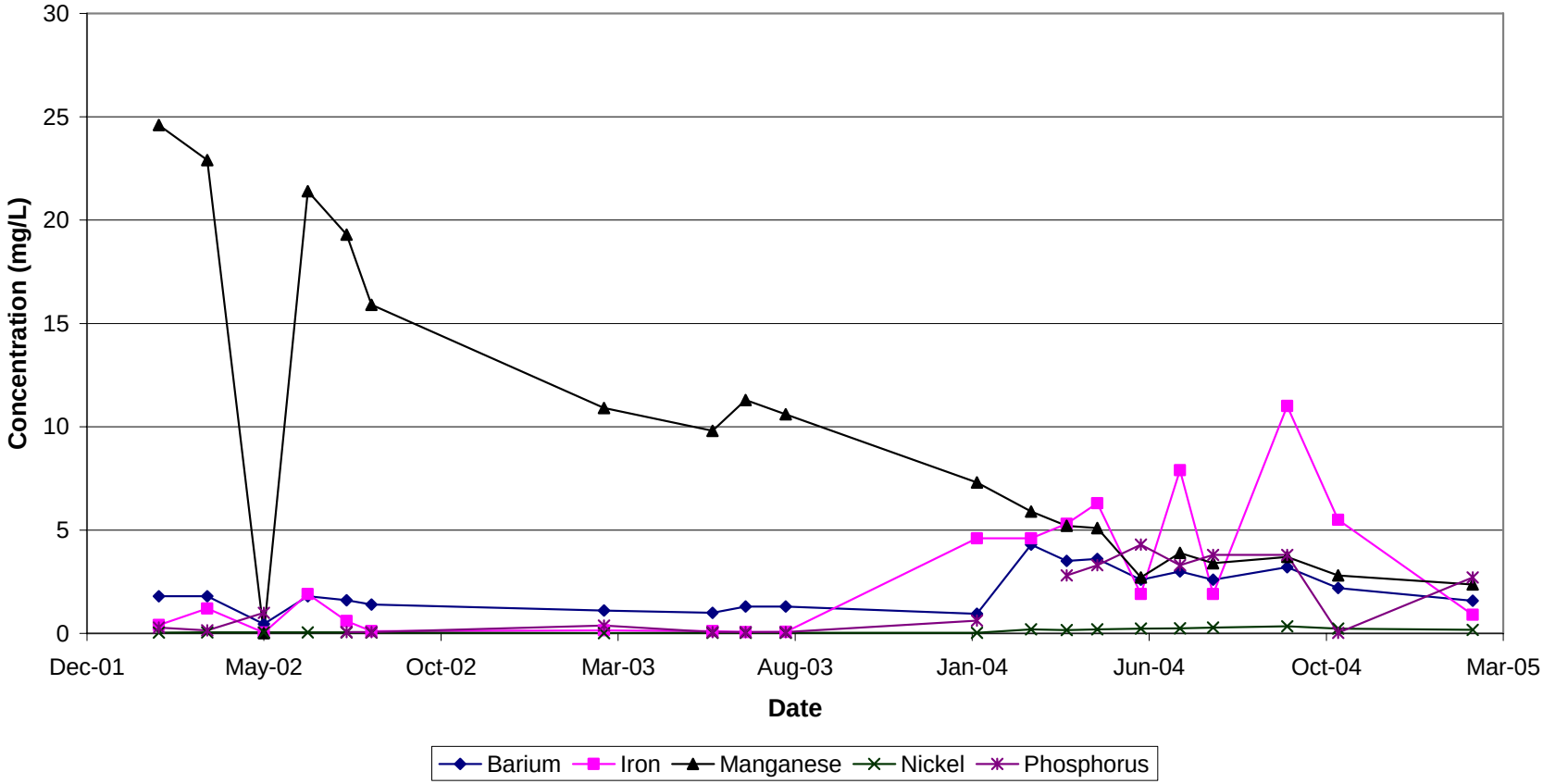


Figure 30a. Profile of leachate dissolved metals for the west-side cell

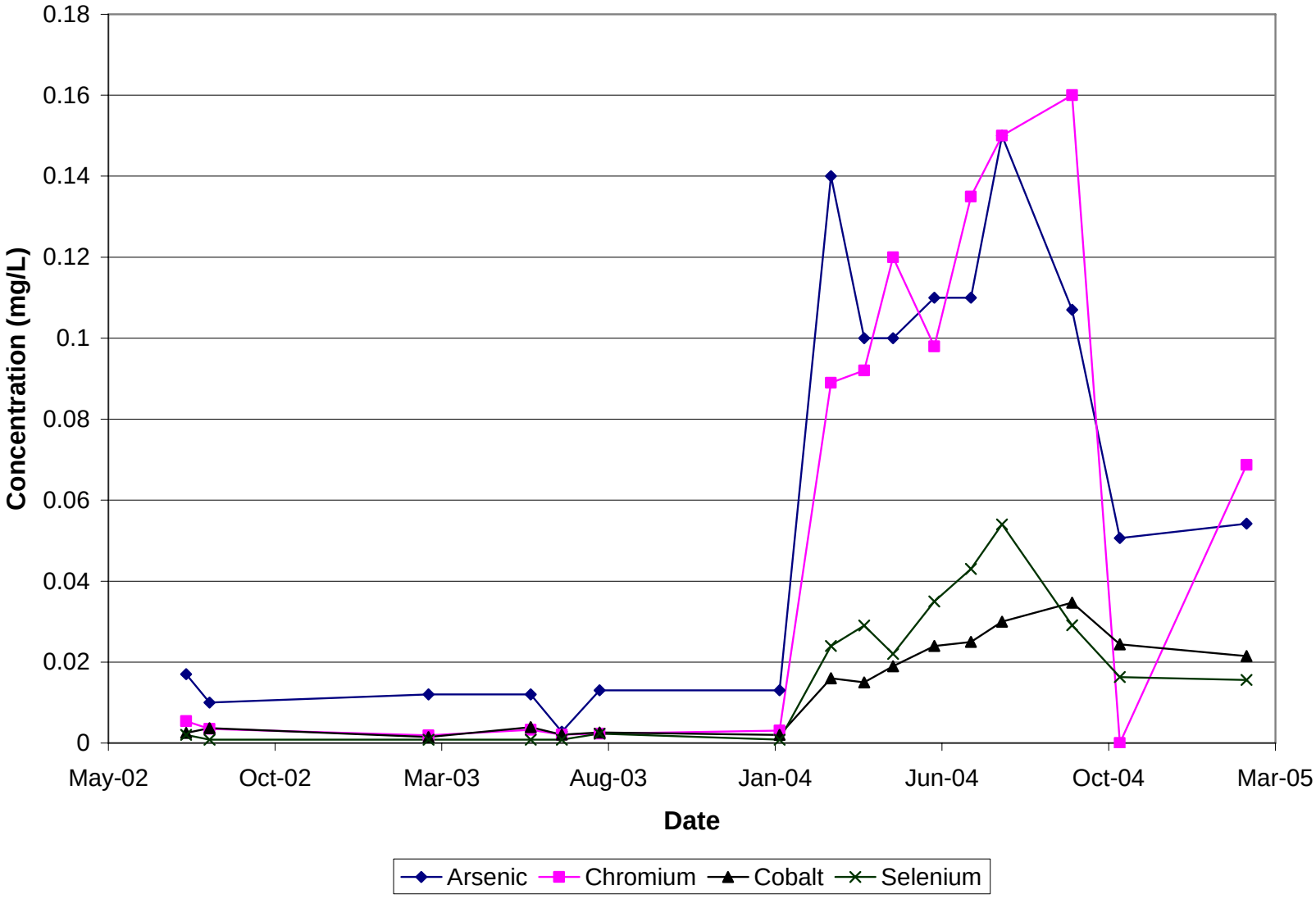


Figure 30b. Profile of leachate dissolved metals for the west-side cell

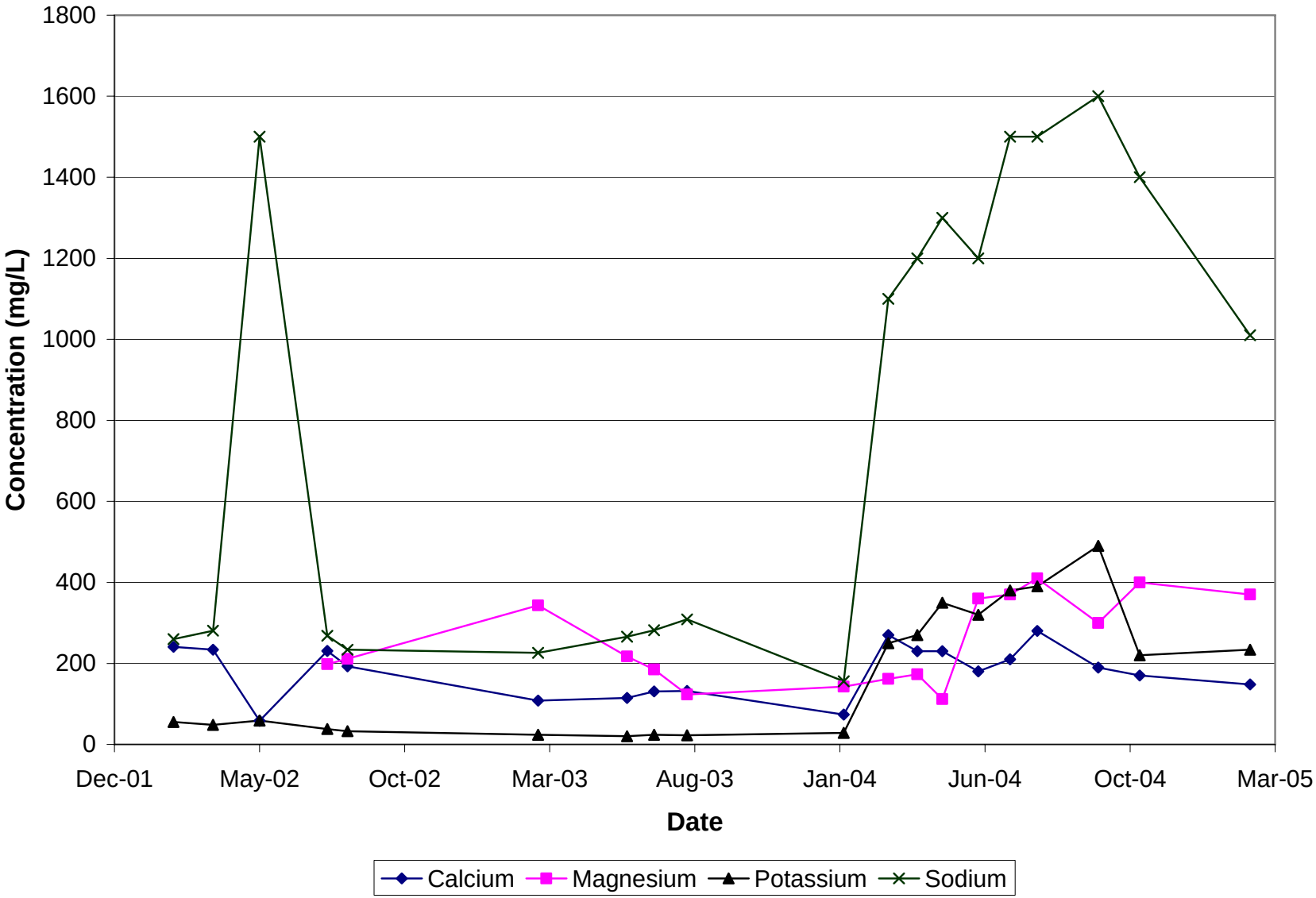


Figure 30c. Profile of leachate dissolved metals for the west-side cell

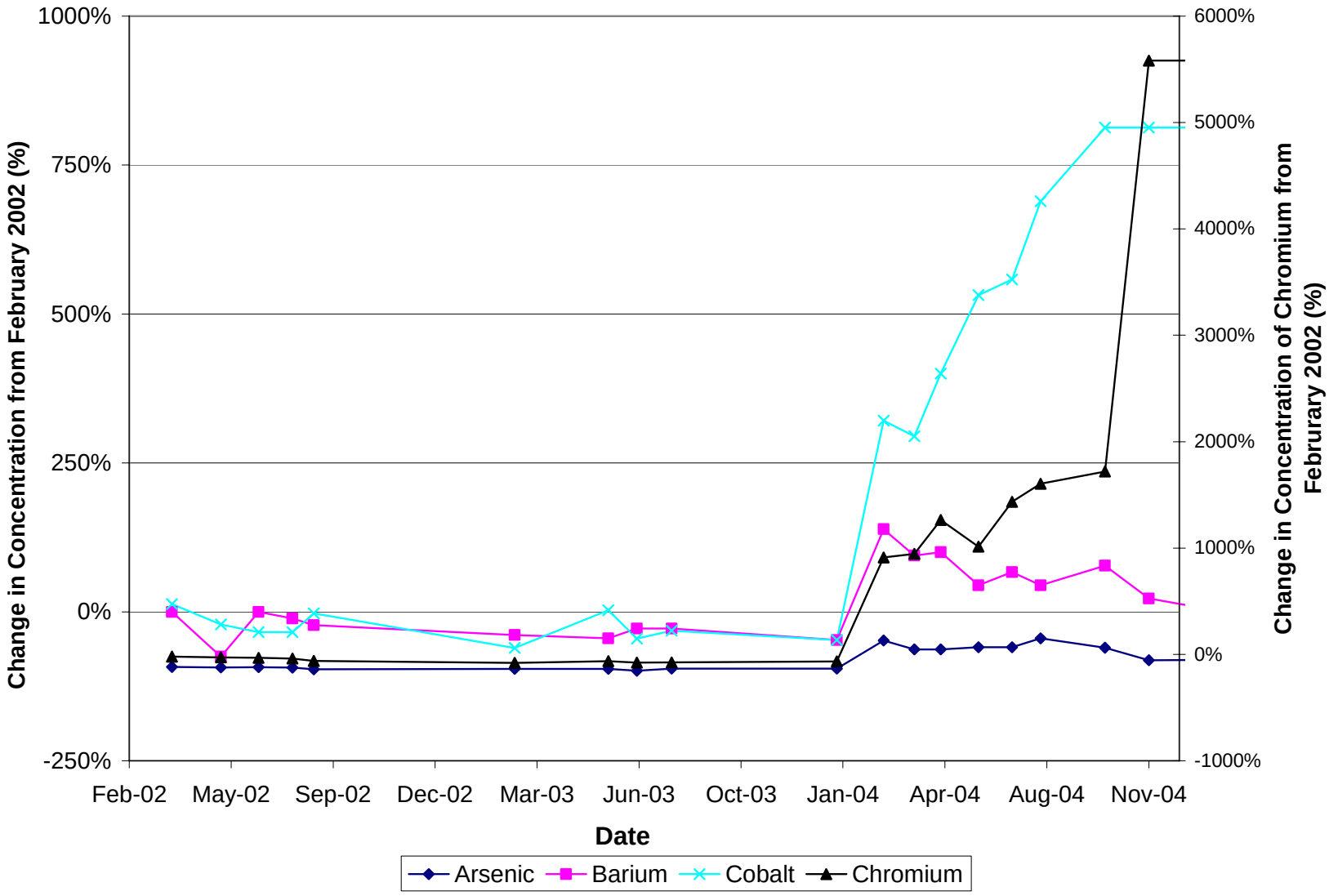


Figure 31. Change in dissolved metals concentration relative to initial concentration measured in February 2002 for the west-side cell

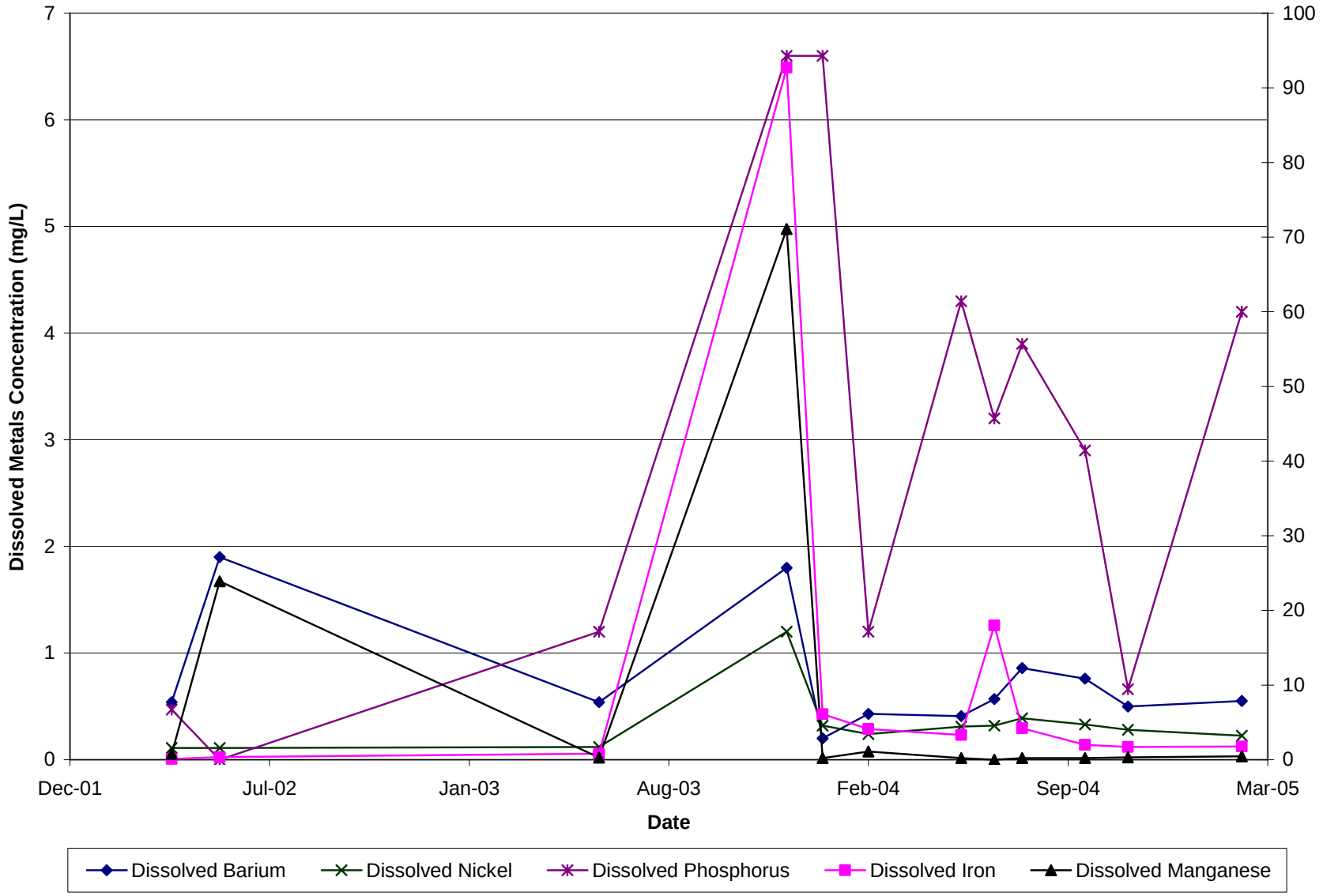


Figure 32a. Profile of leachate dissolved metals for the southeast aerobic cell

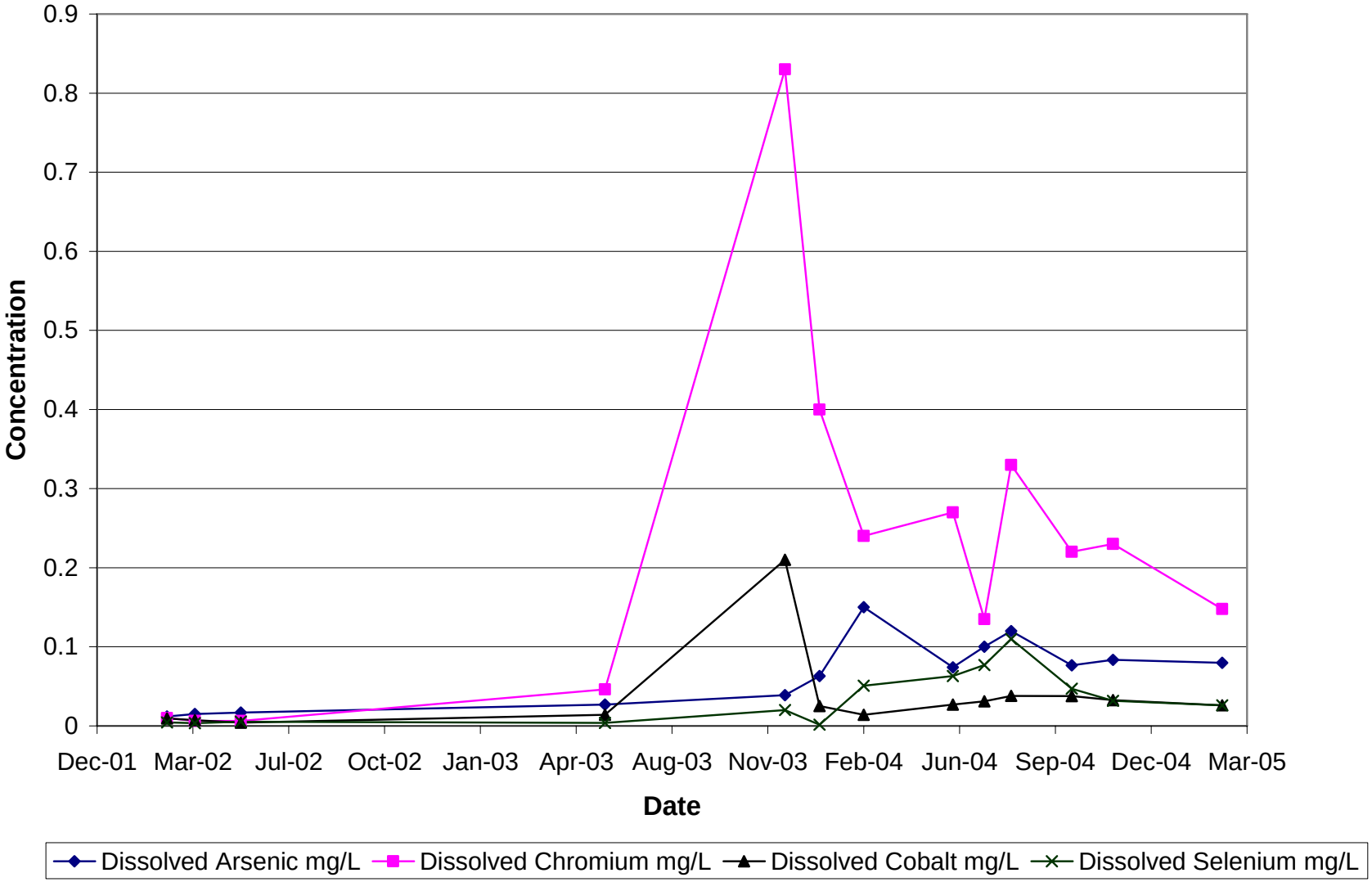


Figure 32b. Profile of leachate dissolved metals for the southeast aerobic cell

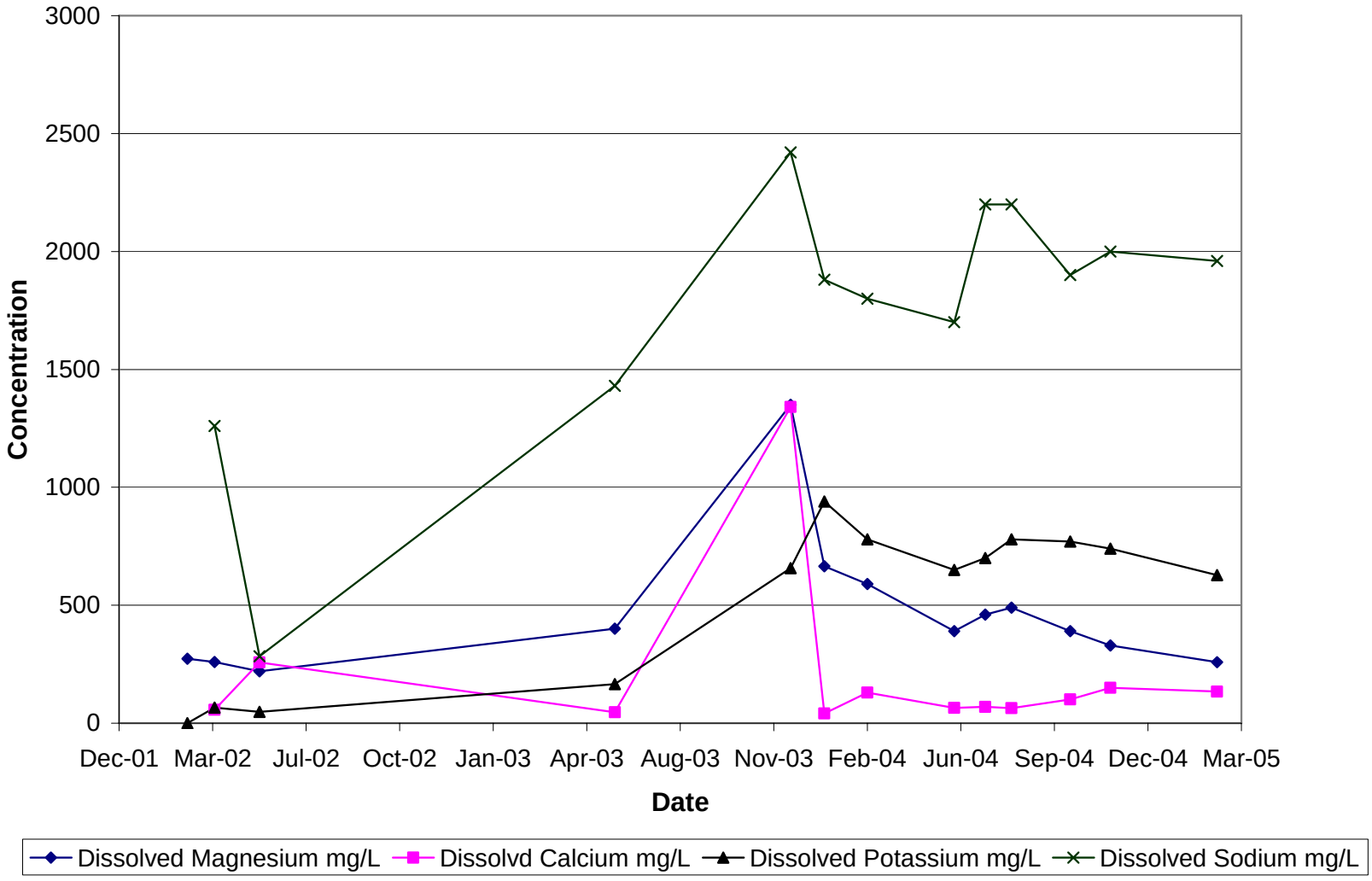


Figure 32c. Profile of leachate dissolved metals for the southeast aerobic cell

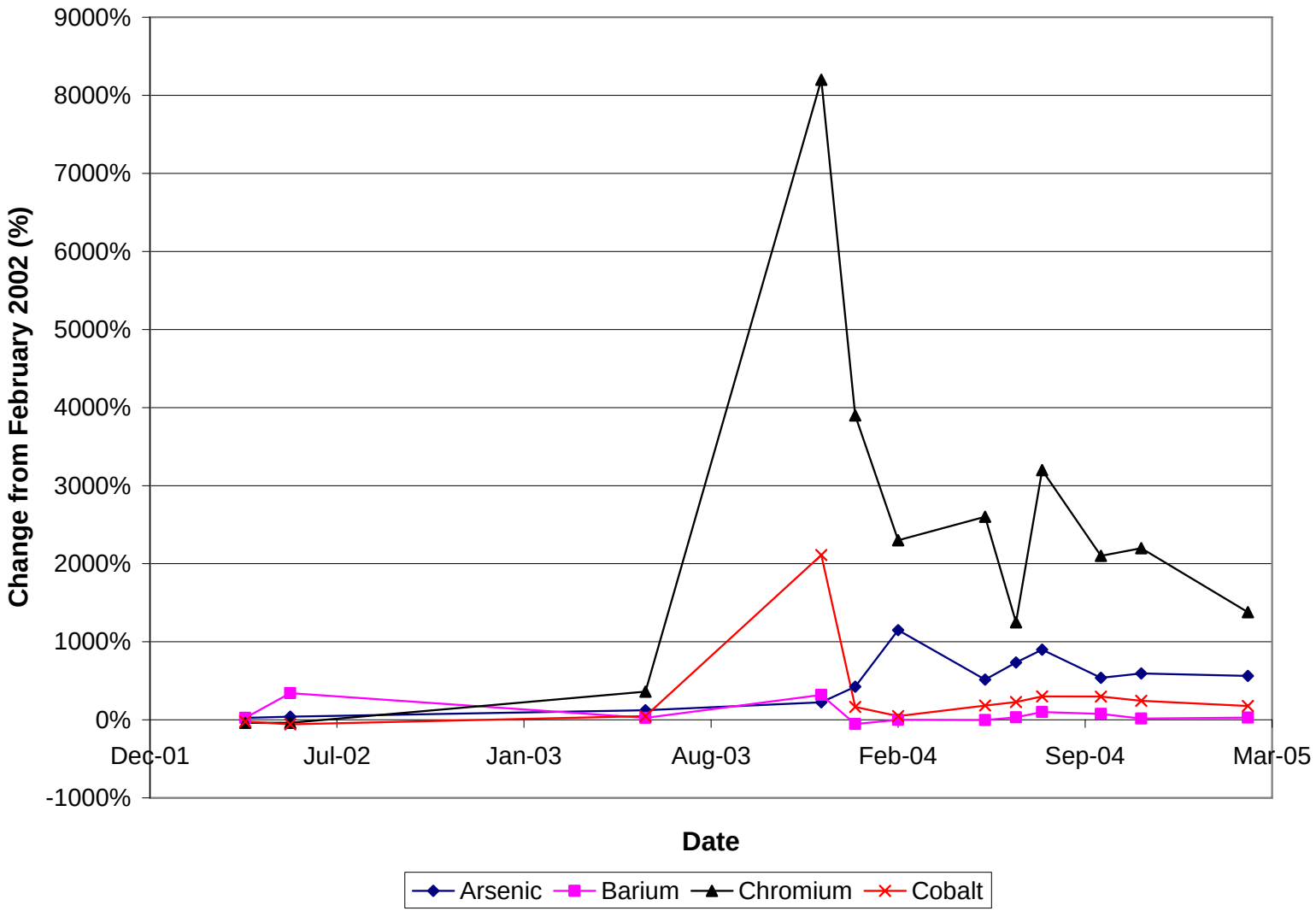


Figure 33. Change in dissolved metals concentration relative to initial concentration measured in February 2002 for the southeast aerobic cell

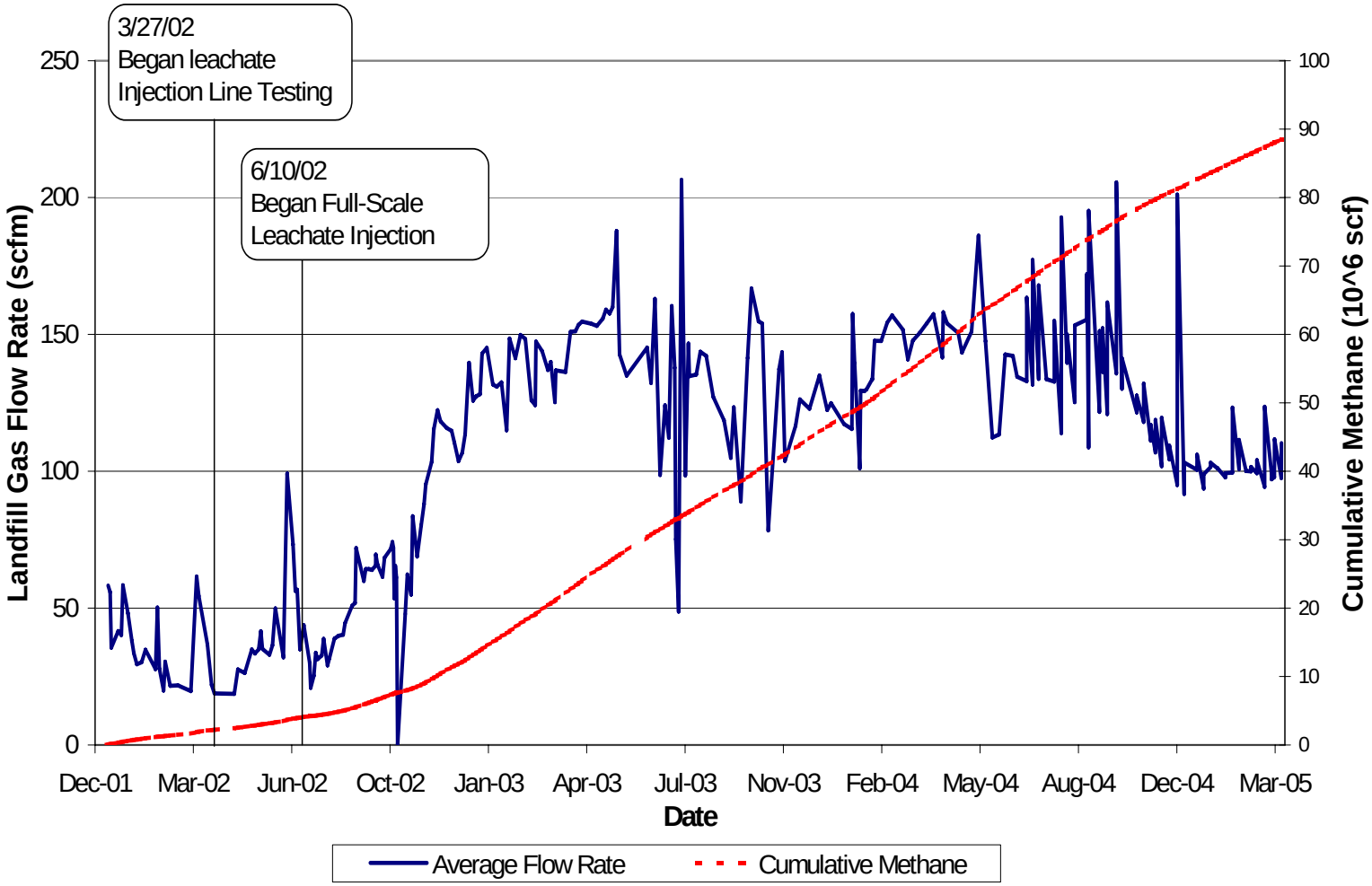


Figure 34. Landfill gas flow rate and cumulative methane for the northeast cell

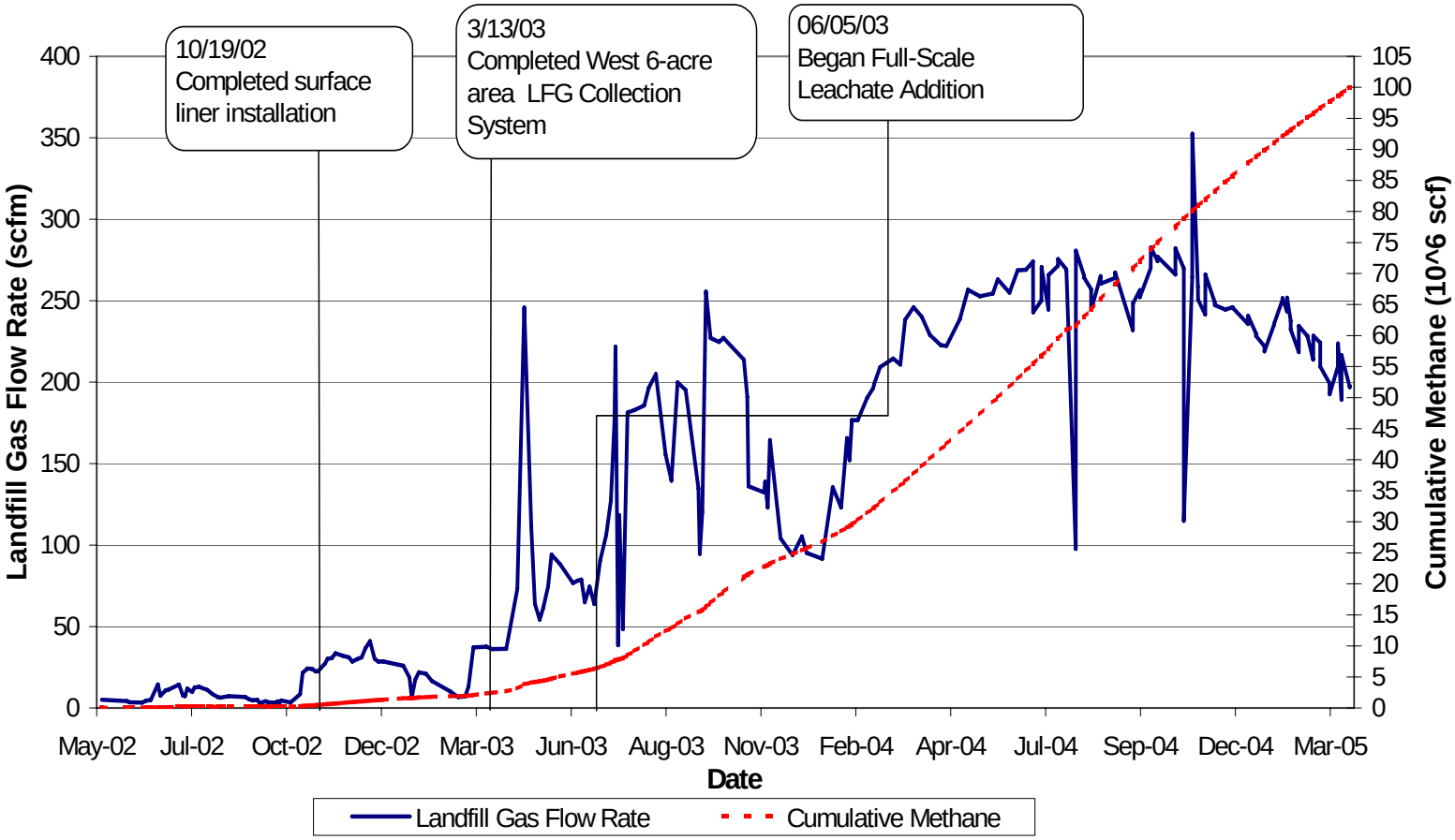


Figure 35. Landfill gas flow rate and cumulative methane for the west-side cell

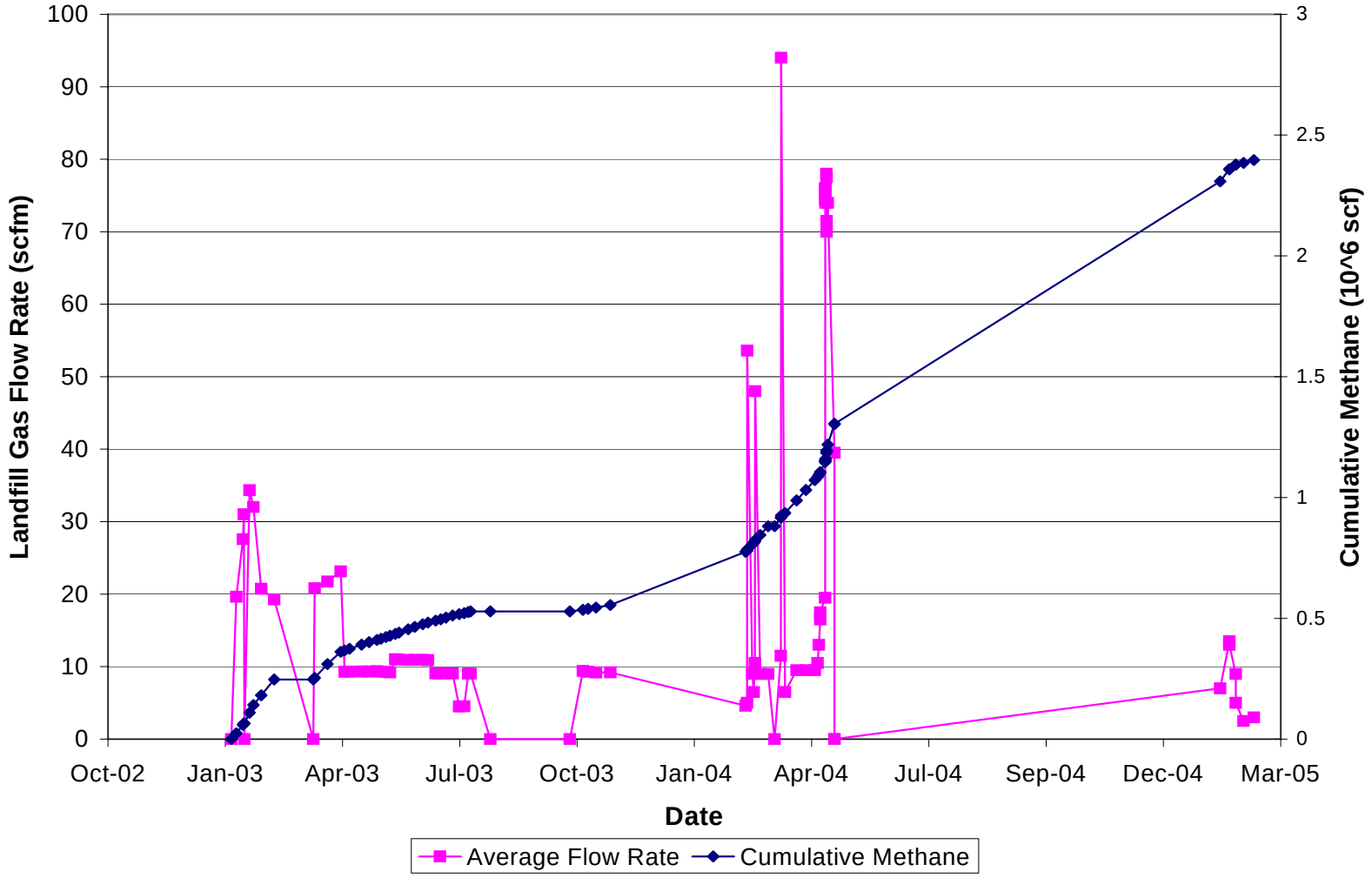


Figure 36. Landfill gas flow rate and cumulative methane for the southeast aerobic cell

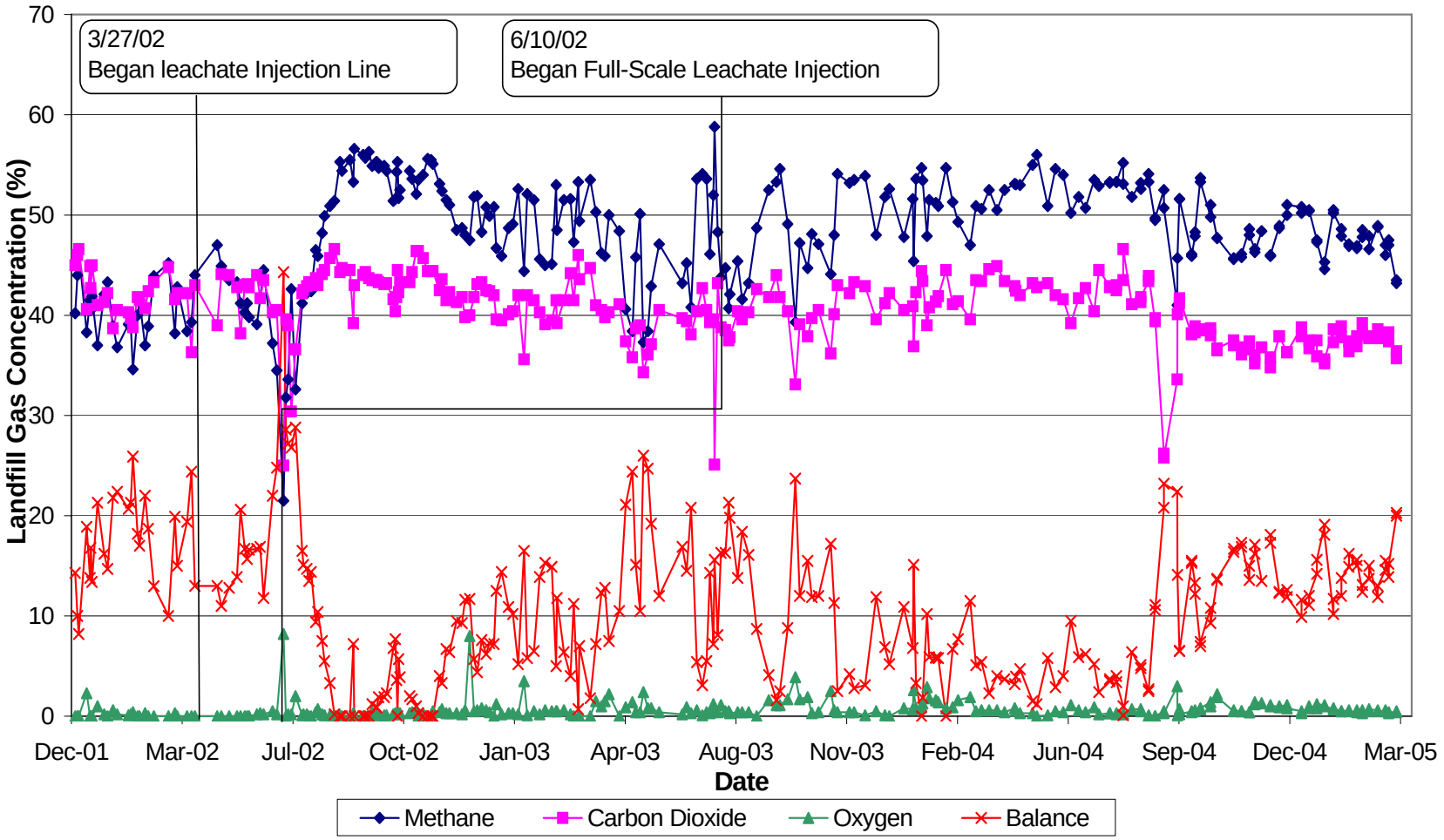


Figure 37. Landfill gas concentrations from gas header line for northeast cell

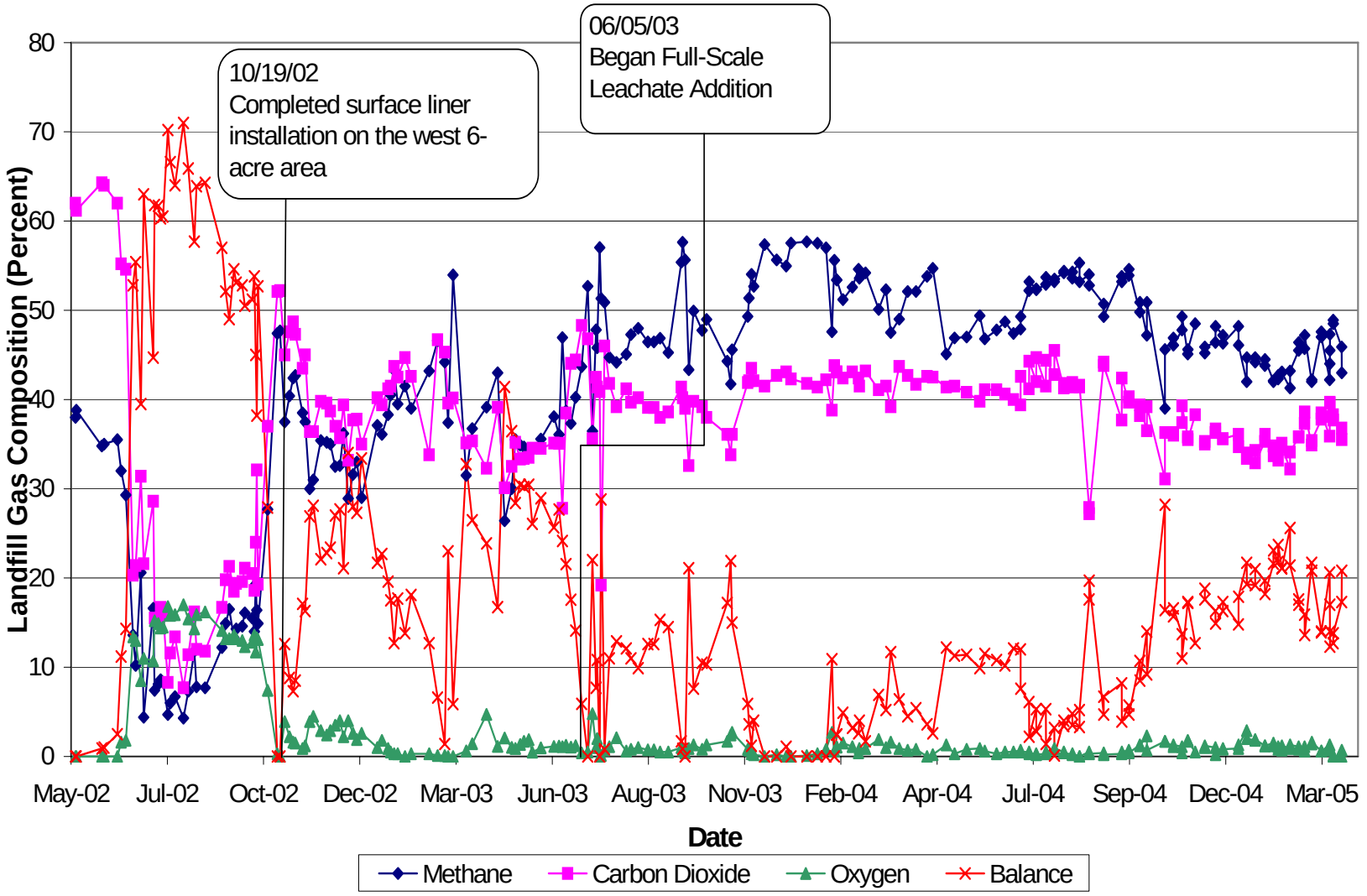


Figure 38. Landfill gas concentrations from gas header line for west-side cell

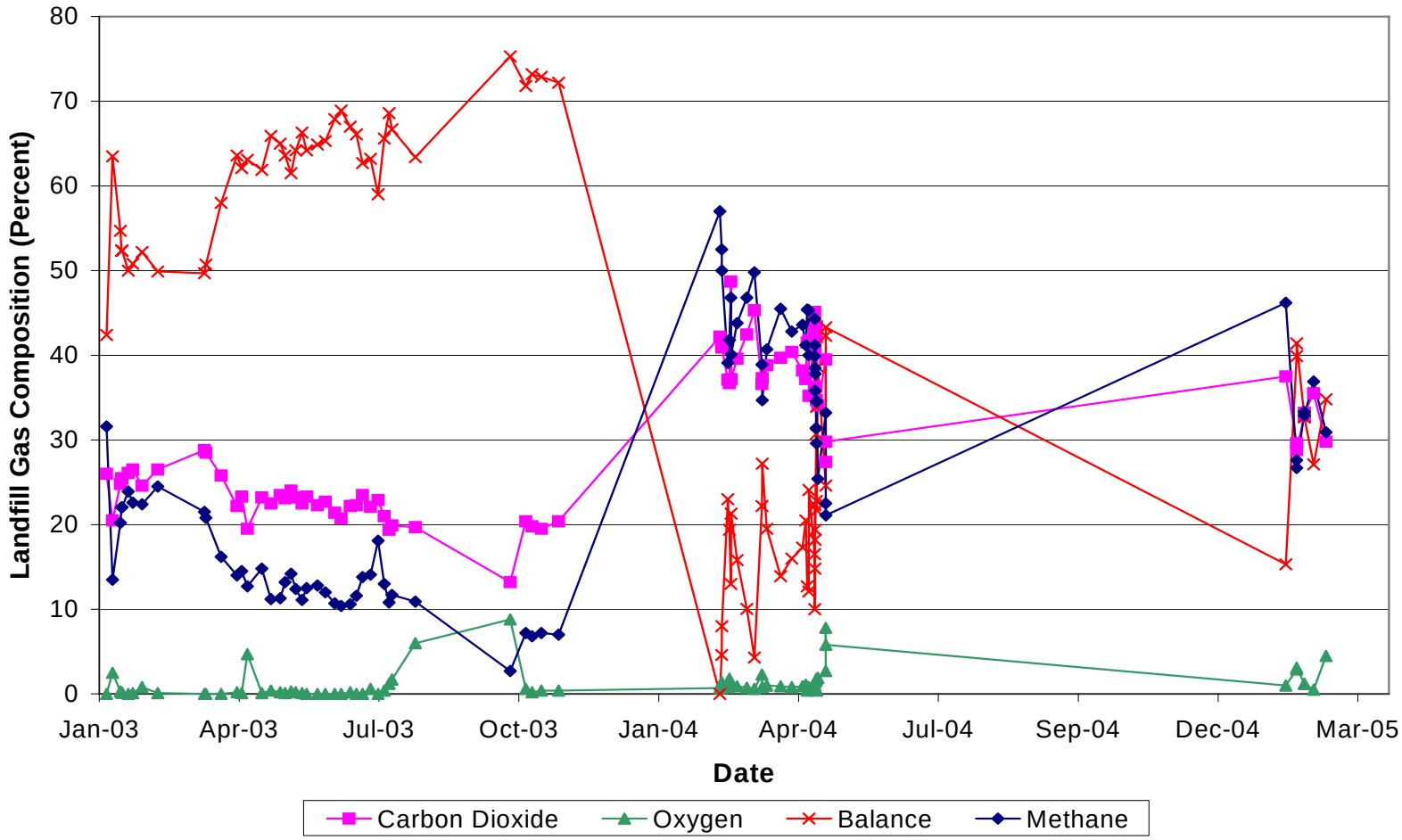


Figure 39. Landfill gas concentrations from gas header line for southeast aerobic cell

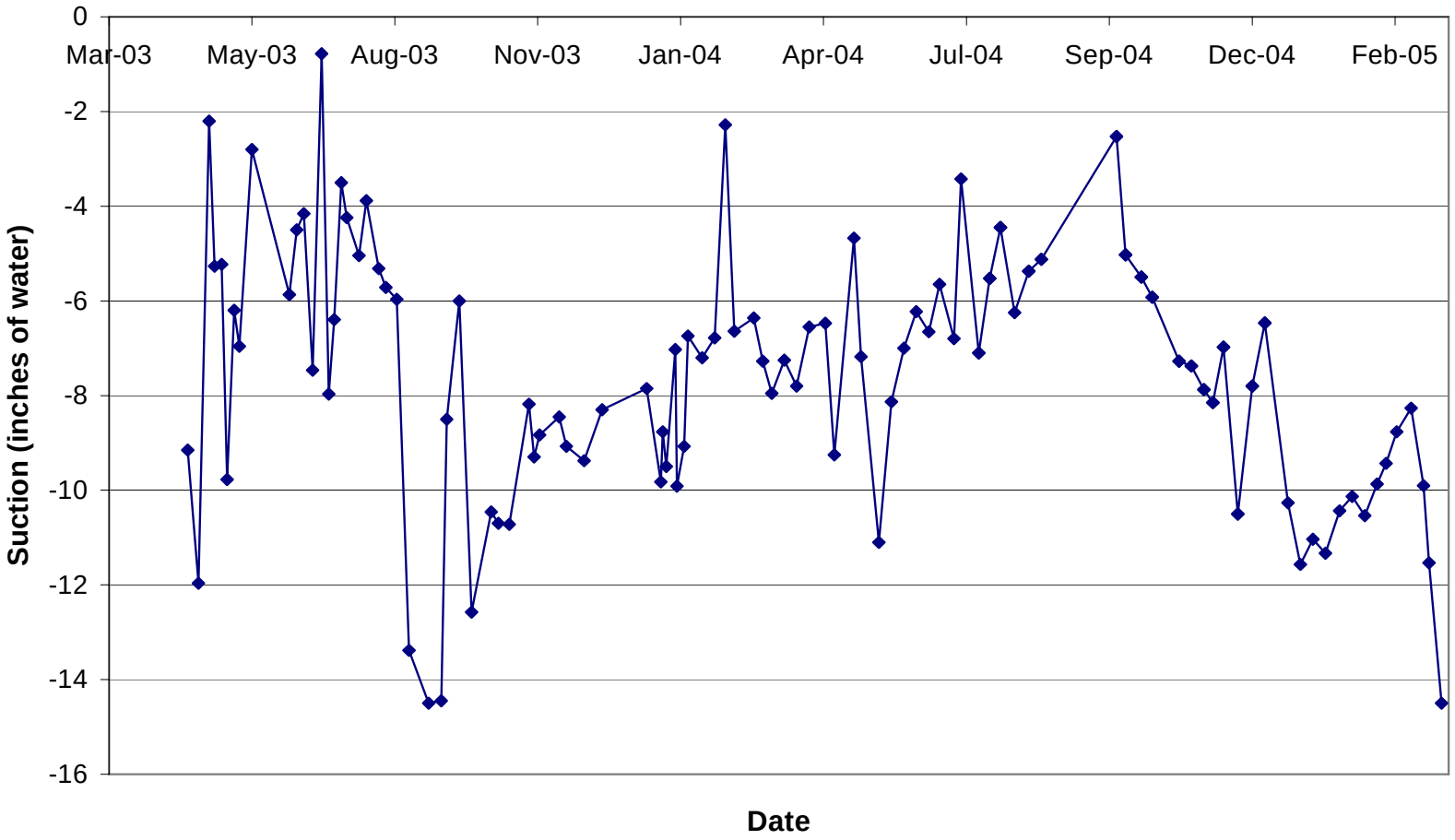


Figure 40. Average suction on the northeast cell

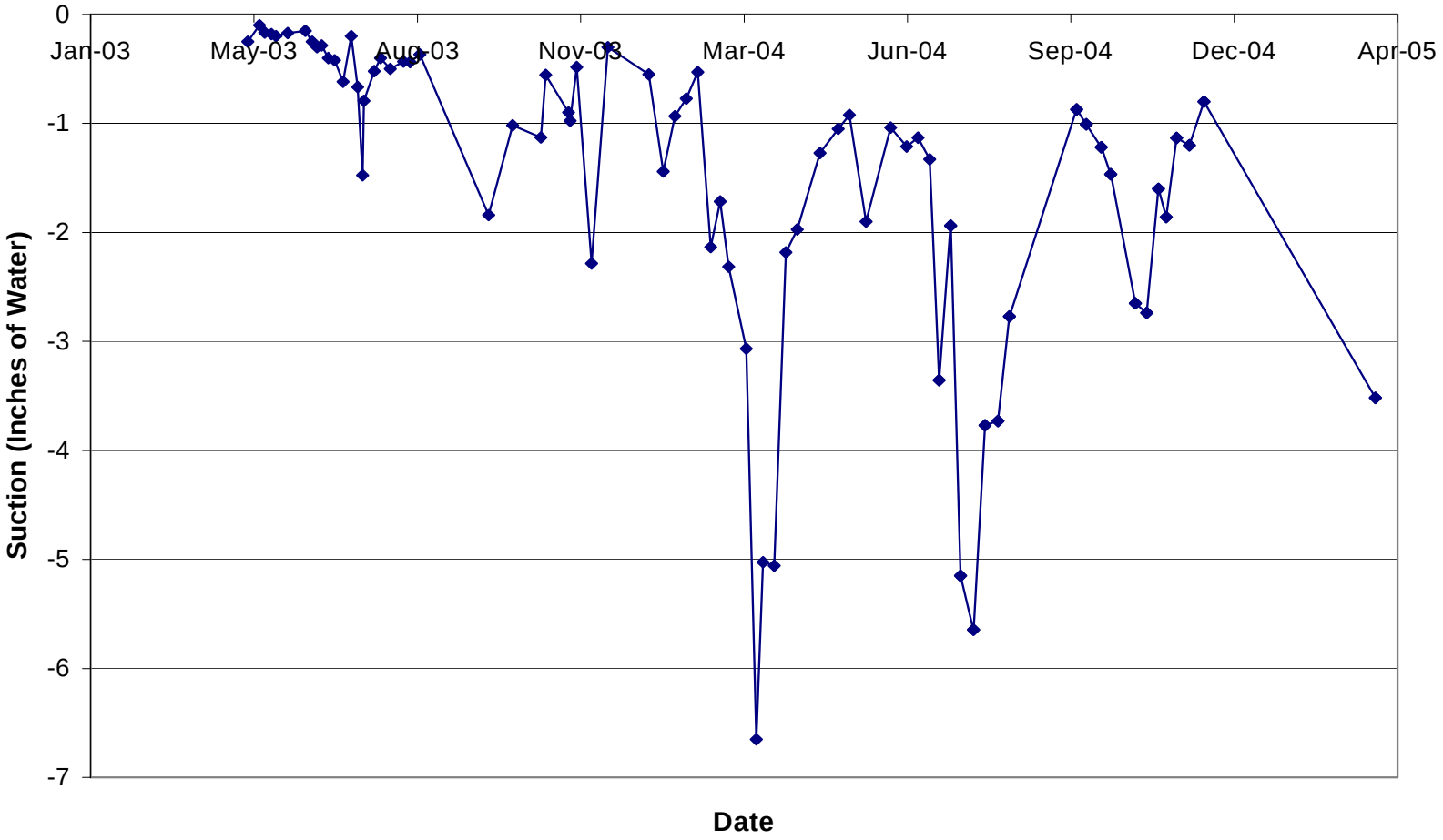


Figure 41. Average suction on the west-side cell

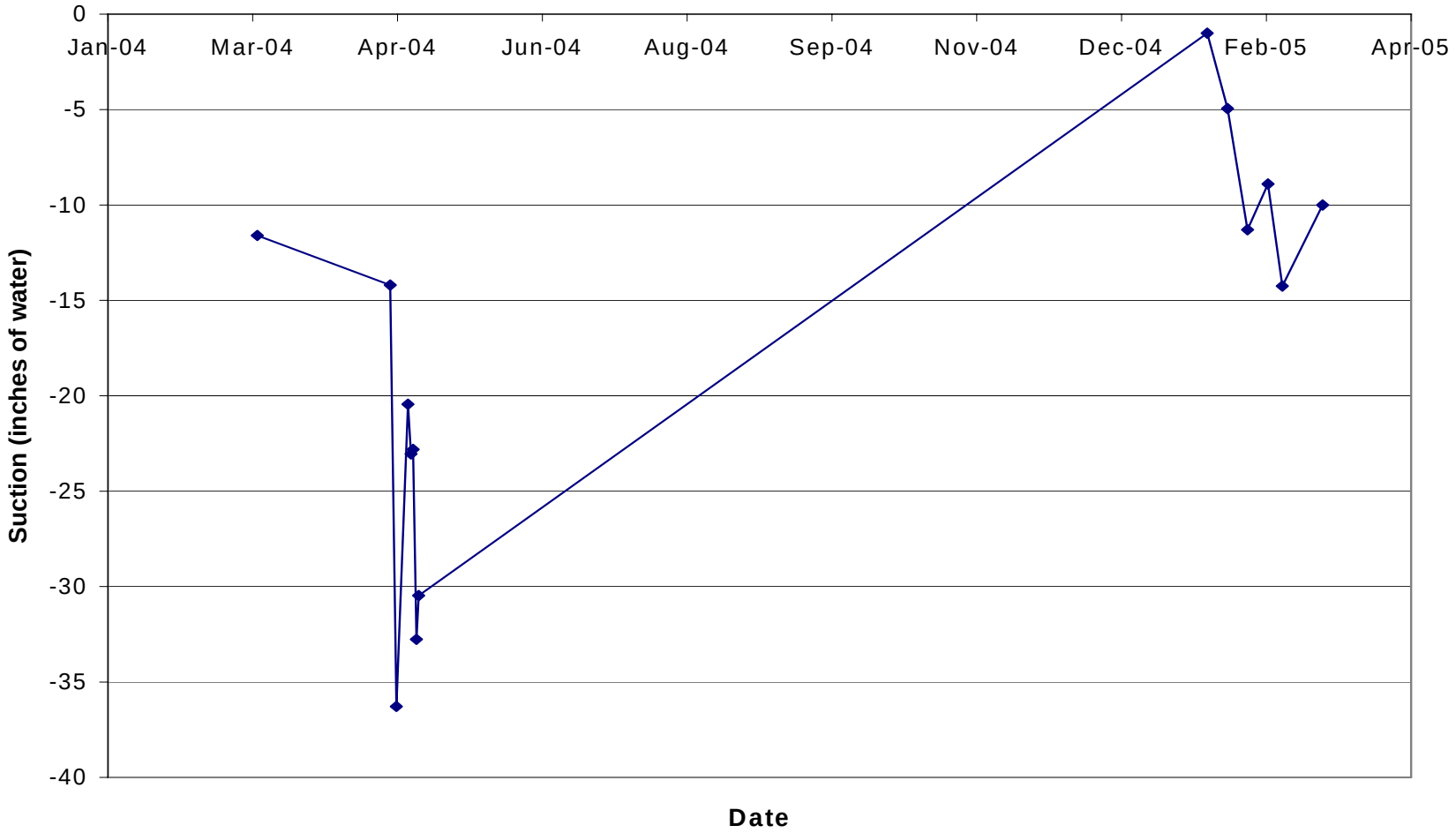


Figure 42. Average suction on the southeast aerobic cell

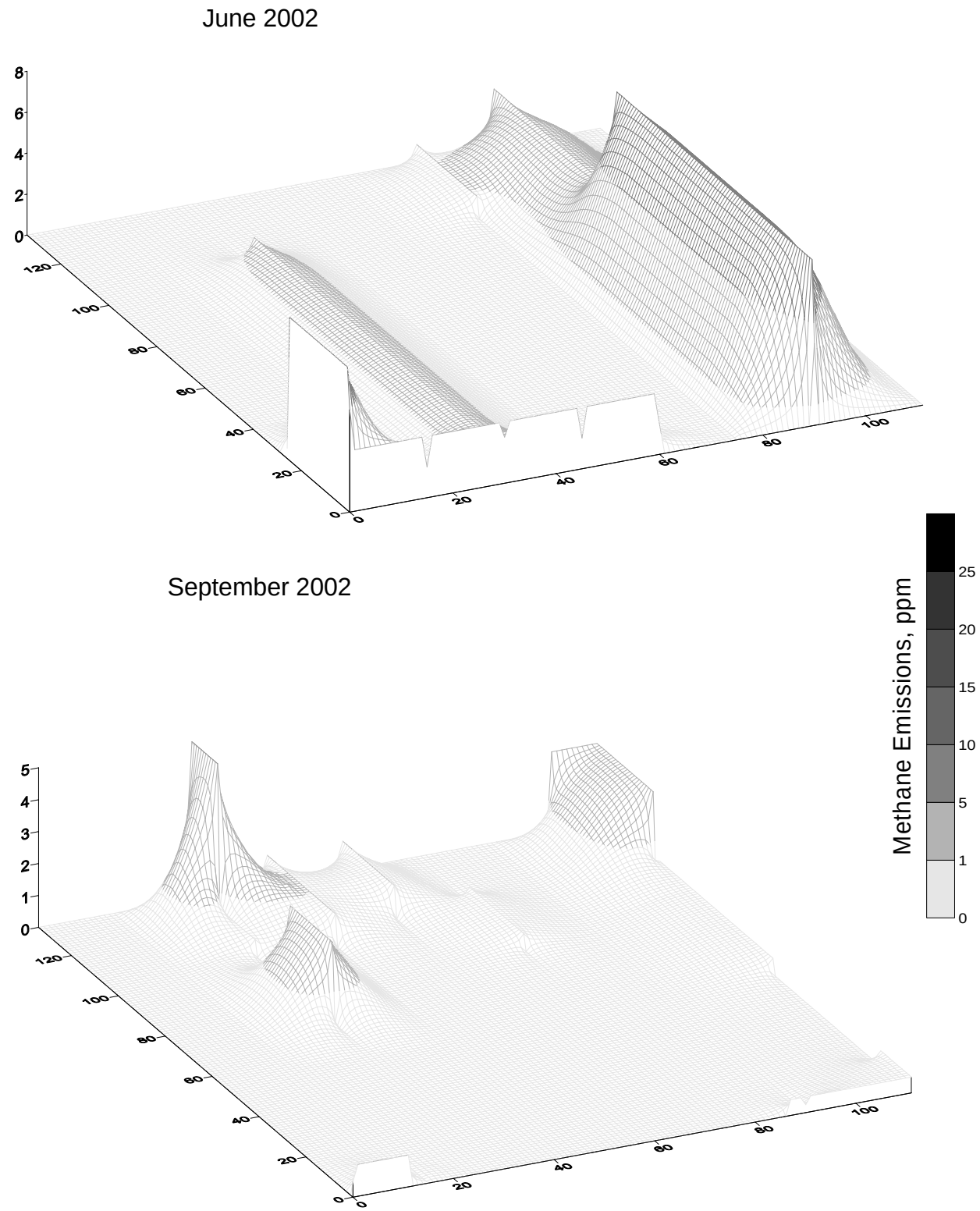


Figure 43. Surface emission map for the northeast cell for 2002, with color scale. The weighted average emissions for the June and September scan were 1.1 and 0.25 ppm, respectively.

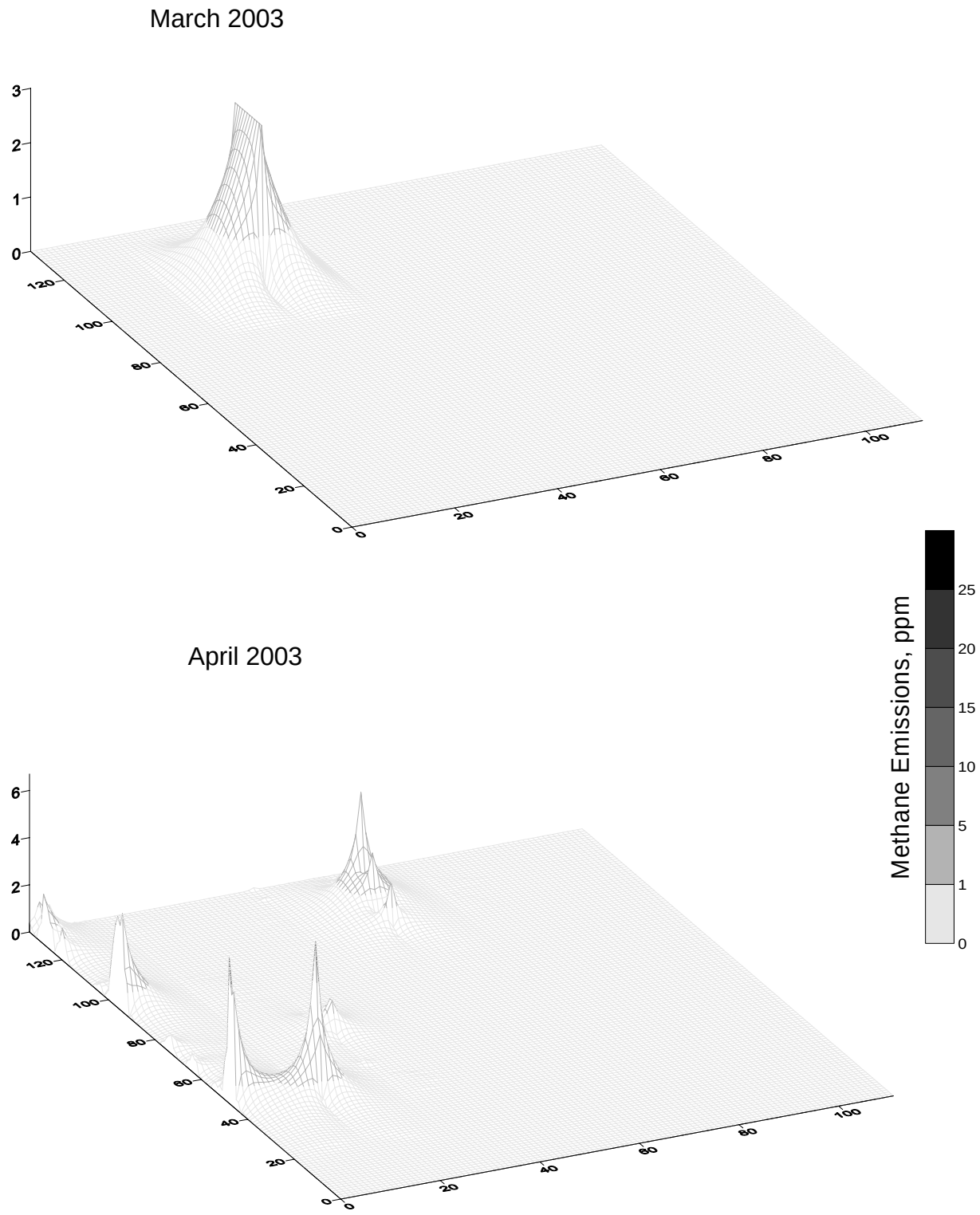


Figure 43 cont. Surface emission maps for the Northeast cell for 2003, with color scale. The weighted average emissions for the March, April, September, and December surface scans were 0.18, 0.08, 3.7, and 0.24 ppm, respectively. Note the color scale for the September scan is different from the other three plots.

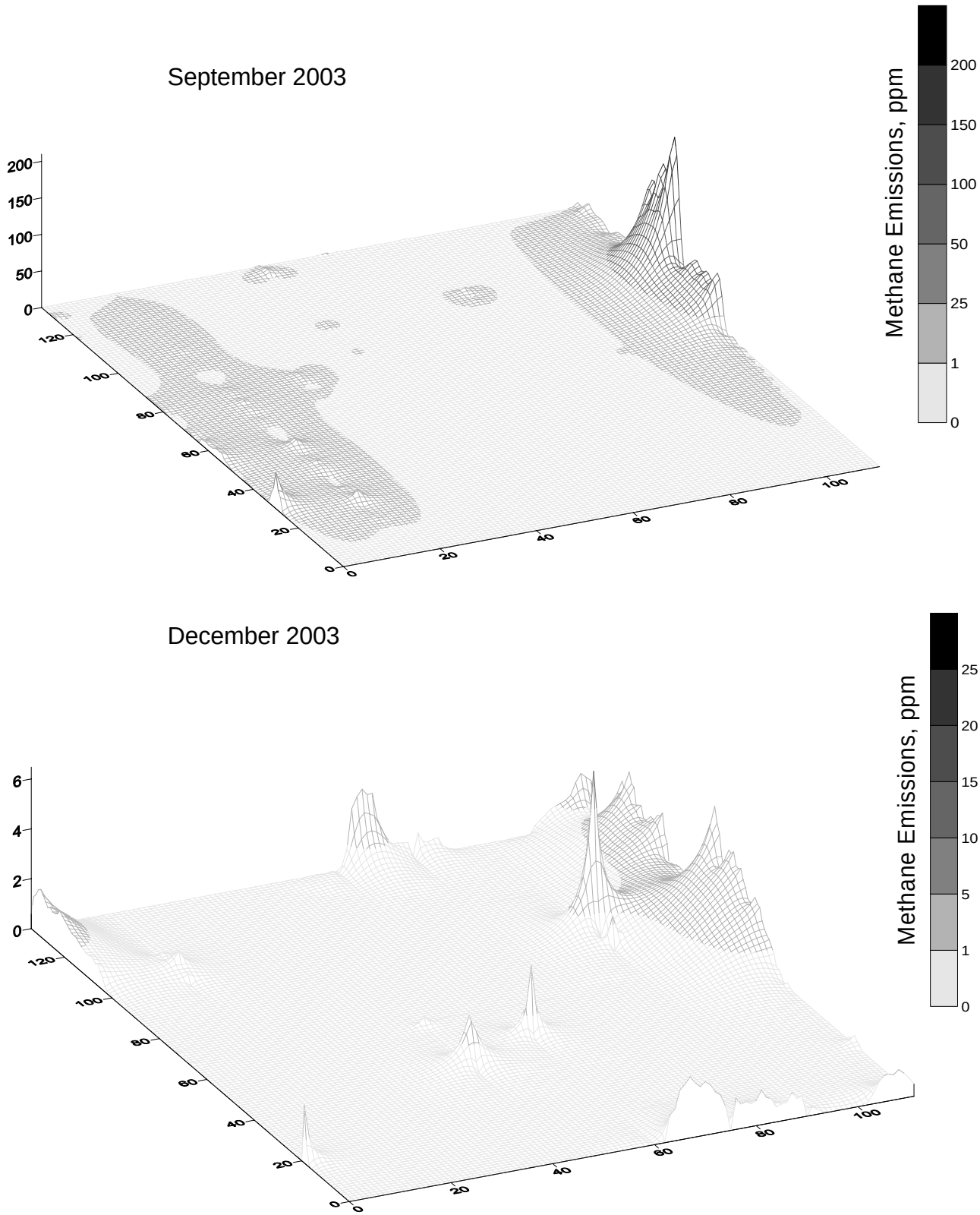


Figure 43 cont. Surface emission maps for the Northeast cell for 2003, with color scale. The weighted average emissions for the March, April, September, and December surface scans were 0.18, 0.08, 3.7, and 0.24 ppm, respectively. Note the color scale for the September scan is different from the other three plots.

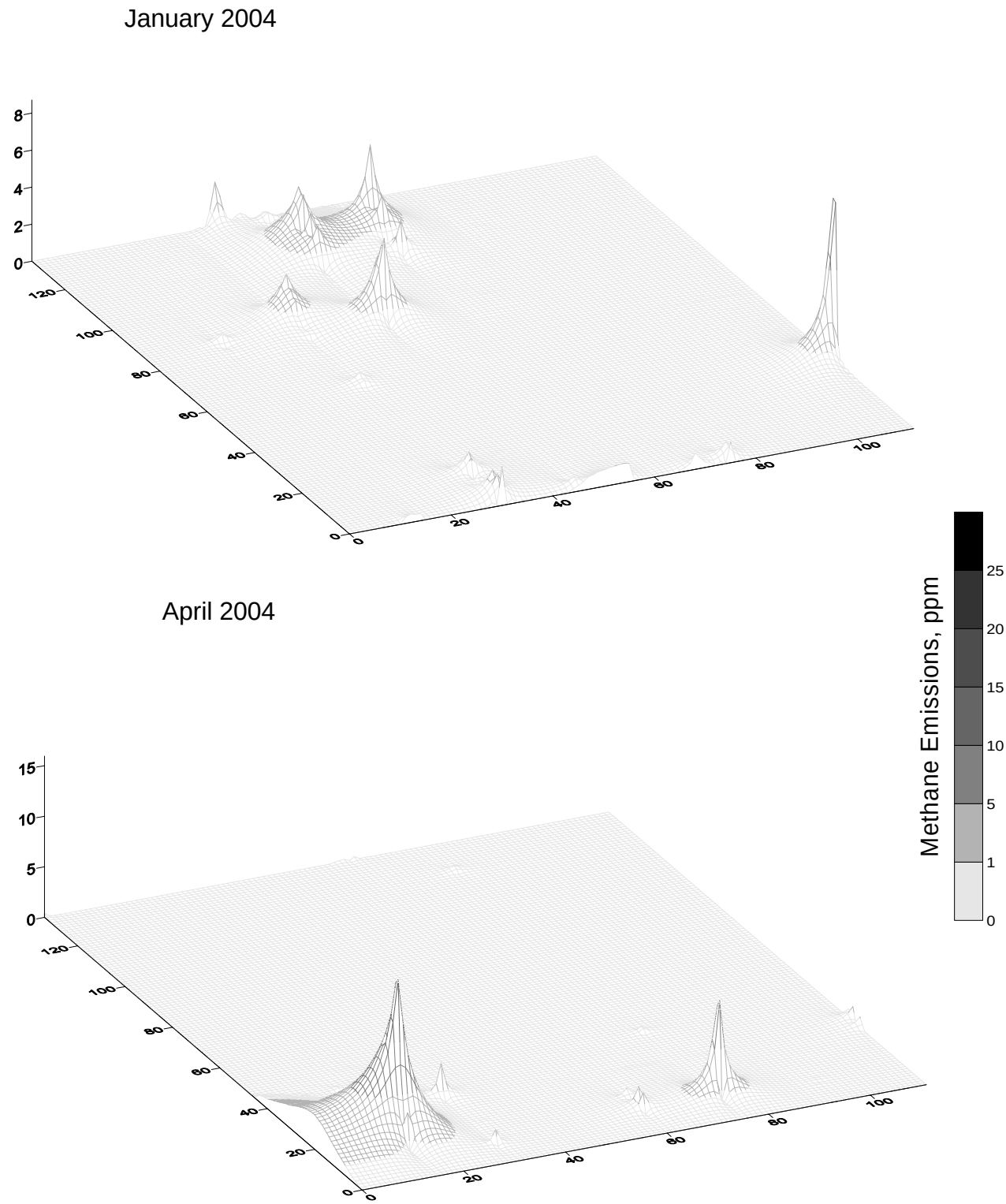


Figure 43 cont. Surface emission maps for the Northeast cell for 2004, with color scale. The weighted average emissions for the January, April, August, and November surface scans were 0.14, 0.10, 0.32, and 5.2 ppm, respectively. Note the color scale for the November scan is different than the other three plots.

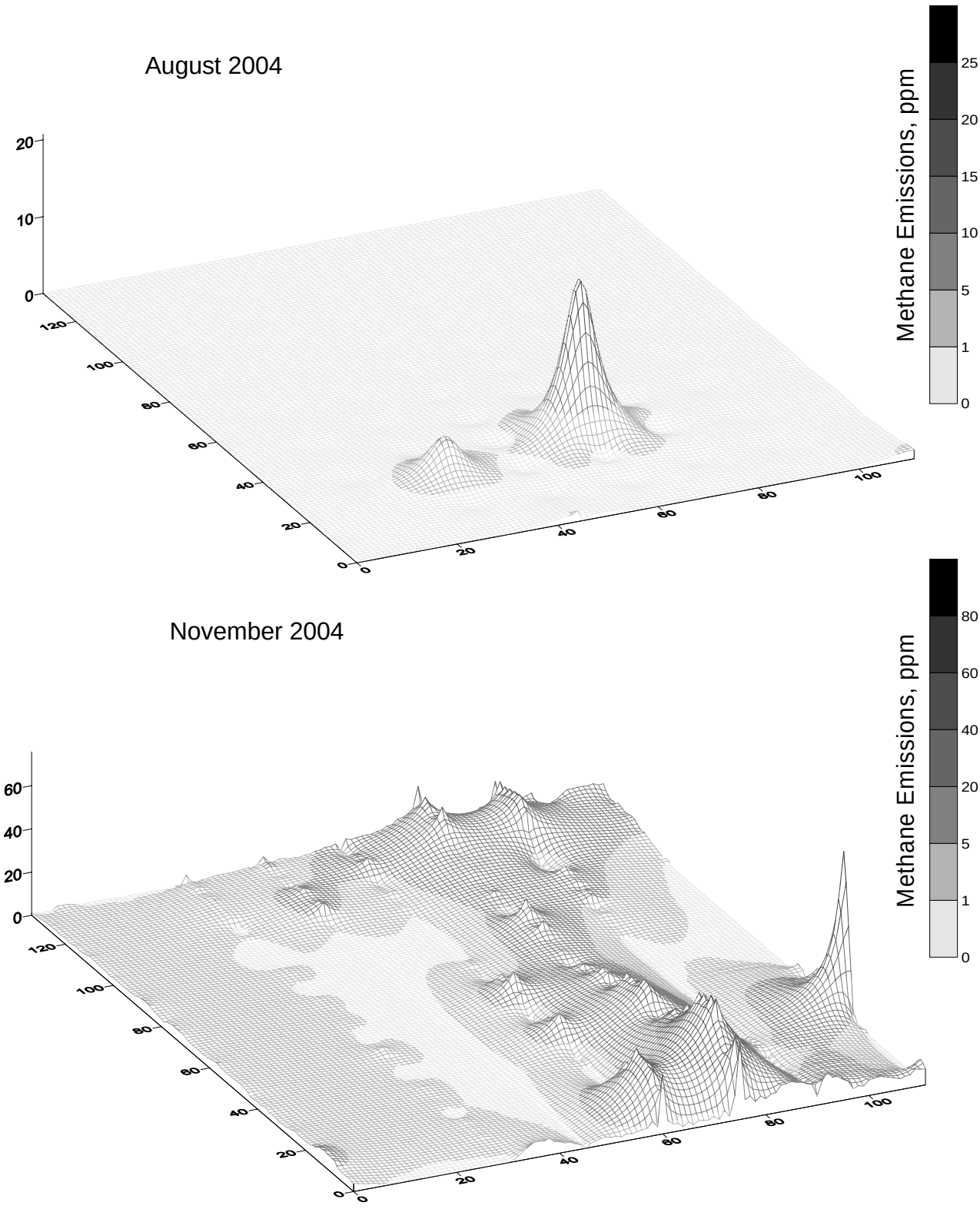


Figure 43 cont. Surface emission maps for the Northeast cell for 2004, with color scale. The weighted average emissions for the January, April, August, and November surface scans were 0.14, 0.10, 0.32, and 5.2 ppm, respectively. Note the color scale for the November scan is different than the other three plots.

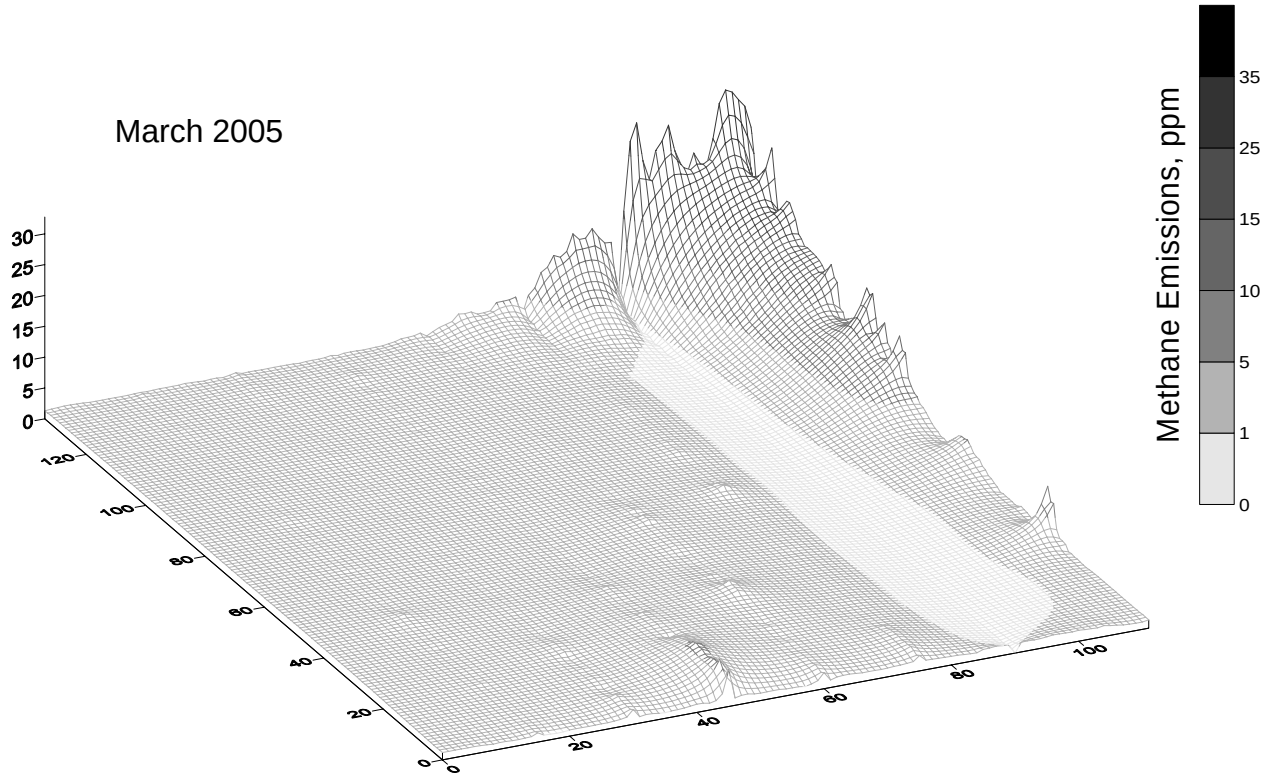


Figure 43 cont. Surface emission maps for the Northeast cell for March 2005, with color scale. The weighted average emissions was 2.7 ppm. Note the color scale is different than the other plots.

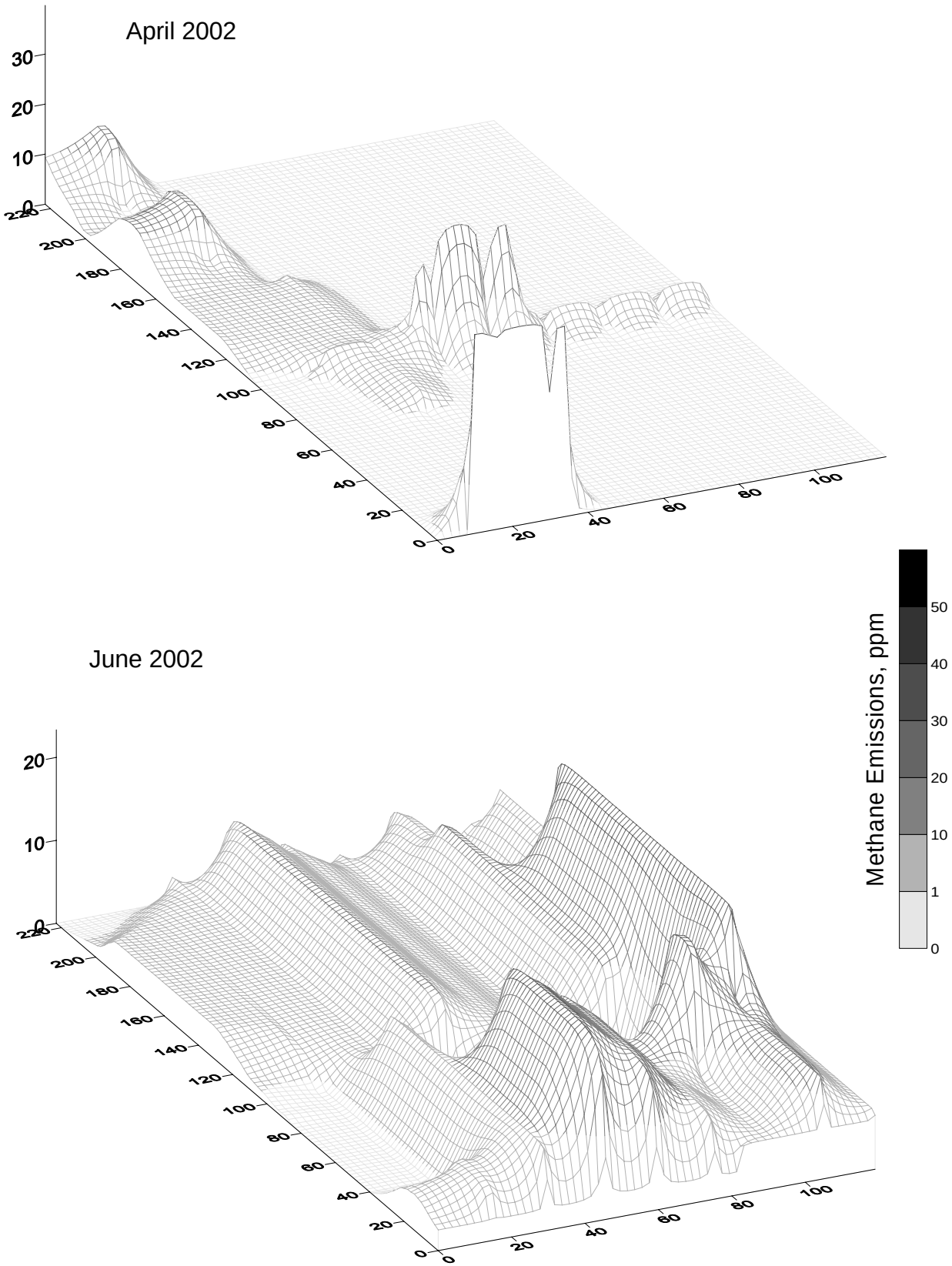


Figure 44. Surface emissions map for the west 6-acre cell for 2002, with color scale. The weighted average emissions for the April, June, and September surface scans were 0.84, 6.5 and 4.2 ppm, respectively.

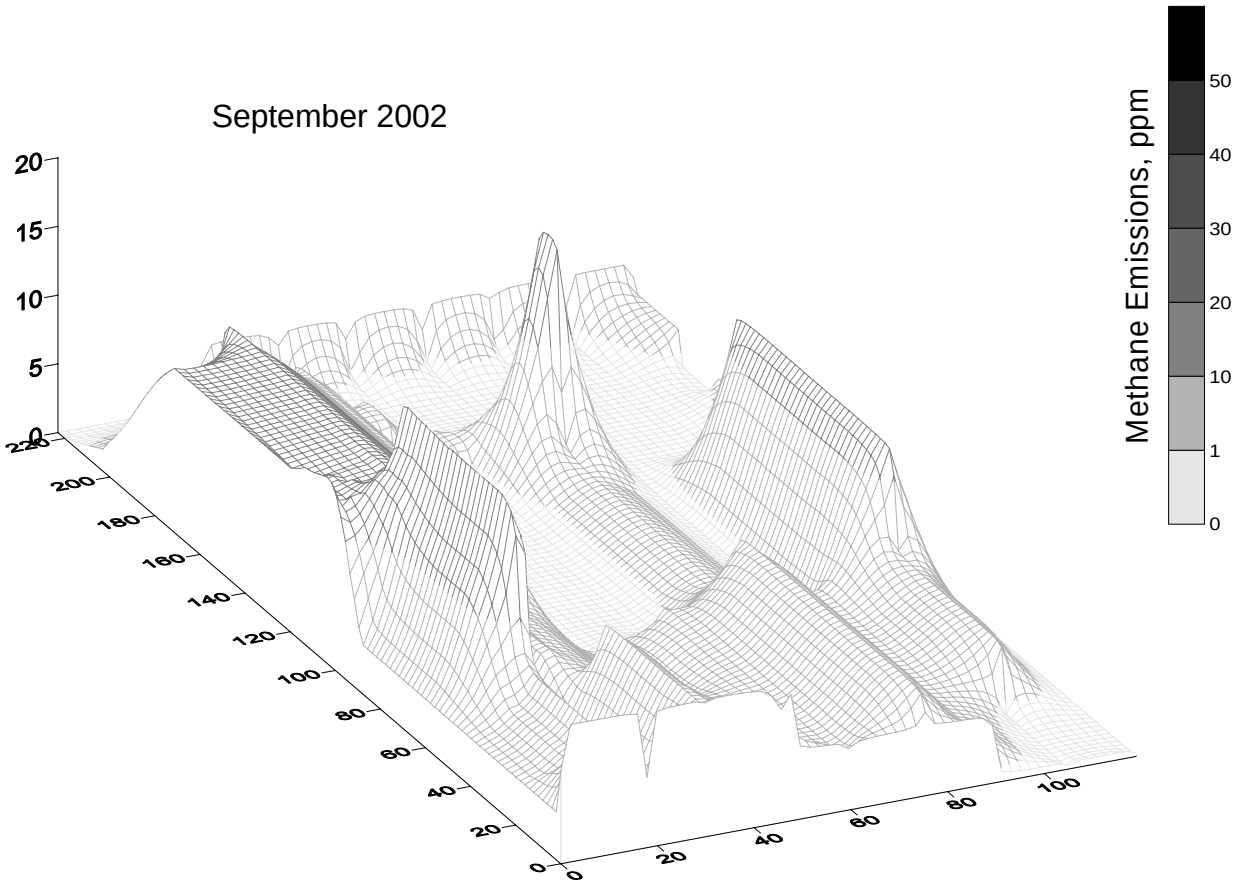


Figure 44 cont. Surface emissions map for the west 6-acre cell for 2002, with color scale. The weighted average emissions for the April, June, and September surface scans were 0.84, 6.5 and 4.2 ppm, respectively.

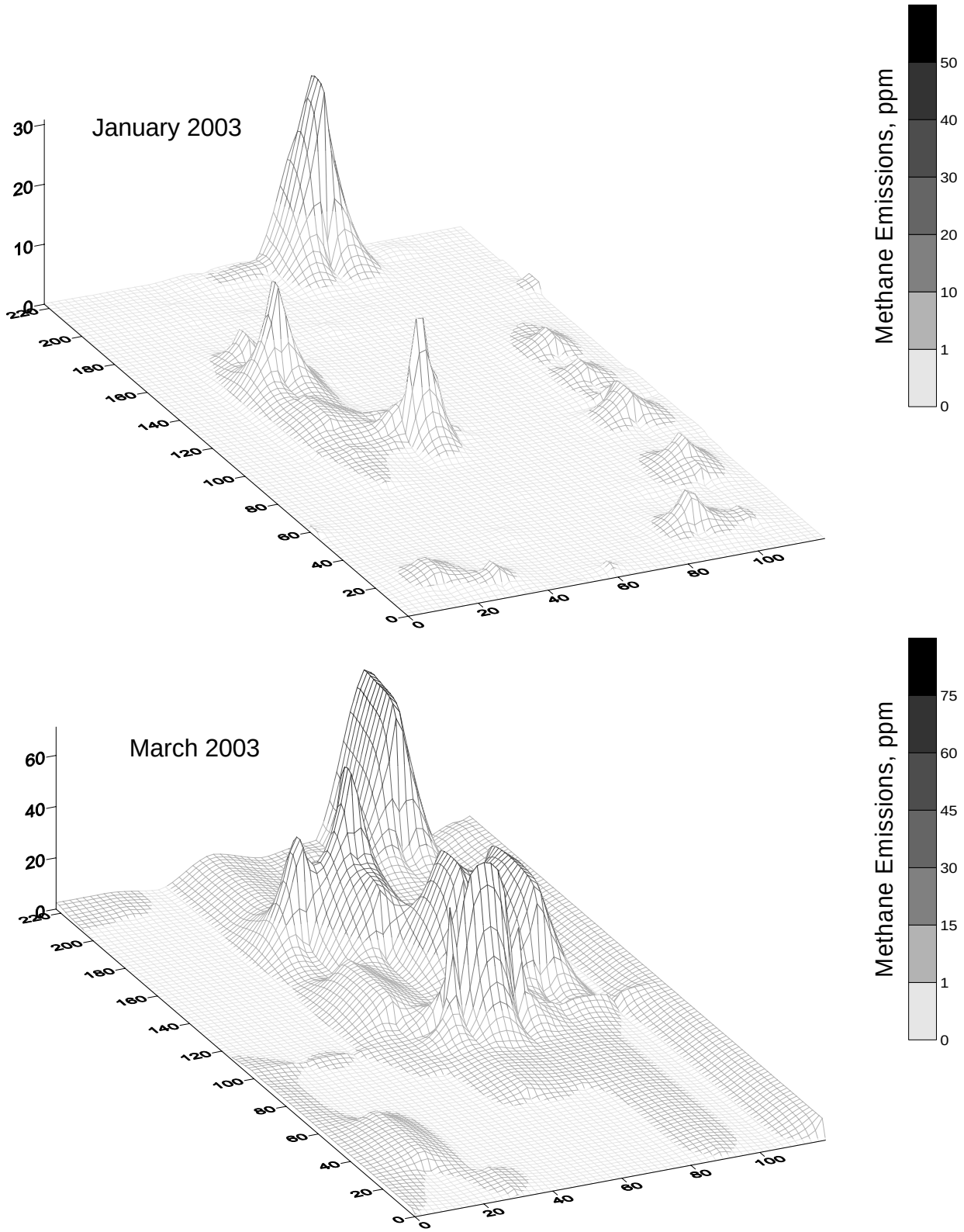


Figure 44 cont. Surface emission maps for the west 6-acre cell for 2003, with color scale. The weighted average emissions for the January, March, April, September, and December 2003 surface scans were 0.70, 5.82, 2.04, 0.64, 10.4 ppm, respectively. Note the color scale for the March 2003 is different from the other plots.

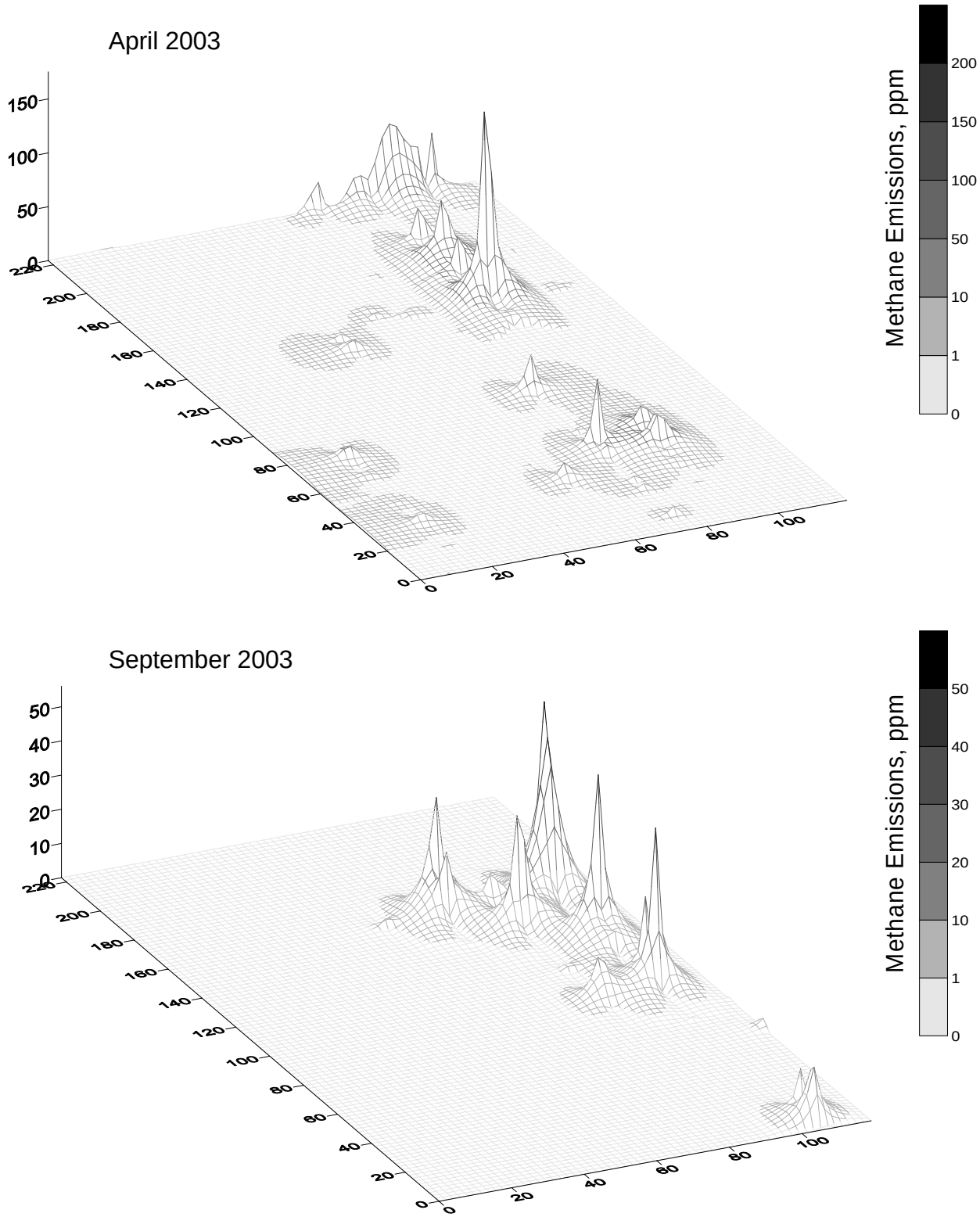


Figure 44 cont. Surface emission maps for the west 6-acre cell for 2003, with color scale. The weighted average emissions for the January, March, April, September, and December 2003 surface scans were 0.70, 5.82, 2.04, 0.64, 10.4 ppm, respectively. Note the color scale for the April 2003 is different from the other plots.

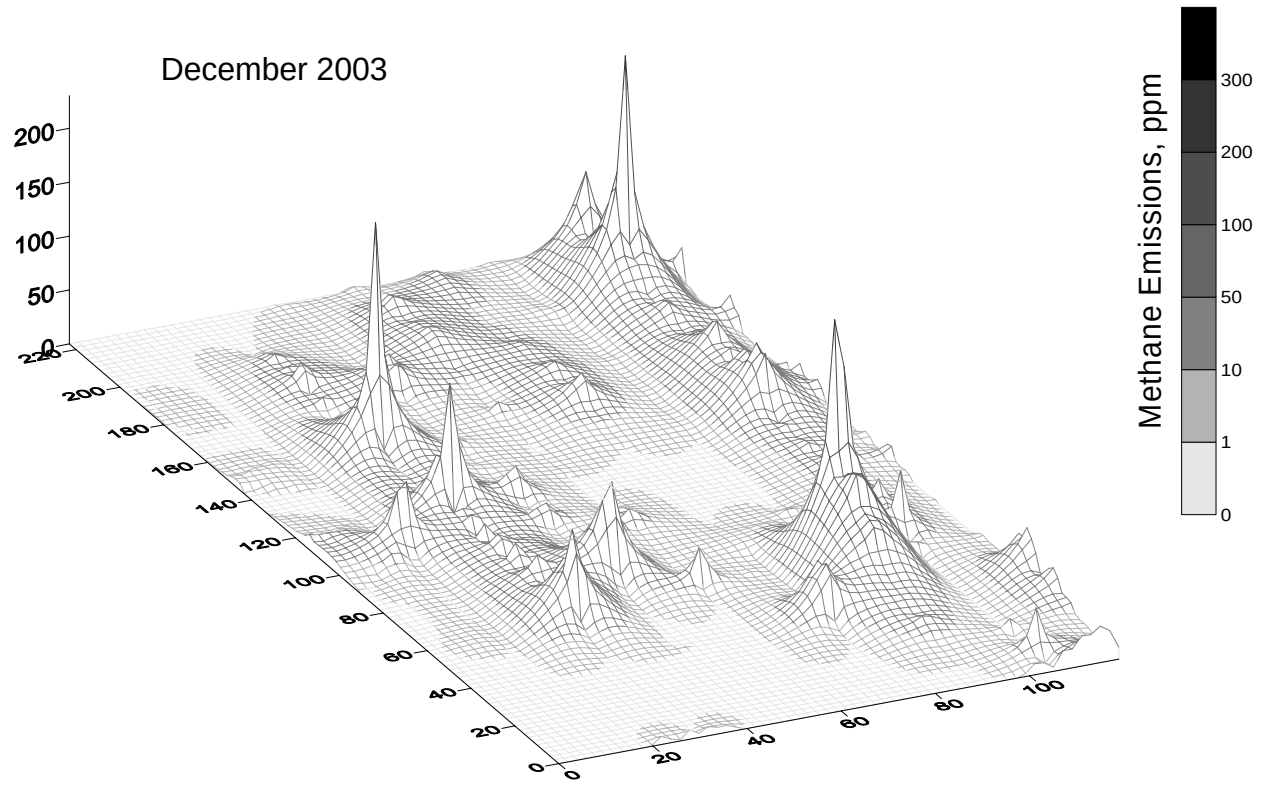


Figure 44 cont. Surface emission maps for the west 6-acre cell for 2003, with color scale. The weighted average emissions for the January, March, April, September, and December 2003 surface scans were 0.70, 5.82, 2.04, 0.64, 10.4 ppm, respectively. Note the color scale for the December 2003 is different from the other plots.

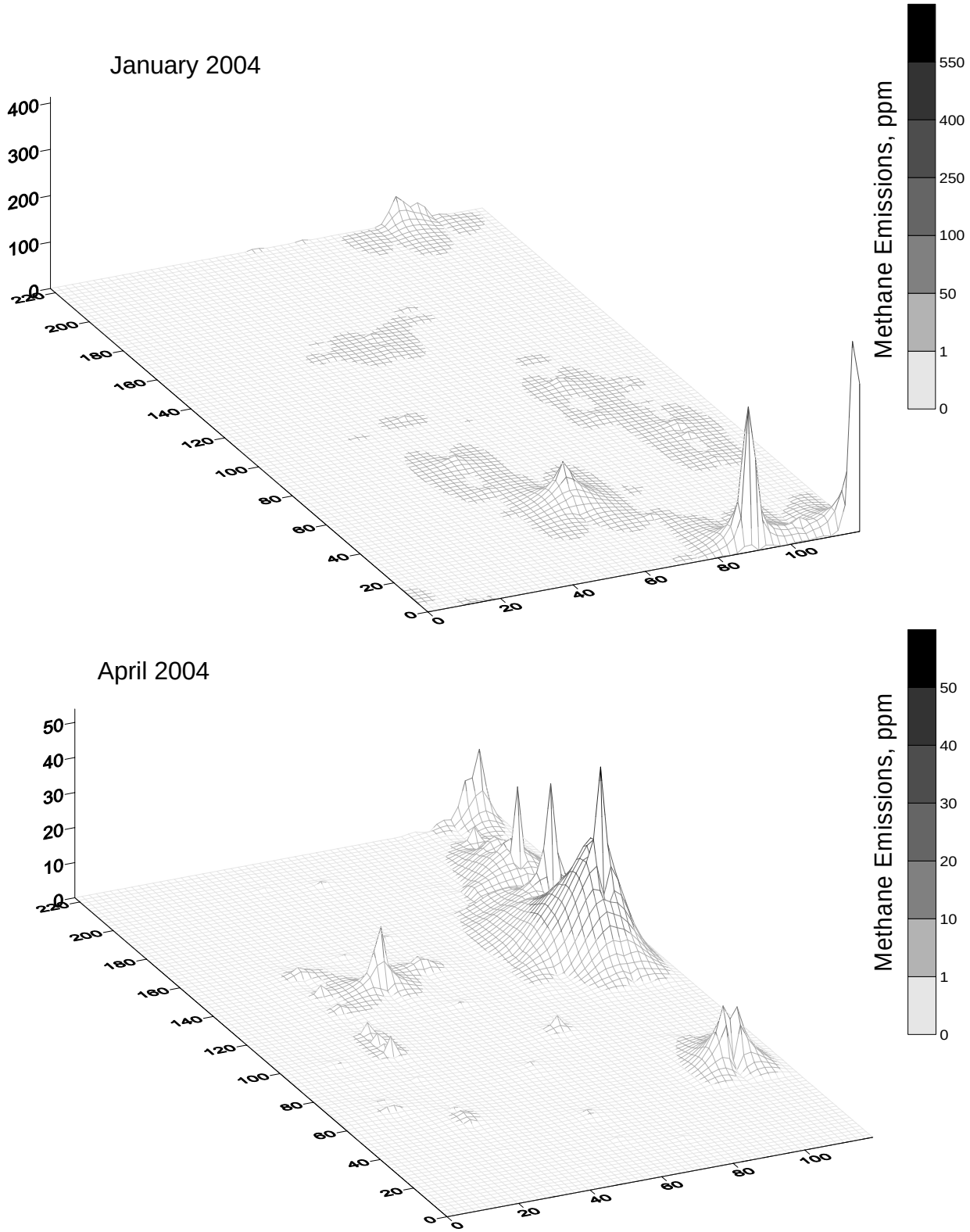


Figure 44 cont. Surface emission maps for the west 6-acre cell for 2004, with color scale. The weighted average emissions for the January, April, August, and November surface scans were 1.96, 0.96, 3.79, and 0.73 ppm, respectively. Note the color scale for the January and April 2004 are different than the other plots.

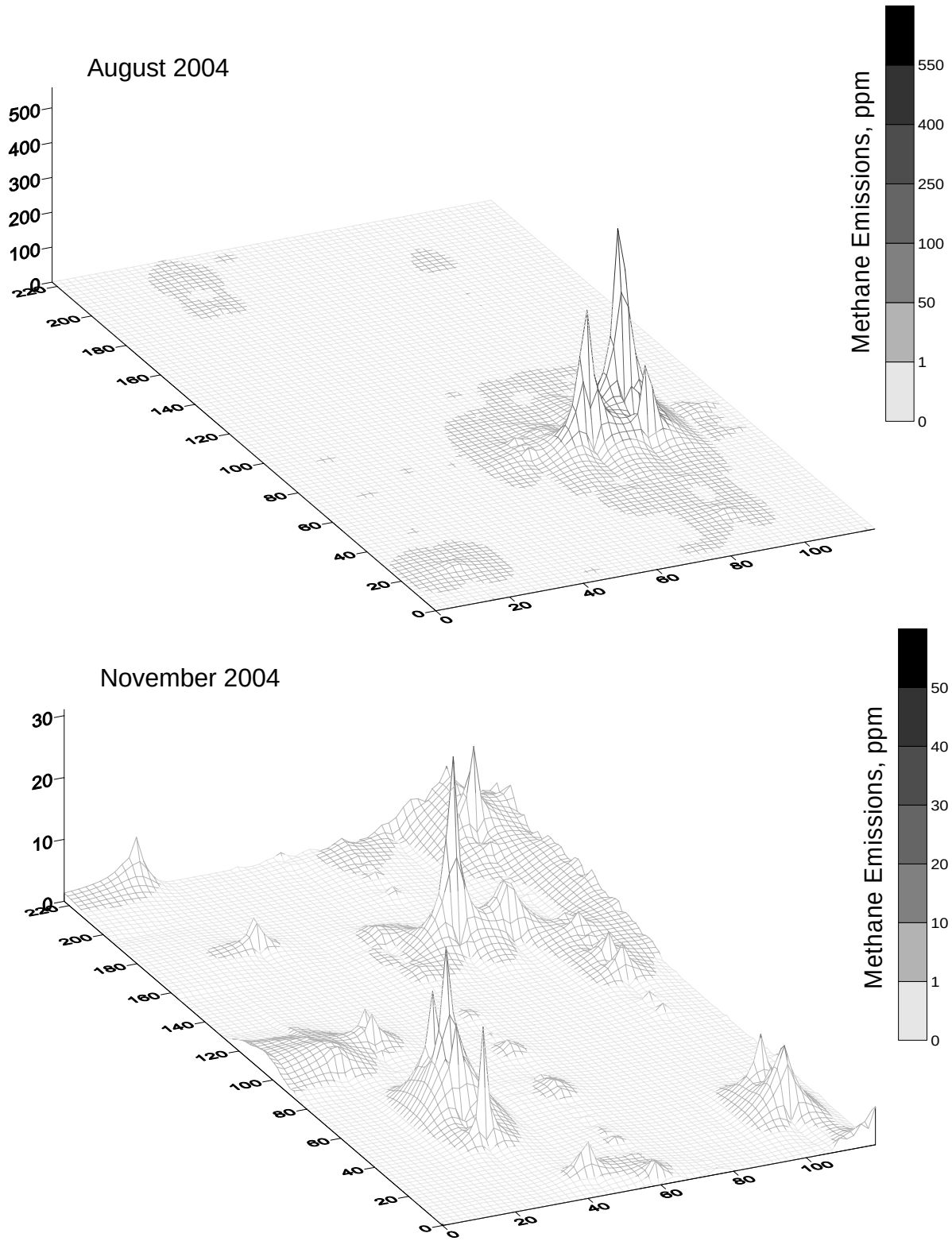


Figure 44 cont. Surface emission maps for the west 6-acre cell for 2004, with color scale. The weighted average emissions for the January, April, August, and November surface scans were 1.96, 0.96, 3.79, and 0.73 ppm, respectively. Note the color scale for the August scan is different from the plots. Note the color scale used for the August 2004 is different from the other plots.

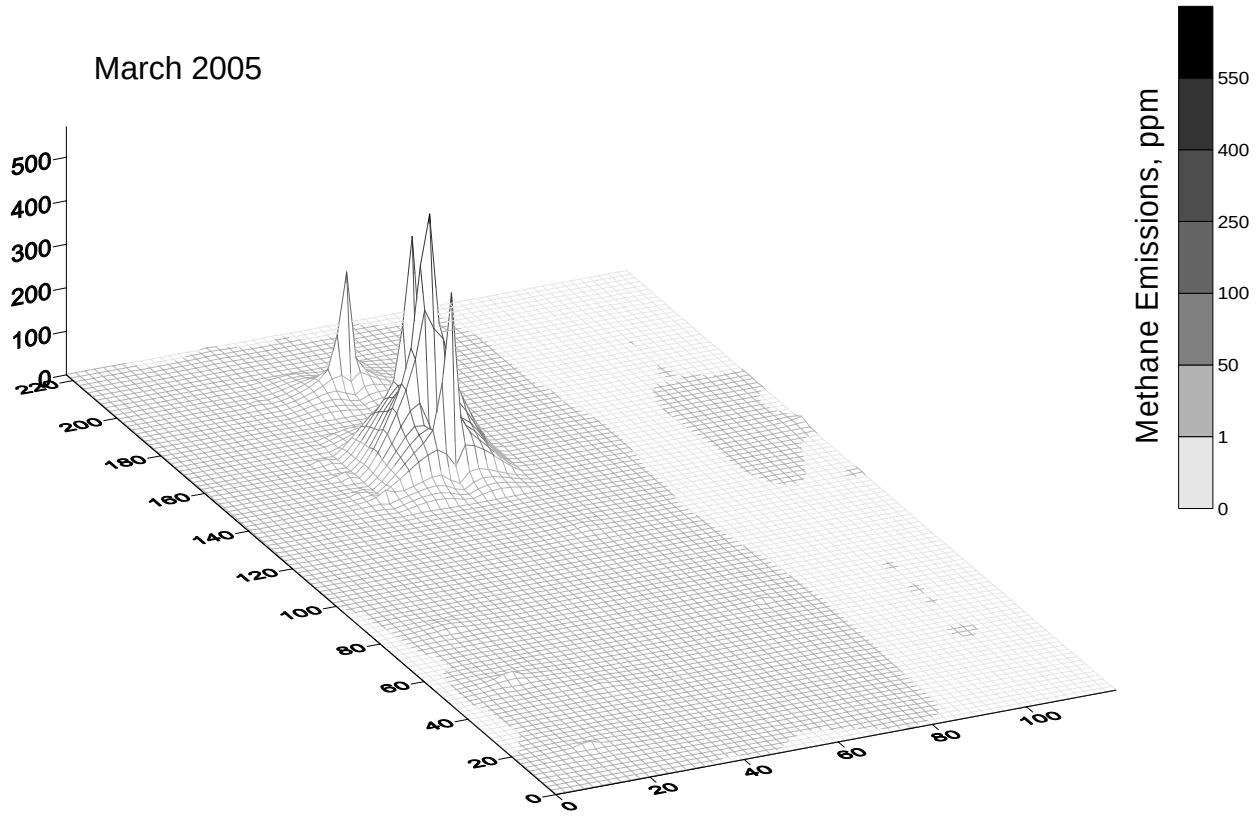


Figure 44 cont. Surface emission maps for the west cell for March 2005, with color scale. The weighted average emissions was 3.97 ppm.

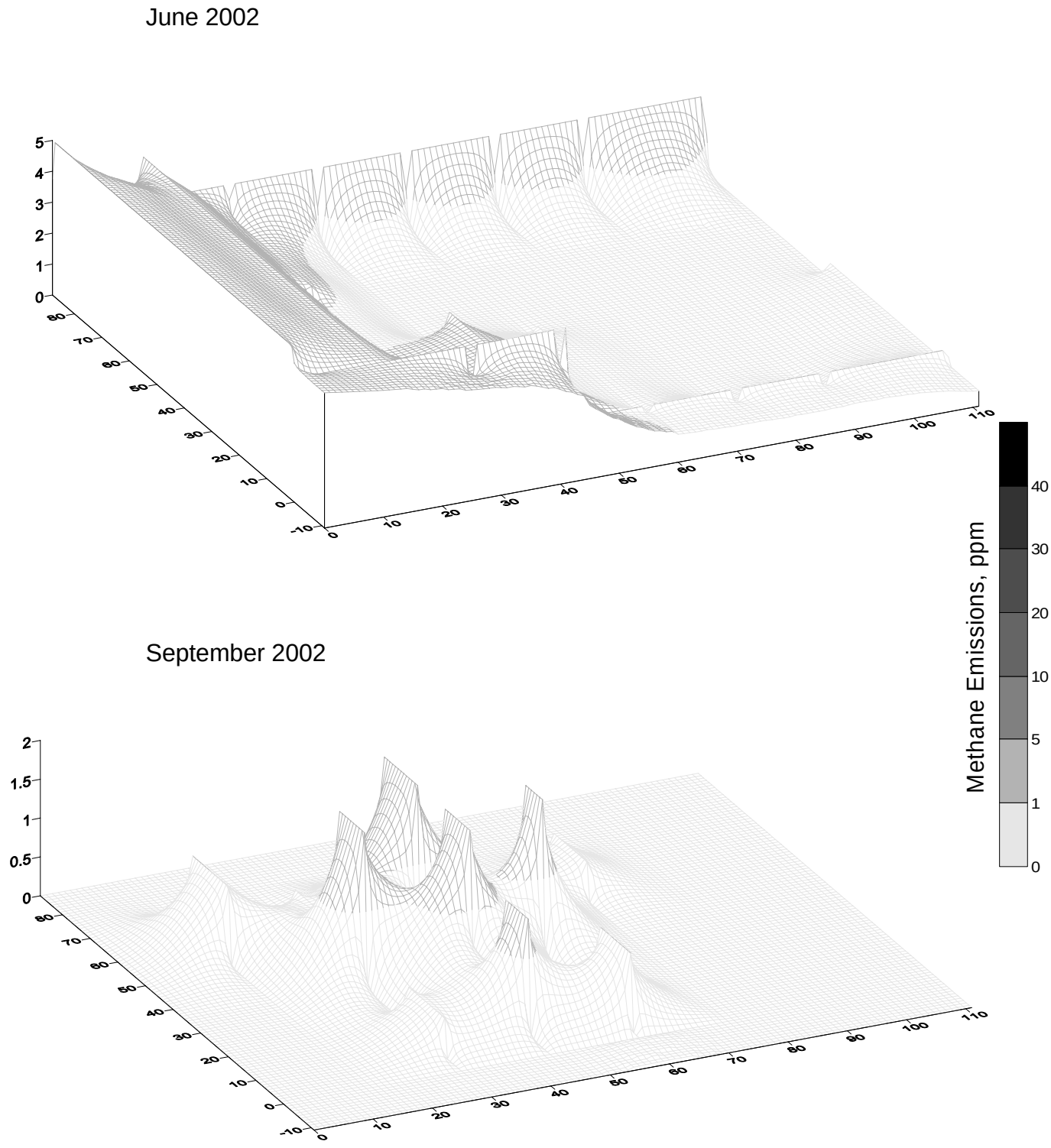


Figure 45. Surface emission map for the southeast cell for 2002, with color scale. The weighted average emissions for the June and September scan were 2.17 and 0.13 ppm, respectively. The April 2002 was not plotted due to no emissions being detected.

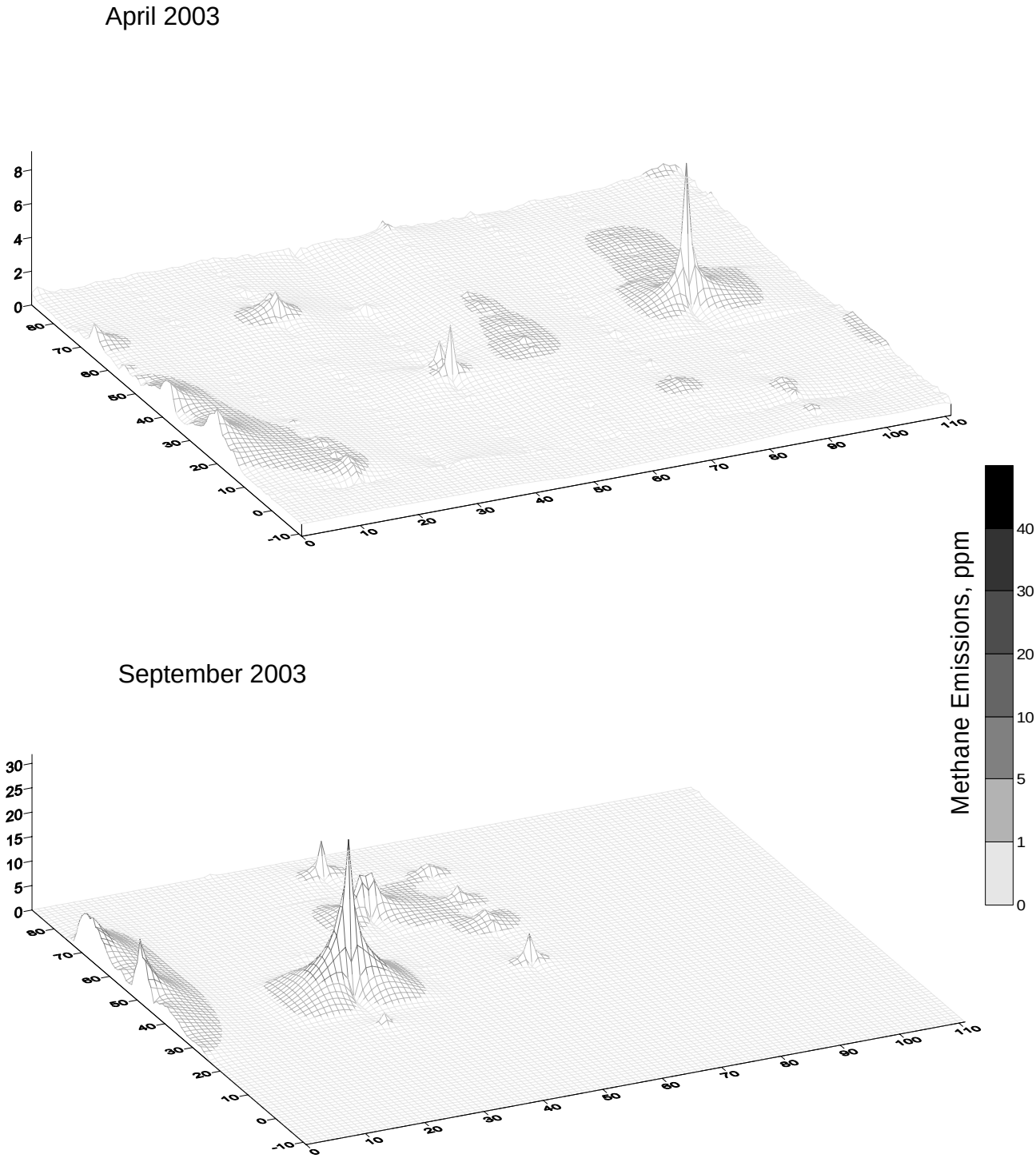


Figure 45 cont. Surface emission map for the southeast cell for 2003, with color scale. The weighted average emissions for the April, September, and December scan were 0.64 and 0.43, and 1.12 ppm, respectively.

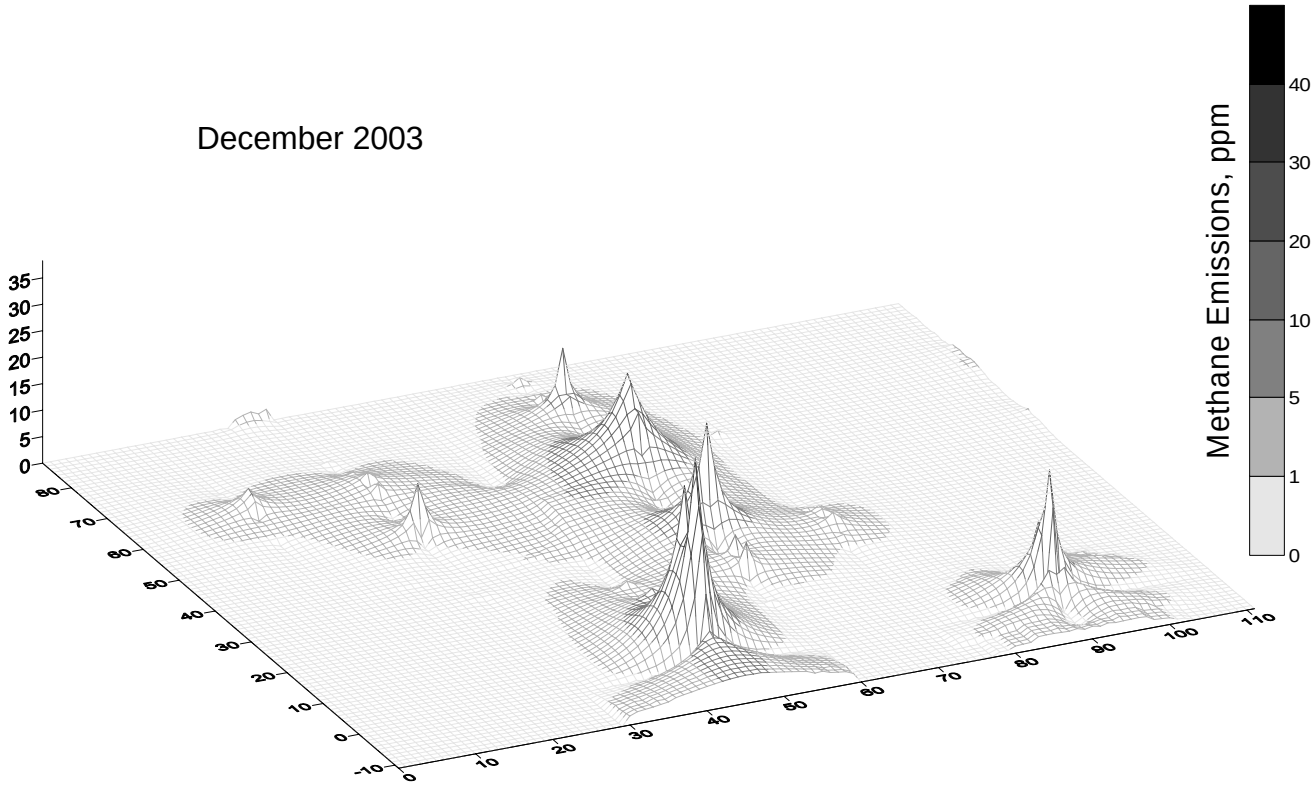


Figure 45 cont. Surface emission map for the southeast cell for 2003, with color scale. The weighted average emissions for the April, September, and December scan were 0.64 and 0.43, and 1.12 ppm, respectively.

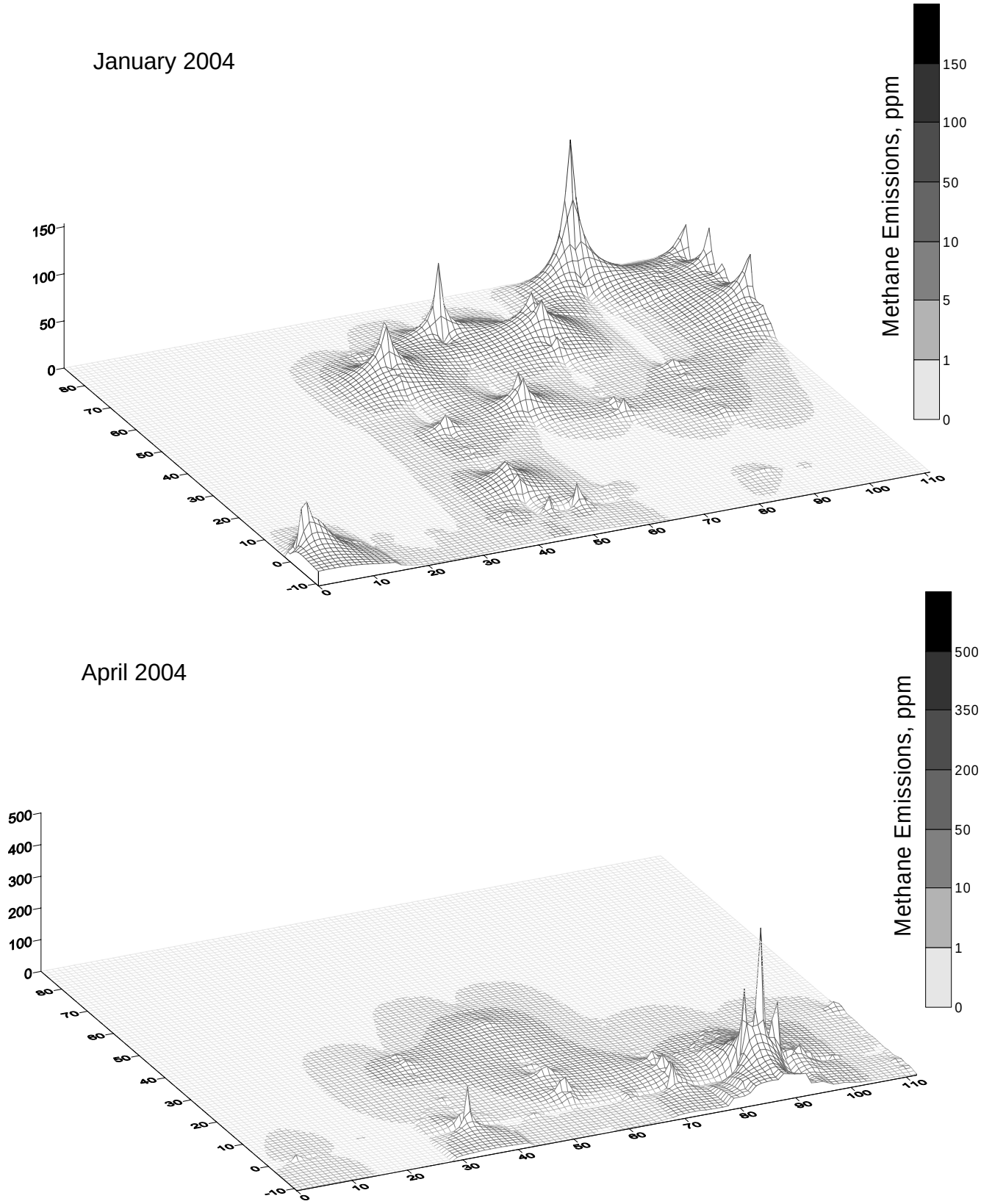


Figure 45 cont. Surface emission map for the southeast cell for 2004, with color scale. The weighted average emissions for the January, April, August and November scan were 4.3, 2.6, 0.79, 7.88 ppm, respectively. Note all 2004 plots have different color scales.

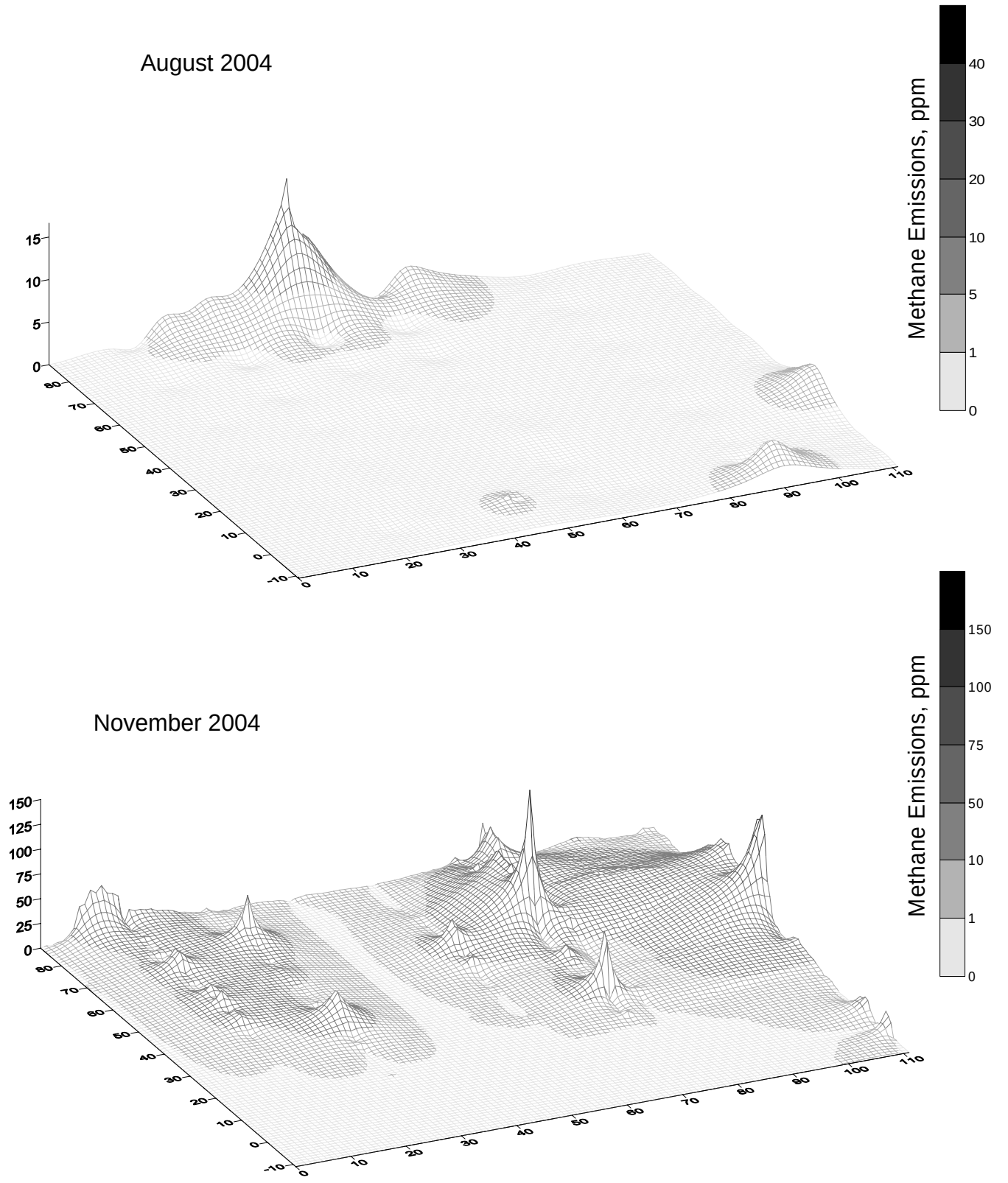


Figure 45 cont. Surface emission map for the southeast cell for 2004, with color scale. The weighted average emissions for the August and November scan were 0.79 and 7.88 ppm, respectively. Note they all have different color scales.

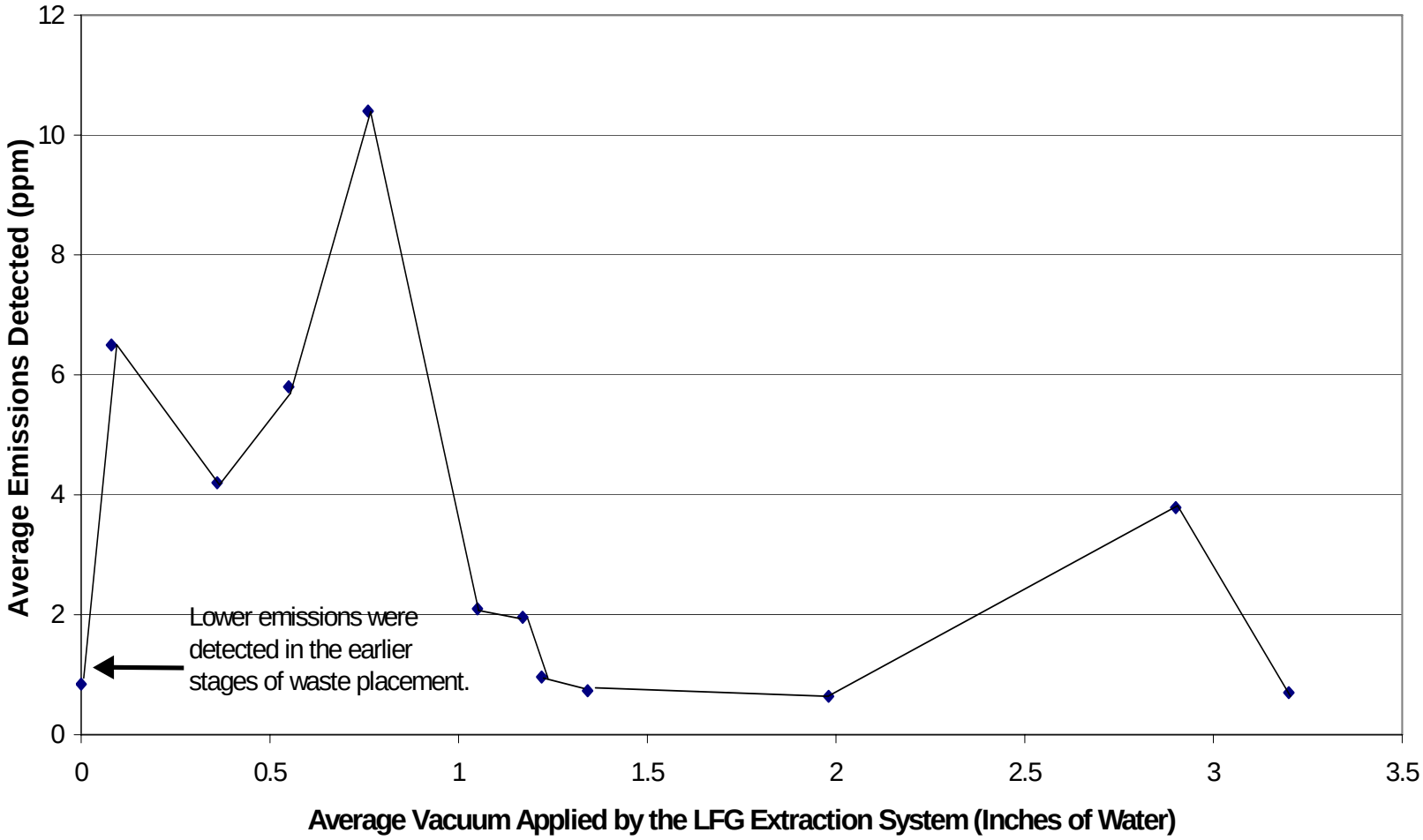


Figure 46. Graph of the average methane emissions detected from the west-side cell as a function of the average vacuum applied by the LFG extraction system

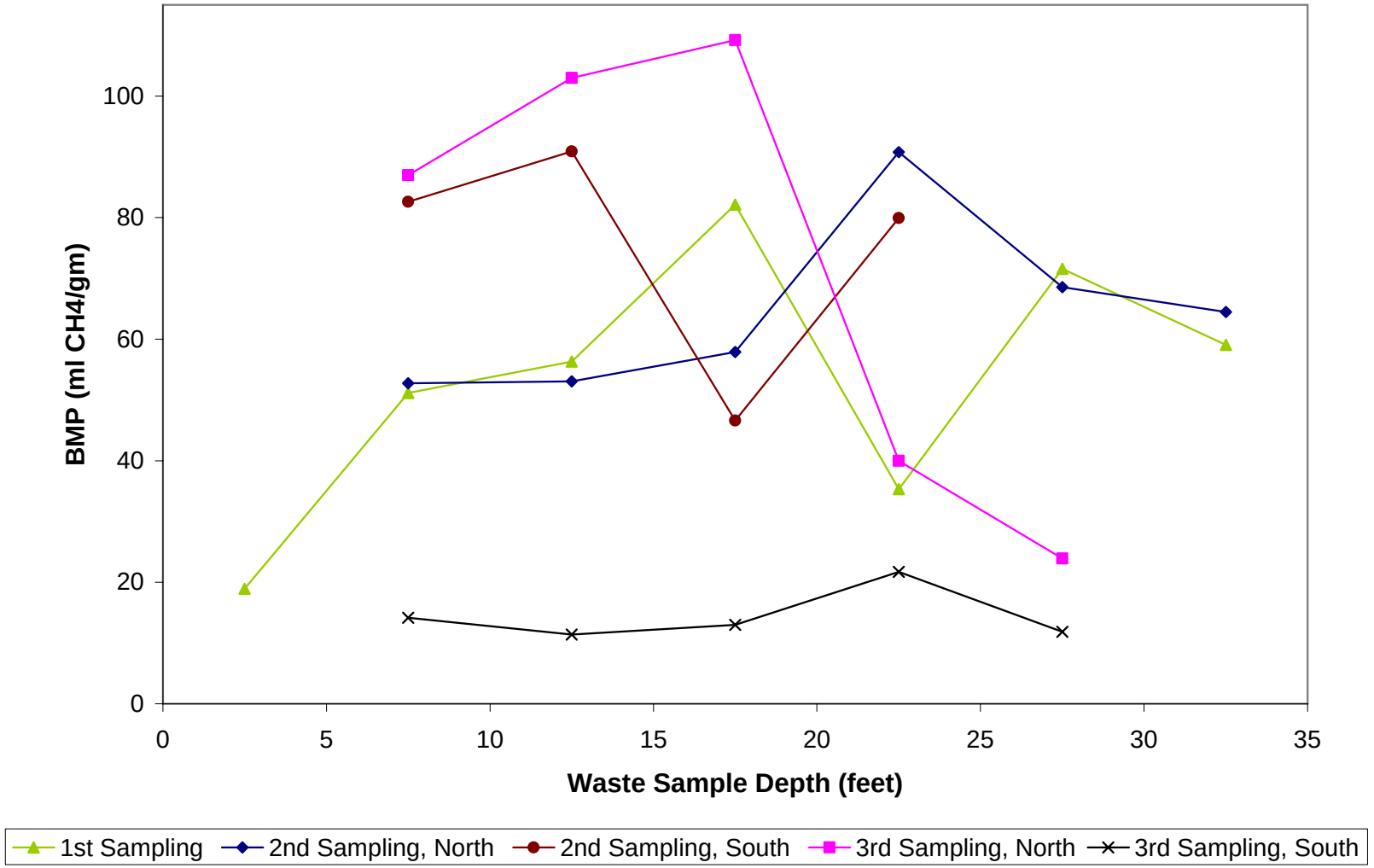


Figure 47. Graph of the biochemical methane potential from waste sampling performed on the northeast cell

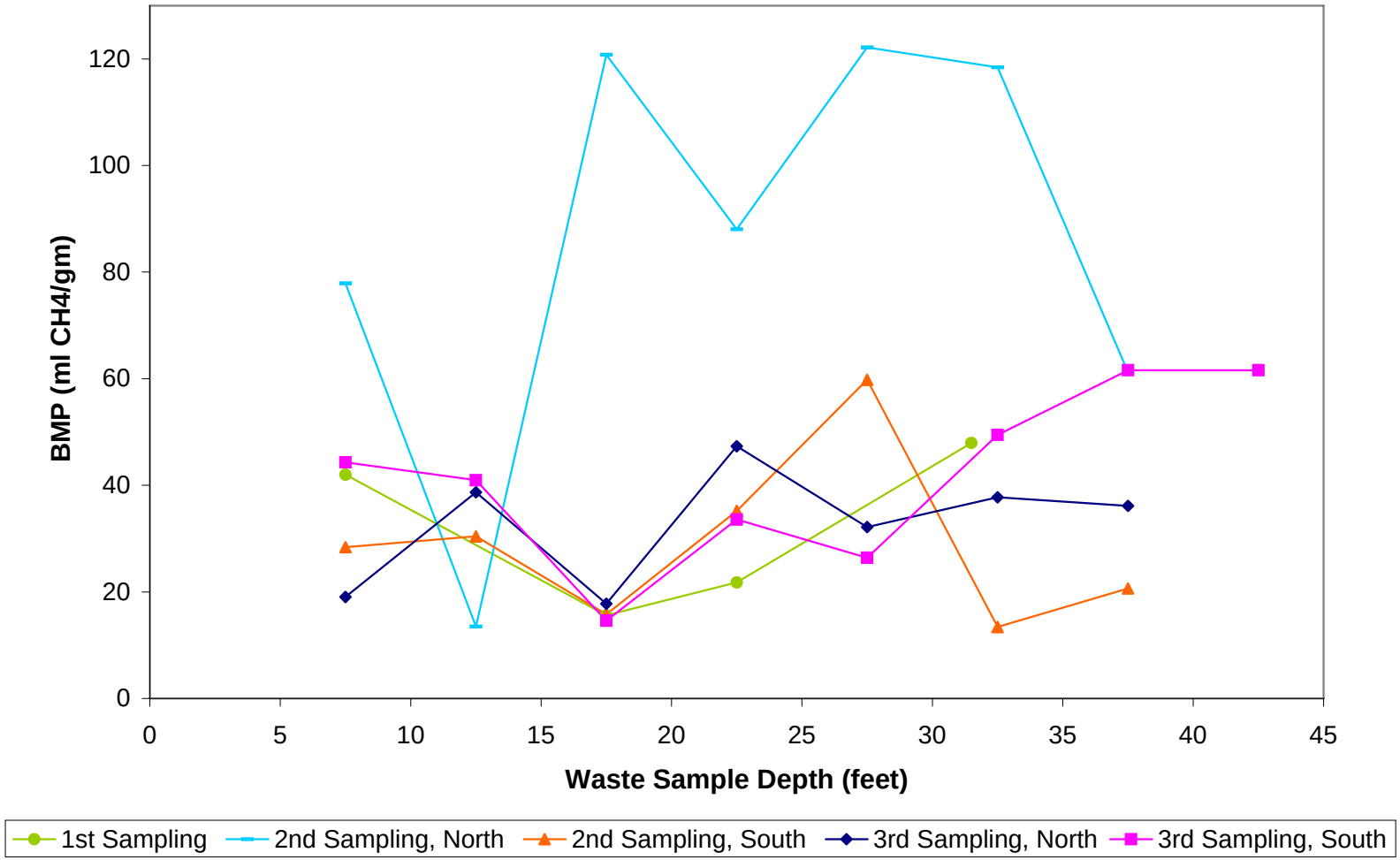


Figure 48. Graph of the biochemical methane potential from waste sampling performed on the west-side cell

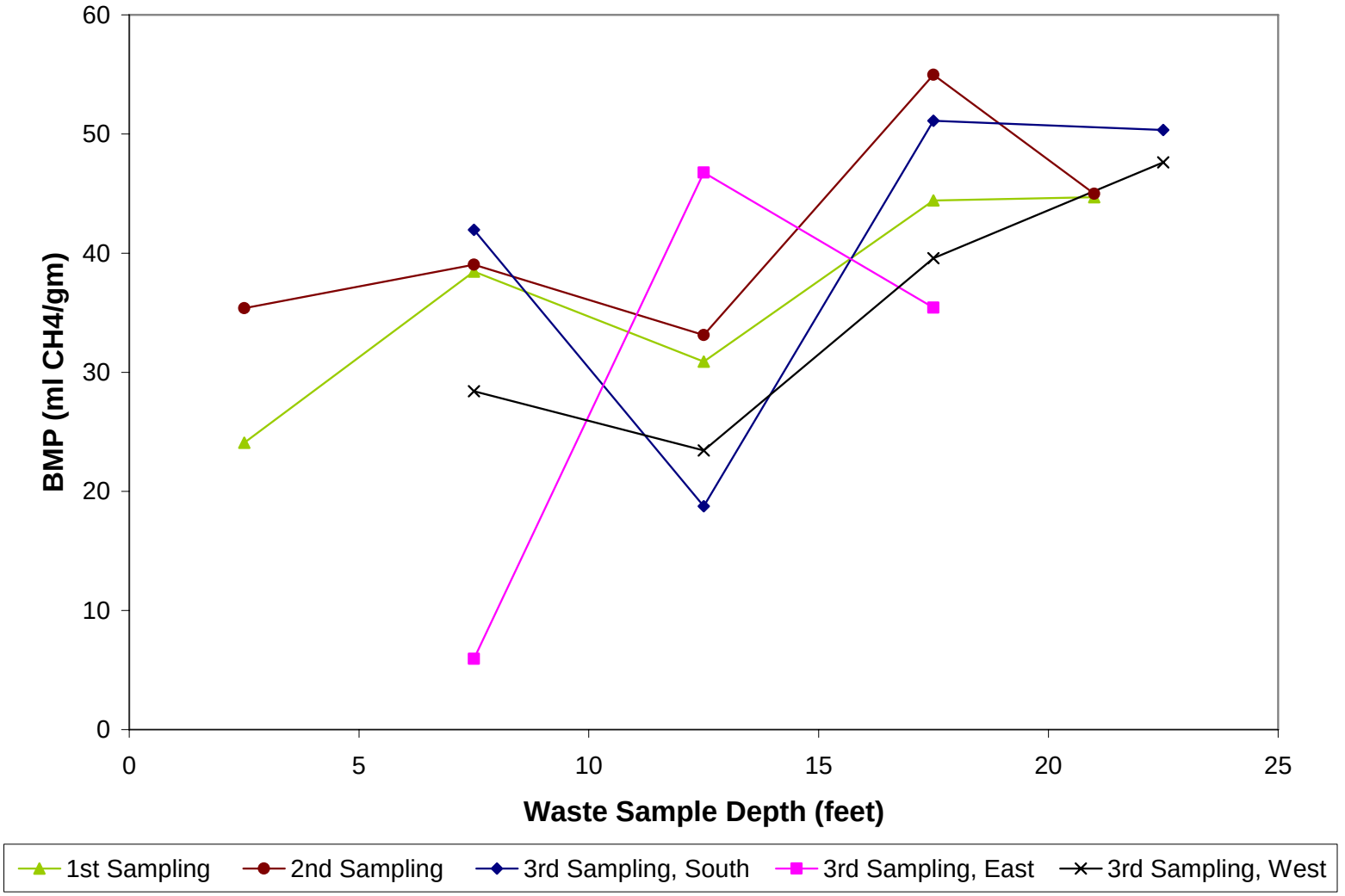


Figure 49. Graph of the biochemical methane potential from waste sampling performed on the southeast aerobic cell

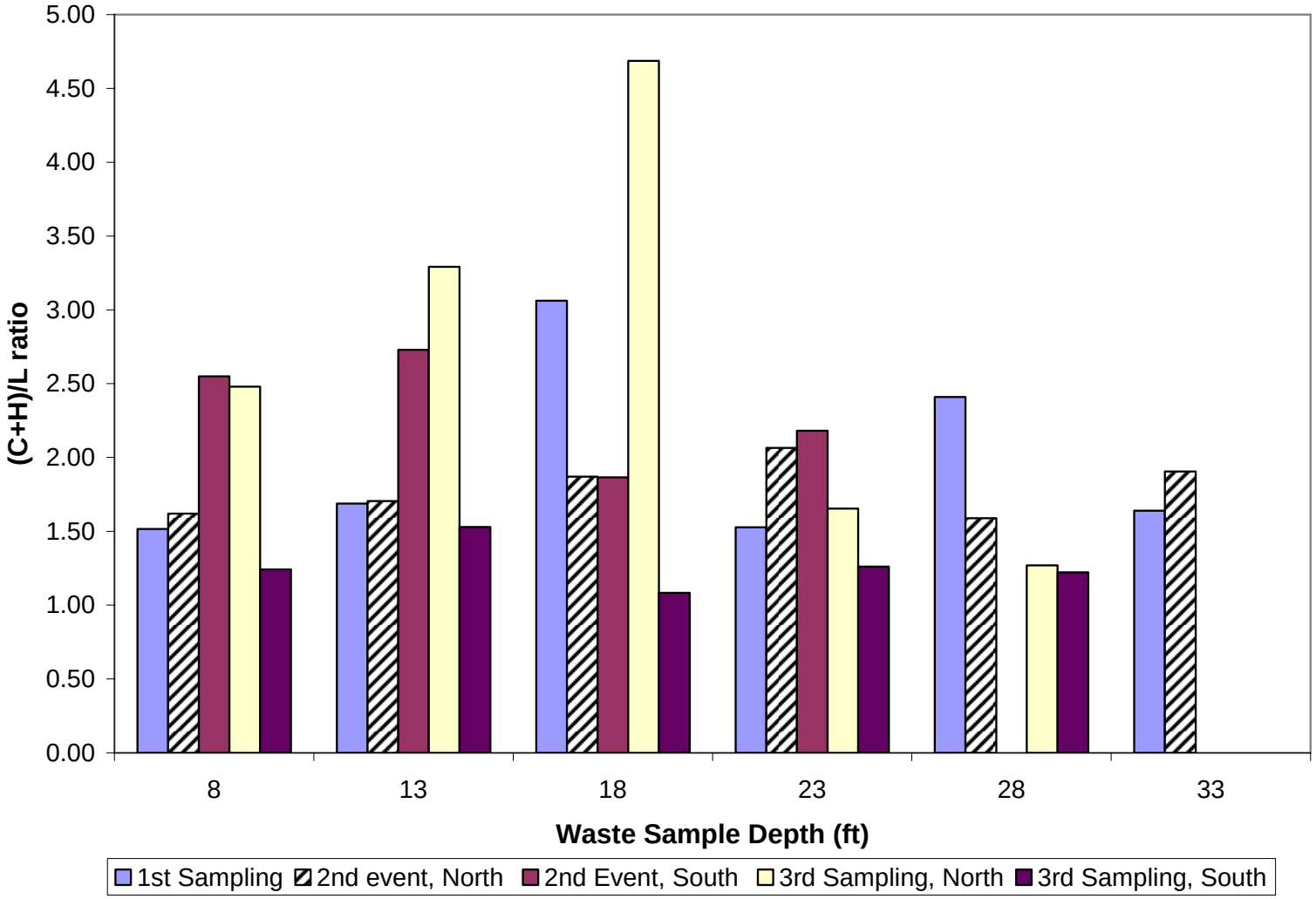


Figure 50. Comparison of (cellulose + hemicellulose)/lignin ratios for the northeast cell

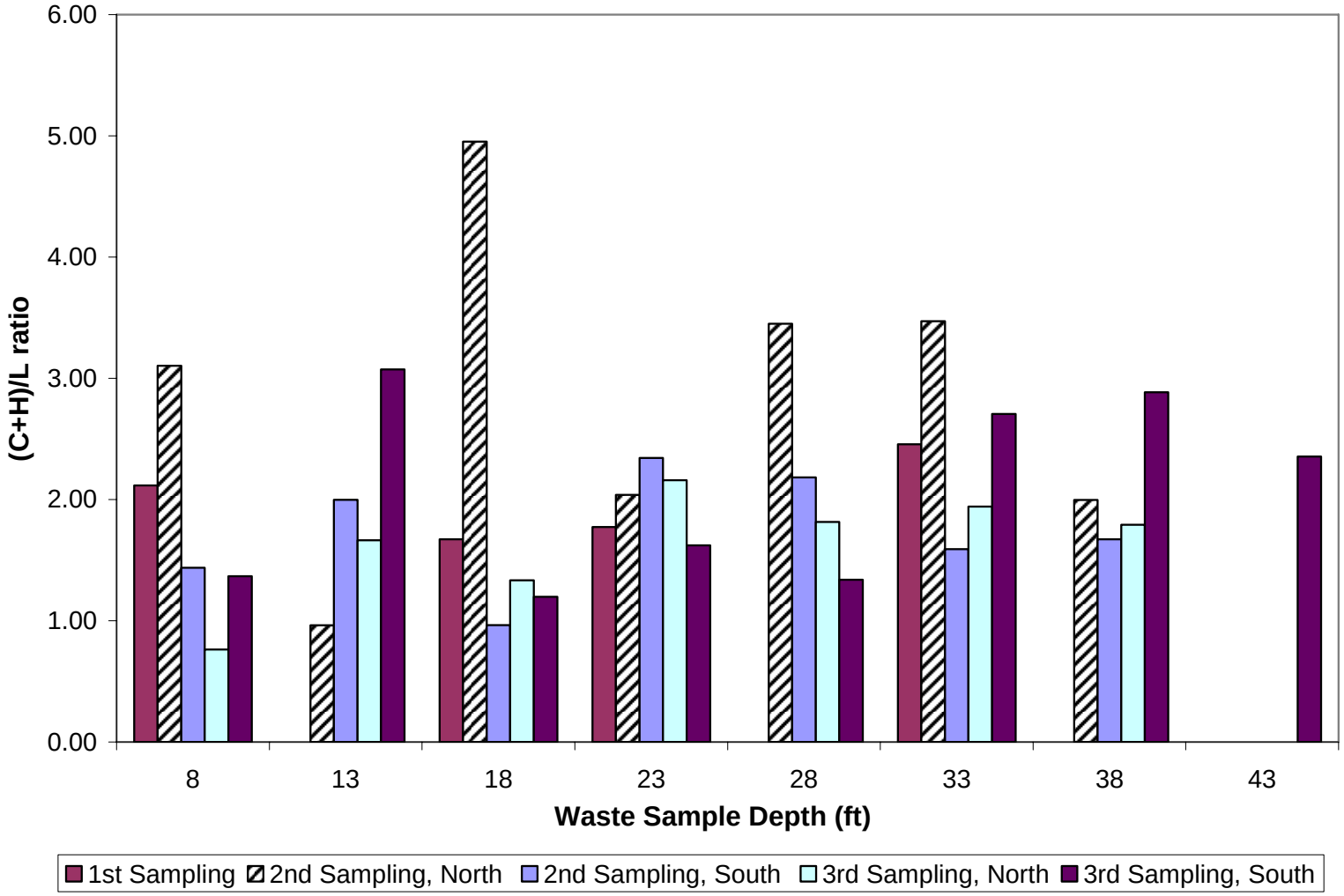


Figure 51. Comparison of (cellulose + hemicellulose)/lignin ratios for the west-side cell

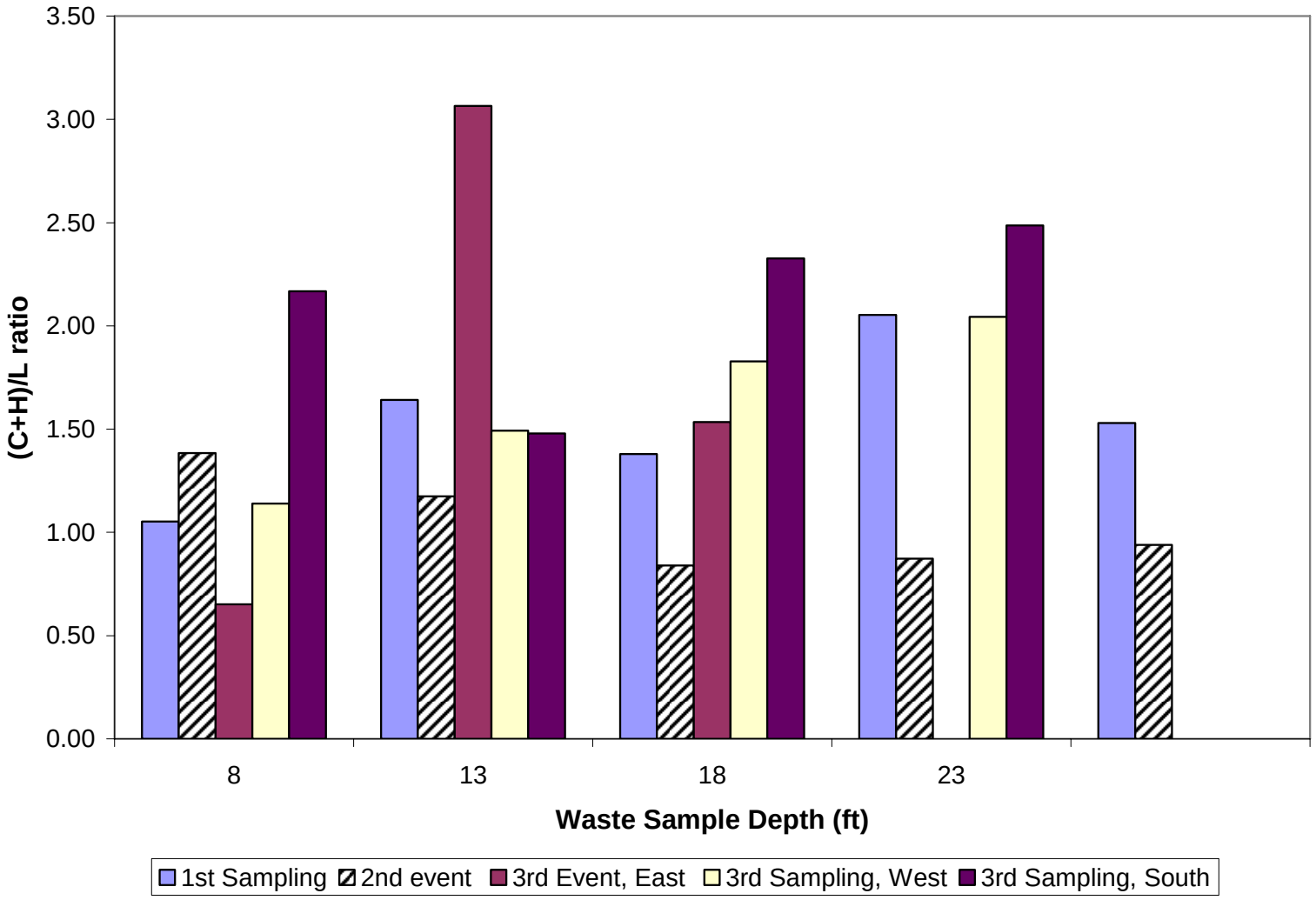


Figure 52. Comparison of (cellulose + hemicellulose)/lignin ratios for the southeast aerobic cell

APPENDIX C - IMAGES

Image 1. Operations layer of the base liner consisting of shredded tires.

Image 2. Pressure tubes installed in LCRS trench

Image 3. Waste placement in valley between the west 6-acre cell and existing conventional module (left side of photo).

Image 4. Waste placement in lift 2 on the northeast 3.5-acre cell, April 2001

Image 5. Waste placement in lift 2 and 3 on the northeast 3.5-acre cell, May 2001

Image 6. Sensor wires were extended to the instrumentation shed and buried in the final cover soil layer. The entire module was then graded in preparation for geomembrane placement.

Image 7. Northeast 3.5-acre cell ready for surface liner installation, September 2001

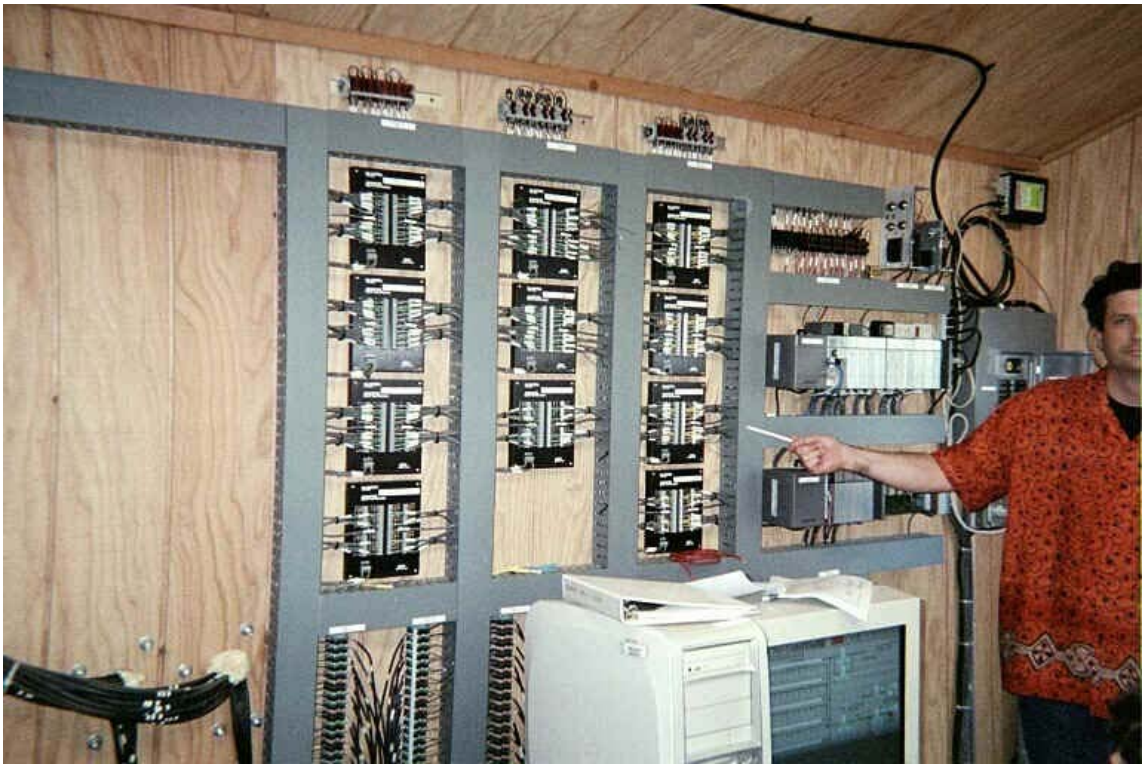


Image 8. Sensors connected to multiplexers mounted on the wall in the shed located at the landfill. The multiplexers were then connected to SLC on PLC.

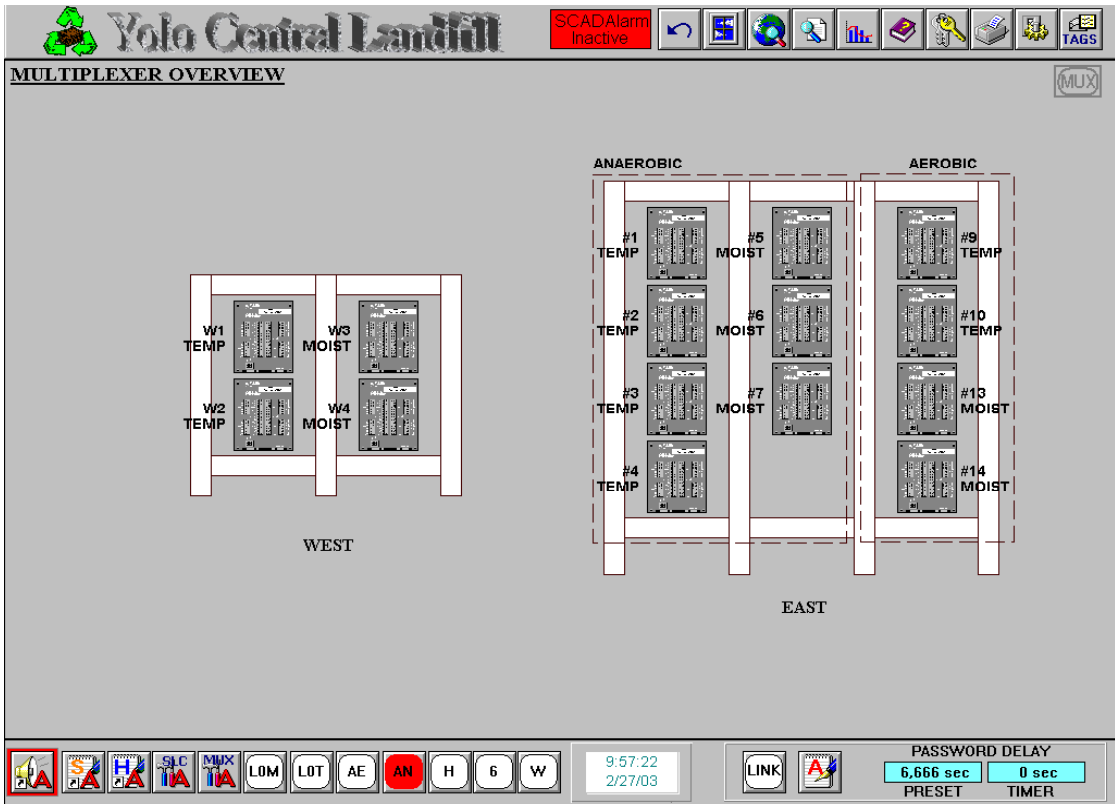


Image 9. Overview of multiplexers for all of the bioreactor cells

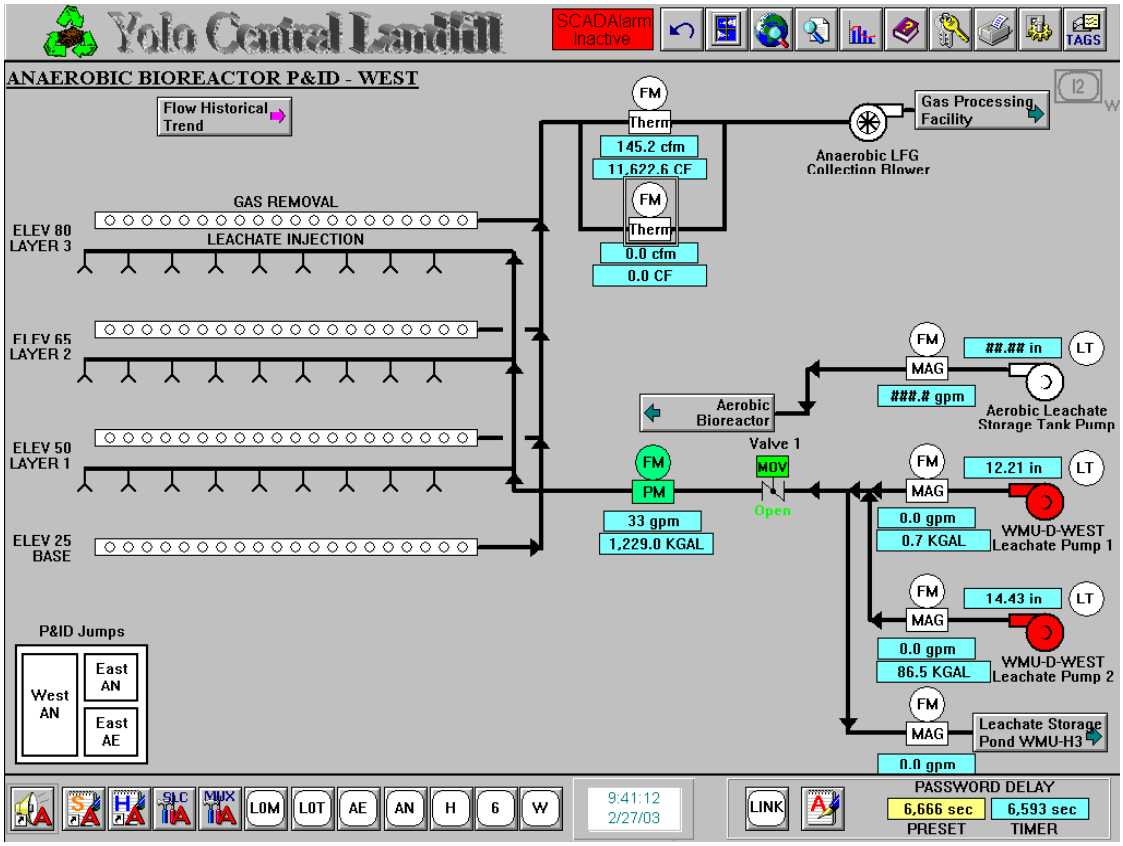


Image 10. West 6-acre piping and instrumentation screen

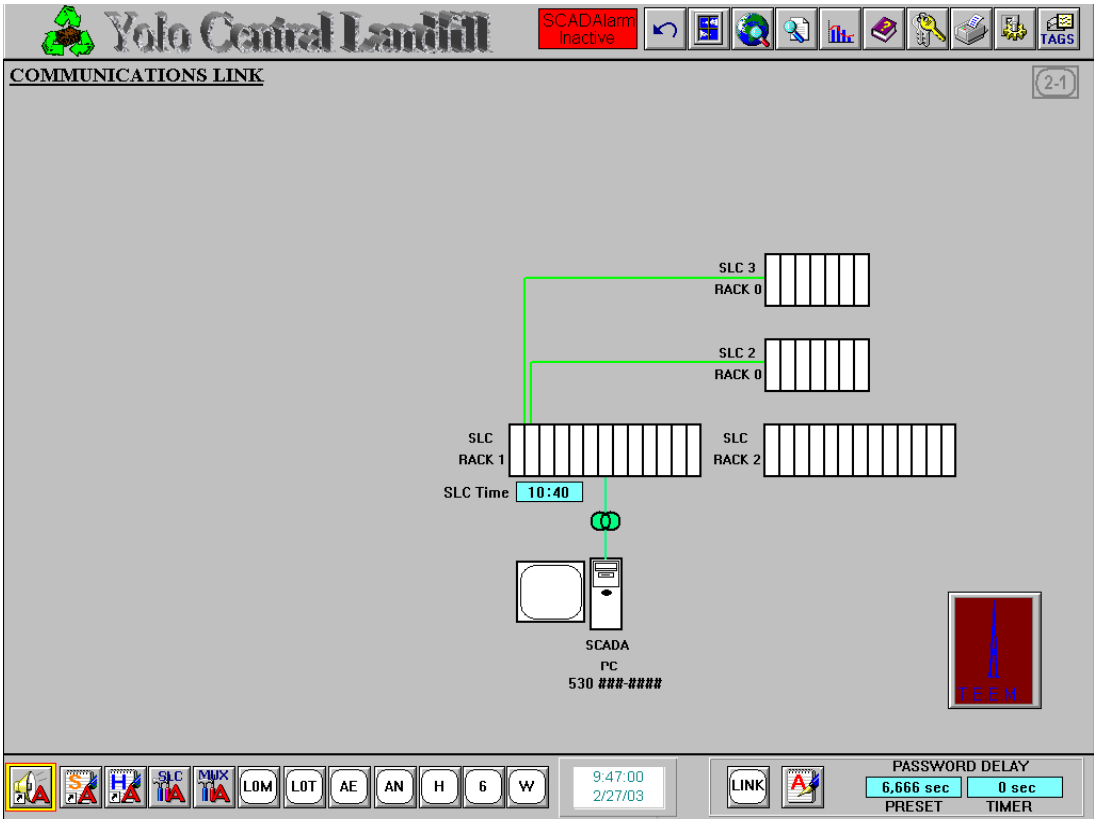


Image 11. The radio link between the PLC and the SCADA computer can be monitored. If the signal is lost, the communication link is displayed in red rather than green.

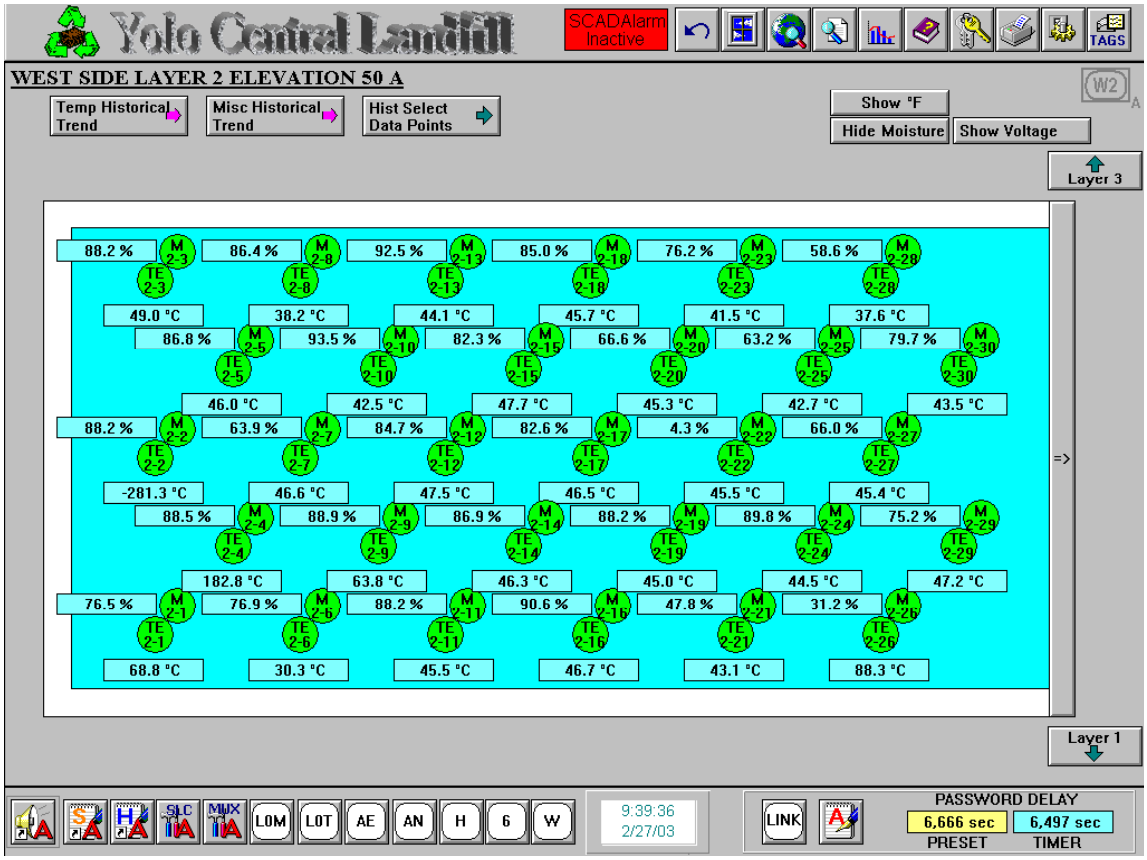


Image 12. Temperature and moisture from the west 6-acre cell can be viewed on the screen.

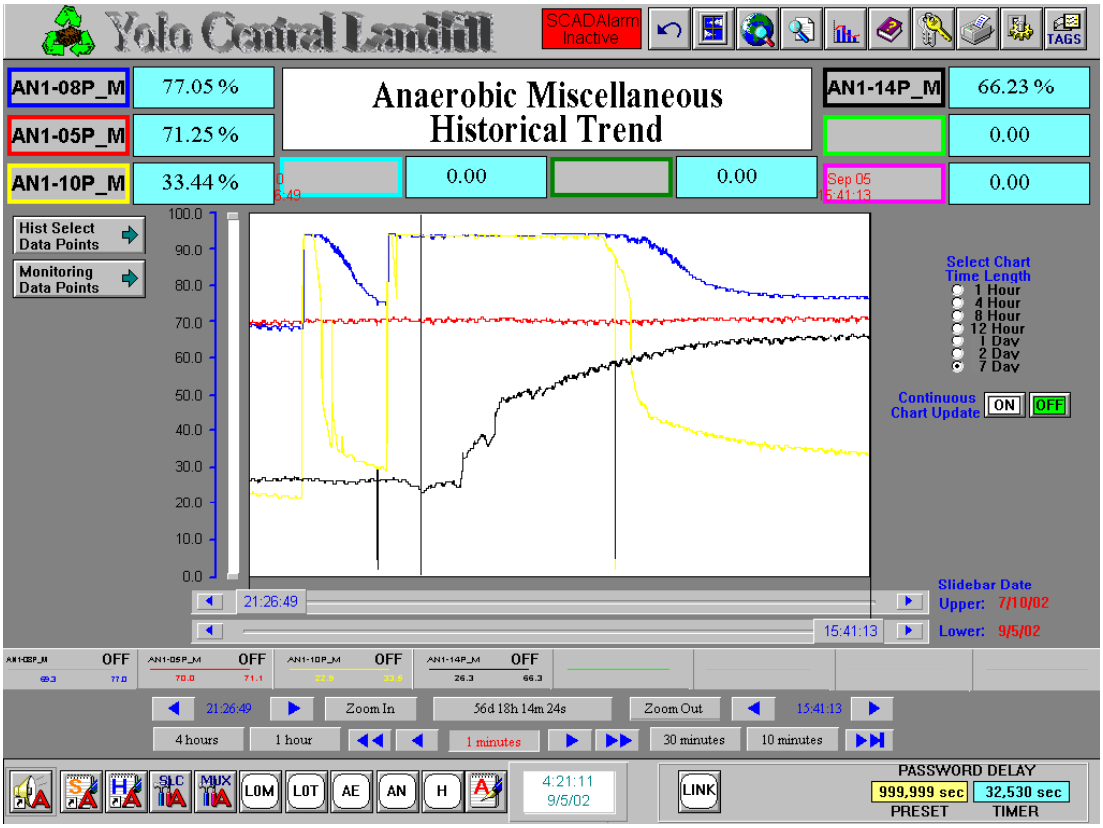


Image 13. Historical trend of moisture levels from layer 3 on the northeast 3.5-acre cell.

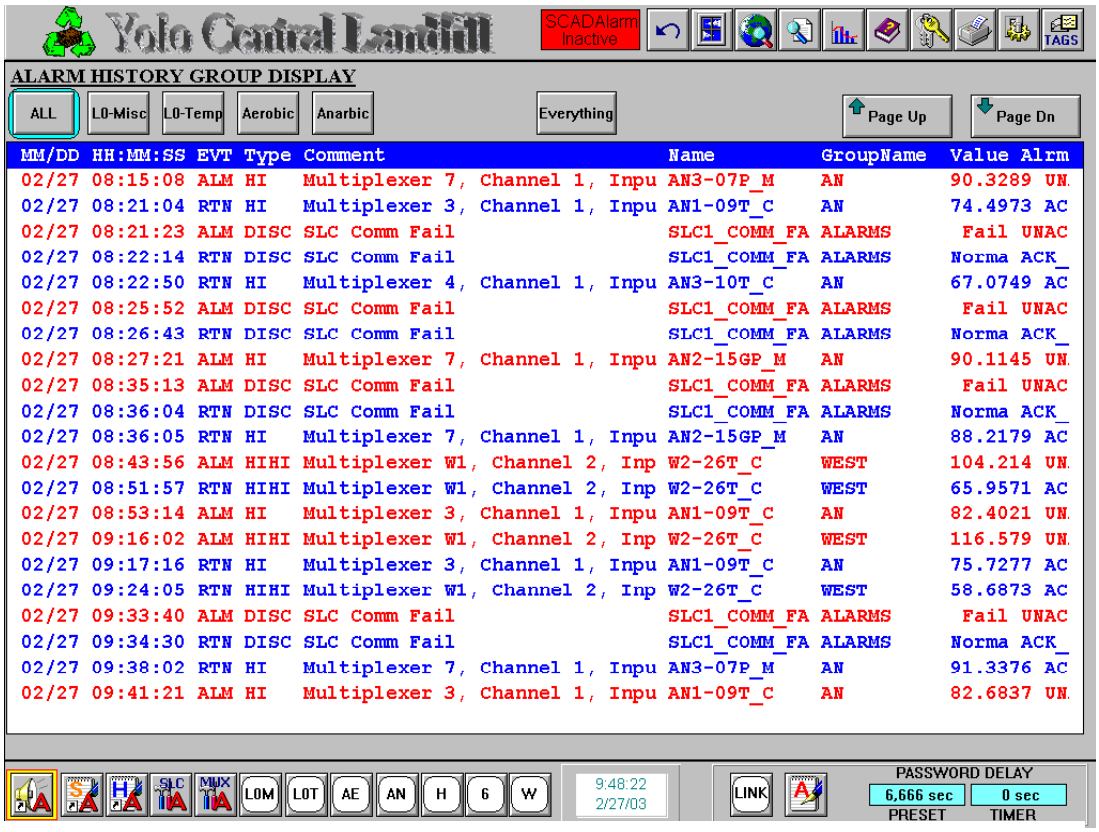


Image 14. Alarms recorded by the SCADA system can be viewed on the screen.

Image 15. Moisture, temperature, and tube installation

Image 16. Gravel drainage layer and leachate collection sump.

Image 17. Installation of leachate injection line, with pea gravel placed over injection holes to prevent clogging.

Image 18. Soil bedding was used where the injection and gas collection lines exited the waste. The lines were then covered with soil to encapsulate them and to minimize the possibility of leachate seeping out of the cell.

Image 19. Each liquid addition pipe was sealed to prevent air intrusion.

Image 20. Injection laterals were fusion welded to the 4-inch diameter HDPE injection header to minimize the possibility of leachate leaks.

Image 21. Installation of the horizontal LFG collection line, with alternating 4 and 6-inch diameter PVC pipes. Filter fabric is wrapped over each joint.

Image 22. Recycled corrugated metal pipe utilized for gas collection piping.

Image 23. Each LFG collection well has a dedicated collection lateral.

Image 24. Recycled pallets were used on the gas collection header line to establish the necessary slope to allow condensate to drain.

Image 25. Flexible couplers were installed to allow thermal expansion and contraction of the pipe.

Image 26. LFG collection lines were connected to the main header line located on the top of the cell.

Image 27. The LFG collection header line was connected to the existing LFG collection system.

Image 28. A steel roller was used to finish the soil surface prior to liner placement

Image 29. The edges of each of the geomembrane panels were double-wedge welded.

Image 30. Detail work around boots, corners, or patches required extrusion welding.

Image 31. Liner being deployed on the east side of the west 6-acre cell.

Image 32. Northeast 3.5-acre surface liner

Image 33. West 6-acre cell surface liner

Image34. The tires were restrained from sliding down the liner by rope anchored at the top of the cell.

Image 35. Sandbags were placed at each tire location for additional weight to prevent wind up-lift of the liner.

Image 36. An excavator-mounted drill rig was used for the sampling event to drill boreholes 25 to 40 feet deep.

Image 37. Excavated waste was placed on liner material located adjacent to the boreholes where samples were then collected.

Image 38. At select locations, samples were collected directly from the auger to record the temperature of the waste as it was removed from the cell.

Image 39. Leak at saddle fitting between injection lateral and mainline. Saddle was removed and reinstalled with new gasket to repair leak

Image 40. Repair of leachate injection mainline. Pipe was cut at defective joint and re-welded by the butt fusion process

Image 41. Scale buildup on the northeast 3.5-acre leachate injection lines.

Image 42. The citric acid solution was monitored for pH as it passed through the injection laterals. As the citric acid displaced the groundwater in the injection lines, the pH dropped to approximately 4 and the injection lines were closed. The injection lines were flushed with groundwater the following day.

Image 43. In the area of water build up, the liner was removed and a trench was excavated and then backfilled with shredded tires and gravel

Image 44. Gas collection line on the northeast 3.5-acre area with fittings to allow sensor lines to exit the piping without leaks.

Image 45. Perforated piping installed below the surface liner on the northeast 3.5-acre cell to increase gas collection.

Image 46. Vertical gas collection lines installed on west 6-acre cell.

Image 47. Pressure transducers were tested for accuracy by submerging the sensors in water at various depths.

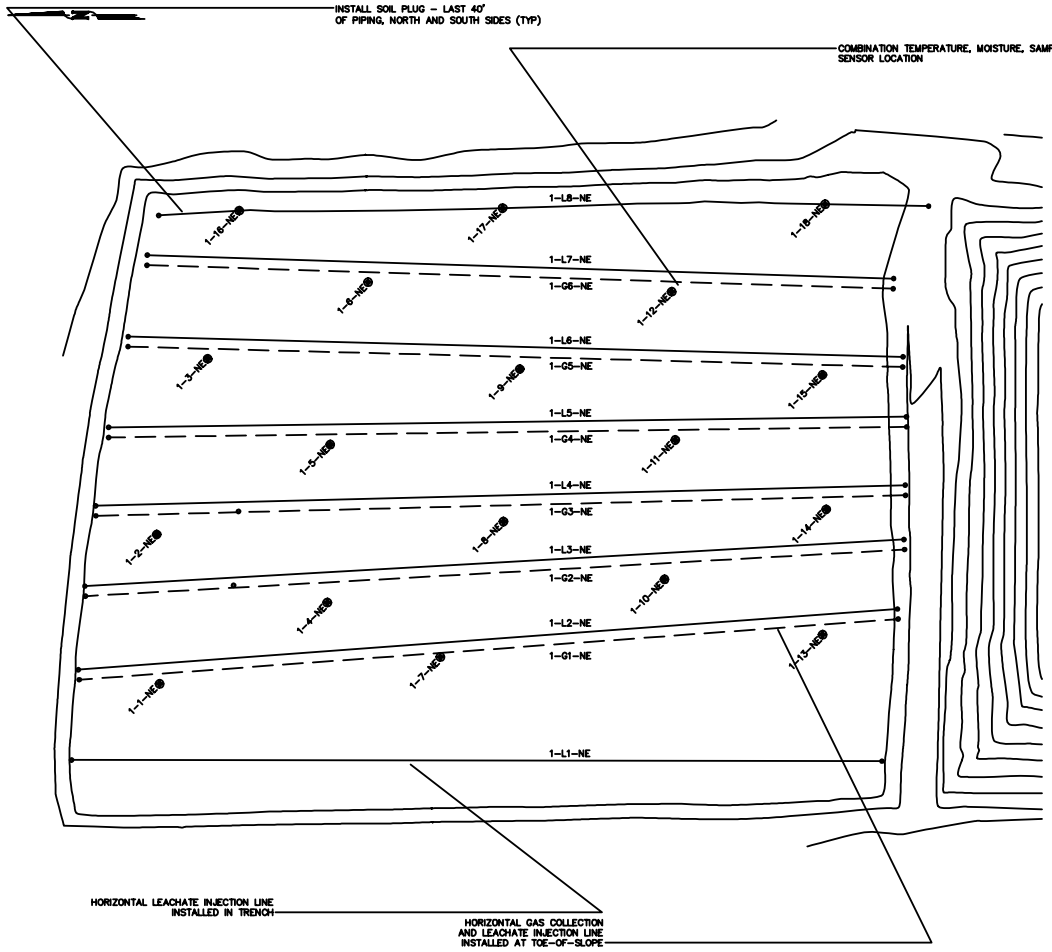
Image 48. Sandbag damaged by seagulls

Image 49. Sandbag is covered by a tire and piece of geomembrane

Image 50. Pipe penetrations on the west 6-acre cell were sealed with waterproof and airtight expansion foam to reduce surface emissions.

Image 51. Permanent geomembrane boot installation.

APPENDIX D – PIPINGS & INSTRUMENTATION DRAWINGS



MONITORING POINT COORDINATES			
SENSOR DESIGNATION	NORTHING	EASTING	ELEVATION (MSL)
1-1-NE	1980055	6651299	40
1-2-NE	1980057	6651433	39
1-3-NE	1980031	6651520	39.5
1-4-NE	1979972	6651399	39.5
1-5-NE	1979971	6651478	39
1-6-NE	1979952	6651568	40.5
1-7-NE	1979916	6651372	40
1-8-NE	1979885	6651440	39
1-9-NE	1979876	6651515	39.5
1-10-NE	1979805	6651411	39.5
1-11-NE	1979799	6651480	39
1-12-NE	1979801	6651554	40.5
1-13-NE	1979726	6651353	40
1-14-NE	1979724	6651446	39
1-15-NE	1979726	6651512	39.5
1-16-NE	1980018	6651594	40
1-17-NE	1979985	6651595	40
1-18-NE	1979725	6651597	40

LEGEND

- HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 20' O/C
- HORIZONTAL GAS COLLECTION LINE, VARIOUS CONFIGURATIONS
- ● THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0–100°C). PRESSURE SENSING TUBE, 1/4–INCH ID BY 3/8 OD LLDPE, AND PVC MOISTURE SENSOR.
- 1–01–NE LEVEL 1, INSTRUMENT LOCATION 1, NORTHEAST ANAEROBIC MODULE
- 1–L1–NE LEVEL 1, LEACHATE INJECTION LINE 1, NORTHEAST ANAEROBIC MODULE
- 1–G1–NE LEVEL 1, GAS EXTRACTION LINE 1, NORTHEAST MODULE

AS-BUILT

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30 15 0 30 60 90
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YOLO COUNTY
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DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

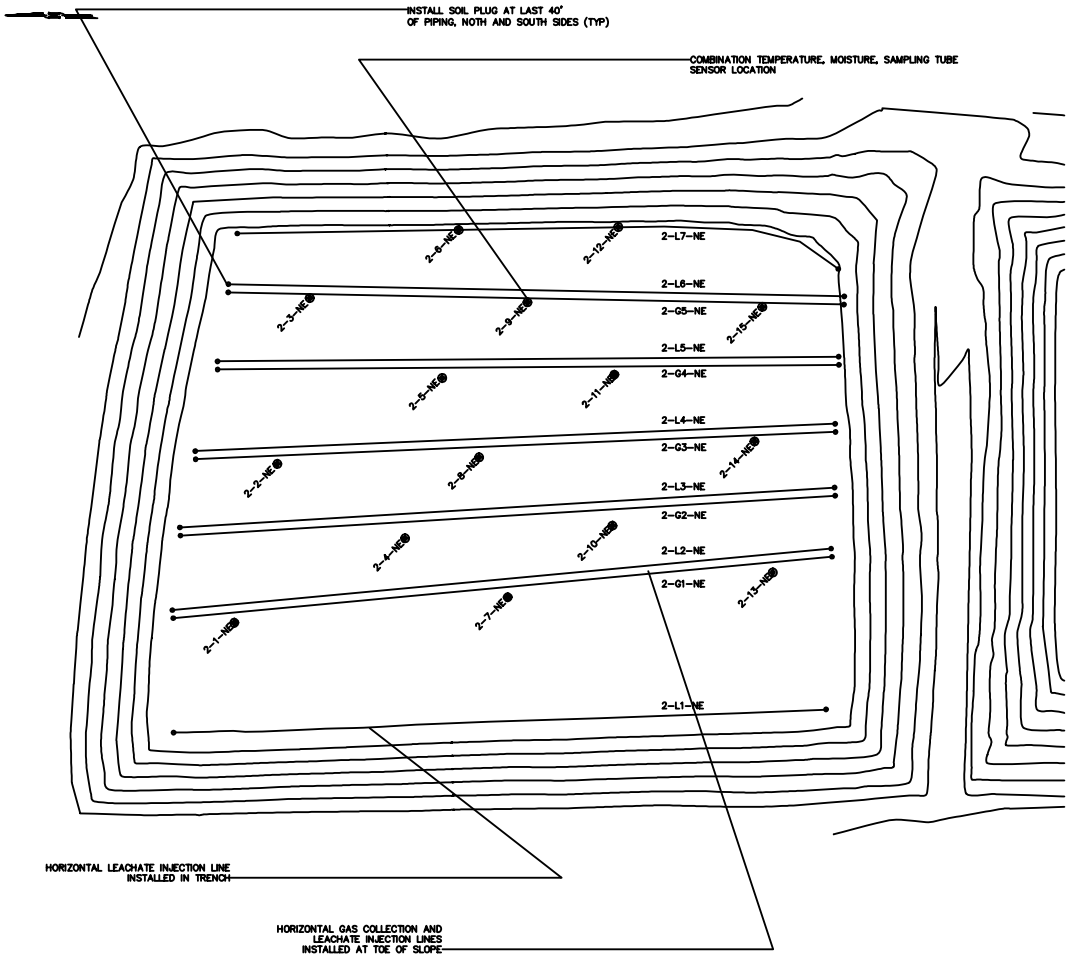
APPROVED _____ 19 ____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
FULL–SCALE BIOREACTOR
NE ANAEROBIC MODULE LEVEL 1 PIPING AND INSTRUMENTATION

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.SN.R.NE
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	
DATE	8/8/02

DETAIL 1



SENSOR DESIGNATION	NORTHING	EASTING	ELEVATION (MSL)
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2-2-NE	1980039	6651460	52.5
2-3-NE	1979990	6651541	49.5
2-4-NE	1979944	6651423	53
2-5-NE	1979925	6651502	51
2-6-NE	1979917	6651574	49.5
2-7-NE	1979883	6651394	54
2-8-NE	1979907	6651463	52.5
2-9-NE	1979884	6651539	49.5
2-10-NE	1979842	6651430	53
2-11-NE	1979841	6651503	51
2-12-NE	1979839	6651576	49.5
2-13-NE	1979784	6651407	54
2-14-NE	1979772	6651471	52.5
2-15-NE	1979769	6651537	49.5

LEGEND

HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 20' O/C

HORIZONTAL GAS COLLECTION LINE, VARIOUS CONFIGHURATIONS

THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0–100°C), PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE, AND PVC MOISTURE SENSOR.

2-01-NE — LEVEL 2, INSTRUMENT LOCATION 1, NORTHEAST ANAEROBIC MODULE

2-L1-NE — LEVEL 2, LEACHATE INJECTION LINE 1, NORTHEAST ANAEROBIC MODULE

2-G1-NE — LEVEL 2, GAS EXTRACTION LINE 1, NORTHEAST MODULE

AS-BUILT

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YOLO COUNTY CENTRAL LANDFILL
FULL-SCALE BIOREACTOR

NE ANAEROBIC MODULE LEVEL 2 PIPING AND INSTRUMENTATION

DRAWING NO.

W.O. NO.	9207
F.B. NO.	T.BM.P.3E
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	
DATE	6/6/02

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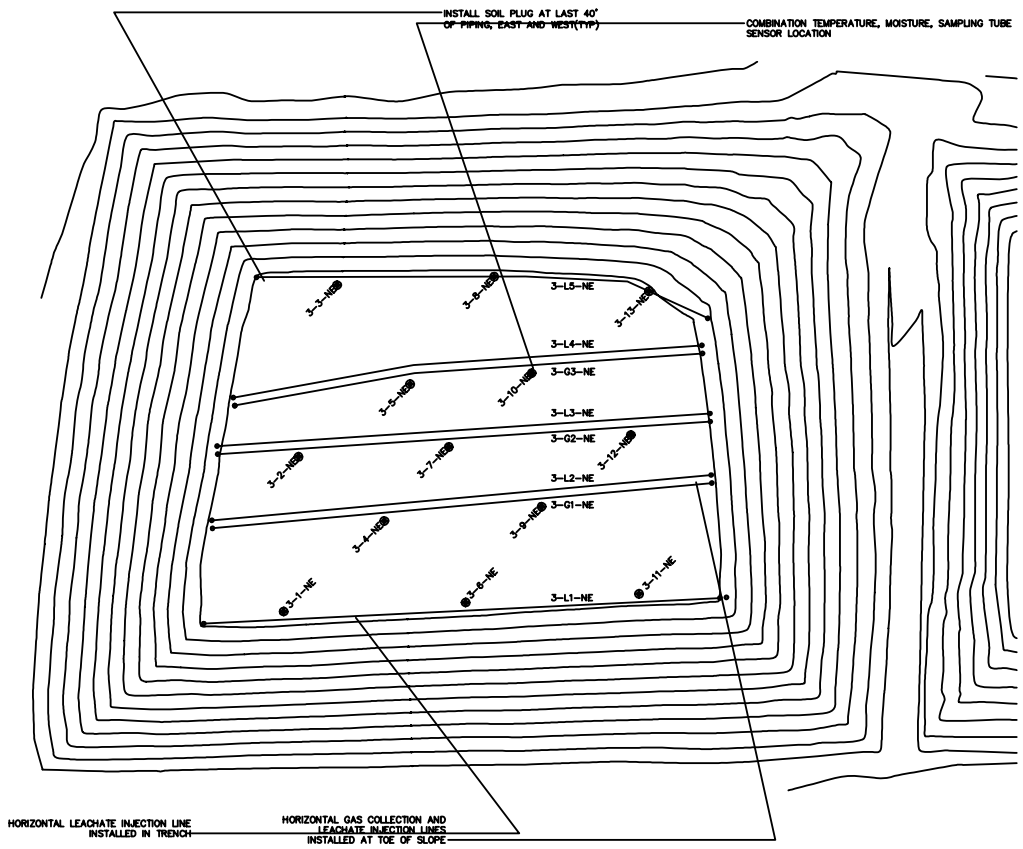

SENSOR DESIGNATION	NORTHING	EASTING	ELEVATION (MSL)
3-1-NE	1979983	6651367	65
3-2-NE	1979976	6651443	65
3-3-NE	1979957	6651528	64
3-4-NE	1979934	6651412	65.5
3-5-NE	1979921	6651479	64.5
3-6-NE	1979883	6651371	65
3-7-NE	1979902	6651448	65
3-8-NE	1979879	6651432	64
3-9-NE	1979856	6651419	65.5
3-10-NE	1979861	6651485	64.5
3-11-NE	1979808	6651376	65
3-12-NE	1979812	6651454	65
3-13-NE	1979803	6651525	64

LEGEND

- HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 20' O/C
- HORIZONTAL GAS COLLECTION LINE, VARIOUS CONFIGHURATIONS
- ● THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0-100°C), PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE, AND PVC MOISTURE SENSOR.
- 3-01-NE LEVEL 3, INSTRUMENT LOCATION 1, NORTHEAST ANAEROBIC MODULE
- 3-L1-NE LEVEL 3, LEACHATE INJECTION LINE 1, NORTHEAST ANAEROBIC MODULE
- 3-G1-NE LEVEL 3, GAS EXTRACTION LINE 1, NORTHEAST MODULE

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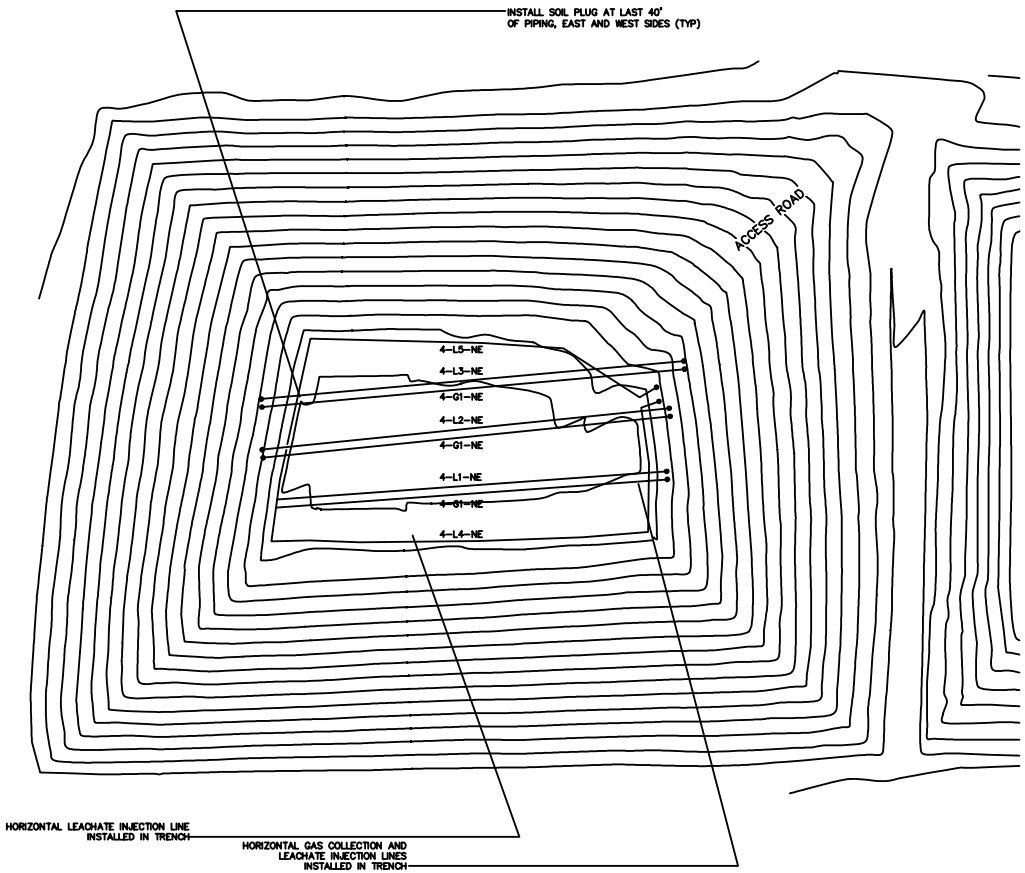
YOLO COUNTY CENTRAL LANDFILL
FULL-SCALE BIOREACTOR
NE ANAEROBIC MODULE LEVEL 3 PIPING AND INSTRUMENTATION

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.9N.R.3E.
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	BY
FILE NAME	———
DATE	8/6/02

DETAIL 3



LEGEND

———	HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 20' O/C
———	HORIZONTAL GAS COLLECTION LINE, VARIOUS CONFIGHURATIONS
4-L1-NE	LEVEL 4, LEACHATE INJECTION LINE 1, NORTHEAST ANAEROBIC MODULE
4-G1-NE	LEVEL 4, GAS EXTRACTION LINE 1, NORTHEAST MODULE

AS-BUILT

30 15 0 30 60 90

GRAPHIC SCALE
1" = 30'

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YOLO COUNTY CENTRAL LANDFILL
FULL-SCALE BIOREACTOR

NE ANAEROBIC MODULE LEVEL 4 PIPING AND INSTRUMENTATION

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.9N.R.3E.
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DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	____
DATE	8/5/02

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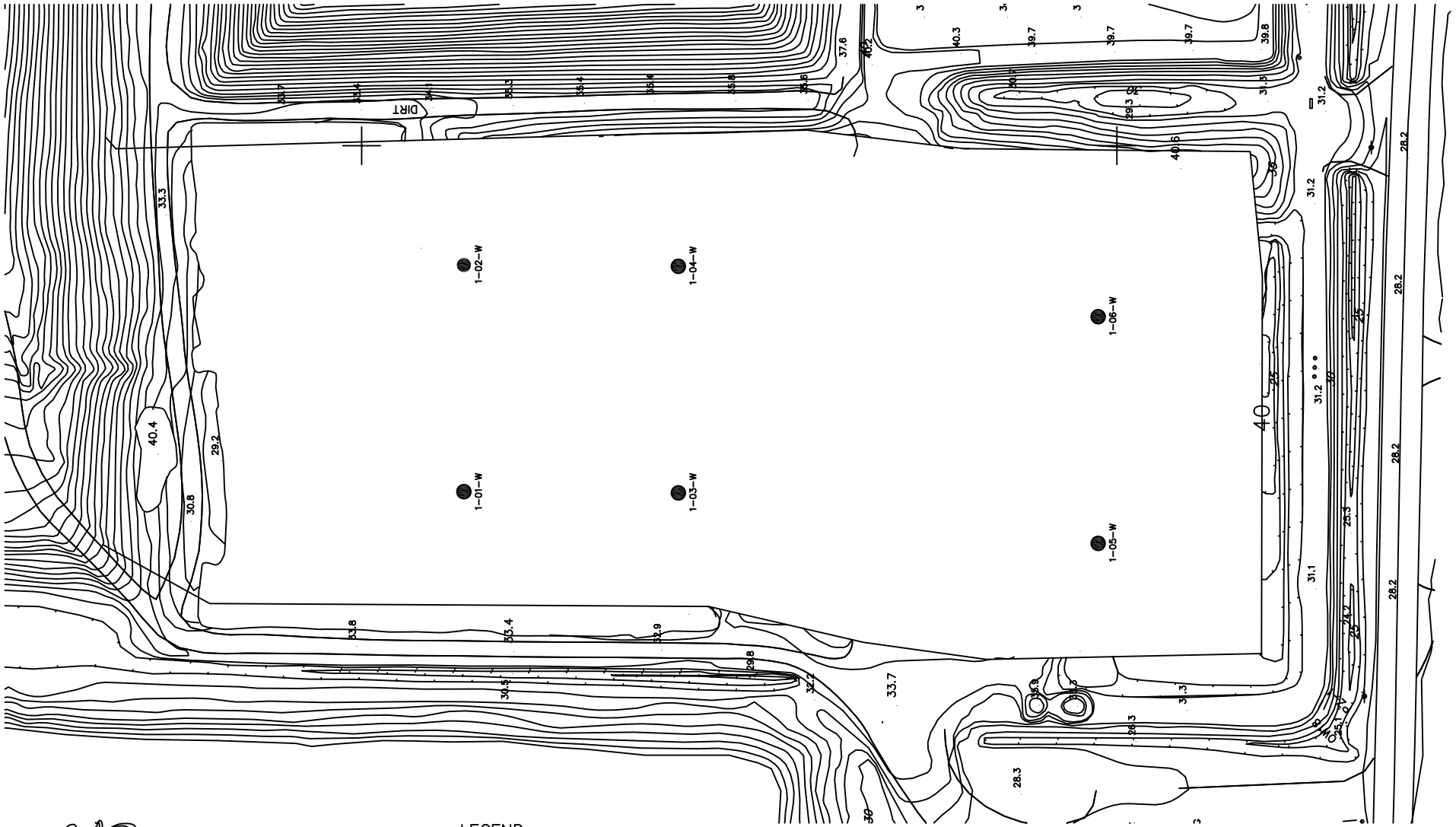
4



LEGEND

● THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0–100°C), AND PVC MOISTURE SENSOR.

1-01-W LEVEL 1, INSTRUMENT LOCATION 1, WEST ANAEROBIC MODULE

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292 WEST BEAMER ST., WOODLAND, CA 95695

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YOLO COUNTY CENTRAL LANDFILL

FULL SCALE BIOREACTOR WEST SIDE, LEVEL 1 PIPING AND INSTRUMENTATION PLAN

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.BK.R.3E.
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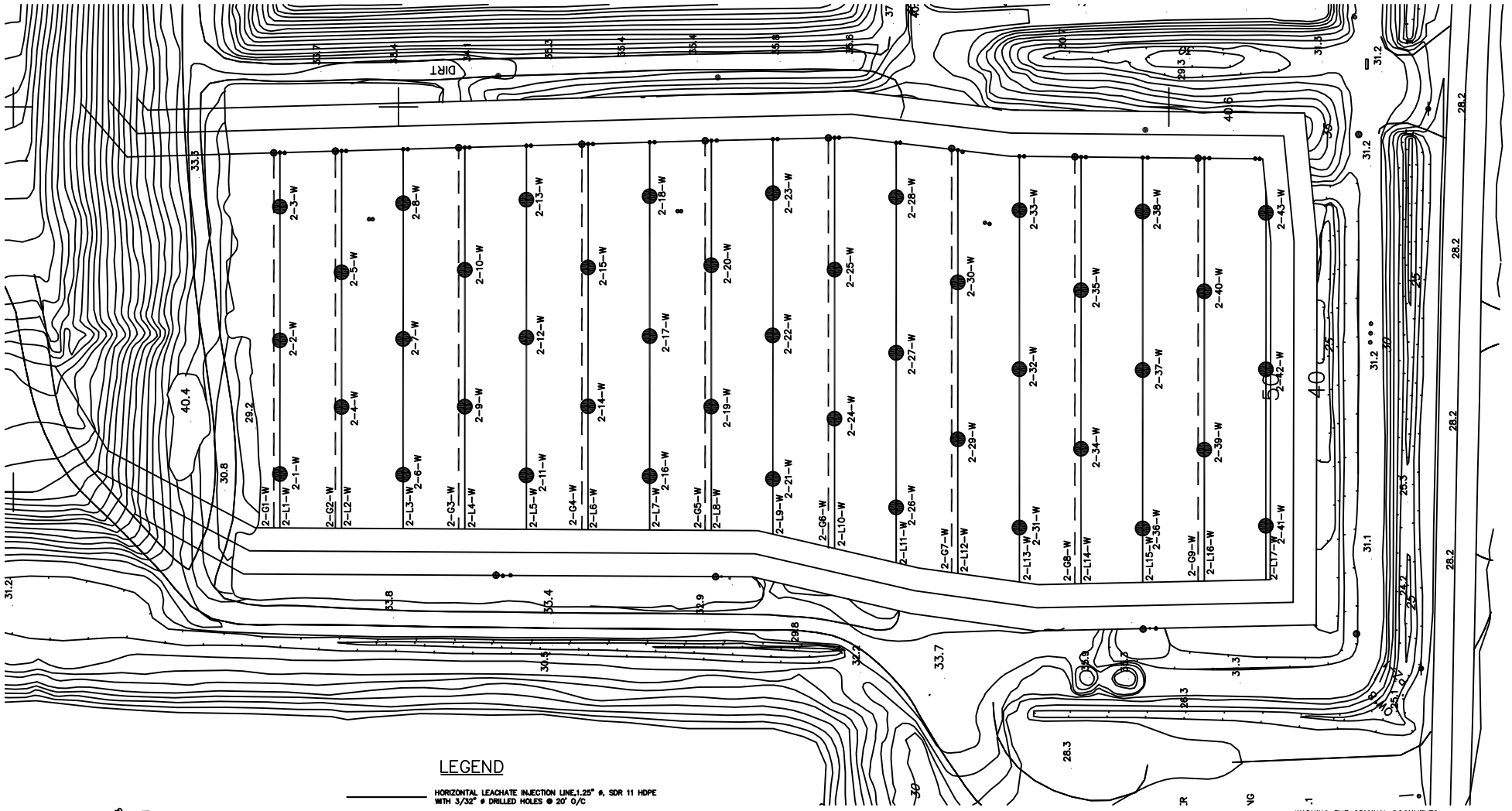
CHECKED BY	XX
FILE NAME	s.dgn
DATE	2/21/02

DETAIL 5



LEGEND

———	HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 20' O/C
— — —	HORIZONTAL GAS COLLECTION LINE, VARIOUS CONFIGURATIONS
●	THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0–100°C), AND PVC MOISTURE SENSOR.
2–01–W	LEVEL 2, INSTRUMENT LOCATION 1, WEST ANAEROBIC MODULE
2–L1–W	LEVEL 2, LEACHATE INJECTION LINE 1, WEST ANAEROBIC MODULE
2–G1–W	LEVEL 2, GAS EXTRACTION LINE 1, WEST ANAEROBIC MODULE

30 15 0 30 60 120

GRAPHIC SCALE
1" = 30'

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292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 19 ____ R. E. NO. _____

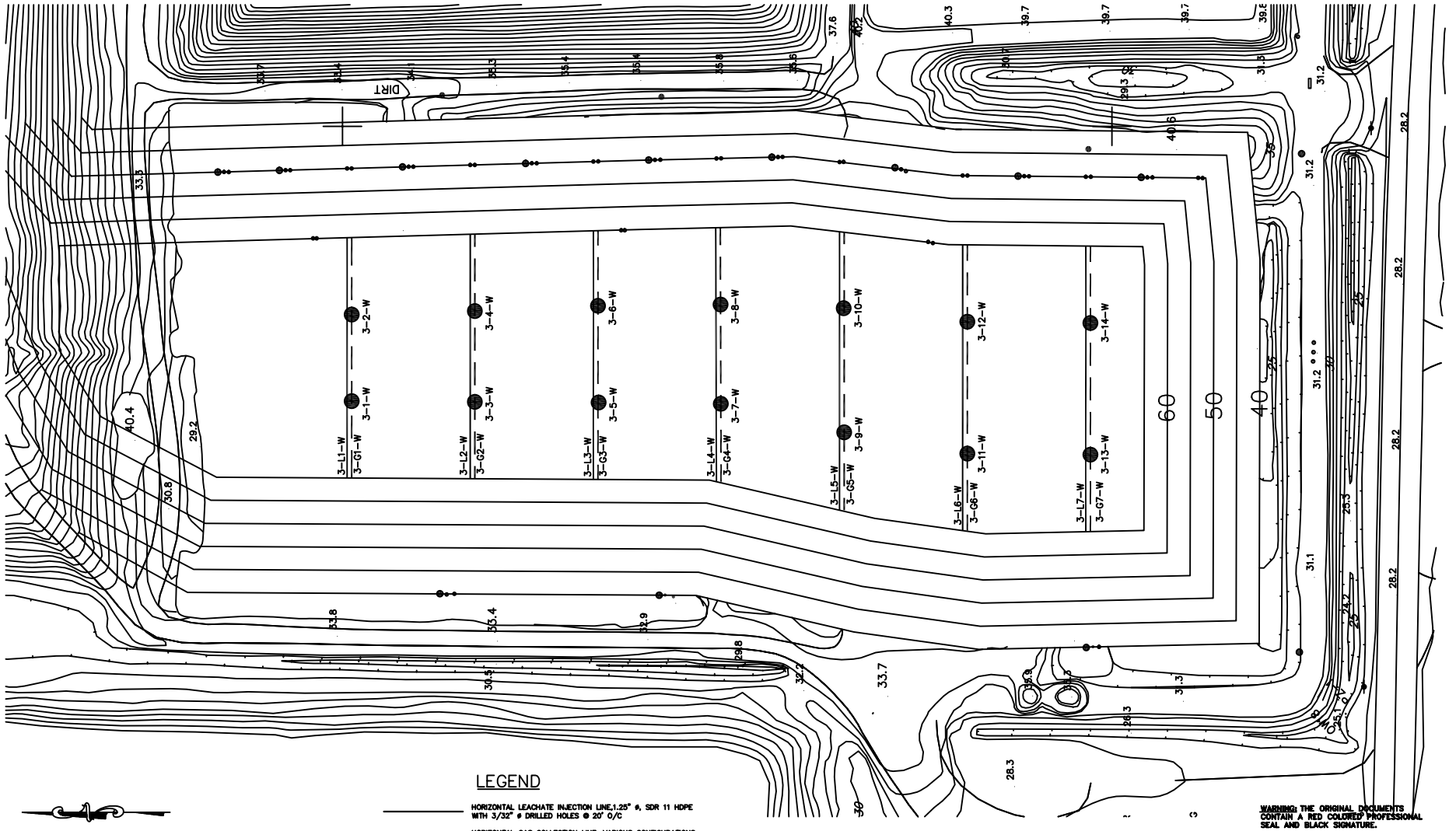
YOLO COUNTY CENTRAL LANDFILL

FULL SCALE BIOREACTOR WEST SIDE, LEVEL 2 PIPING AND INSTRUMENTATION PLAN

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T-BKJR,3E
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	XX
FILE NAME	P2-DET6
DATE	2/21/02

DETAIL 6



WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PLANNING & PUBLIC WORKS
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

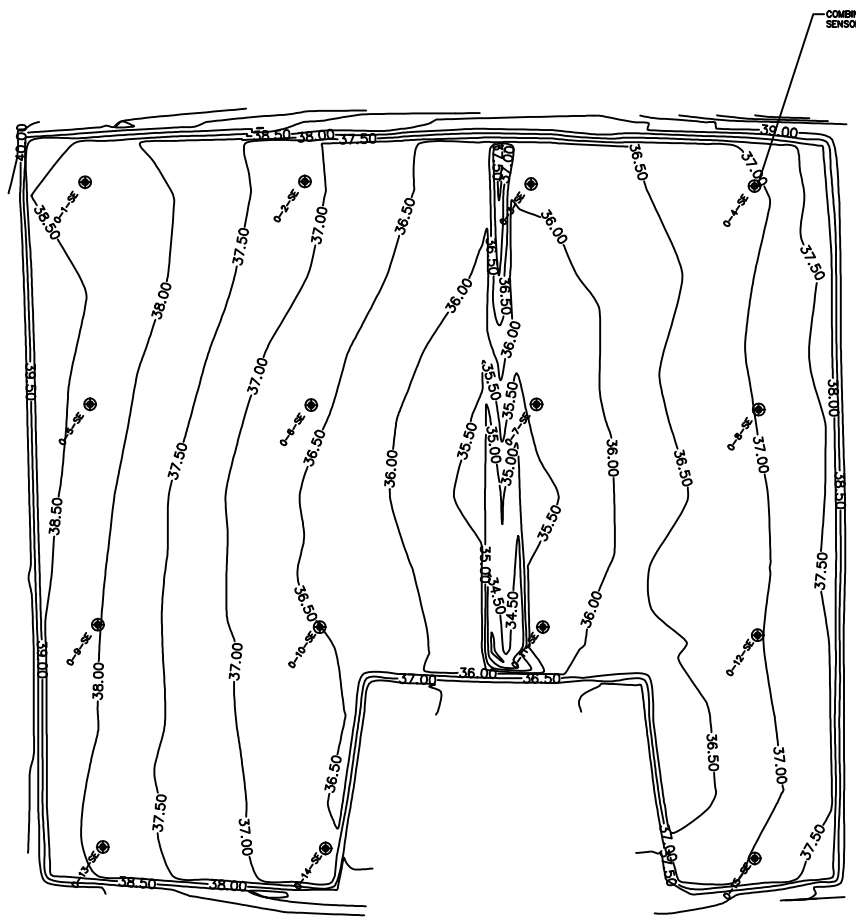
APPROVED _____ 19 ____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
FULL SCALE BIOREACTOR
WEST SIDE, LEVEL 3
PIPING AND
INSTRUMENTATION PLAN

DRAWING NO. _____

W.O. NO. 9207
F.B. NO. T.9N.R.3E.
DESIGN BY JDK
DRAWN BY JDK
CHECKED BY XX
FILE NAME
DATE /21/02

DETAIL
7



SENSOR DESIGNATION	NORTHING	EASTING	ELEVATION (MSL)
0-1-SE	1979442	6651322	38.4
0-2-SE	1979442	6651406	37
0-3-SE	1979442	6651482	36
0-4-SE	1979441	6651557	37
0-5-SE	1979567	6651334	38.2
0-6-SE	1979567	6651408	36.6
0-7-SE	1979567	6651484	35.5
0-8-SE	1979566	6651559	37
0-9-SE	1979493	6651336	38
0-10-SE	1979493	6651411	36.5
0-11-SE	1979493	6651486	35.6
0-12-SE	1979490	6651558	37
0-13-SE	1979419	6651338	37.9
0-14-SE	1979418	6651413	36.7
0-15-SE	1979415	6651557	37

LEGEND

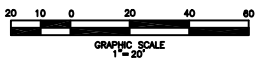
● THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0-100°C), PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE, AND, AT LOCATIONS 05, 07, 14, AND 15, A PVC MOISTURE SENSOR.

0-1-SE LEVEL 0, INSTRUMENT LOCATION 1, SOUTHEAST ANAEROBIC MODULE

NOTES

1. STRIPS OF GEOCOMPOSITE DRAIN NET PLACED UNDER LINER COOLING AND LINER COOLING/SETTLEMENT PIPES TO PROMOTE BETTER DRAINAGE UNDER PIPES.

AS-BUILT



WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PLANNING & PUBLIC WORKS
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

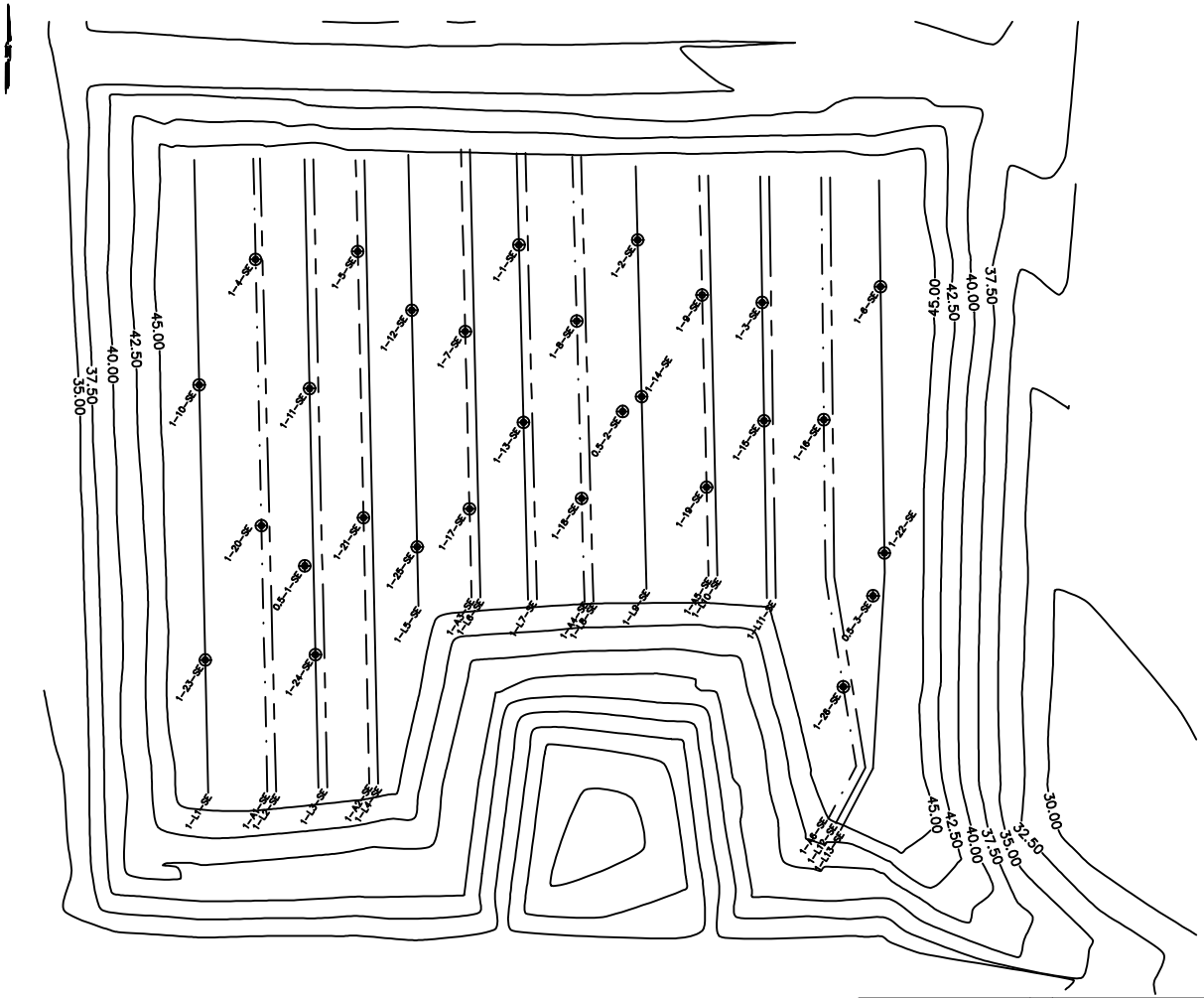
APPROVED _____ 19 ____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
FULL-SCALE BIOREACTOR
SE AEROBIC MODULE LEVEL 0 PIPING AND INSTRUMENTATION

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.9N.R.3E.
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	—
DATE	6/6/02

DETAIL 8



SENSOR DESIGNATION	NORTHING	EASTING	ELEVATION (MSL)
1-1-SE	1979615	6851443	42
1-2-SE	1979617	6851484	43
1-3-SE	1979598	6851524	46
1-4-SE	1979611	6851364	44.5
1-5-SE	1979613	6851389	44
1-6-SE	1979601	6851268	37
1-7-SE	1979596	6851423	42
1-8-SE	1979580	6851463	43
1-9-SE	1979592	6851505	46
1-10-SE	1979568	6851335	44.5
1-11-SE	1979567	6851373	44.5
1-12-SE	1979563	6851407	44
1-13-SE	1979565	6851445	43
1-14-SE	1979564	6851485	43
1-15-SE	1979556	6851526	46
1-16-SE	1979556	6851346	47
1-17-SE	1979539	6851427	42
1-18-SE	1979530	6851469	43
1-19-SE	1979534	6851507	46
1-20-SE	1979521	6851356	44.5
1-21-SE	1979523	6851391	44
1-22-SE	1979511	6851567	47
1-23-SE	1979475	6851357	44.5
1-24-SE	1979477	6851475	44.5
1-25-SE	1979513	6851409	44
1-26-SE	1979466	6851553	47
0.5-1-SE	1979507	6851371	41
0.5-2-SE	1979559	6851478	39.5
0.5-3-SE	1979497	6851583	41

LEGEND

- HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 10' O/C
- HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, sCHEDULE 80 CPVC WITH 3/32" ø DRILLED HOLES @ 10' O/C
- HORIZONTAL AIR COLLECTION LINE, ALTERNATING 4 AND 6-INCH CPVC
- HORIZONTAL AIR COLLECTION LINE, ALTERNATING 6 AND 8-INCH COORIGATED METAL PIPE WITH HDPE INJECTION LINE INSIDE.
- ● THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0-100°C), PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE, AND PVC MOISTURE SENSOR.
- 0.5-1-SE LEVEL 0.5, INSTRUMENT LOCATION 1, SOUTHEAST ANAEROBIC MODULE
- 1-1-SE LEVEL 1, INSTRUMENT LOCATION 1, SOUTHEAST ANAEROBIC MODULE
- 1-L1-SE LEVEL 1, LEACHATE INJECTION LINE 1, SOUTHEAST ANAEROBIC MODULE
- 1-A1-SE LEVEL 1, AIR COLLECTION LINE 1, SOUTHEAST MODULE

NOTES

1. ALL PIPING AND INSTRUMENTATION INSTALLED IN 3-FOOT WIDE BY 2-FOOT DEEP TRENCH. ALL TRENCHES WERE BACKFILLED WITH TIRES.
2. SENSORS DESIGNATED 0.5 WERE INSTALLED APPROXIMATELY 4-FEET ABOVE THE AEROBIC LINER.

AS-BUILT

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

20 10 0 20 40 60
GRAPHIC SCALE
1" = 20'

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PLANNING & PUBLIC WORKS
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

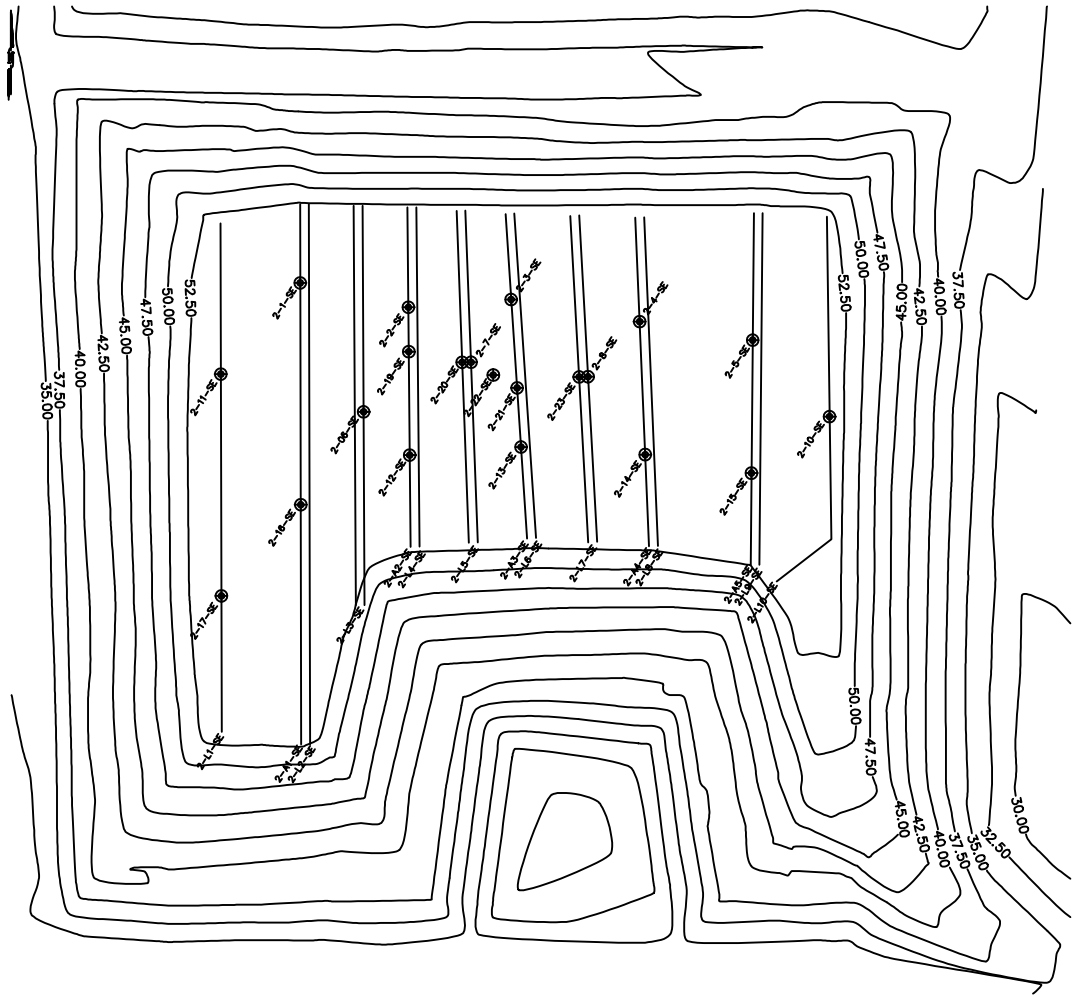
APPROVED _____ 19 _____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
FULL-SCALE BIOREACTOR
SE AEROBIC MODULE LEVEL 1 PIPING AND INSTRUMENTATION

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.9NR.3E.
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	
DATE	6/6/02

DETAIL 9



SENSOR DESIGNATION	NORTHING	EASTING	ELEVATION (MSL)
2-1-SE	1979604	6851380	51
2-2-SE	1979596	6851417	51
2-3-SE	1979589	6851452	52
2-4-SE	1979581	6851495	52.5
2-5-SE	1979585	6851433	52
2-6-SE	1979561	6851402	51
2-7-SE	1979572	6851435	51.5
2-8-SE	1979572	6851475	52
2-9-SE	NOT INSTALLED		
2-10-SE	1979559	6851559	52
2-11-SE	1979573	6851454	51
2-12-SE	1979546	6851418	51
2-13-SE	1979549	6851455	52
2-14-SE	1979548	6851497	52.5
2-15-SE	1979540	6851433	52
2-16-SE	1979529	6851381	51
2-17-SE	1979498	6851354	51
2-18-SE	SENSOR LOST		
2-19-SE	1979561	6851417	51
2-20-SE	1979577	6851435	56
2-21-SE	1979569	6851454	57
2-22-SE	1979574	6851446	56
2-23-SE	1979572	6851475	57

LEGEND

- HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 10' O/C
- HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, sCHEDULE 80 CPVC WITH 3/32" ø DRILLED HOLES @ 10' O/C
- HORIZONTAL AIR COLLECTION LINE, ALTERNATING 4 AND 6-INCH CPVC
- HORIZONTAL AIR COLLECTION LINE, ALTERNATING 6 AND 8-INCH COORIGATED METAL PIPE WITH HDPE INJECTION LINE INSIDE.
- ● THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0-100°C), PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE, AND PVC MOISTURE SENSOR.
- 2-1-SE LEVEL 2, INSTRUMENT LOCATION 1, SOUTHEAST ANAEROBIC MODULE
- 2-L1-SE LEVEL 2, LEACHATE INJECTION LINE 1, SOUTHEAST ANAEROBIC MODULE
- 2-A1-SE LEVEL 2, AIR COLLECTION LINE 1, SOUTHEAST MODULE

NOTES

1. ALL PIPING AND INSTRUMENTATION INSTALLED IN 3-FOOT WIDE BY 2-FOOT DEEP TRENCH. ALL TRENCHES WERE BACKFILLED WITH TIRES.
2. SENSORS DESIGNATED 0.5 WERE INSTALLED APPROXIMATELY 4-FEET ABOVE THE AEROBIC LINER.

AS-BUILT

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

20 10 0 20 40 60
GRAPHIC SCALE
1" = 20'

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PLANNING & PUBLIC WORKS
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

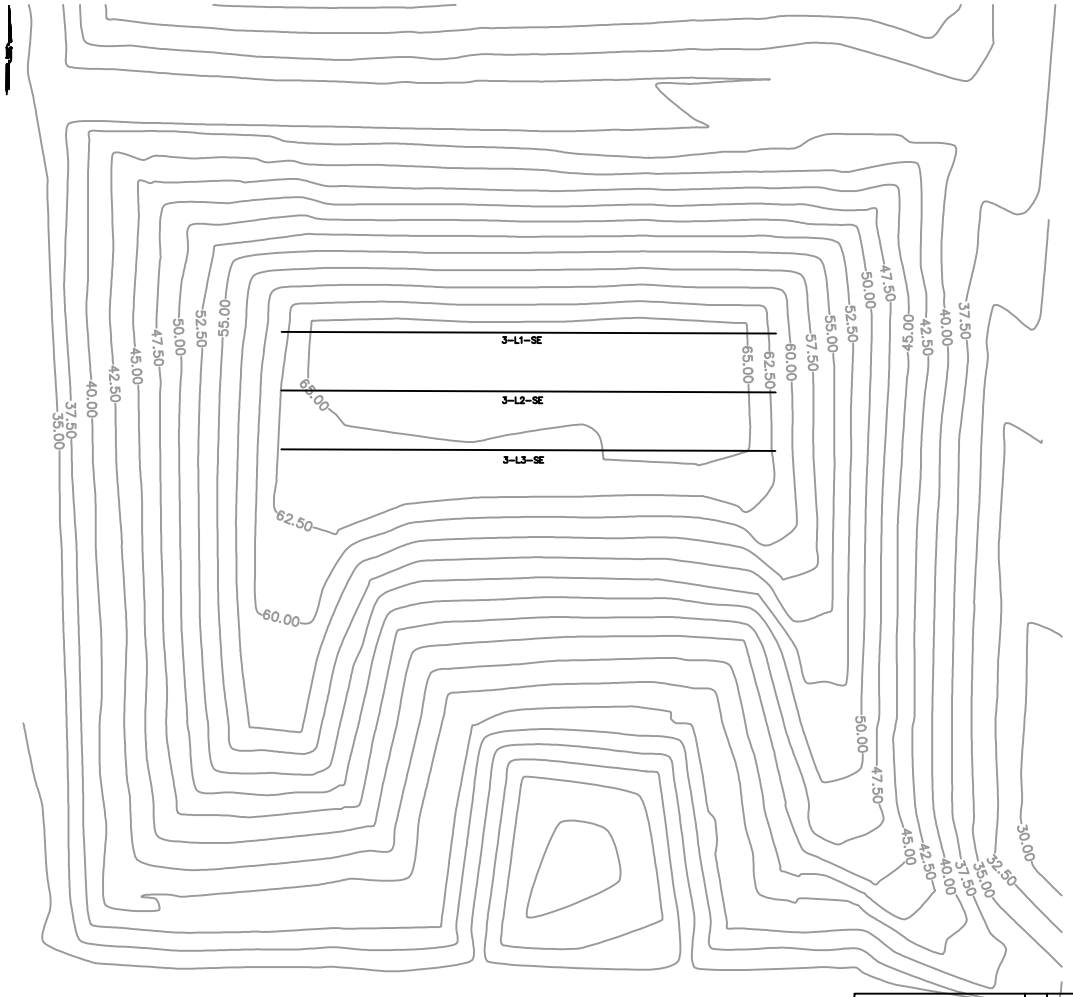
APPROVED _____ 19 ____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
FULL-SCALE BIOREACTOR
SE AEROBIC MODULE LEVEL 2 PIPING AND INSTRUMENTATION

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.BK/8.3E
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	———
DATE	8/8/02

DETAIL
10



20 10 0 20 40 60

GRAPHIC SCALE
1" = 20'

LEGEND

HORIZONTAL LEACHATE INJECTION LINE,1.25" ø, SDR 11 HDPE WITH 3/32" ø DRILLED HOLES @ 10' O/C

3-L1-SE LEVEL 3, LEACHATE INJECTION LINE 1, SOUTHEAST ANAEROBIC MODULE

NOTES

1. ALL PIPING AND INSTRUMENTATION INSTALLED IN 3-FOOT WIDE BY 2-FOOT DEEP TRENCH. ALL TRENCHES WERE BACKFILLED WITH TIRES.

AS-BUILT

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO	REVISIONS / DESCRIPTIONS	DATE	APP'V

YOLO COUNTY
DEPARTMENT OF PLANNING & PUBLIC WORKS
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 19 ____ R. E. NO. _____

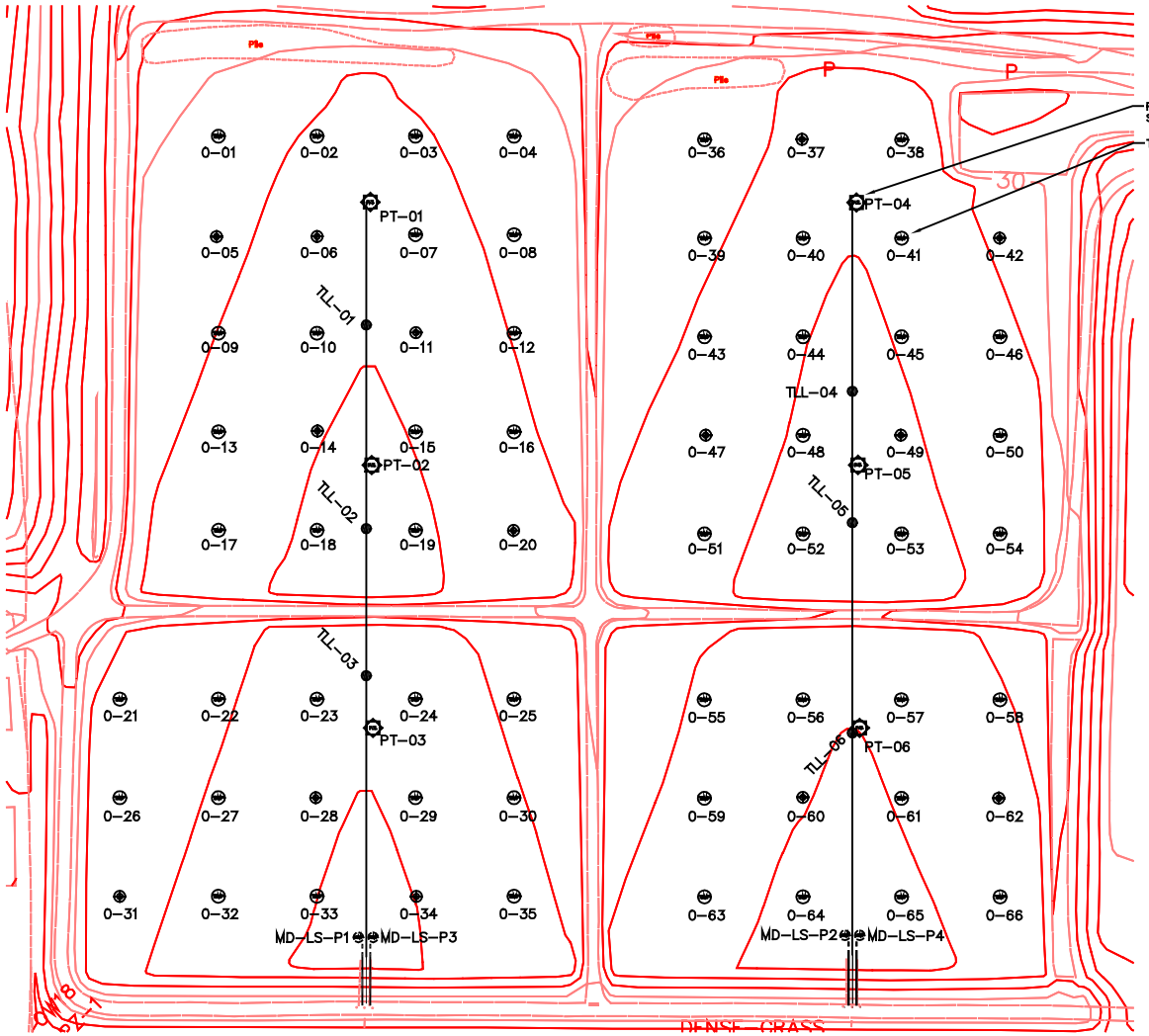
YOLO COUNTY CENTRAL LANDFILL
FULL-SCALE BIOREACTOR
SE AEROBIC MODULE LEVEL 3 PIPING AND INSTRUMENTATION

DRAWING NO. _____

W.O. NO.	9207
F.B. NO.	T.9N.R.3E.
DESIGN BY	JDX
DRAWN BY	JDX
CHECKED BY	RY
FILE NAME	
DATE	8/6/02

DETAIL '11

MONITORING POINT COORDINATES			
SENSOR DESIGNATION	NORTHING	EASTING	ELEVATION (MSL)
0-01	1980033	6650992	29
0-02	1980033	6651067	28
0-03	1980033	6651142	28
0-04	1980033	6651217	29
0-05	1979958	6650992	29
0-06	1979958	6651067	27.5
0-07	1979958	6651142	27.5
0-08	1979958	6651217	29
0-09	1979883	6650992	28
0-10	1979883	6651067	27
0-11	1979883	6651142	27
0-12	1979883	6651217	28.5
0-13	1979808	6650992	28
0-14	1979808	6651067	26.5
0-15	1979808	6651142	26.5
0-16	1979808	6651217	28
0-17	1979733	6650992	27.5
0-18	1979733	6651067	26
0-19	1979733	6651142	26
0-20	1979733	6651217	27.5
0-21	1980030	6651362	29
0-22	1980030	6651437	27.5
0-23	1980030	6651512	27.5
0-24	1979955	6651362	28
0-25	1979955	6651437	27
0-26	1979955	6651512	27
0-27	1979955	6651587	28.5
0-28	1979880	6651362	28
0-29	1979880	6651437	26.5
0-30	1979880	6651512	26.5
0-31	1979880	6651587	28
0-32	1979805	6651362	27.5
0-33	1979805	6651437	26
0-34	1979805	6651512	26
0-35	1979805	6651587	27.5
0-36	1979730	6651362	27
0-37	1979730	6651437	25.5
0-38	1979730	6651512	25.5
0-39	1979730	6651587	27
0-40	1979604	6650917	28
0-41	1979604	6650922	26
0-42	1979604	6651067	25
0-43	1979604	6651142	25
0-44	1979604	6651217	26.5
0-45	1979529	6650917	27
0-46	1979529	6650922	26
0-47	1979529	6651067	24.5
0-48	1979529	6651142	24.5
0-49	1979529	6651217	26
0-50	1979454	6650917	27
0-51	1979454	6650922	25.5
0-52	1979454	6651067	24
0-53	1979454	6651142	24
0-54	1979454	6651217	25.5
0-55	1979604	6651362	26
0-56	1979604	6651437	24.5
0-57	1979604	6651512	24.5
0-58	1979604	6651587	26
0-59	1979529	6651362	25.5
0-60	1979529	6651437	24
0-61	1979529	6651512	24
0-62	1979529	6651587	25.5
0-63	1979454	6651362	25
0-64	1979454	6651437	24
0-65	1979454	6651512	23.5
0-66	1979454	6651587	25



INSTRUMENT DESIGNATION

0-02	THERMISTER, MOISTURE SENSOR, AND PRESSURE SENSING TUBE DESIGNATION. 0-02 DESIGNATES LEVEL 0, INSTRUMENT NUMBER 2
PT-01	PRESSURE TRANSDUCER AND PRESSURE SENSING TUBE. PT-01 DESIGNATES PRESSURE TRANSDUCER NUMBER 1
TLL-01	TRENCH LIQUID LEVEL, LOCATION 1

LEGEND

- PRESSURE TRANSDUCER, DRUCK MODEL PTX 1830, 0-1 PSIG
- THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0-100°C). AND PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE.
- THERMISTER, QUALITY THERMISTER NTC PROBE, 10,000 OHM RESISTANCE AT 25°C, TOLERANCE ±0.2°C (0-100°C), PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE, AND PVC MOISTURE SENSOR.
- PRESSURE SENSING TUBE, 1/4-INCH ID BY 3/8 OD LLDPE.

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PLANNING & PUBLIC WORKS
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

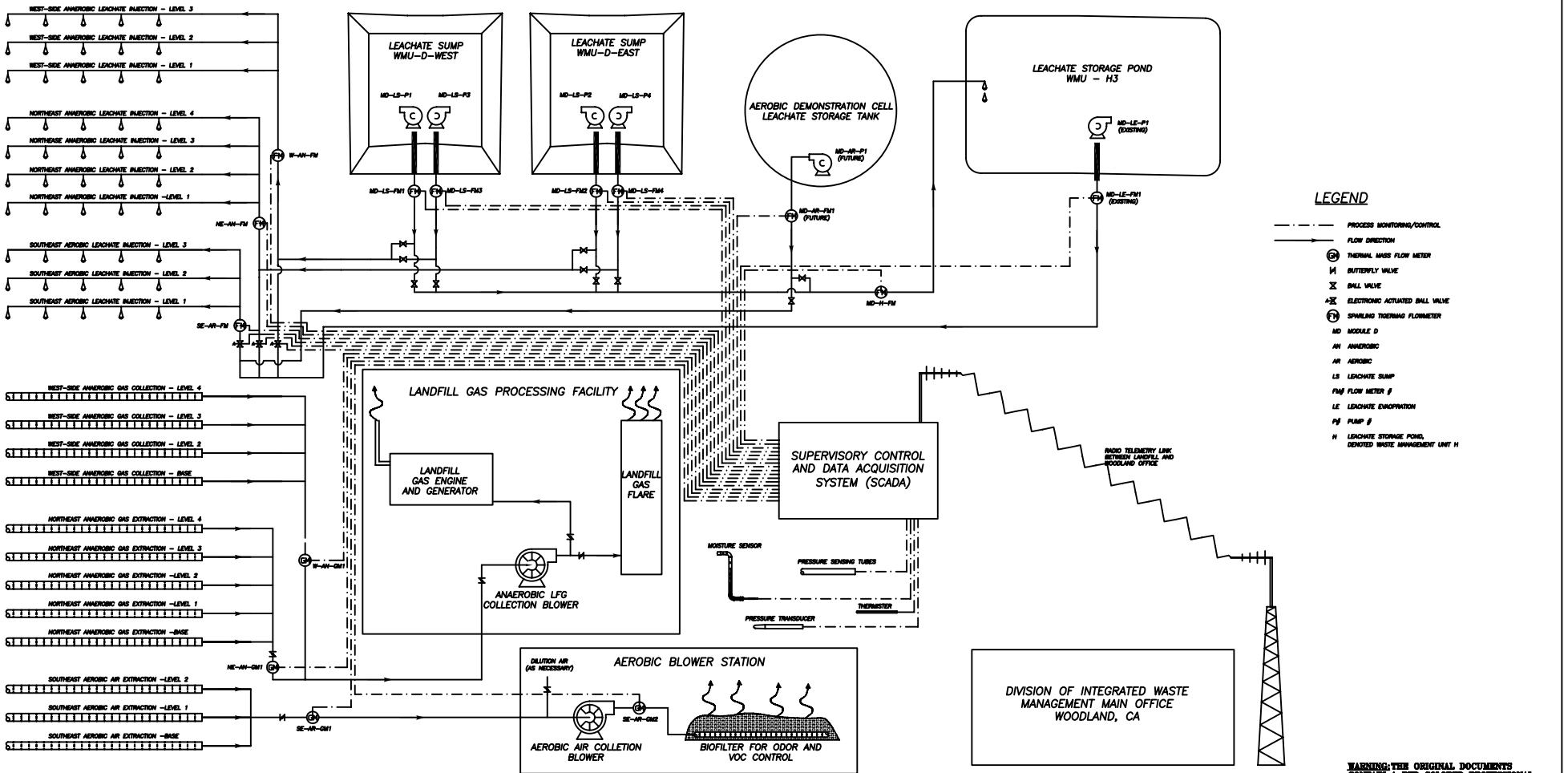
APPROVED _____ 20__ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
FULL SCALE BIOREACTOR
BASE LINER INSTRUMENTATION PLAN

DRAWING NO. _____

W.O. NO. 9209
FIL. NO. 7
DESIGN BY JDK
DRAWN BY JDK
CHECKED BY RY
FILE NAME BASE_INST
DATE 8/14/20

DETAIL 12



WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

AS-BUILT

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PLANNING & PUBLIC WORKS
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 WEST BEAMER ST., WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

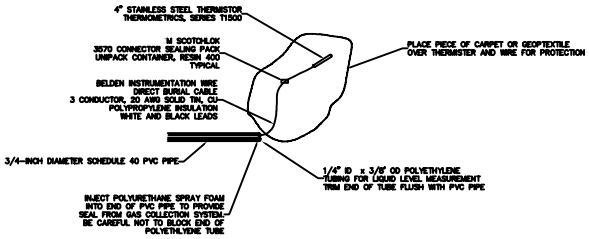
APPROVED _____ 19 ____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
FULL–SCALE BIORREACTOR

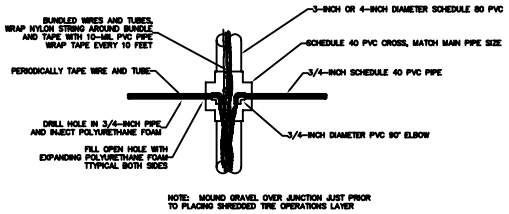
PROCESS FLOW DIAGRAM

DRAWING NO. _____

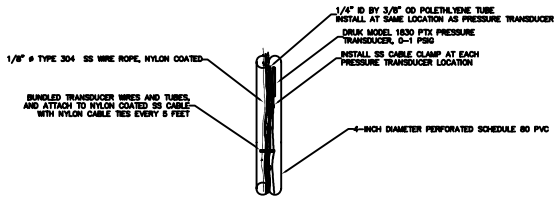
W.O. NO.	9287
F.B. NO.	T.9NR.5E.
DESIGN BY	JDK
DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	—
DATE	11/25/02
SHEET	3
OF	24



1/20 BASE THERMISTER AND PRESSURE TUBE
N.T.S

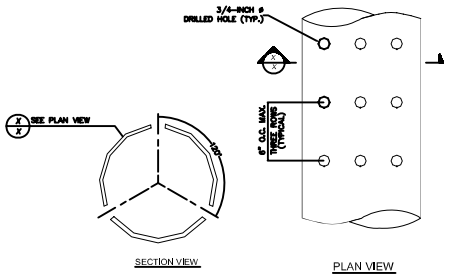


2/20 BASE INSTRUMENTATION PIPE JUNCTION
N.T.S

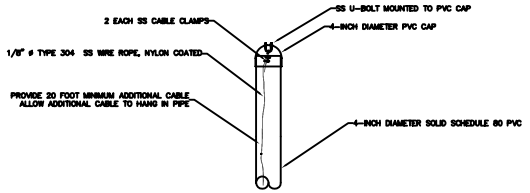


3/20 PRESSURE TRANSDUCER INSTALLATION
N.T.S

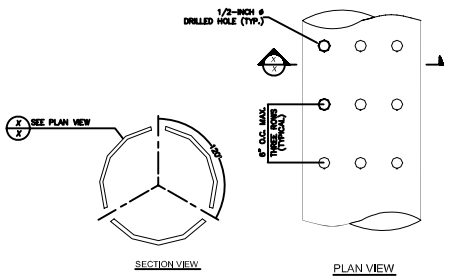
4/20 LINER COOLING PIPE PERFORATION DETAIL
N.T.S



5/20 PERFORATED PVC PRESSURE TRANSDUCER CONDUIT AND GAS COLLECTION PIPE DETAIL
N.T.S



6/20 PRESSURE TRANSDUCER PIPE CLEAN OUT
N.T.S



7/20 PERFORATED PVC INSTUMRNTATION WIRE CONDUIT AND GAS COLLECTION PIPE DETAIL
N.T.S

AS-BUILT

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION
DIVISION OF INTEGRATED WASTE MANAGEMENT
600 A STREET, ROOM 168 DAVIS, CALIFORNIA

DIRECTOR OF PUBLIC WORKS

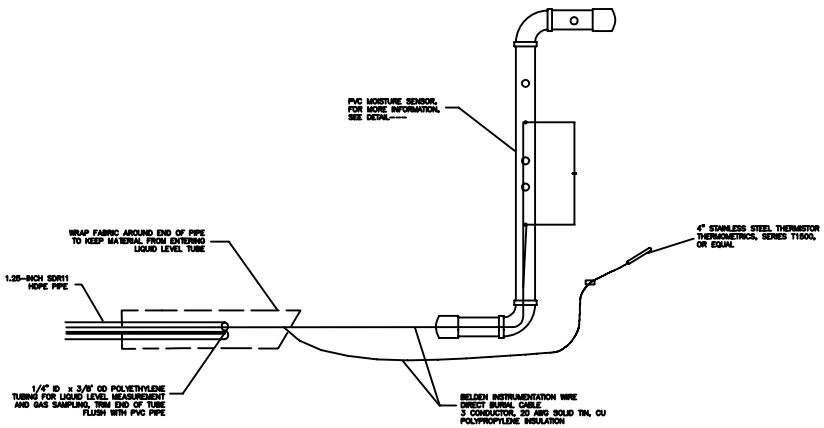
APPROVED _____ 19 ____ R. E. NO. _____

YOLO COUNTY CENTRAL LANDFILL
MODULE D, PHASE 1

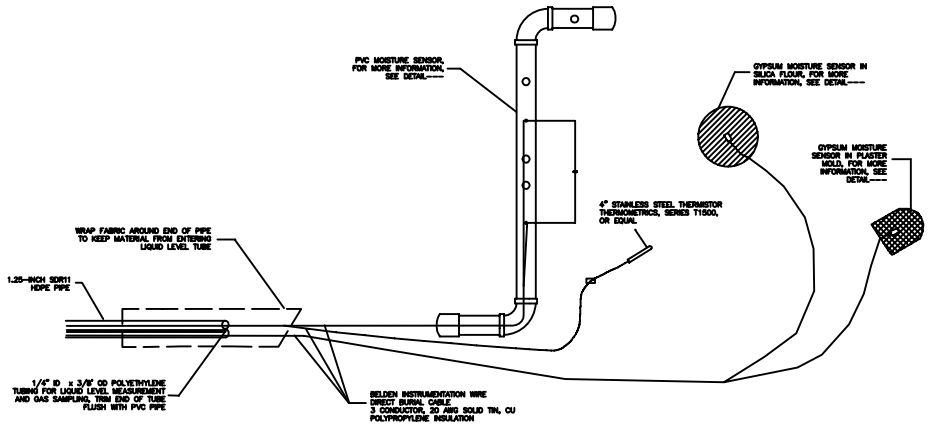
BASE INSTRUMENTATION DETAILS

DRAWING NO. YCCL-1996-00

W.O. NO.	9299
F.B. NO.	T.MAR.DE.
DESIGN BY	JBK
DRAWN BY	JBK
CHECKED BY	RY
FILE NAME	DETAILS
DATE	8/15/00
SHEET	20
OF	X



X/X PVC MOISTURE AND TEMP INSTALLATION DETAIL
N.T.S



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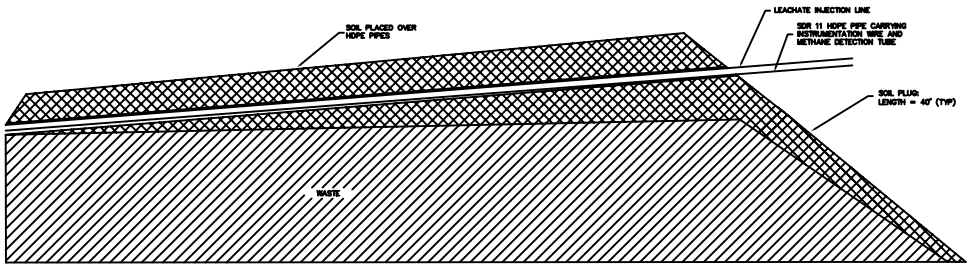
N.T.S

ELEV VIEW



X/X SOIL PLUG INSTALLATION DETAIL
N.T.S

AS-BUILT

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION
DIVISION OF INTEGRATED WASTE MANAGEMENT
600 A STREET, ROOM 150 DAVIS, CALIFORNIA

DIRECTOR OF PUBLIC WORKS

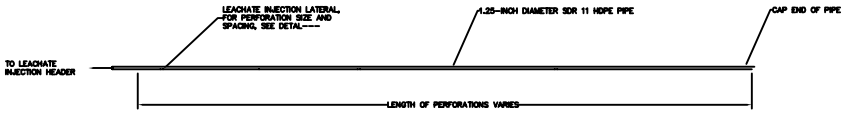
APPROVED _____ 19 ____ B. E. NO. _____

YOLO COUNTY CENTRAL LANDFILL
MODULE D, PHASE 1

BASE INSTRUMENTATION DETAILS

DRAWING NO. YCCL-1996-00

W.O. NO.	9299
C.E. NO.	T.WAR.DE.
DESIGN BY	JBK
DRAWN BY	JBK
CHECKED BY	RY
FILE NAME	DETAILS
DATE	8/15/00
SHEET	20
OF	X



X LEACHATE INJECTION LINE DETAIL
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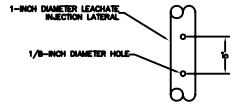

X LEACHATE INJECTION LATERAL PERFORATION DETAIL
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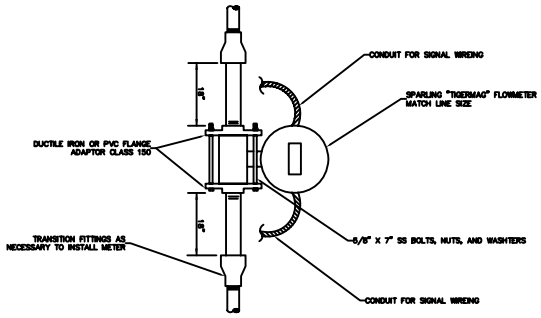


6 FLOWMETER
SCALE: NONE

NOTES
1.
2.

AS-BUILT

REDUCED DRAWING

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION
DIVISION OF INTEGRATED WASTE MANAGEMENT
600 A STREET, ROOM 150 DAVIS, CALIFORNIA

DIRECTOR OF PUBLIC WORKS

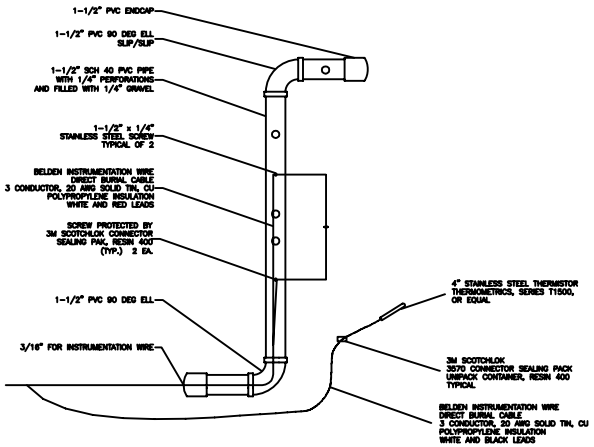
APPROVED _____ 19 ____ B. E. NO. _____

YOLO COUNTY CENTRAL LANDFILL
MODULE D, PHASE 1

LEACHATE INJECTION DDETAILS

DRAWING NO. YCCL-1996-00

W.O. NO.	9299
C.B. NO.	T.WAR.DE.
DESIGN BY	JBK
DRAWN BY	JBK
CHECKED BY	RY
FILE NAME	DETAILS
DATE	8/15/00
SHEET	25
OF	X



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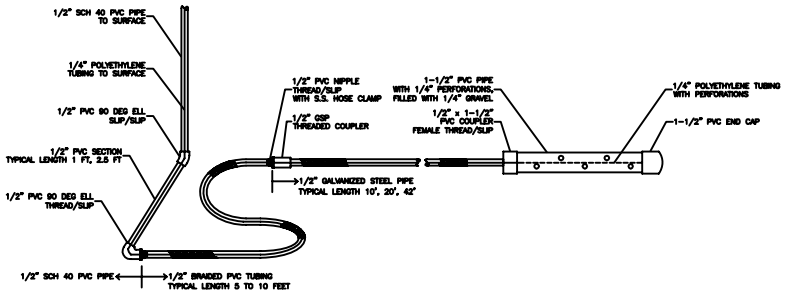

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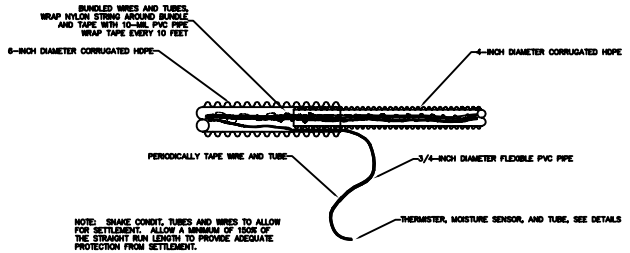

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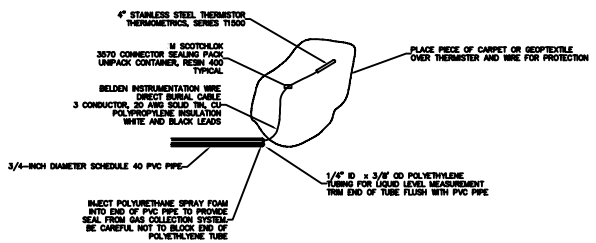


1/20 BASE THERMISTER AND PRESSURE TUBE
N.T.S

REDUCED DRAWING

AS-BUILT

NOTES

1.

2.

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

NO.	REVISIONS / DESCRIPTIONS	DATE	APPV

YOLO COUNTY
DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION
DIVISION OF INTEGRATED WASTE MANAGEMENT
600 A STREET, ROOM 150 DAVIS, CALIFORNIA

DIRECTOR OF PUBLIC WORKS

APPROVED _____ 19 ____ R. E. NO. _____

YOLO COUNTY CENTRAL LANDFILL
MODULE D, PHASE 1

MONITORING EQUIPMENT DETAILS

DRAWING NO. YCCL-1996-00

W.O. NO.	9299
F.B. NO.	T.MAR.DE.
DESIGN BY	JW
DRAWN BY	JDK
CHECKED BY	RY
FILE NAME	DETAILS
DATE	8/15/00
SHEET	26
OF	X

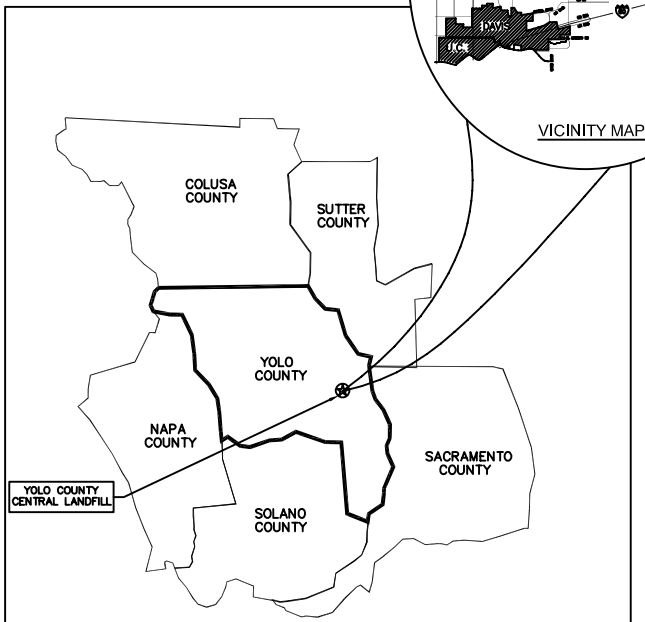
YOLO COUNTY CENTRAL LANDFILL
AEROBIC / ANAEROBIC BIOREACTOR SURFACE LINERS

PREPARED FOR :

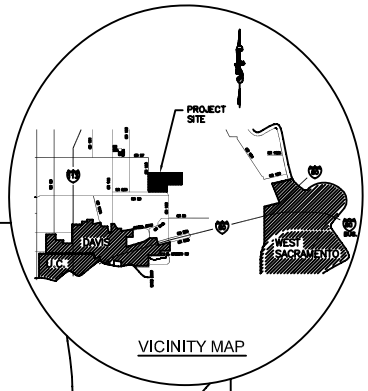
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT

STATE OF CALIFORNIA

INDEX OF DRAWINGS



REGIONAL MAP



VICINITY MAP

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/16/01	SUBMITTED FOR BID	PHD	TVH	TVH	TVH
1	06/20/01	ADDENDUM # 1	PHD	TVH	TVH	TVH
2	06/27/01	SUBMITTED FOR CONSTRUCTION	PHD	TVH	TVH	TVH

DATE OF ISSUE: 06/27/01
DESIGNED BY: TVH
DRAWN BY: PHD
CHECKED BY: TVH
APPROVED BY: TVH

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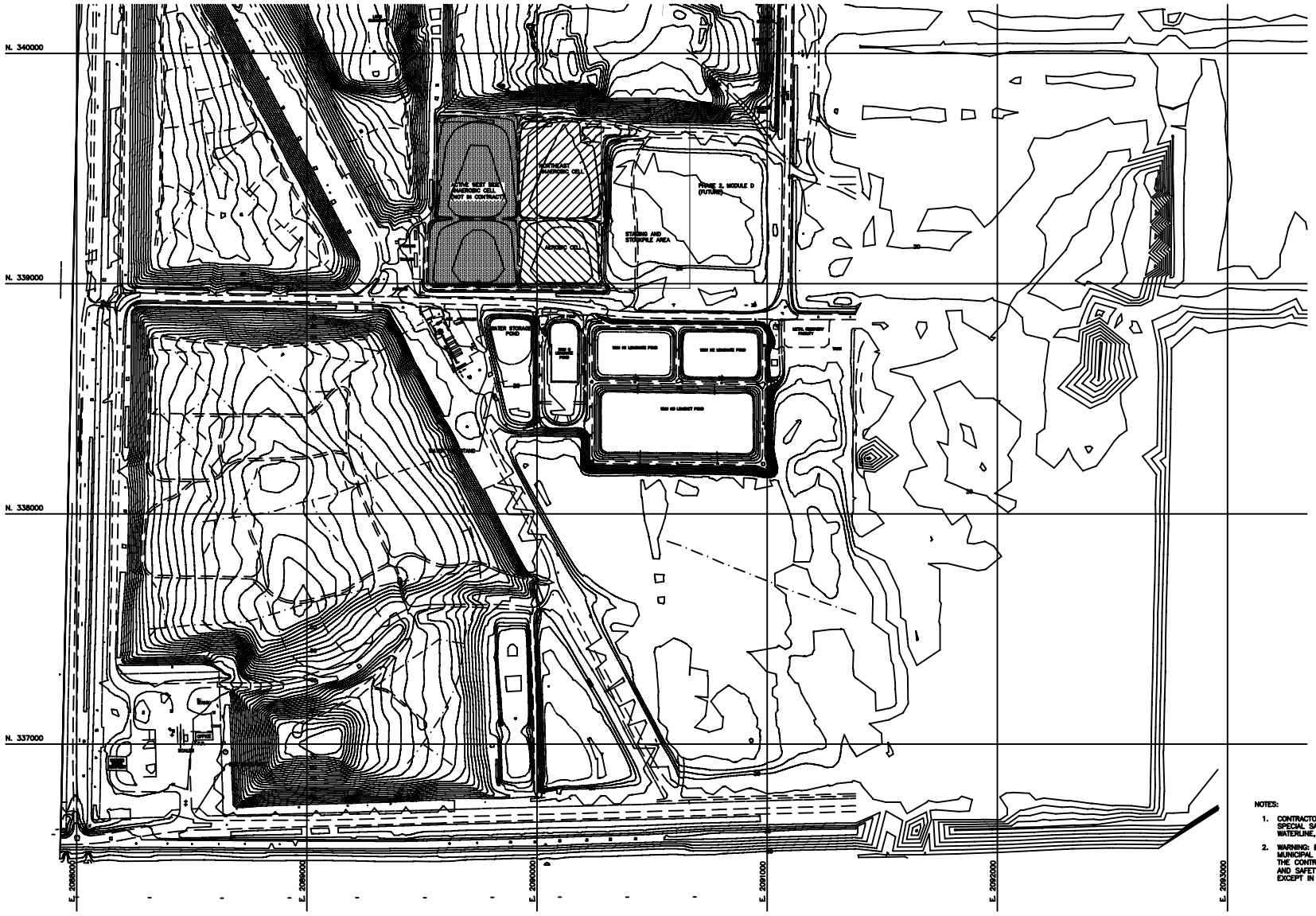
Grass Valley, CA • Santiago, Chile • Mendoza & Buenos Aires, Argentina • Lima, Peru • Manila, Philippines
12438 Loma Rica Drive, Ste. C, Grass Valley, CA 95945 (530) 272-2448 (530) 272-8533 fax

COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
500 WEST HERMAN STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR SURFACE LINERS

TITLE SHEET & LOCATION MAP

DRAWING NO. 01 OF 12
PROJECT NO. 931010.16



NOTES:

1. CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING AND PROTECTING ALL UTILITIES. SPECIAL SAFETY PRECAUTIONS TO BE TAKEN WHEN WORKING IN THE VICINITY OF GAS, WATERLINE, ELECTRICAL LINES, OR LEACHATE LINES.
2. WARNING: BECAUSE THE CONTRACTOR MAY BE WORKING IN AND AROUND DECOMPOSING MUNICIPAL SOLID WASTE, FLAMMABLE GASSES SUCH AS METHANE MAY BE PRESENT. THE CONTRACTOR SHALL TAKE SPECIAL PRECAUTIONS AS NECESSARY FOR THE HEALTH AND SAFETY OF HIS WORKERS. NO SMOKING SHALL BE ALLOWED ON THE LANDFILL SITE EXCEPT IN DESIGNATED AREAS AS DETERMINED BY THE OWNER.

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/18/96	SUBMITTED FOR BID	JVB	TVH	TVH	TVH
1	06/26/96	ADDENDUM #1	JVB	TVH	TVH	TVH
2	08/27/96	SUBMITTED FOR CONSTRUCTION	JVB	TVH	TVH	TVH

DATE OF ISSUE: 08/27/96
DESIGNED BY: TVH
DRAWN BY: JVB
CHECKED BY: TVH
APPROVED BY: TVH

VECTOR ENGINEERING, INC.
Grass Valley, CA • Santiago, Chile • Mendoza & Buenos Aires, Argentina • Lima, Peru • Manila, Philippines
12438 Loma Rica Drive, Ste. C, Grass Valley, CA 95945 (530) 272-2448 (530) 272-8533 fax

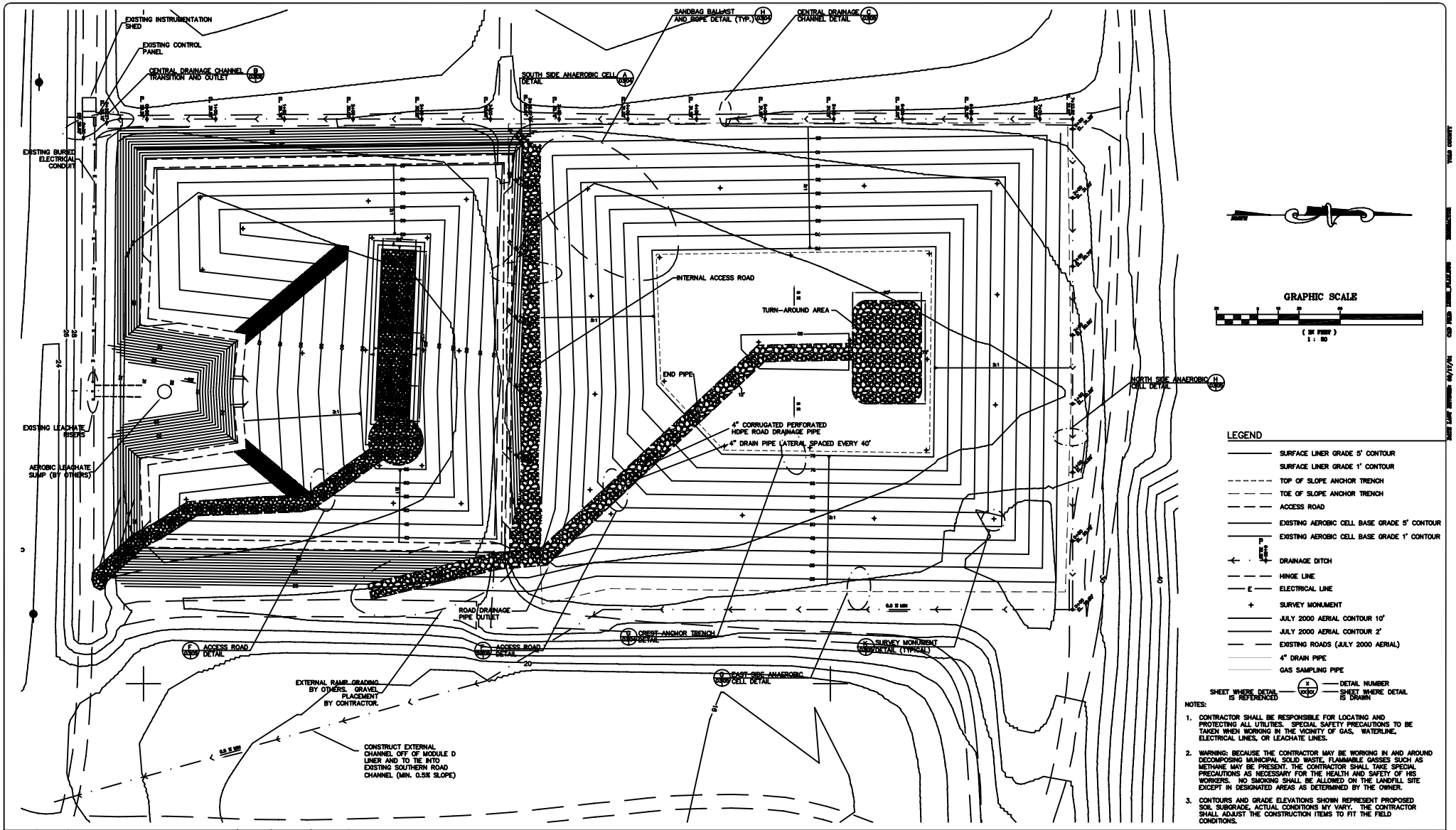
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 96 _____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS

FACILITIES LAYOUT

DRAWING NO. 02 OF 12
PROJECT NO. 931010.18



NOTES:

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3. CONTOURS AND GRADE ELEVATIONS SHOWN REPRESENT PROPOSED SOIL SUBGRADE, ACTUAL CONDITIONS MY VARY. THE CONTRACTOR SHALL ADJUST THE CONSTRUCTION ITEMS TO FIT THE FIELD CONDITIONS.

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/18/01	SUBMITTED FOR BID	JVE	TVE	TVE	TVE
1	06/20/01	ADDENDUM #1	JVE	TVE	TVE	TVE
2	06/27/01	SUBMITTED FOR CONSTRUCTION	JVE	TVE	TVE	TVE

DATE OF ISSUE 06/27/01
DESIGNED BY: TVE
DRAWN BY: JVE
CHECKED BY: TVE
APPROVED BY: TVE

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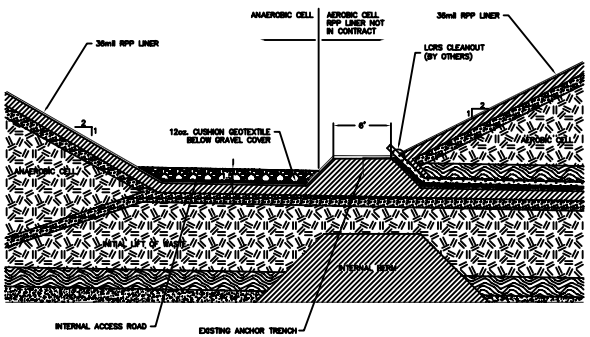
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 _____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL

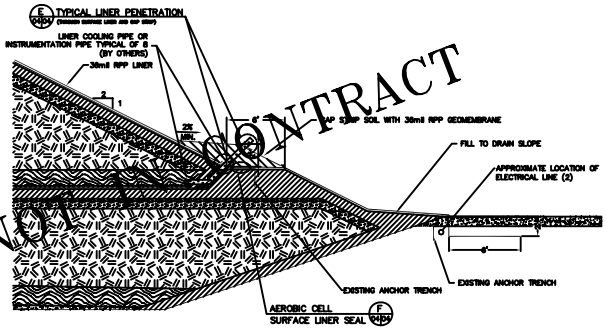
AEROBIC/ANAEROBIC BIOREACTOR SURFACE LINERS

SURFACE LINER PLAN

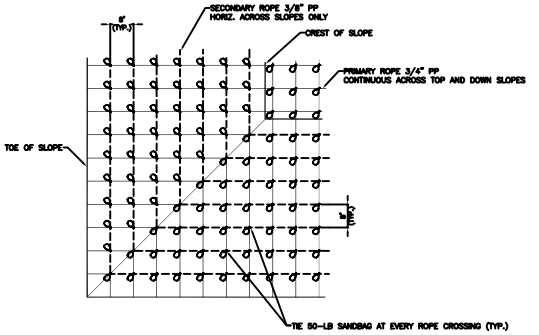
DRAWING NO. 03 OF 12
PROJECT NO. 931010.18



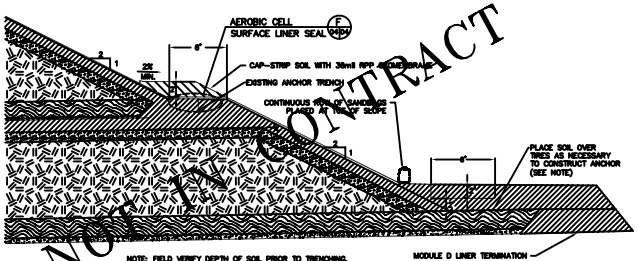
A 03|04 SOUTH SIDE ANAEROBIC CELL NTS



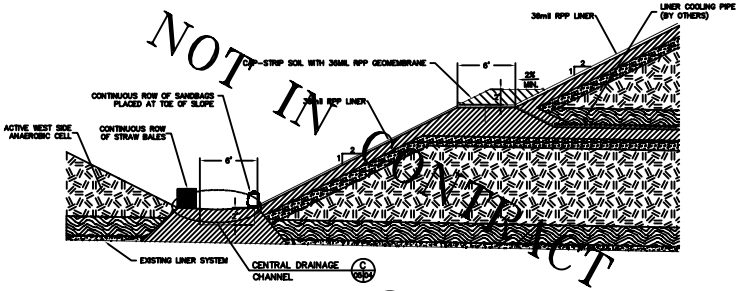
B 03|04 SOUTH SIDE AEROBIC CELL NTS



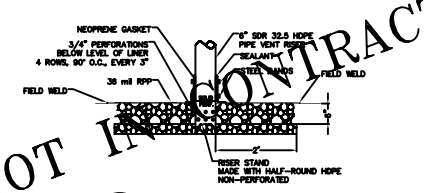
H 03|04 SANDBAG BALLAST AND ROPE LAYOUT (TYP.) NTS



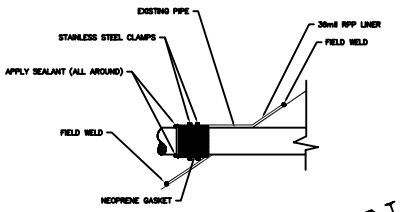
C 03|04 EAST SIDE AEROBIC CELL NTS



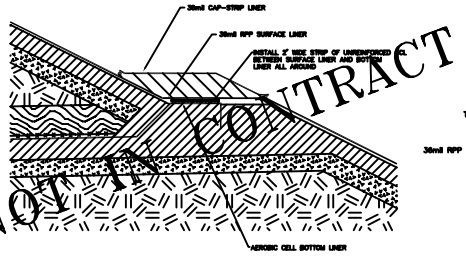
D 03|04 WEST SIDE AEROBIC CELL NTS



I 05|04 PIPE VENT BOOT NTS



E 04|04 TYPICAL LINER PENETRATION NTS



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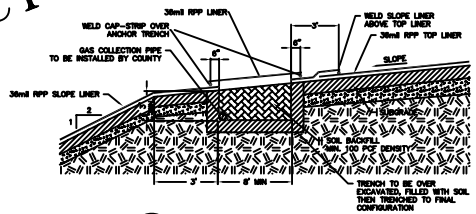
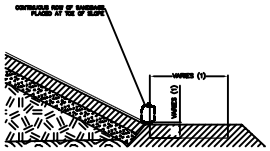


G 03|04 CREST ANCHOR TRENCH DETAIL NTS



J 08|04 SURFACE LINER TOE ANCHOR TRENCH (TYP.) NTS

SHEET WHERE DETAIL IS REFERENCED — X 00|00 — DETAIL NUMBER / SHEET WHERE DETAIL IS DRAWN

NOTES:

1. DEPTH AND WIDTH INCREASE BY ONE FOOT FOR ANAEROBIC CELL TO 3 FT. AND 7 FT., RESPECTIVELY.
2. CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING AND PROTECTING ALL UTILITIES. SPECIAL SAFETY PRECAUTIONS TO BE TAKEN WHEN WORKING IN THE VICINITY OF GAS, WATERLINE, ELECTRICAL LINES, OR LEACHATE LINES.
3. WARNING: BECAUSE THE CONTRACTOR MAY BE WORKING IN AND AROUND DECOMPOSING MUNICIPAL SOLID WASTE, FLAMMABLE GASES SUCH AS METHANE MAY BE PRESENT. THE CONTRACTOR SHALL TAKE SPECIAL PRECAUTIONS AS NECESSARY FOR THE HEALTH AND SAFETY OF HIS WORKERS. NO SMOKING SHALL BE ALLOWED ON THE LANDFILL SITE EXCEPT IN DESIGNATED AREAS AS DETERMINED BY THE OWNER.

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/26/01	SUBMITTED FOR BID	PEB	TYR	TYR	TYR
1	08/30/01	ADDENDUM #1	PEB	TYR	TYR	TYR
2	09/27/01	SUBMITTED FOR CONSTRUCTION	PEB	TYR	TYR	TYR

DATE OF ISSUE: 09/27/01
DESIGNED BY: TYR
DRAWN BY: PEB
CHECKED BY: TYR
APPROVED BY: TYR

VECTOR ENGINEERING, INC.
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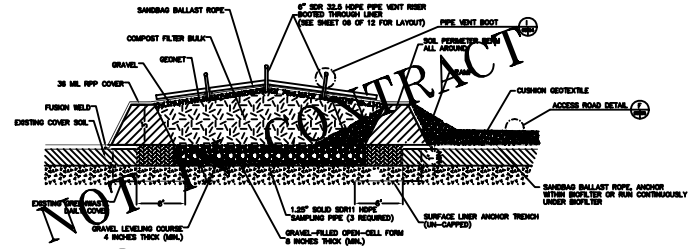
12438 Loma Rica Drive, Ste. C, Grass Valley, CA 95945 (530) 272-2448 (530) 272-8533 fax

COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 _____
R. E. NO.

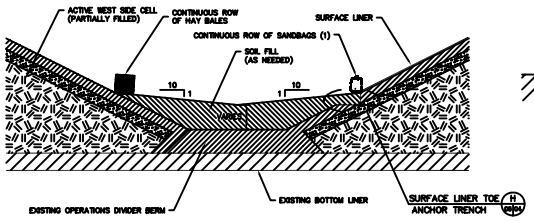
YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS

LINER DETAILS

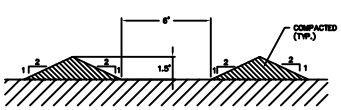
DRAWING NO.
04 OF 12
PROJECT NO.
931010.18



A 03 05 BIOFILTER DETAIL (EAST–WEST SECTION) NTS



C 03 05 C 05 05 CENTRAL DRAINAGE CHANNEL SECTION A – A' NTS



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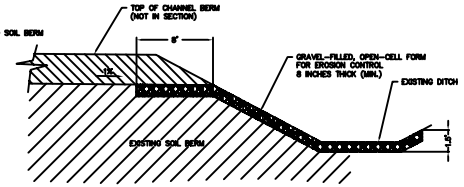
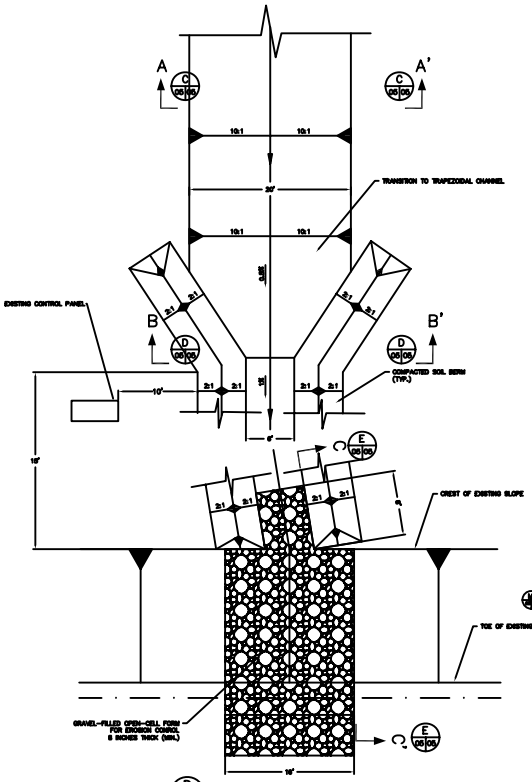
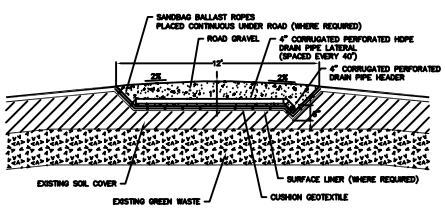


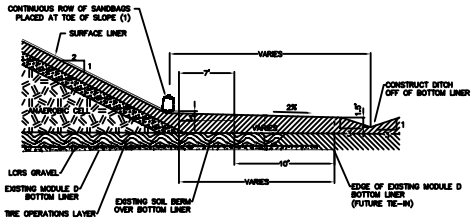
E 05 05 CENTRAL DRAINAGE CHANNEL SECTION C – C' NTS



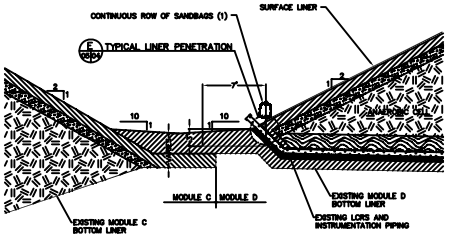
B 03 05 CENTRAL DRAINAGE CHANNEL TRANSITION AND OUTLET NTS



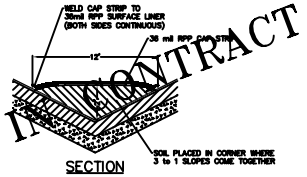
F 03 05 ACCESS ROAD DETAIL NTS



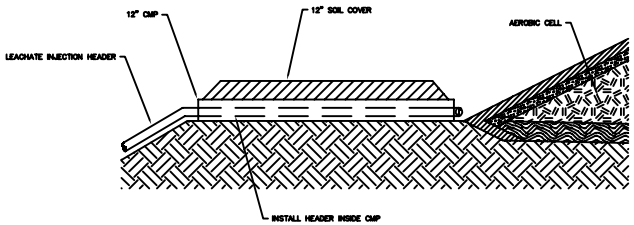
G 03 05 EAST SIDE ANAEROBIC CELL NTS

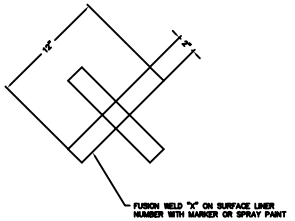


H 03 05 NORTH SIDE ANAEROBIC CELL NTS

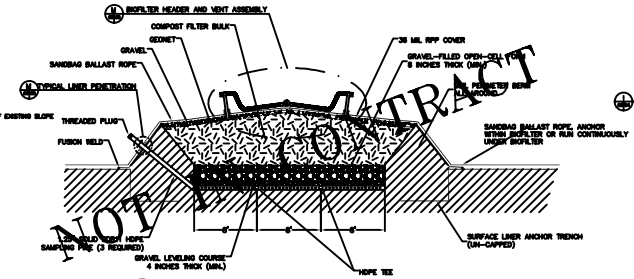


I 03 05 AEROBIC CELL SOUTH CORNER ANCHOR NTS

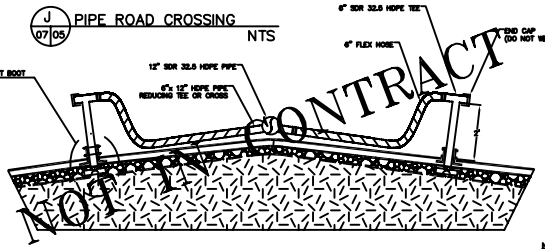




K 03 05 SURVEY MONUMENT NTS



L 05 05 BIOFILTER NORTH–SOUTH SECTION NTS



J 07 05 PIPE ROAD CROSSING NTS

M 08 05 M 05 05 BIOFILTER HEADER AND VENT ASSEMBLY NTS

SHEET WHERE DETAIL IS REFERENCED — x 00 00 — DETAIL NUMBER / SHEET WHERE DETAIL IS DRAWN

NOTES:
1. SAND BAGS TO BE PLACED SIDE-BY-SIDE ALONG THE TOE OF ALL SLOPES FOR ENERGY DISSIPATION FROM RUN-OFF. THESE SANDBAGS ARE IN ADDITION TO THE SURFACE LINER BALLAST SHOWN IN OTHER DETAILS.

NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/14/06	SUBMITTED FOR BID	PEB	TYR	TYR	TYR
1	06/30/06	ADDENDUM #1	PEB	TYR	TYR	TYR
2	08/17/06	SUBMITTED FOR CONSTRUCTION	PEB	TYR	TYR	TYR

DATE OF ISSUE: 08/17/06
DESIGNED BY: TYR
DRAWN BY:
CHECKED BY: TYR
APPROVED BY: TYR

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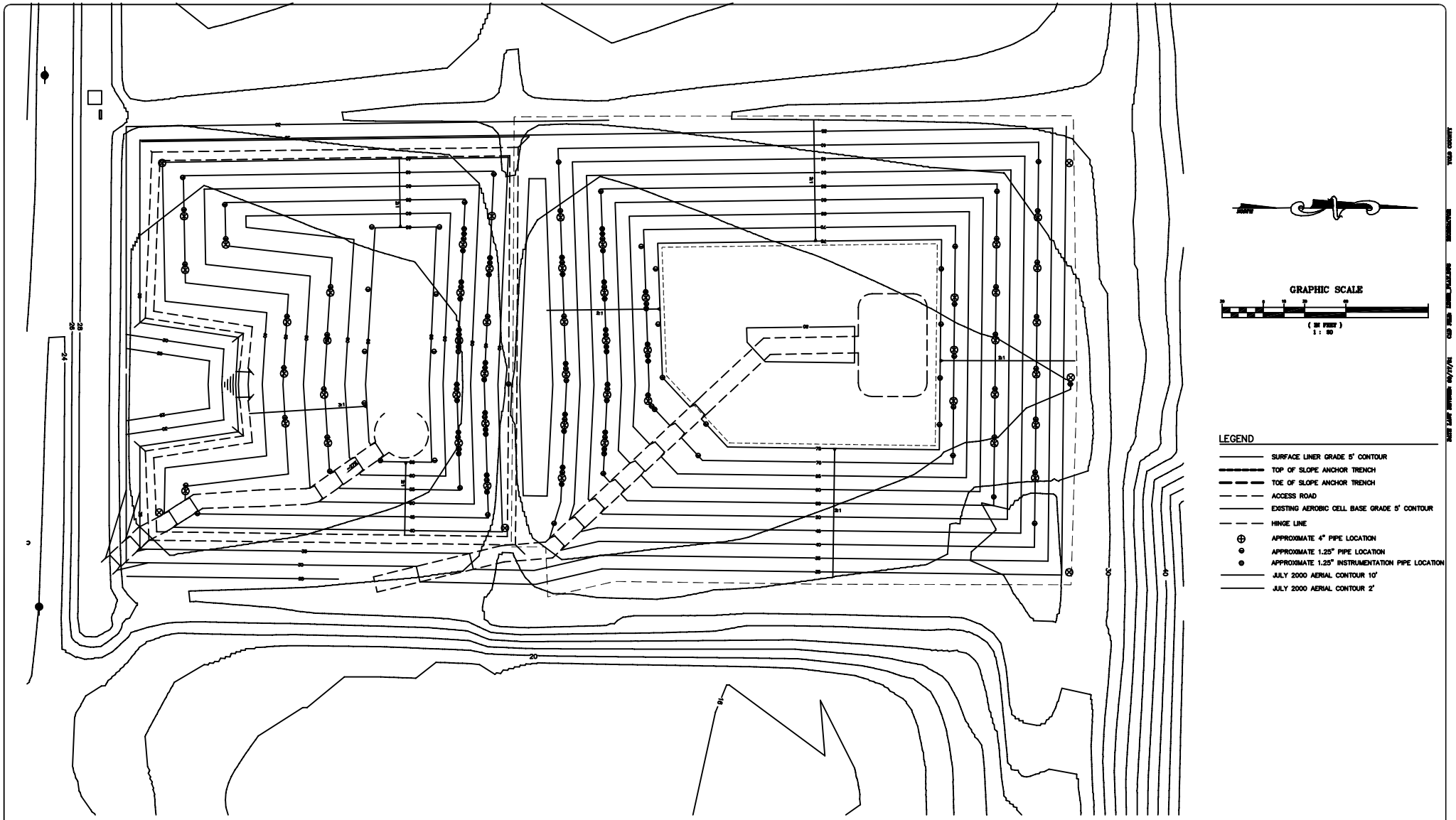
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 ____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS
DETAILS

DRAWING NO. 05 OF 12
PROJECT NO. 931010.18



REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/16/01	SUBMITTED FOR BID	JVE	TVE	TVE	TVE
1	06/30/01	ADDENDUM # 1	JVE	TVE	TVE	TVE
2	08/17/01	SUBMITTED FOR CONSTRUCTION	JVE	TVE	TVE	TVE

DATE OF ISSUE 08/17/01
DESIGNED BY: TVE
DRAWN BY: JVE
CHECKED BY: TVE
APPROVED BY: TVE

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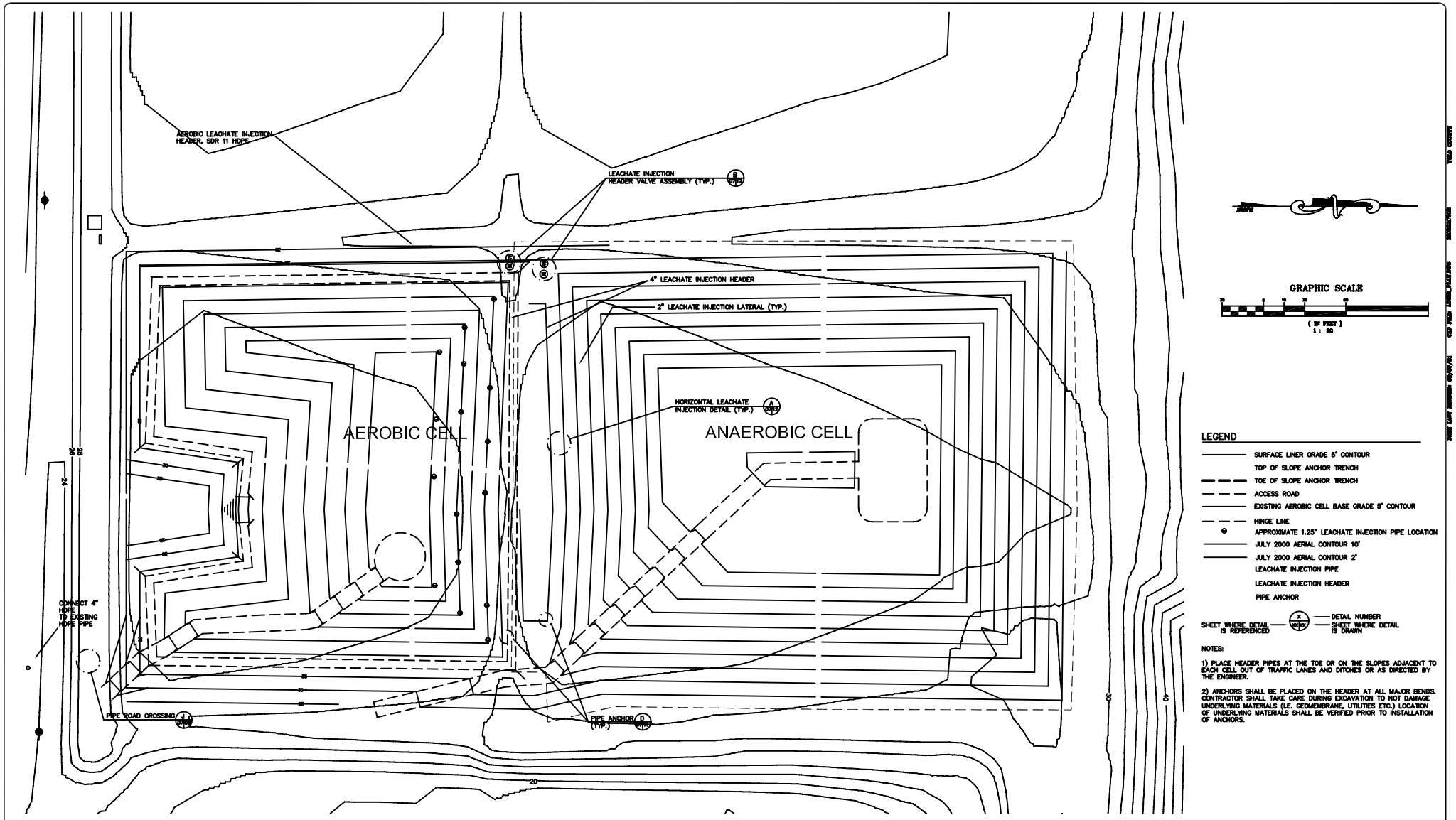
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 _____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS

PIPE PENETRATION LAYOUT

DRAWING NO.
06 OF 12
PROJECT NO.
931010.16



REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	08/30/01	ADDENDUM #1	JVB	TVB	TVB	TVB
1	09/07/01	SUBMITTED FOR CONSTRUCTION	JVB	TVB	TVB	TVB

DATE OF ISSUE: 09/07/01
DESIGNED BY: TVB
DRAWN BY: JVB
CHECKED BY: TVB
APPROVED BY: TVB

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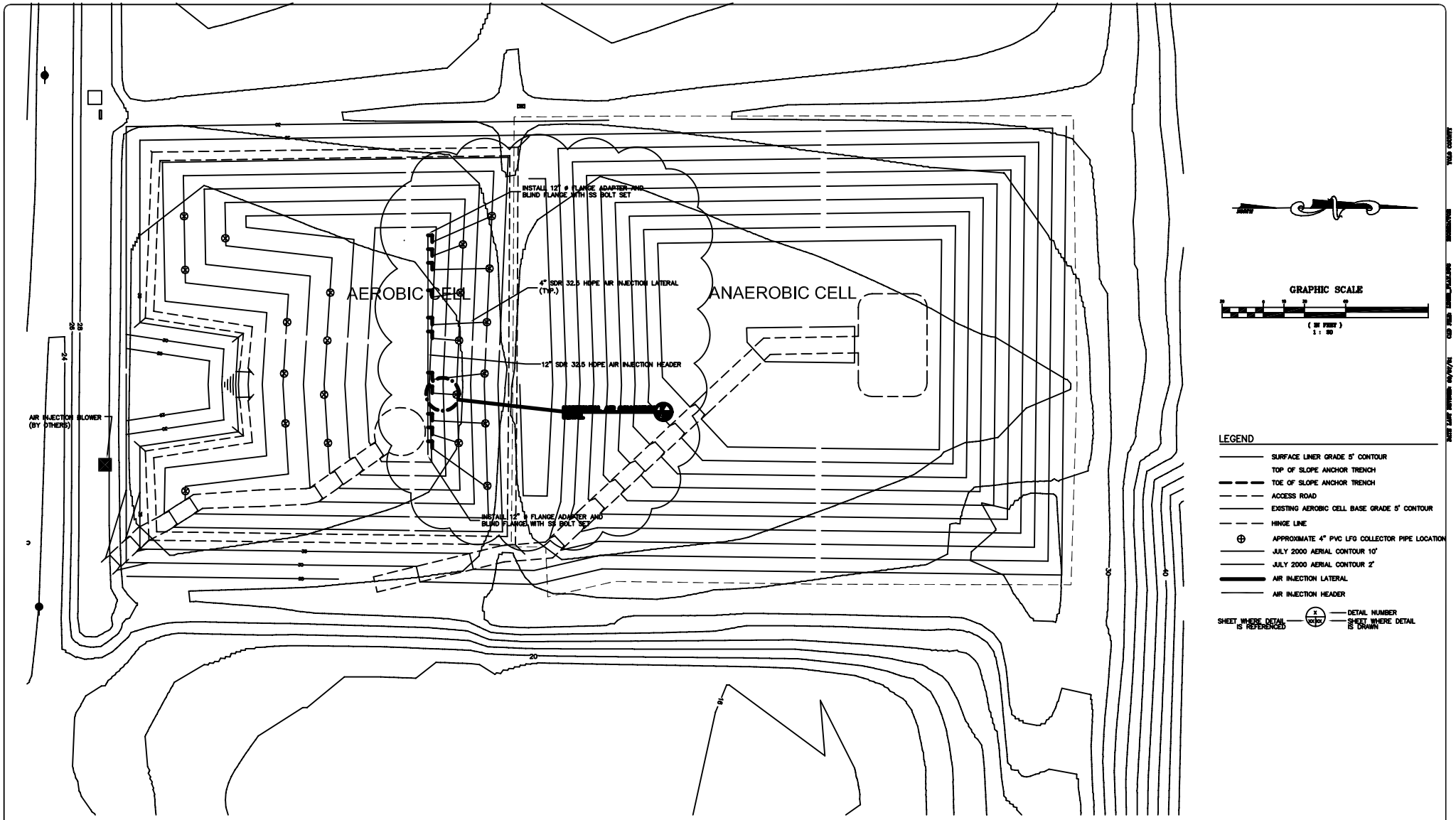
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS
LEACHATE INJECTION PIPE LAYOUT

DRAWING NO. 07 OF 12
PROJECT NO. 951010.16



REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/30/01	ADDENDUM # 1	JVS	TVH	TVH	TVH
1	08/07/01	SUBMITTED FOR CONSTRUCTION	JVS	TVH	TVH	TVH
2	9/13/01	REVISED PIPING LAYOUT	JSC	JSC	BH	BH

DATE OF ISSUE: 08/07/01
DESIGNED BY: TVH
DRAWN BY: TVH
CHECKED BY: TVH
APPROVED BY: TVH

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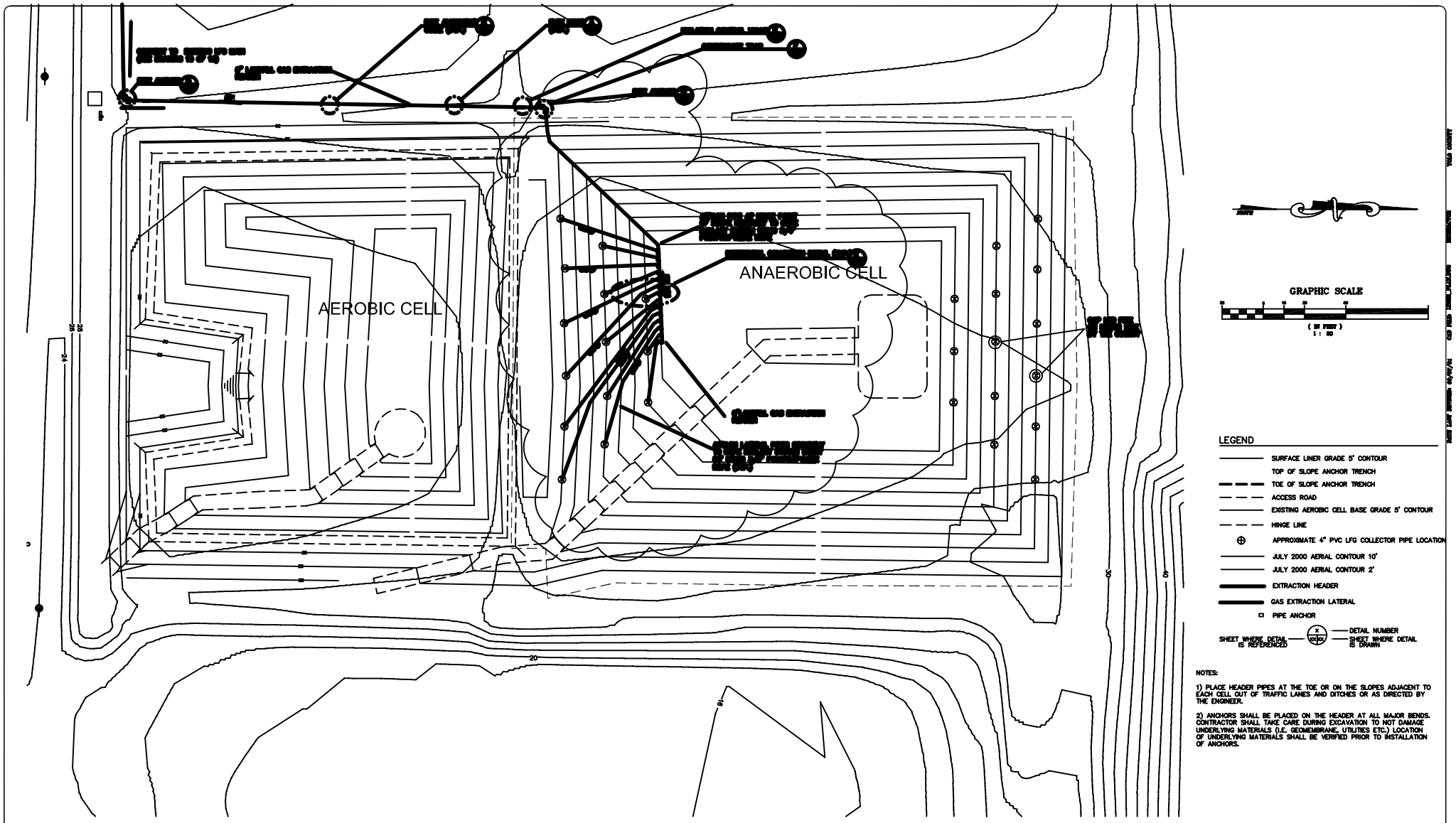
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS
AIR COLLECTION PIPE LAYOUT

DRAWING NO. 08 OF 12
PROJECT NO. 931010.18



NOTES:

1) PLACE HEADER PIPES AT THE TOE OR ON THE SLOPES ADJACENT TO EACH CELL OUT OF TRAFFIC LANES AND DITCHES OR AS DIRECTED BY THE ENGINEER.

2) ANCHORS SHALL BE PLACED ON THE HEADER AT ALL MAJOR BENDS. CONTRACTOR SHALL TAKE CARE DURING EXCAVATION TO NOT DAMAGE UNDERLYING MATERIALS (I.E. GEOMEMBRANE, UTILITIES ETC.) LOCATION OF UNDERLYING MATERIALS SHALL BE VERIFIED PRIOR TO INSTALLATION OF ANCHORS.

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/30/01	ADDENDUM #1	JVE	TYE	TYE	TYE
1	08/07/01	SUBMITTED FOR CONSTRUCTION	JVE	TYE	TYE	TYE
2	9/12/01	REVISED PIPING LAYOUT	JEE (YOLO)	JEE (YOLO)	JEE (YOLO)	JEE (YOLO)

DATE OF ISSUE: 09/07/01
DESIGNED BY: TYE
DRAWN BY: JVE
CHECKED BY: TYE
APPROVED BY: TYE

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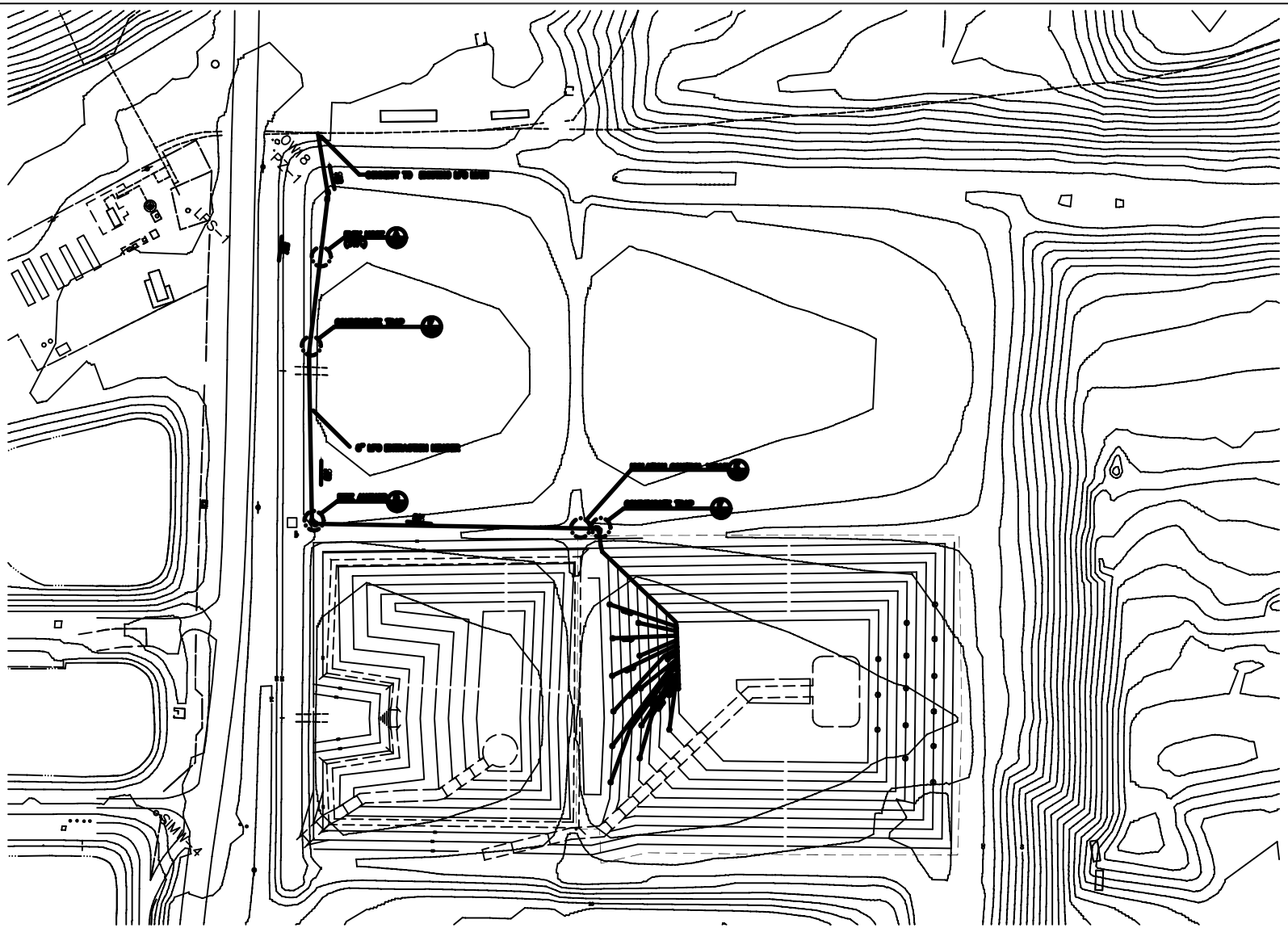
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS
LFG EXTRACTION PIPE LAYOUT

DRAWING NO. 09 OF 12
PROJECT NO. 931010.18



GRAPHIC SCALE

(IN FEET)
1 : 80'

LEGEND

- SURFACE LINER GRADE 5' CONTOUR
- TOP OF SLOPE ANCHOR TRENCH
- TOE OF SLOPE ANCHOR TRENCH
- ACCESS ROAD
- EXISTING AEROBIC CELL BASE GRADE 5' CONTOUR
- HINGE LINE
- APPROXIMATE 4" PVC LFG COLLECTOR PIPE LOCATION
- JULY 2000 AERIAL CONTOUR 10'
- JULY 2000 AERIAL CONTOUR 2'
- EXTRACTION HEADER
- PIPE ANCHOR

SHEET WHERE DETAIL IS REFERENCED — X / XX/XX — DETAIL NUMBER / SHEET WHERE DETAIL IS DRAWN

NOTES:

1) PLACE HEADER PIPES AT THE TOE OR ON THE SLOPES ADJACENT TO EACH CELL OUT OF TRAFFIC LANES AND DITCHES OR AS DIRECTED BY THE ENGINEER.

2) ANCHORS SHALL BE PLACED ON THE HEADER AT ALL MAJOR BENDS. CONTRACTOR SHALL TAKE CARE DURING EXCAVATION TO NOT DAMAGE UNDERLYING MATERIALS (I.E. GEOMEMBRANE, UTILITIES ETC.) LOCATION OF UNDERLYING MATERIALS SHALL BE VERIFIED PRIOR TO INSTALLATION OF ANCHORS.

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	08/30/01	ADDENDUM #1	JVB	TVB	TVB	TVB
1	09/07/01	SUBMITTED FOR CONSTRUCTION	JVB	TVB	TVB	TVB

DATE OF ISSUE: 08/07/01
DESIGNED BY: TVB
DRAWN BY: JVB
CHECKED BY: TVB
APPROVED BY: TVB

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PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

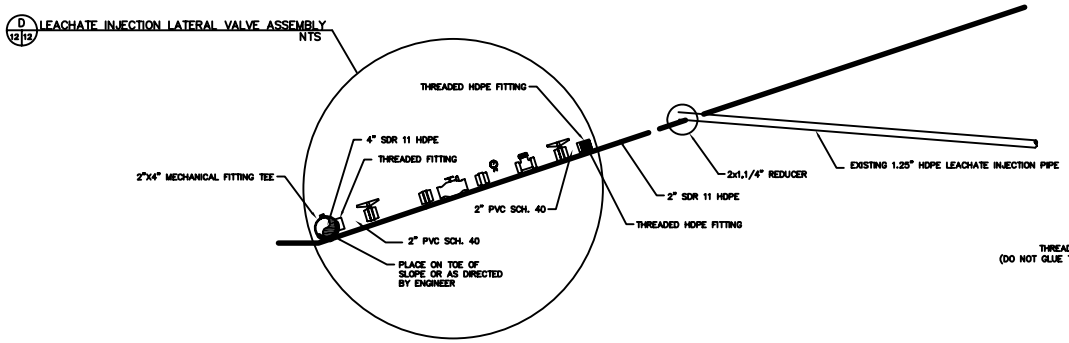
APPROVED _____ 20____ R. E. NO.

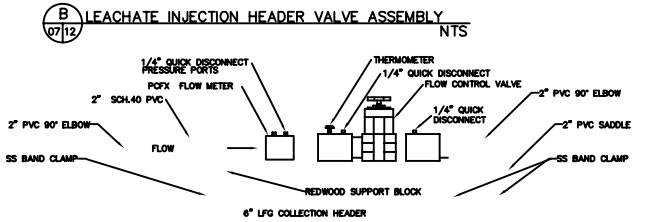
YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS

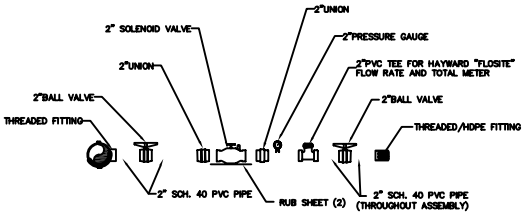
LFG EXTRACTION HEADER CONNECTION

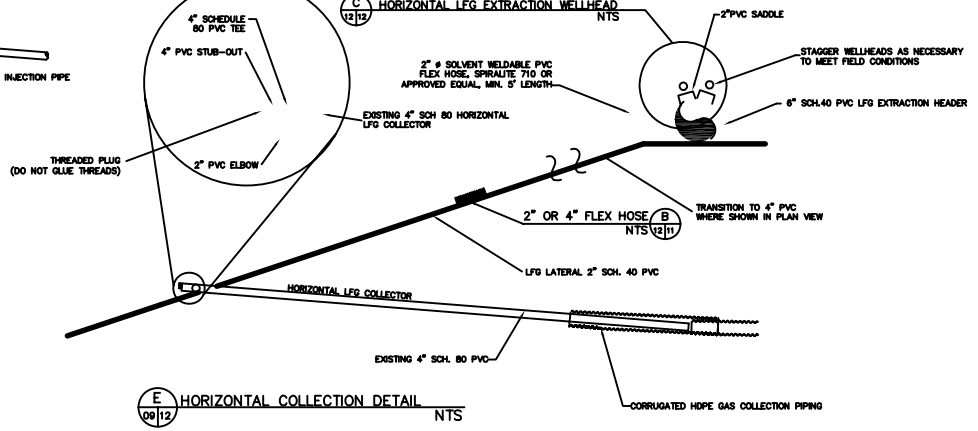
DRAWING NO.
10 OF 12

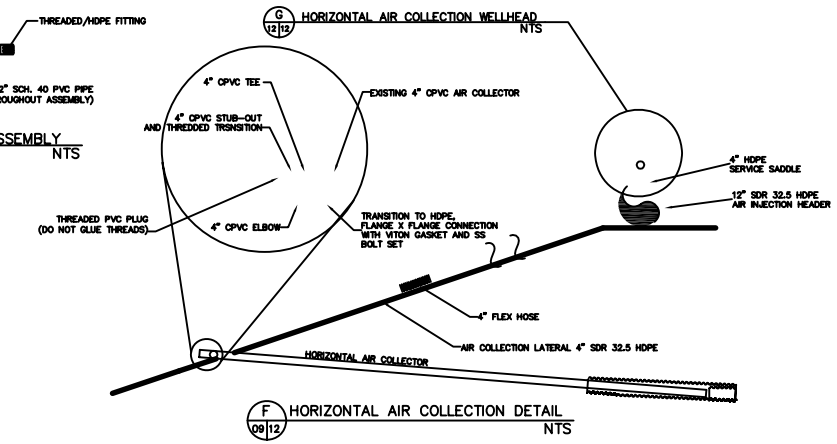
PROJECT NO.
931010.18

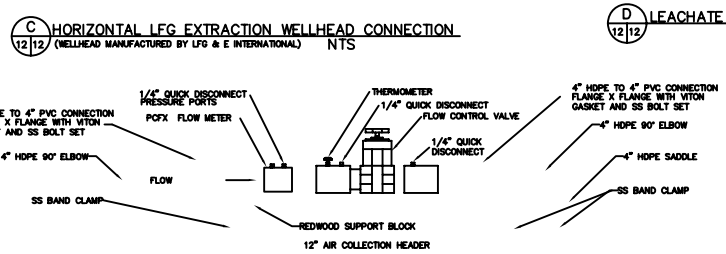












NOTES:
1. ANCHOR ALL PIPES TO SANDBAG BALLAST SYSTEM
2. PROTECT LINER BY PLACING GEOTEXTILE OR EXTRA GEOMEMBRANE AT ALL CONTACT POINTS WHERE DAMAGE MAY OCCUR AS DETERMINED BY THE ENGINEER.

SHEET WHERE DETAIL IS REFERENCED — x / xx/xx — DETAIL NUMBER / SHEET WHERE DETAIL IS DRAWN

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	06/30/04	ADDENDUM #1	JVE	TVE	TVE	TVE
1	08/24/04	SUBMITTED FOR CONSTRUCTION	JVE	TVE	TVE	TVE
2	8/25/04	REVISED WELLHEAD DETAILS	JBE (7/05)	JBE (7/05)	JBE (7/05)	JBE (7/05)

DATE OF ISSUE: 08/18/04
DESIGNED BY: TVE
DRAWN BY: JVE
CHECKED BY: TVE
APPROVED BY: TVE

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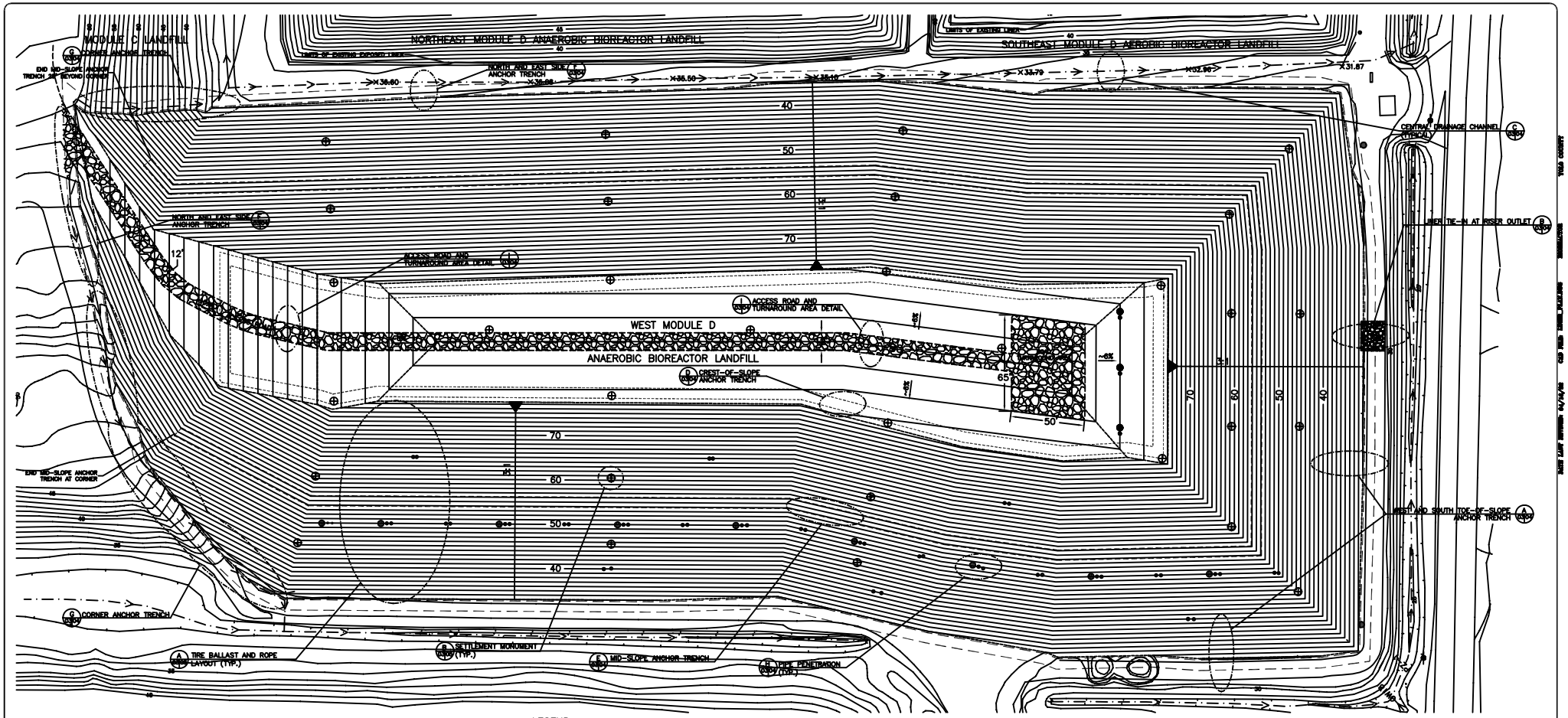
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 _____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
AEROBIC/ANAEROBIC BIOREACTOR
SURFACE LINERS
PIPE SYSTEM DETAILS

DRAWING NO. 12 OF 12
PROJECT NO. 931010.16



LEGEND

- SURFACE LINER GRADE 5' CONTOUR
- SURFACE LINER GRADE 1' CONTOUR
- CREST-OF-SLOPE ANCHOR TRENCH
- MID-SLOPE ANCHOR TRENCH
- TOE-OF-SLOPE ANCHOR TRENCH
- PROPOSED ROAD
- ×36.08 SPOT ELEVATION (CARTER-BURGESS, NOV. 30, 2001)
- DRAINAGE
- 4" PIPE PENETRATION
- 1.25" PIPE PENETRATION
- HINGE LINE
- SETTLEMENT MONUMENT
- JULY 2001 AERIAL CONTOUR 5'
- JULY 2001 AERIAL CONTOUR 1'
- EXISTING ROADS (JULY 2001 AERIAL)

SHEET WHERE DETAIL IS REFERENCED — (X) XX/XX — DETAIL NUMBER / SHEET WHERE DETAIL IS DRAWN

NOTES:

1. CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING AND PROTECTING ALL UTILITIES. SPECIAL SAFETY PRECAUTIONS TO BE TAKEN WHEN WORKING IN THE VICINITY OF GAS, WATERLINE, ELECTRICAL LINES, OR LEACHATE LINES.
2. WARNING: BECAUSE THE CONTRACTOR MAY BE WORKING IN AND AROUND DECOMPOSING MUNICIPAL SOLID WASTE, FLAMMABLE GASSES SUCH AS METHANE MAY BE PRESENT. THE CONTRACTOR SHALL TAKE SPECIAL PRECAUTIONS AS NECESSARY FOR THE HEALTH AND SAFETY OF HIS WORKERS. NO SMOKING SHALL BE ALLOWED ON THE LANDFILL SITE EXCEPT IN DESIGNATED AREAS AS DETERMINED BY THE OWNER.
3. CONTOURS AND GRADE ELEVATIONS SHOWN REPRESENT PROPOSED SOIL SUBGRADE. ACTUAL CONDITIONS MY VARY. THE CONTRACTOR SHALL ADJUST THE CONSTRUCTION ITEMS TO FIT THE FIELD CONDITIONS.
4. BASE TOPOGRAPHY PROVIDED BY CARTER-BURGESS, NOVEMBER 30, 2001 AND AERIAL PHOTO, JULY 2001.

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	04/10/02	ISSUED FOR BID AND CONSTRUCTION	BED	TYR	TYR	TYR

DATE OF ISSUE: 04/10/02
DESIGNED BY: TYR
DRAWN BY: BED
CHECKED BY: TYR
APPROVED BY: TYR

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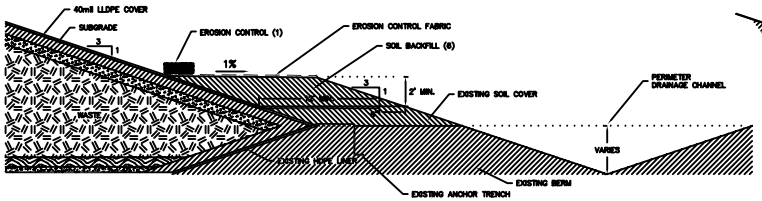
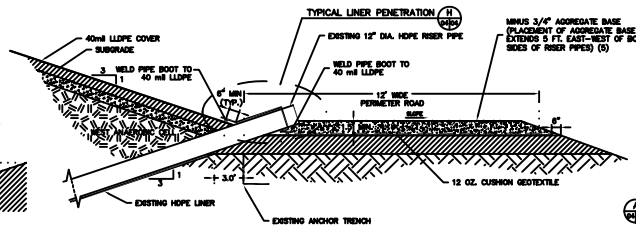
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 _____ R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
WEST MODULE D ANAEROBIC BIOREACTOR
SURFACE LINER
SURFACE LINER PLAN

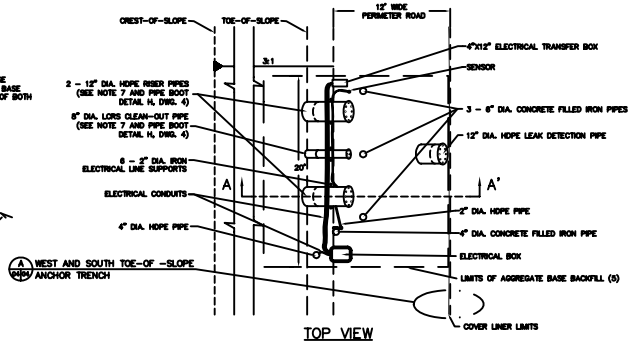
DRAWING NO. 03 OF 05
PROJECT NO. 931010.19



A/03/04 A/04/04 WEST AND SOUTH TOE-OF-SLOPE ANCHOR TRENCH NTS

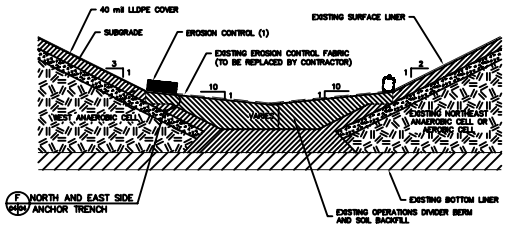


SECTION A-A'

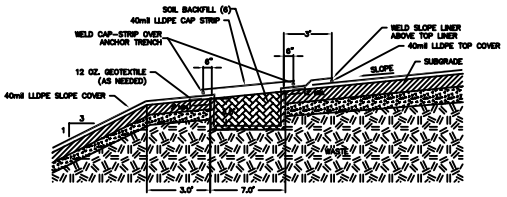


TOP VIEW

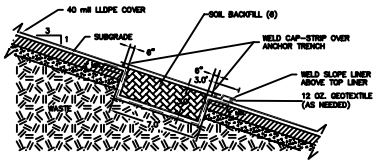
B/03/04 LINER TIE-IN AT RISER OUTLET NTS



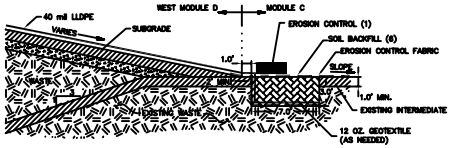
C/03/04 CENTRAL DRAINAGE CHANNEL (TYPICAL) NTS



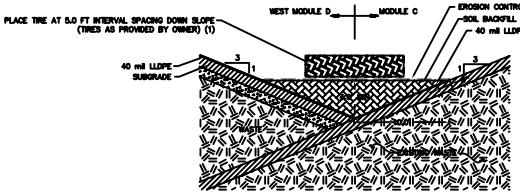
D/03/04 CREST-OF-SLOPE ANCHOR TRENCH (SEE NOTE 4) NTS



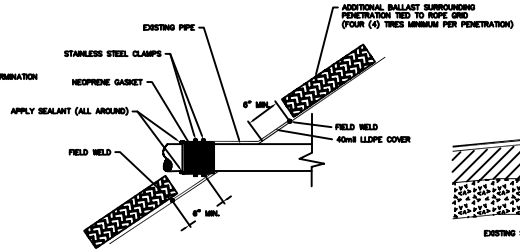
E/03/04 MID-SLOPE ANCHOR TRENCH (SEE NOTE 4) NTS



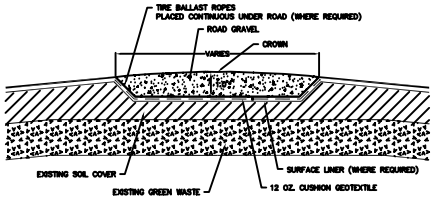
F/03/04 F/04/04 NORTH AND EAST SIDE ANCHOR TRENCH (SEE NOTE 4) NTS



G/03/04 CORNER ANCHOR TRENCH NTS



H/03/04 H/04/04 TYPICAL LINER PENETRATION NTS



I/03/04 ACCESS ROAD AND TURNAROUND AREA DETAIL NTS

NOTES:

1. TIRES TO BE PLACED SIDE-BY-SIDE ALONG THE TOE OF ALL SLOPES FOR ENERGY DISSIPATION FROM RUN-OFF. THESE TIRES ARE IN ADDITION TO THE SURFACE LINER BALLAST SHOWN IN OTHER DETAILS.
2. CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING AND PROTECTING ALL UTILITIES. SPECIAL SAFETY PRECAUTIONS TO BE TAKEN WHEN WORKING IN THE VICINITY OF GAS, WATERLINE, ELECTRICAL LINES, OR LEACHATE LINES.
3. WARNING: BECAUSE THE CONTRACTOR MAY BE WORKING IN AND AROUND DECOMPOSING MUNICIPAL SOLID WASTE, FLAMMABLE GASES SUCH AS METHANE MAY BE PRESENT. THE CONTRACTOR SHALL TAKE SPECIAL PRECAUTIONS AS NECESSARY FOR THE HEALTH AND SAFETY OF HIS WORKERS. NO SMOKING SHALL BE ALLOWED ON THE LANDFILL SITE EXCEPT IN DESIGNATED AREAS AS DETERMINED BY THE OWNER.
4. ANY WASTE THAT IS EXCAVATED SHALL BE REMOVED AND TRANSPORTED TO THE ACTIVE LANDFILL FACE IMMEDIATELY.
5. PLACE AGGREGATE BASE MATERIAL AROUND EXISTING PIPES AND ELECTRICAL CONDUITS IN ORDER TO MAINTIAN ACCESSABILITY FOR MAINTENANCE.
6. SOIL BACKFILL SHALL BE COMPACTED TO A RELATIVELY FIRM AND UNYIELDING CONDITION AND 100 PCF WET DENSITY.
7. INSTALL PIPE BOOTS AROUND RISER PIPES AND LCRS CLEAN-OUT ONLY. CUT GEOMEMBRANE PENETRATIONS FOR ALL OTHER APPURTENANCES SUCH THAT GEOMEMBRANE IS A TIGHT FIT. DO NOT PLACE BACKFILL AGAINST ELECTRICAL BOXES AND OTHER SENSITIVE DEVICES PER THE COUNTY'S DIRECTION.

SHEET WHERE DETAIL IS REFERENCED — xx/xx — DETAIL NUMBER / SHEET WHERE DETAIL IS DRAWN

NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	04/18/05	ISSUED FOR BID AND CONSTRUCTION	MED	TYR	TYR	TYR

DATE OF ISSUE: 04/18/05
DESIGNED BY: TYR
DRAWN BY: MED
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APPROVED BY: TYR

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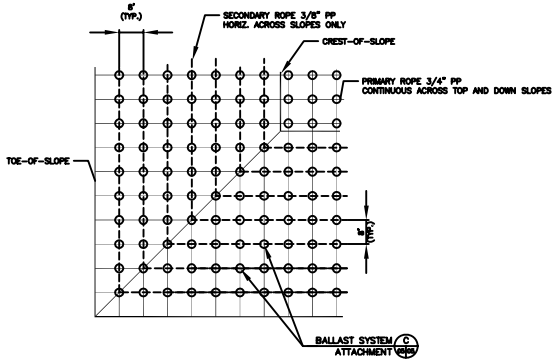
12438 Loma Rica Drive, Ste. C, Grass Valley, CA 95945 (530) 272-2448 (530) 272-8533 fax

COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 _____
R. E. NO.

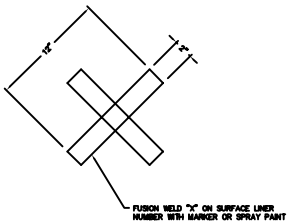
YOLO COUNTY CENTRAL LANDFILL
WEST MODULE D ANAEROBIC BIOREACTOR
SURFACE LINER

LINER DETAILS

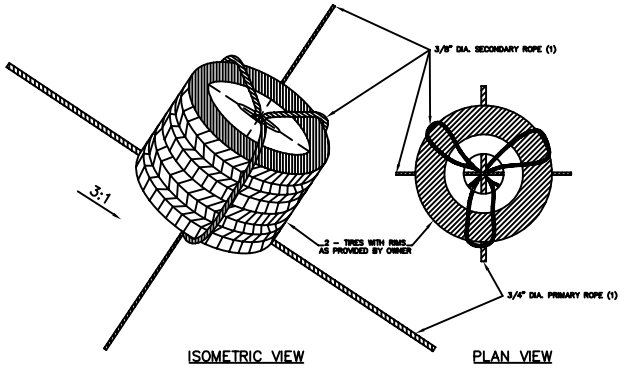
DRAWING NO. 04 OF 05
PROJECT NO. 931010.19



A 03 05 TIRE BALLAST AND ROPE LAYOUT (TYPICAL) NTS



B 03 05 SETTLEMENT MONUMENT (TYPICAL) NTS



C 03 05 BALLAST SYSTEM ATTACHMENT NTS

NOTES:

1. 3/8" DIA. SECONDARY ROPE FOR SIDE SLOPES ONLY; 3/4" DIA. PRIMARY ROPE FOR USE USE ON TOP DECK IN BOTH DIRECTIONS (SEE DETAIL A, SHEET 5 OF 5).

SHEET WHERE DETAIL IS REFERENCED — X 02 05 — DETAIL NUMBER / SHEET WHERE DETAIL IS DRAWN

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
0	04/10/02	ISSUED FOR BID AND CONSTRUCTION	BED	TYR	TYR	TYR

DATE OF ISSUE: 04/10/02
DESIGNED BY: TYR
DRAWN BY: BED
CHECKED BY: TYR
APPROVED BY: TYR

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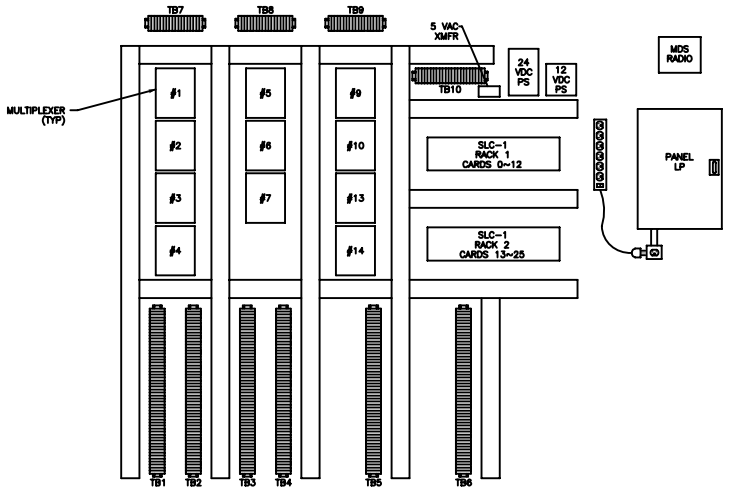
COUNTY OF YOLO
PLANNING & PUBLIC WORKS DEPARTMENT
292 WEST BEAMER STREET WOODLAND, CA 95695
ASSISTANT DIRECTOR OF PUBLIC WORKS
APPROVED _____ 20 _____
R. E. NO.

YOLO COUNTY CENTRAL LANDFILL
WEST MODULE D ANAEROBIC BIOREACTOR
SURFACE LINER

GENERAL DETAILS

DRAWING NO. 05 OF 05
PROJECT NO. 951010.19



SLC-1 WALL LAYOUT OVERVIEW

NOT TO SCALE

FILE: 0007JE02

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
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R. E. NO.

REGISTERED PROFESSIONAL ENGINEER
SHARON M. KINTZLER
NO. 15698
Exp. 9-30-2012
ELECTRICAL
STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

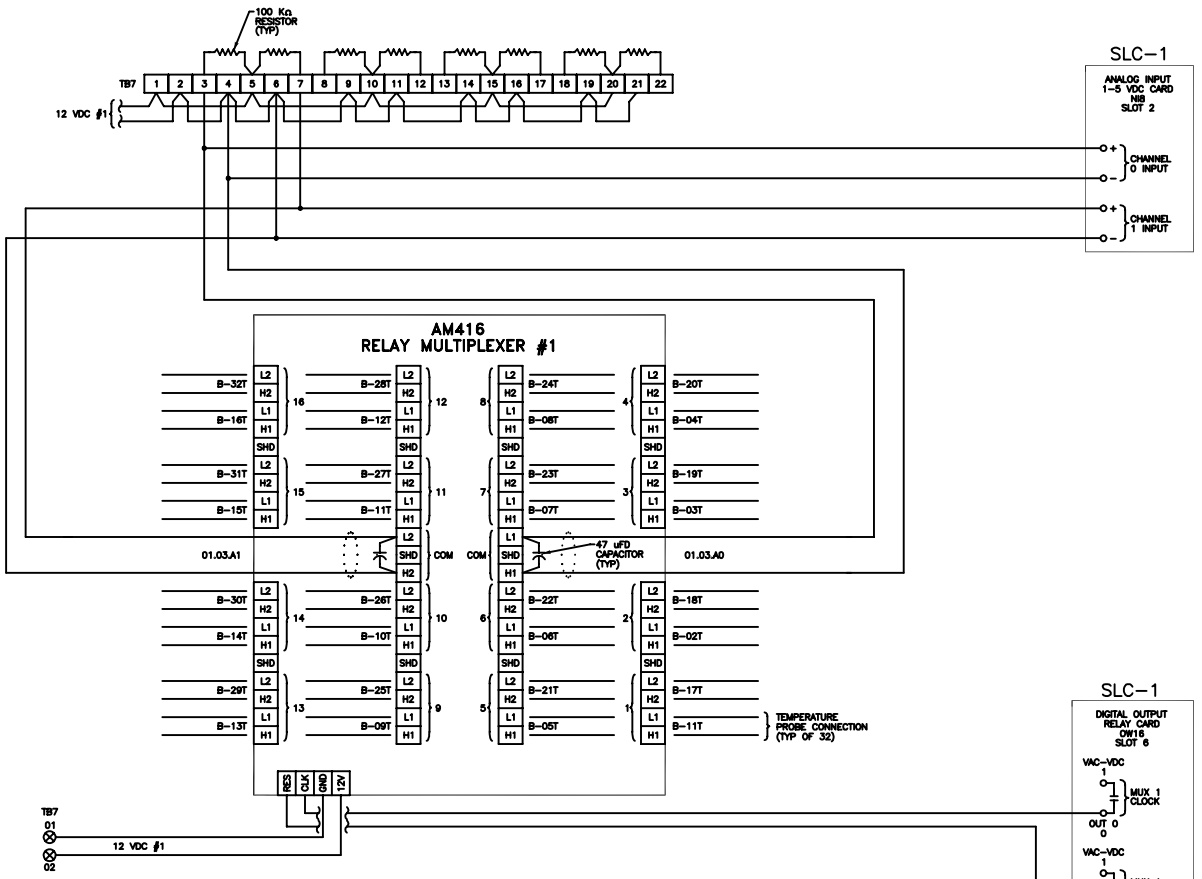
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 WALL LAYOUT OVERVIEW

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-8144

SHEET: 2 OF 24

DRAWING NO.	REV.
E2	0



MULTIPLEXER #1 WIRING DIAGRAM

FILE: 0007JE03

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
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292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS — APPROVED _____ 20 ____ — R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15698 Exp. 9-30-2005 ELECTRICAL STATE OF CALIFORNIA

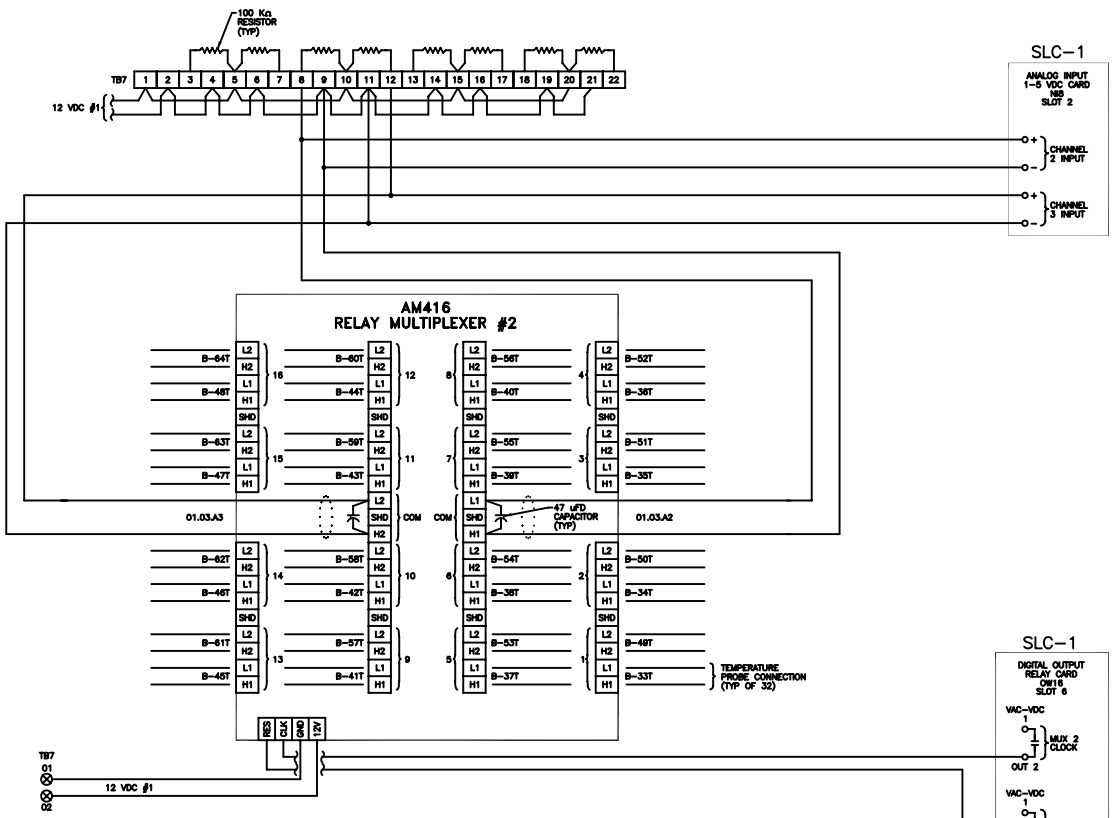
SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER #1 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5125 BROADWAY
SACRAMENTO, CA. 95817
916-457-8144

SHEET: 3 OF 24
DRAWING NO.: E3
REV.: 0



MULTIPLEXER #2 WIRING DIAGRAM

FILE: 0007JE03

REV.	DATE	DESCRIPTION	DSN BY	DWN BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
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292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

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R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SIMON M. KUNTZMAN NO. 15698 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER #2 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
2020 BROADWAY
SACRAMENTO, CA 95817
916-457-6144

SHEET: 4 OF 24

DRAWING NO.	REV.
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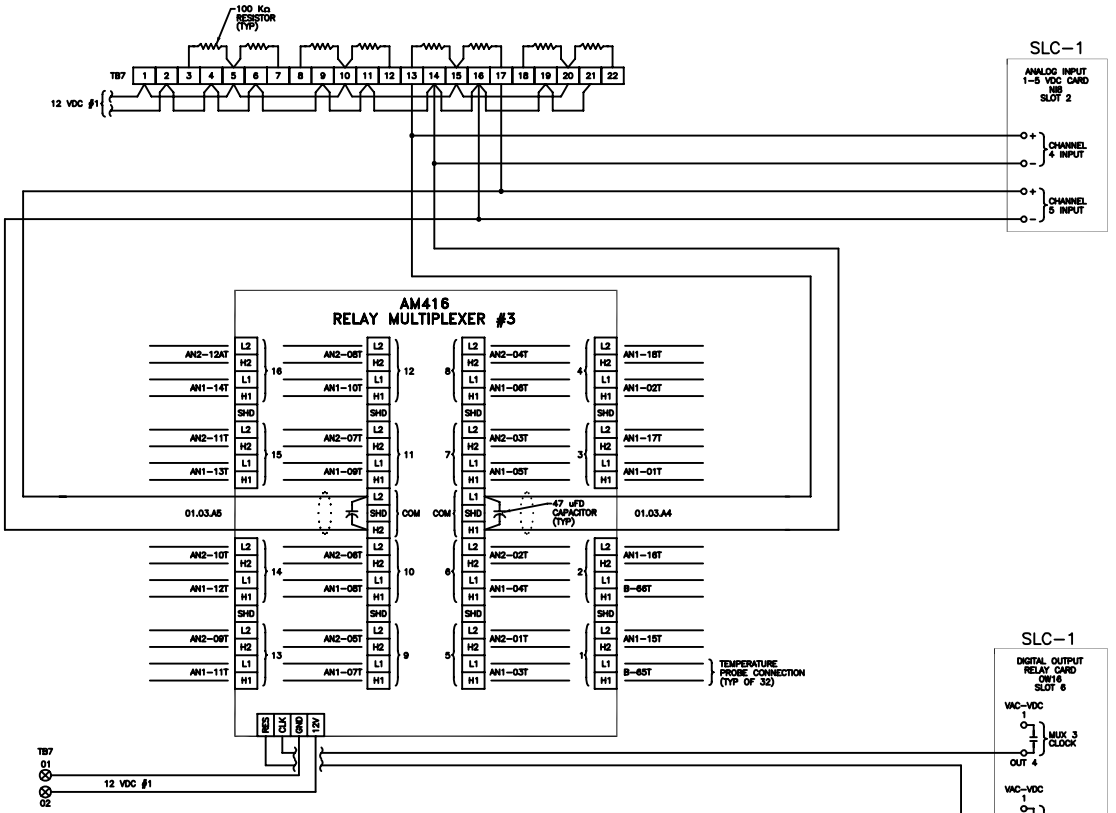

MULTIPLEXER #3 WIRING DIAGRAM

FILE: 0007JE03

REV.	DATE	DESCRIPTION	DSN BY	DRW BY

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SCALE: AS SHOWN	PROJECT NO.: -	TASK NO.: -

PROJECT: YOLO COUNTY EPA PROJECT XL
BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER #3 WIRING DIAGRAM

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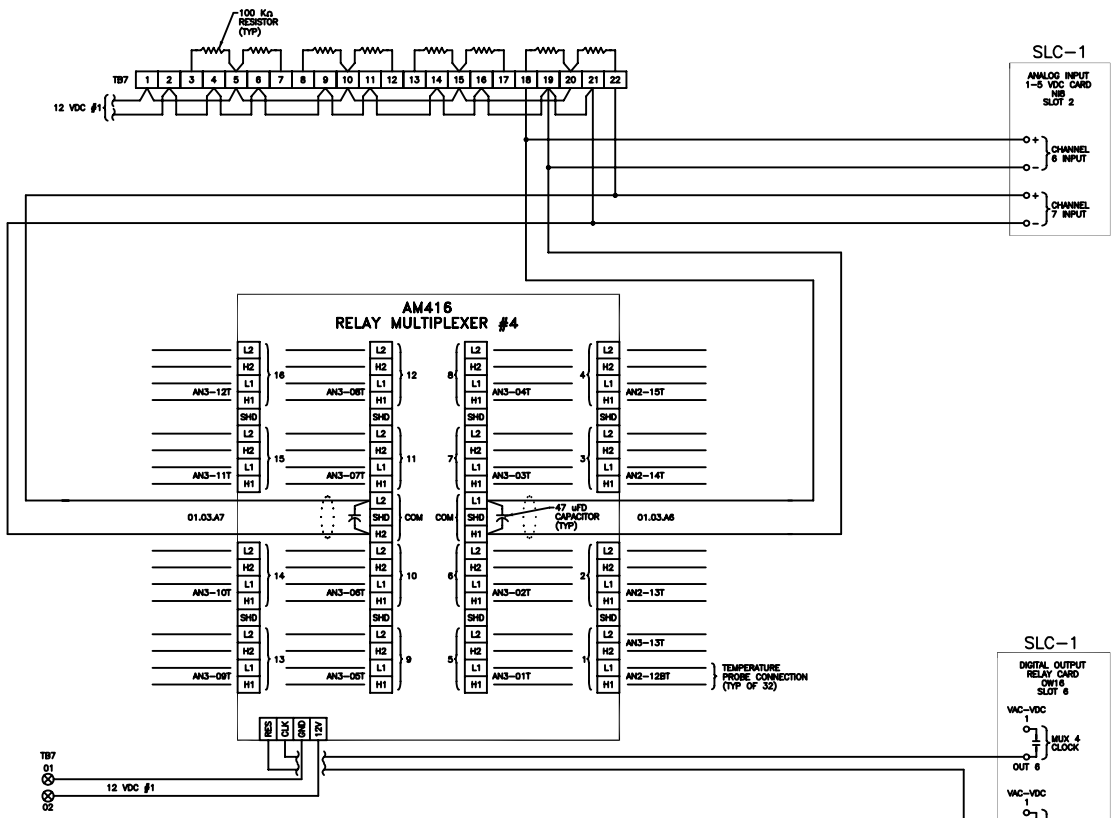
2020 BROADWAY
SACRAMENTO, CA 95817
916-457-6144

SHEET: 5 OF 24	
DRAWING NO.	REV.
E5	0



MULTIPLEXER #4 WIRING DIAGRAM

FILE: 0007JE03

REV.	DATE	DESCRIPTION	DSN BY	DWN BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
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292 West Beamer Street Woodland, California 95695

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REGISTERED PROFESSIONAL ENGINEER SIMON W. KWONG NO. 15698 Exp 3-31-2001 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: – | TASK NO.: –

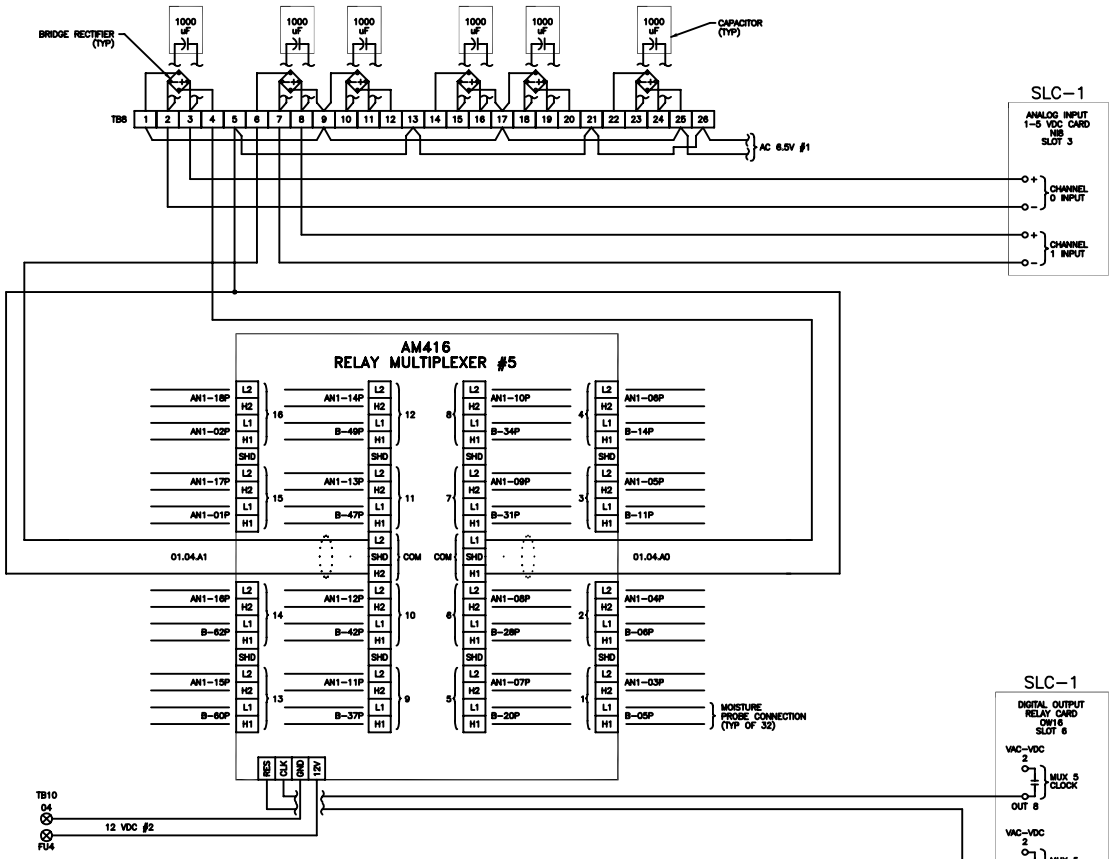
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER #4 WIRING DIAGRAM

SHN Consulting Engineers & Geologists
916-457-3144
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
2020 BROADWAY SACRAMENTO, CA 95817

SHEET: 6 OF 24

DRAWING NO.	REV.
E6	0



MULTIPLEXER #5 WIRING DIAGRAM

FILE: 0007JE03

REV.	DATE	DESCRIPTION	DSN BY	DWN BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
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292 West Beamer Street Woodland, California 95695

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REGISTERED PROFESSIONAL ENGINEER SIMON M. KWONG NO. 15698 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

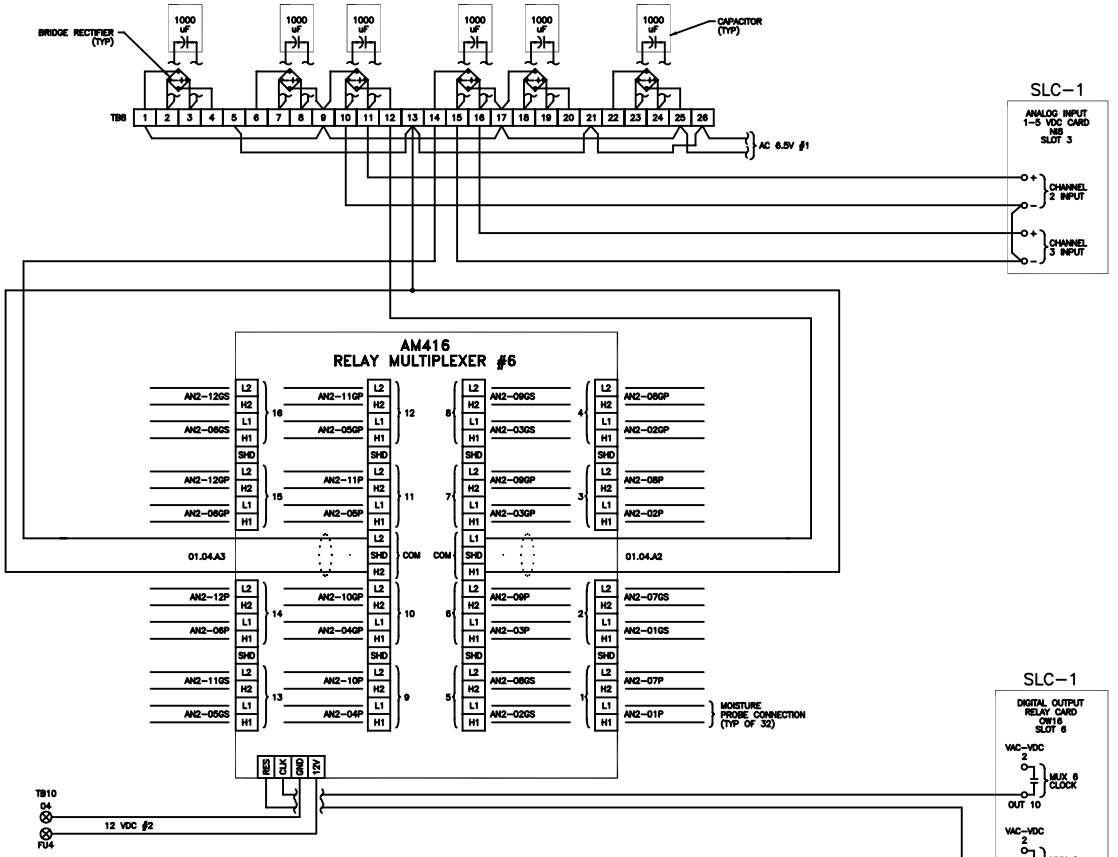
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: MOISTURE MULTIPLEXER #5 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
2020 BROADWAY SACRAMENTO, CA 95817
916-457-0144

SHEET: 7 OF 24

DRAWING NO.	REV.
E7	0



MULTIPLEXER #6 WIRING DIAGRAM

FILE: 0007JE08

REV.	DATE	DESCRIPTION	DSN BY	DRW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
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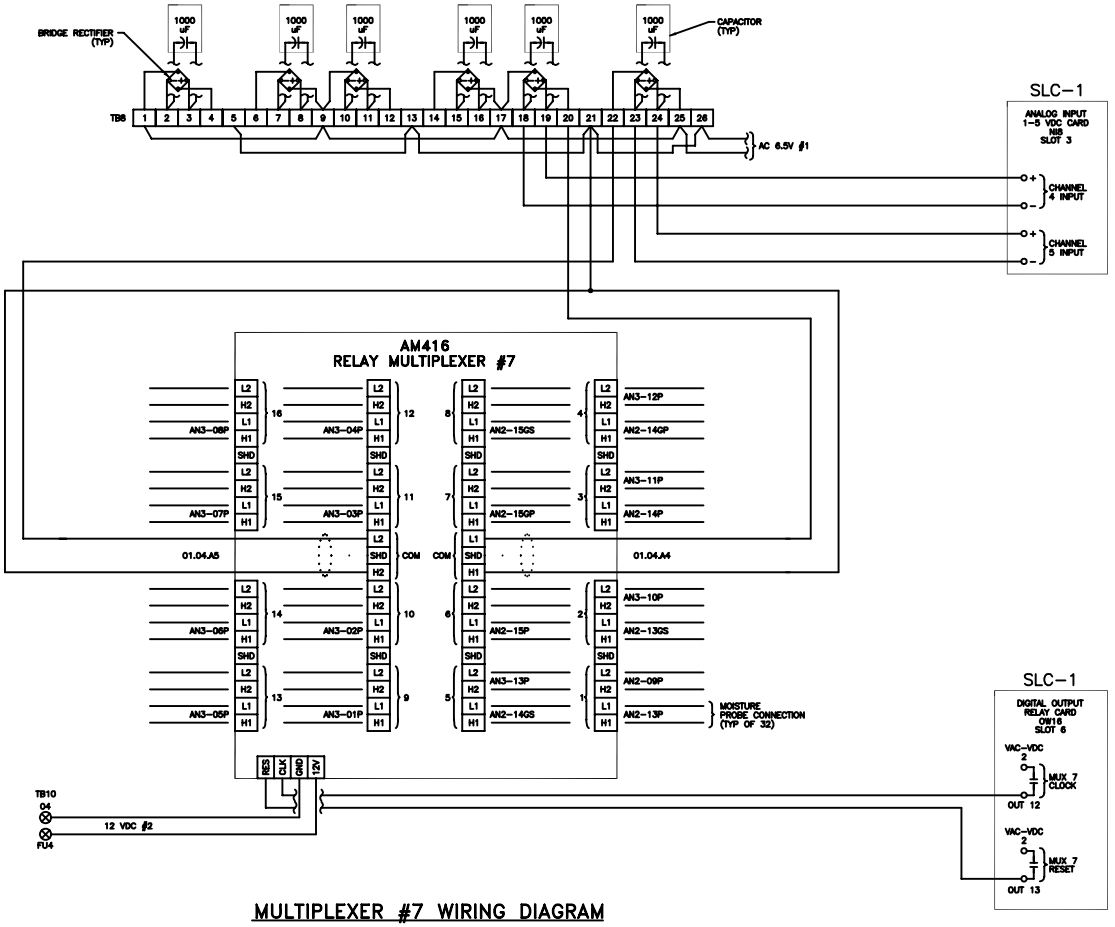
REGISTERED PROFESSIONAL ENGINEER SIMON M. KWONG ELECTRICAL STATE OF CALIFORNIA NO. 15698 Exp 3-31-2001

SCALE: AS SHOWN	PROJECT NO.: -	TASK NO.: -	
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR			
SHEET TITLE: MOISTURE MULTIPLEXER #6 WIRING DIAGRAM			
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT 2020 BROADWAY SACRAMENTO, CA 95817 916-457-6144		SHEET: 8 OF 24	
		DRAWING NO. E8	REV. 0



MULTIPLEXER #7 WIRING DIAGRAM

FILE: 0007JE09

REV.	DATE	DESCRIPTION	DSN BY	DWN BY

YOLO COUNTY
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292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

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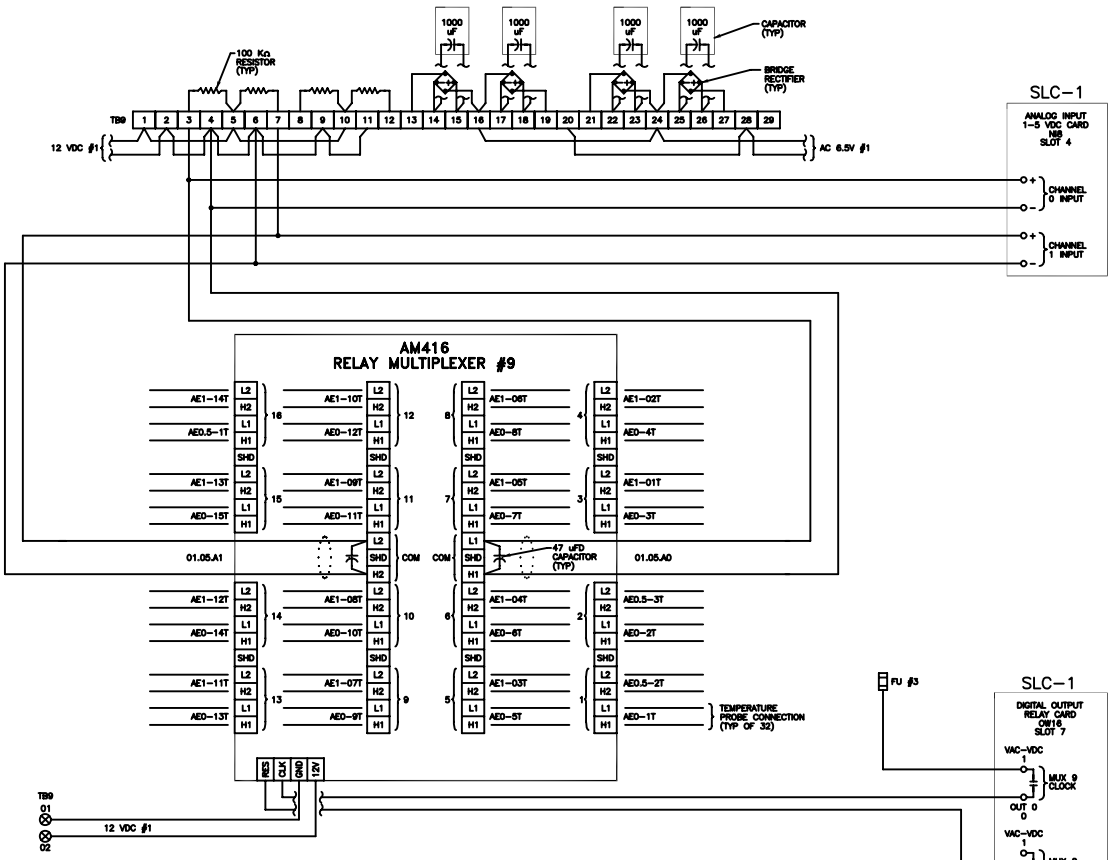
R. E. NO. _____

REGISTERED PROFESSIONAL ENGINEER SIMON M. KUNTZMAN NO. 15698 Exp 3-31-2001 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN	PROJECT NO.: -	TASK NO.: -	
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR			
SHEET TITLE: MOISTURE MULTIPLEXER #7 WIRING DIAGRAM			
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT 2020 BROADWAY SACRAMENTO, CA 95817 916-457-0144		SHEET: 9 OF 24 DRAWING NO.: E9	REV.: 0



MULTIPLEXER #9 WIRING DIAGRAM

FILE: 0007JE10

REV.	DATE	DESCRIPTION	DSN BY	DRW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

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REGISTERED PROFESSIONAL ENGINEER SIMON M. KWONG NO. 15698 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

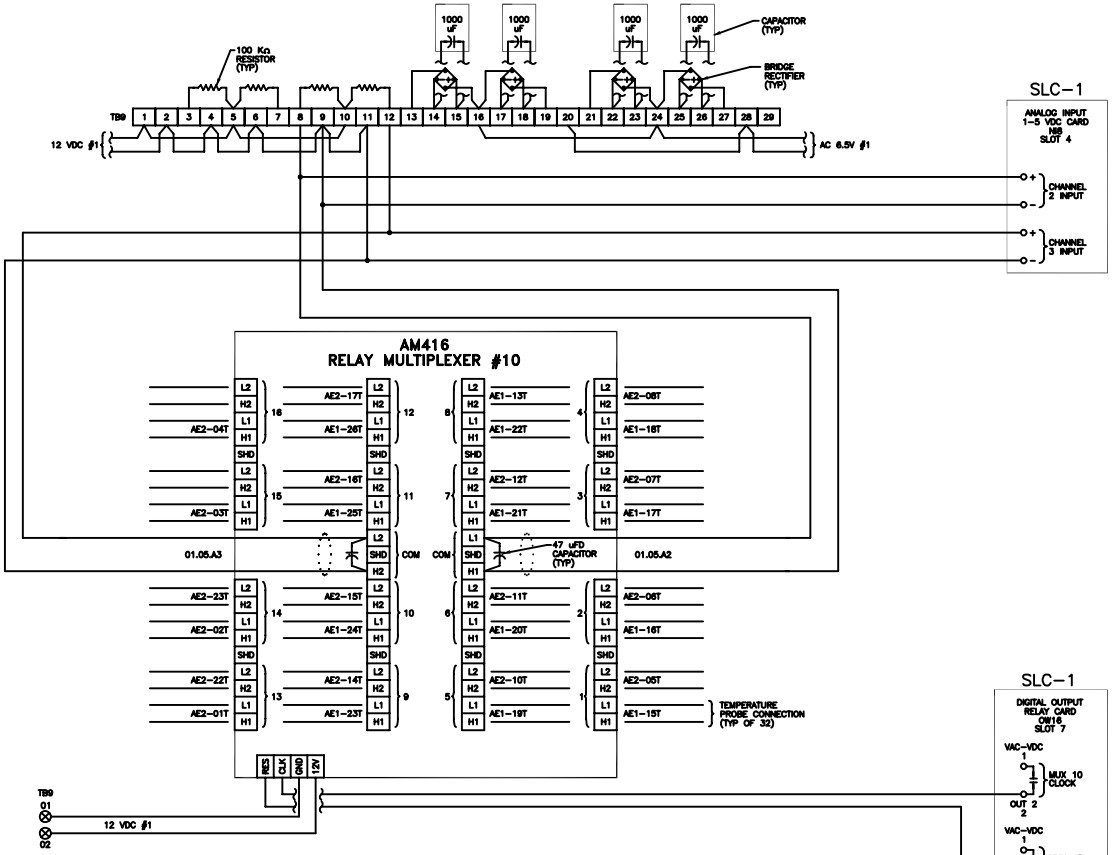
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER #9 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
2022 BROADWAY
SACRAMENTO, CA 95817
916-457-0144

SHEET: 10 OF 24

DRAWING NO.	REV.
E10	0



MULTIPLEXER #10 WIRING DIAGRAM

FILE: 0007JE10

REV.	DATE	DESCRIPTION	DSN BY	DWN BY

YOLO COUNTY
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DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SIMON M. KWONG NO. 15698 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

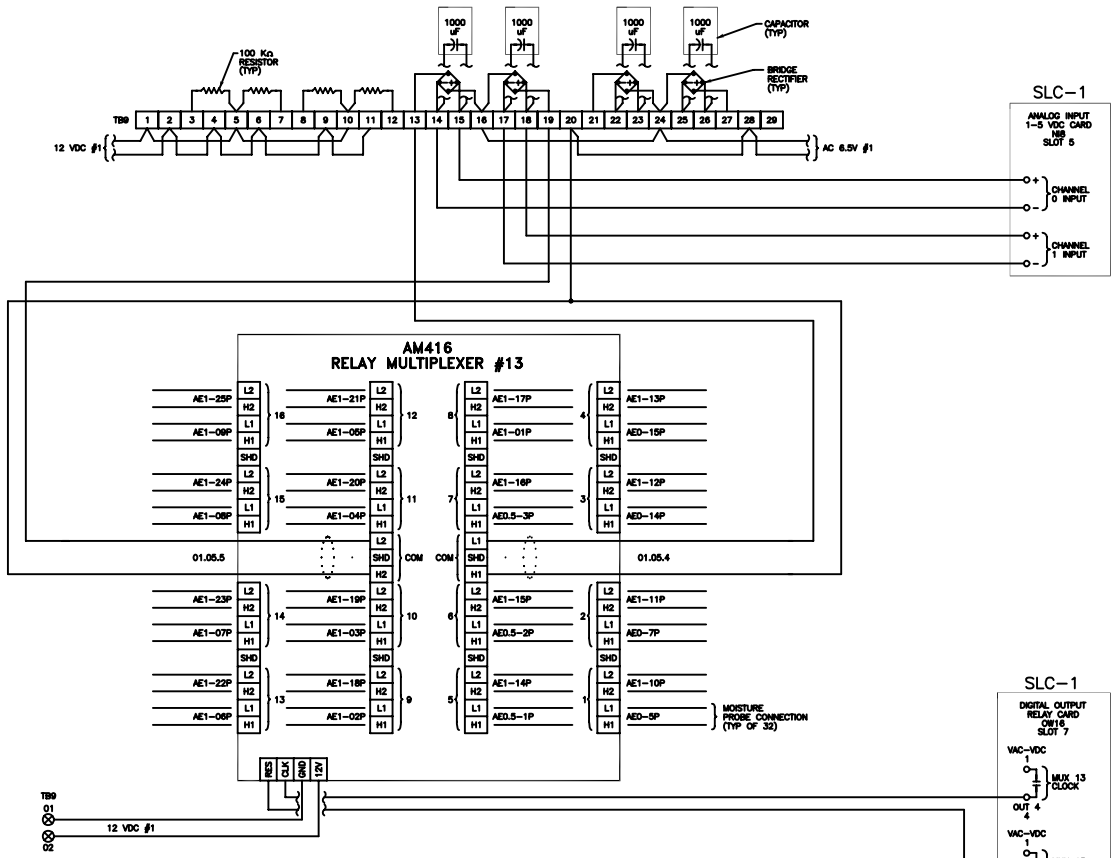
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER #10 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
2020 BROADWAY SACRAMENTO, CA 95817
916-457-0144

SHEET: 11 OF 24

DRAWING NO.	REV.
E11	0



MULTIPLEXER #13 WIRING DIAGRAM

FILE: 0007JE12

REV.	DATE	DESCRIPTION	DSN BY	DWN BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

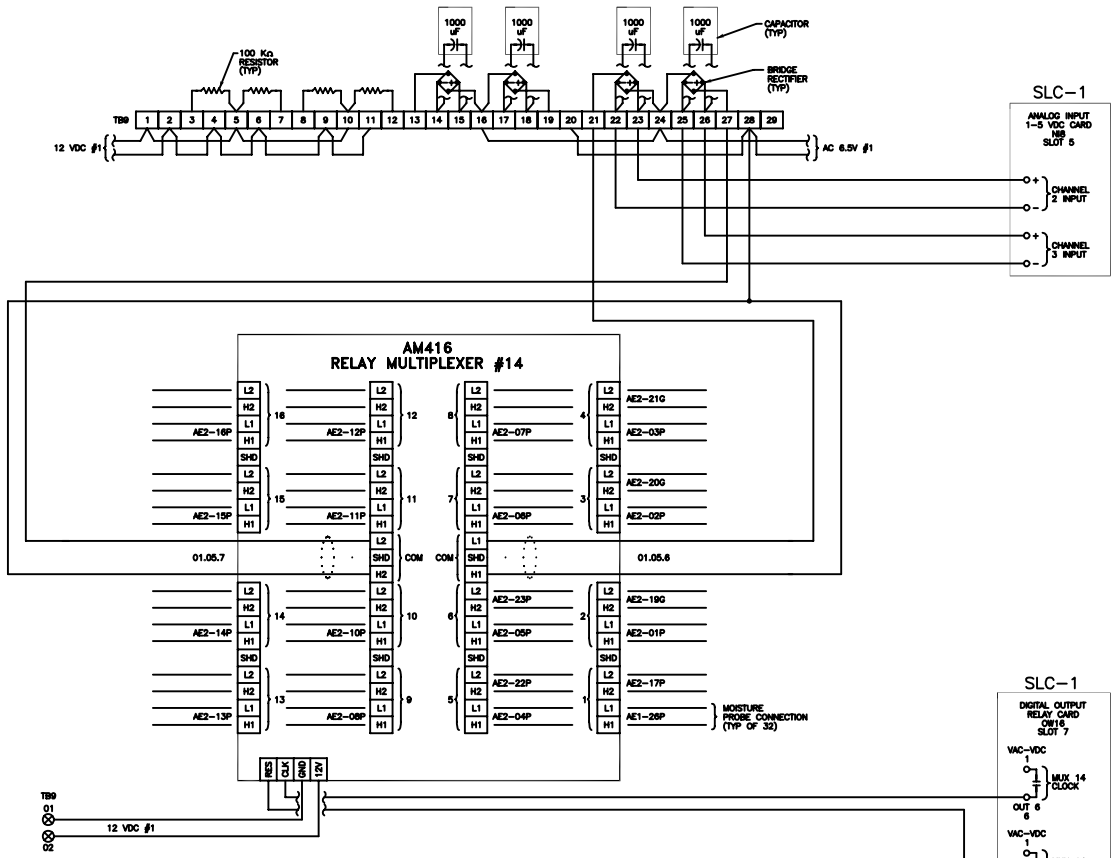
ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO. _____

REGISTERED PROFESSIONAL ENGINEER SIMON M. KWONG NO. 15698 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN	PROJECT NO.: -	TASK NO.: -	
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR			
SHEET TITLE: MOISTURE MULTIPLEXER #13 WIRING DIAGRAM			
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT 2020 BROADWAY SACRAMENTO, CA 95817 916-457-6144		SHEET: 12 OF 24	
		DRAWING NO. E12	REV. 0



MULTIPLEXER #14 WIRING DIAGRAM

FILE: 0007JE13

REV.	DATE	DESCRIPTION	DSN BY	DWN BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO. _____

REGISTERED PROFESSIONAL ENGINEER SIMON M. KWONG NO. 15698 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

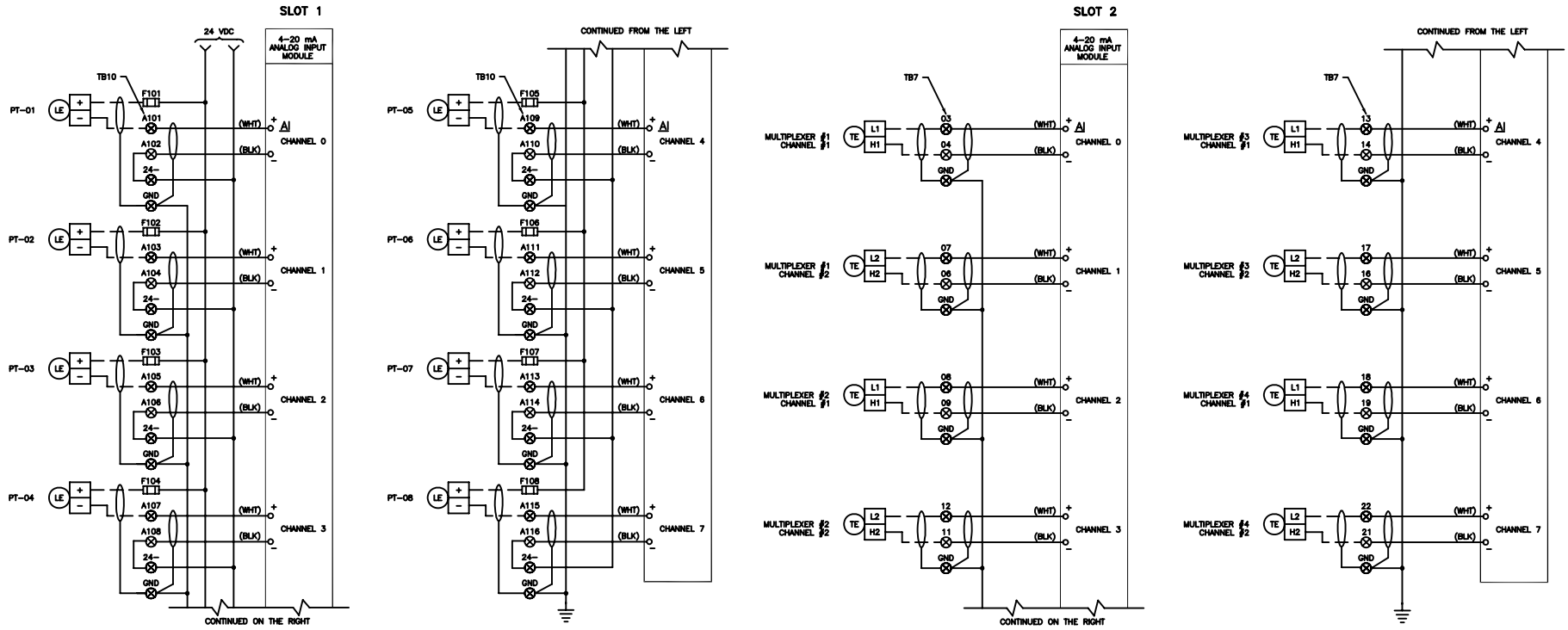
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: MOISTURE MULTIPLEXER #14 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
2020 BROADWAY SACRAMENTO, CA 95817
916-457-0144

SHEET: 13 OF 24

DRAWING NO.	REV.
E13	0



AI CARD 01

AI CARD 02

FILE: 0007JE14

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15698 Exp. 12-31-2002 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: – | TASK NO.: –

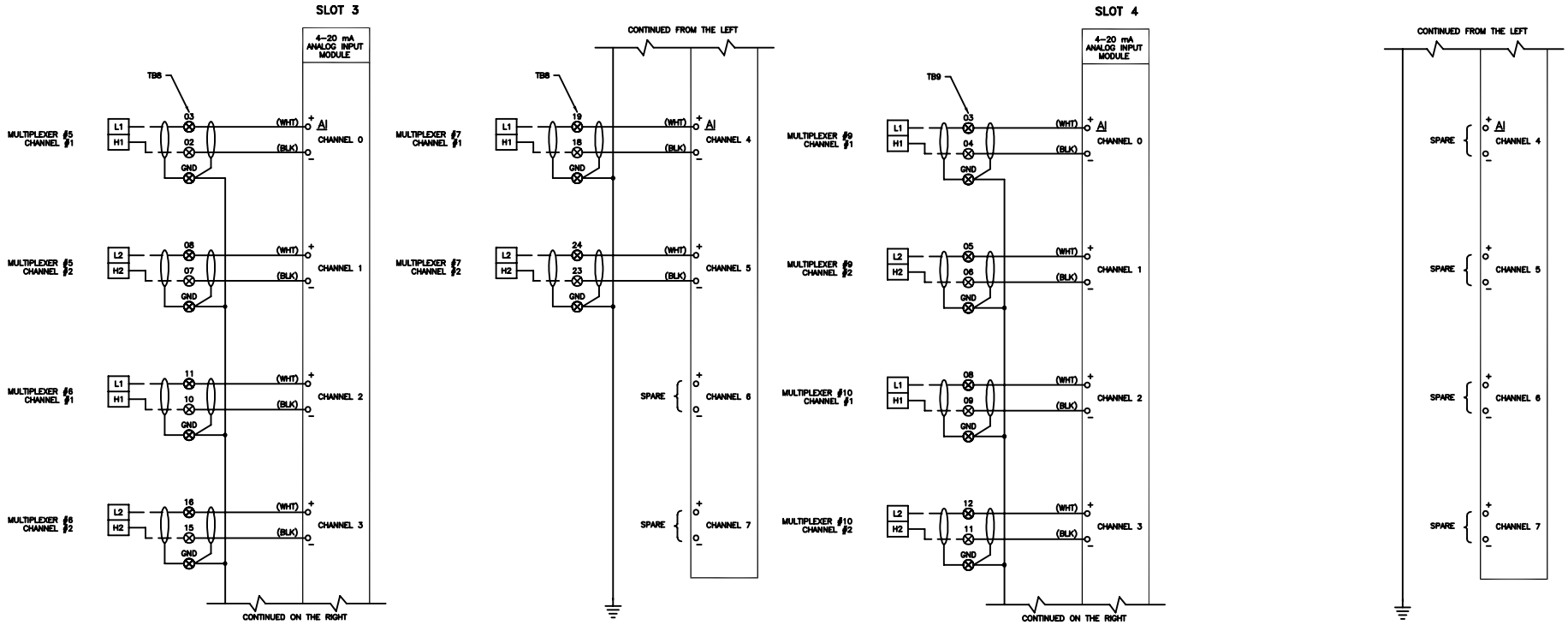
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC–1 ANALOG INPUT CARDS 01 & 02 WIRING DIA.

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY SACRAMENTO, CA. 95817
916–457–8144

SHEET: 14 OF 24

DRAWING NO.	REV.
E14	0



AI CARD 03

AI CARD 04

FILE: 0007JE15

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15698 Exp. 12-31-2002 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: – | TASK NO.: –

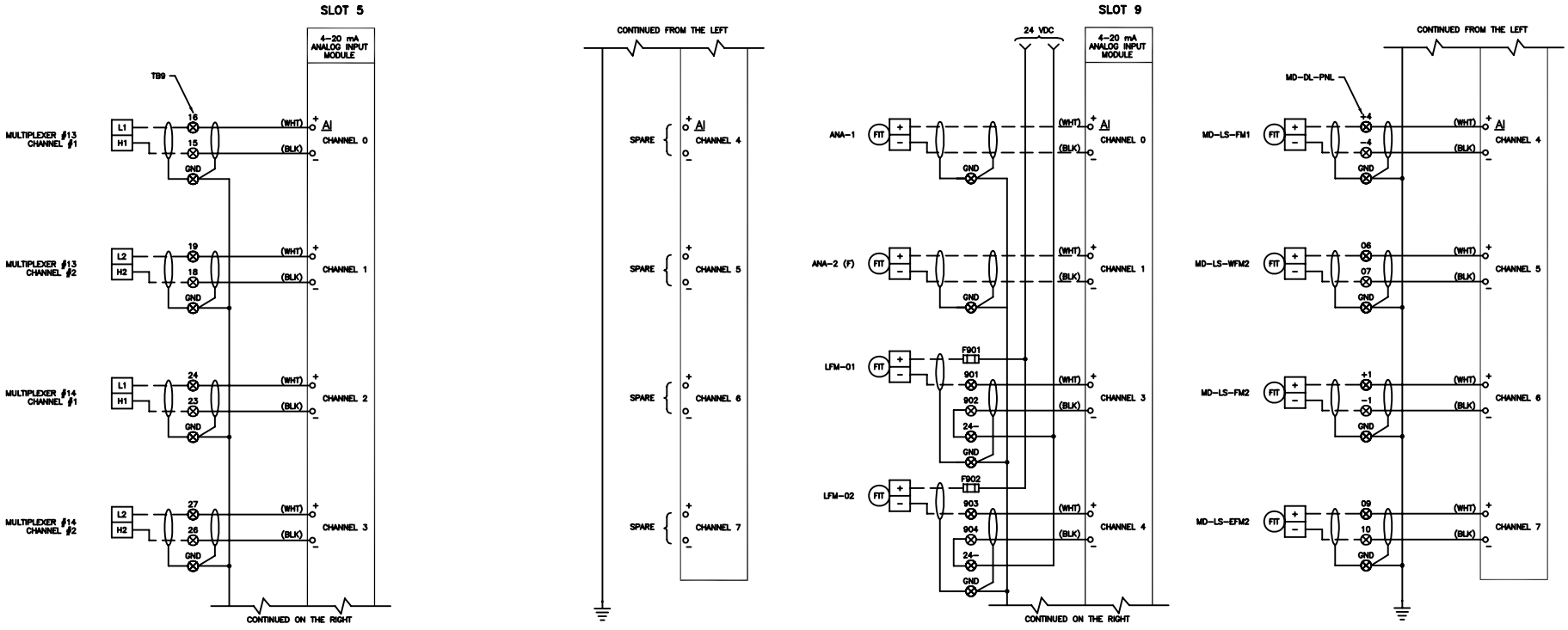
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC–1 ANALOG INPUT CARDS 03 & 04 WIRING DIA.

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916–457–5144

SHEET: 16 OF 24

DRAWING NO.	REV.
E15	0



AI CARD 05

AI CARD 09

FILE: 0007JE16

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

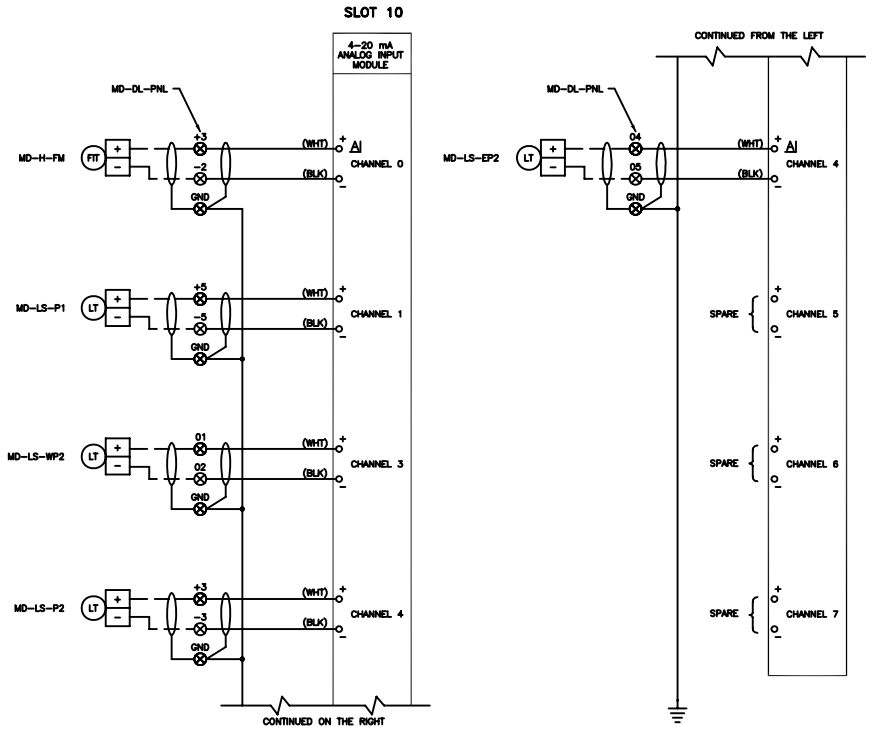
R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15688 Exp. 12-31-2003 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN	PROJECT NO.: –	TASK NO.: –	
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR			
SHEET TITLE: SLC–1 ANALOG INPUT CARDS 05 & 09 WIRING DIA.			

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
3123 BROADWAY
SACRAMENTO, CA. 95817
916–457–6144

SHEET: 16 OF 24	
DRAWING NO.	REV.
E16	0



AI CARD 10

FILE: 0007JE17

REV.	DATE	DESCRIPTION	BRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER
SHARON M. KINTZLER
NO. 15698
Exp. 12-31-2008
ELECTRICAL
STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: – | TASK NO.: –

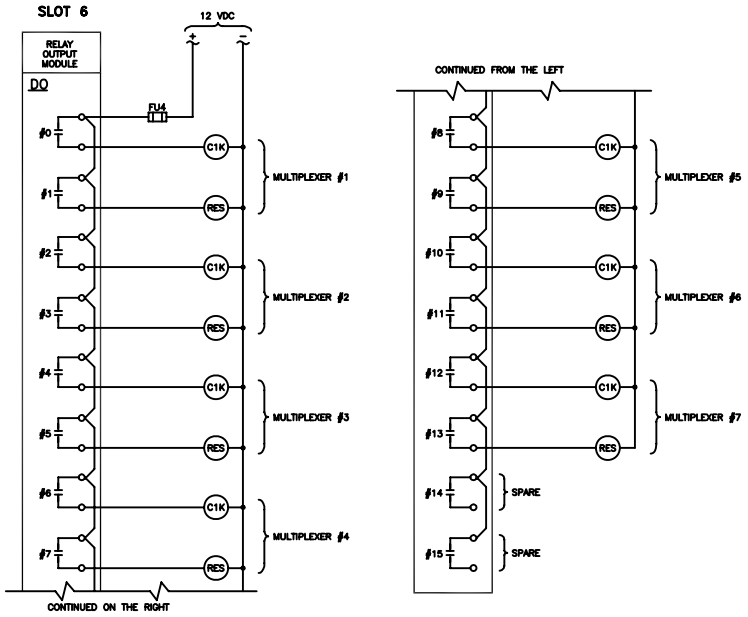
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC–1 ANALOG INPUT CARD 10 WIRING DIAGRAM

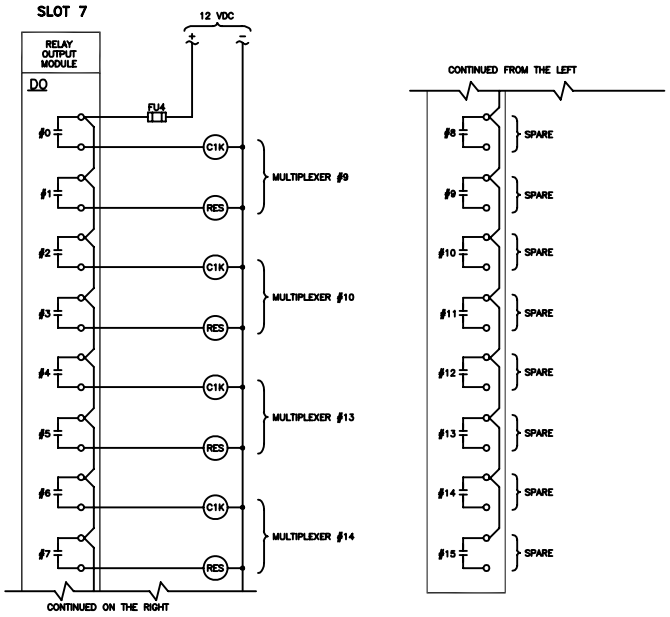
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916–457–8144

SHEET: 17 OF 24

DRAWING NO.	REV.
E17	0



DO CARD 06



DO CARD 07

FILE: 0007JE18

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER
SHARON M. KINTZLER
NO. 15688
Exp. 12-31-2008
ELECTRICAL
STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

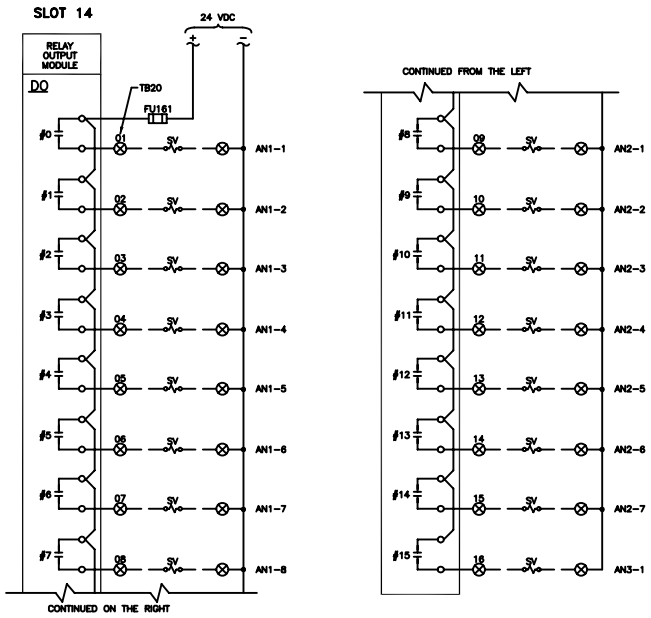
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 DIGITAL OUTPUT CARDS 06 & 07 WIRING DIA.

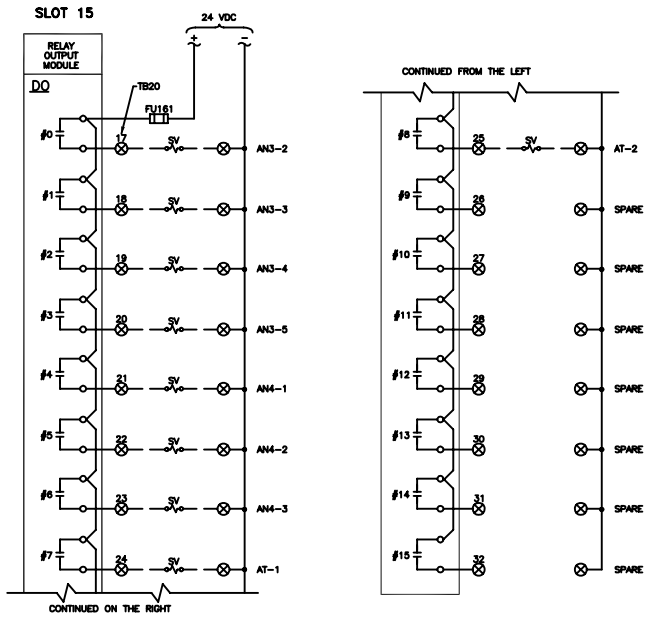
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-6144

SHEET: 18 OF 24

DRAWING NO.	REV.
E18	0



DO CARD 13



DO CARD 14

FILE: 0007JE19

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15688 Sept-30-2003 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

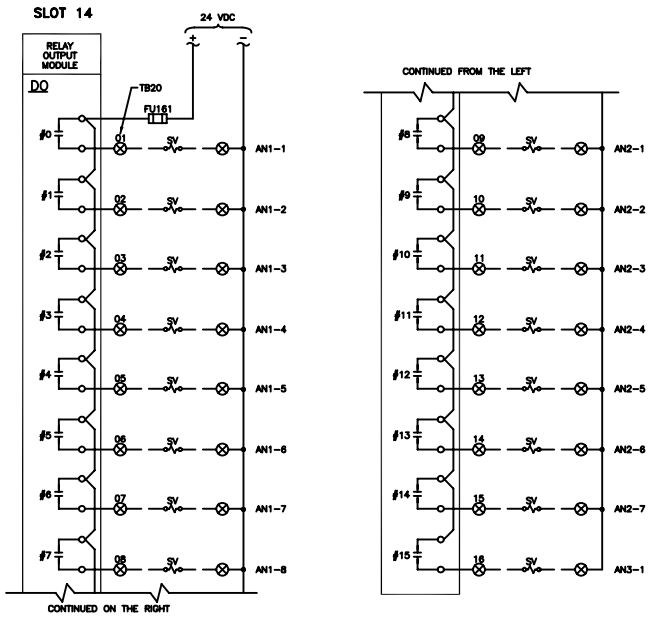
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 DIGITAL OUTPUT CARDS 13 & 14 WIRING DIA.

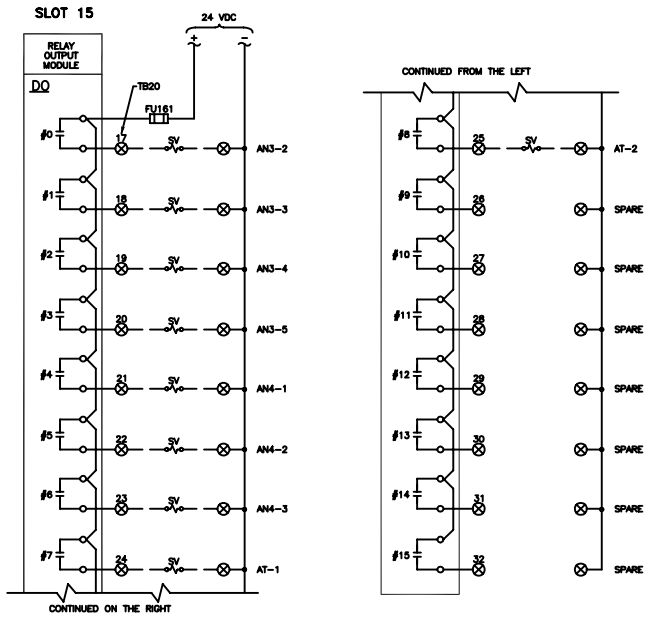
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-6144

SHEET: 19 OF 24

DRAWING NO.	REV.
E19	0



DO CARD 13



DO CARD 14

FILE: 0007JE19

REV.	DATE	DESCRIPTION	DRN BY	DVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15688 Sept-30-2003 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

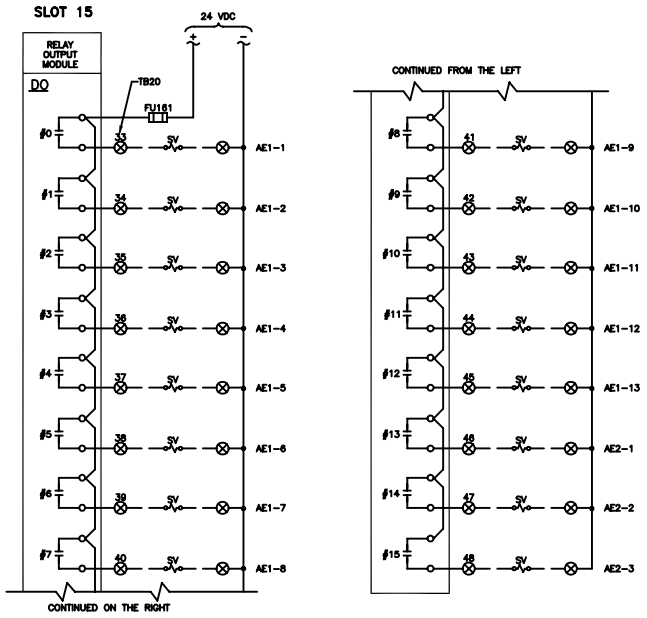
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 DIGITAL OUTPUT CARDS 13 & 14 WIRING DIA.

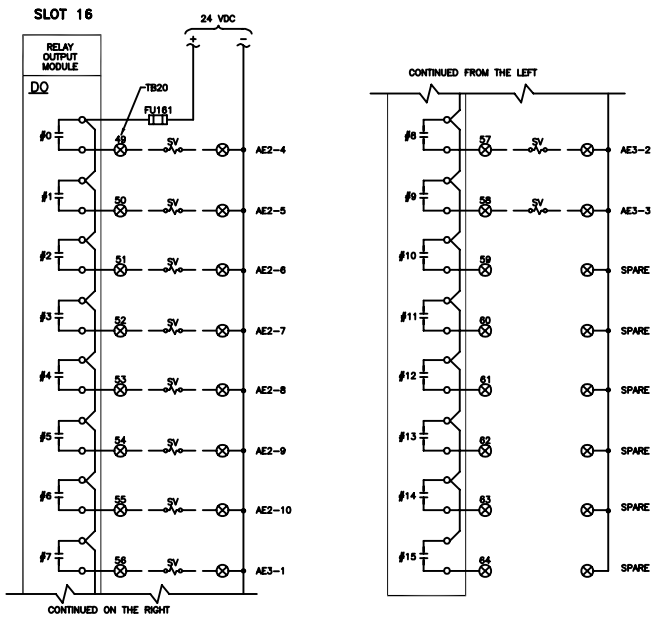
A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-6144

SHEET: 19 OF 24

DRAWING NO.	REV.
E19	0



DO CARD 15



DO CARD 16

FILE: 0007JE20

REV.	DATE	DESCRIPTION	DRN BY	DVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15688 Exp. 12-31-2003 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

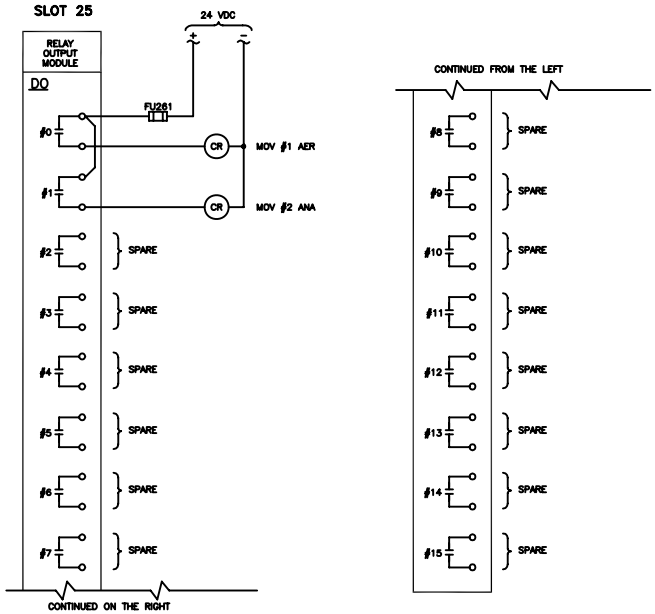
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 DIGITAL OUTPUT CARDS 15 & 16 WIRING DIA.

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-8144

SHEET: 20 OF 24

DRAWING NO.	REV.
E20	0



DO CARD 15

FILE: 0007JE21

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER
SHARON M. KINTZLER
NO. 15698
Exp. 9-30-2
ELECTRICAL
STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

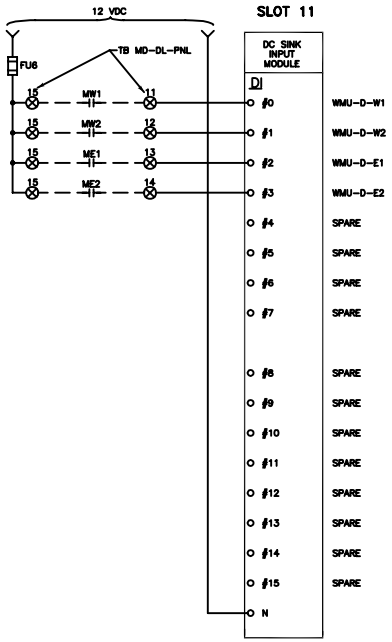
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 DIGITAL OUTPUT CARD 25 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-8144

SHEET: 21 OF 24

DRAWING NO.	REV.
E21	0



DI CARD 11

FILE: 0007JE21

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER
SHARON M. KINTZLER
NO. 15698
Exp. 9-30-2012
ELECTRICAL
STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

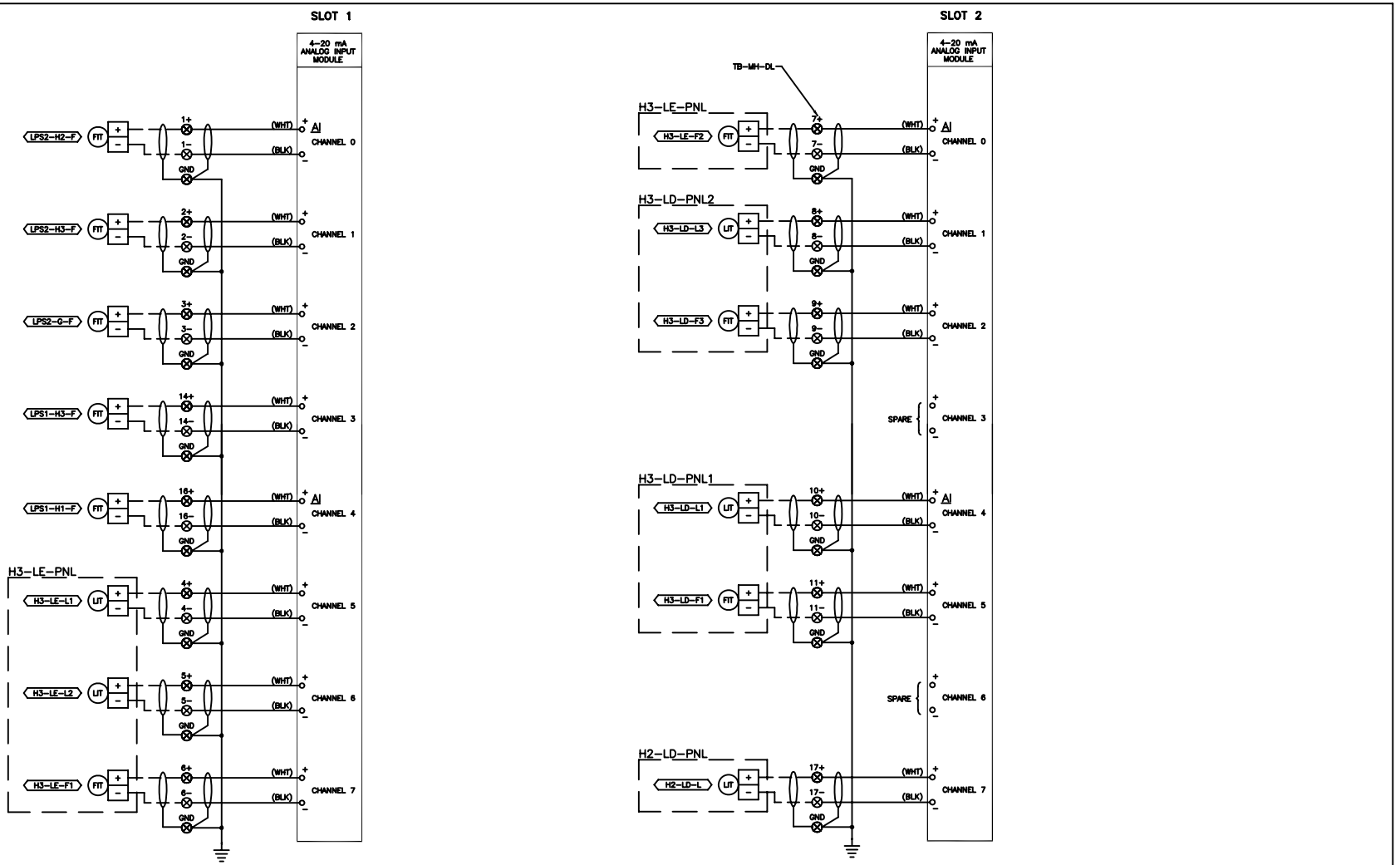
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 DIGITAL INPUT CARD 11 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-8144

SHEET: 22 OF 24

DRAWING NO.	REV.
E22	0



FILE: 0007JE23

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15688 Exp. 12-31-2003 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: – | TASK NO.: –

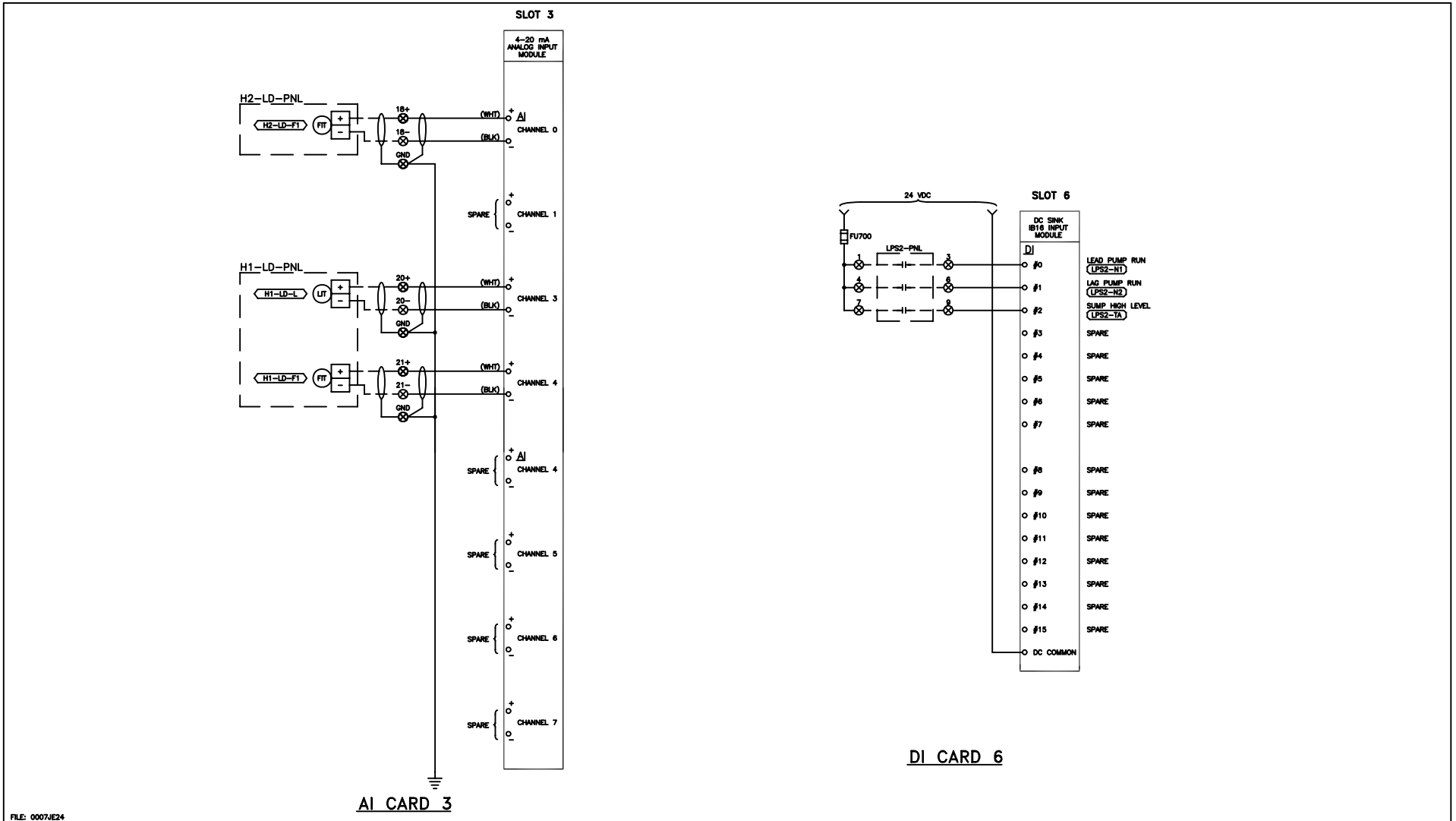
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC–2 ANALOG INPUT CARDS 1 & 2 WIRING DIA.

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916–457–6144

SHEET: 23 OF 24

DRAWING NO.	REV.
E23	0



AI CARD 3

DI CARD 6

FILE: 0007JE24

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KIRKLAND NO. 15698 Exp. 9-30-2005 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: – | TASK NO.: –

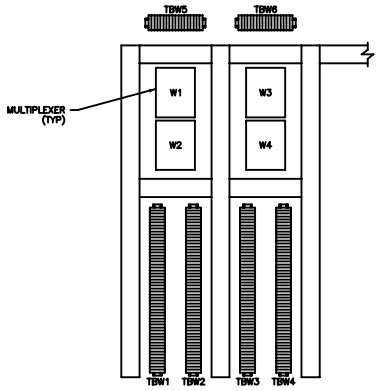
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC–2 AI CARD 3 & DI CARD 6 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916–457–8144

SHEET: 24 OF 24

DRAWING NO.	REV.
E24	0



SLC-1 WALL LAYOUT OVERVIEW WEST 6 ACRE CELL

NOT TO SCALE

FILE: 0209DE02

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER
SHARON M. KINTZLOW
NO. 15698
Exp. 9-30-2005
ELECTRICAL
STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

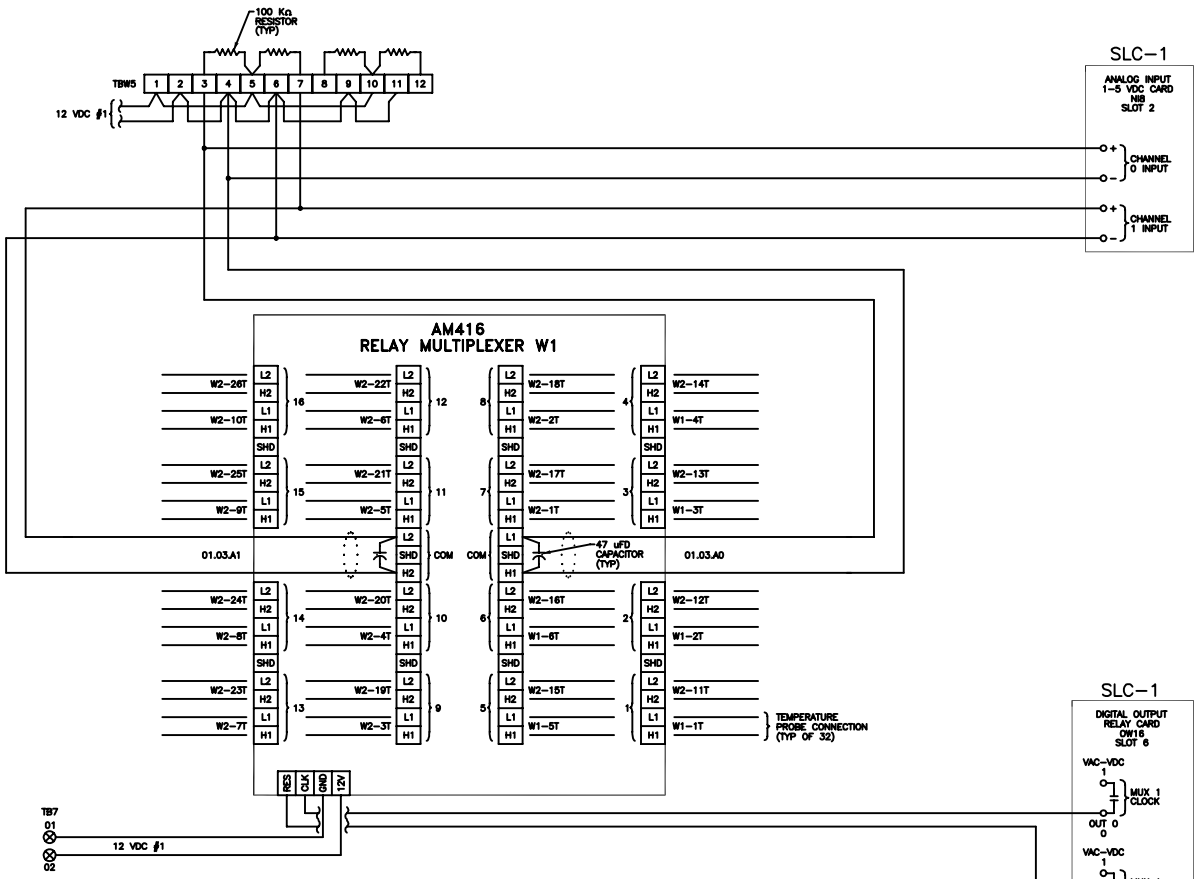
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: SLC-1 WALL LAYOUT OVERVIEW WEST

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5123 BROADWAY
SACRAMENTO, CA. 95817
916-457-5144

SHEET: 2 OF 6

DRAWING NO.	REV.
E2	0



MULTIPLEXER W1 WIRING DIAGRAM

FILE: 0209DE03

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15698 Exp. 6-30-2001 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

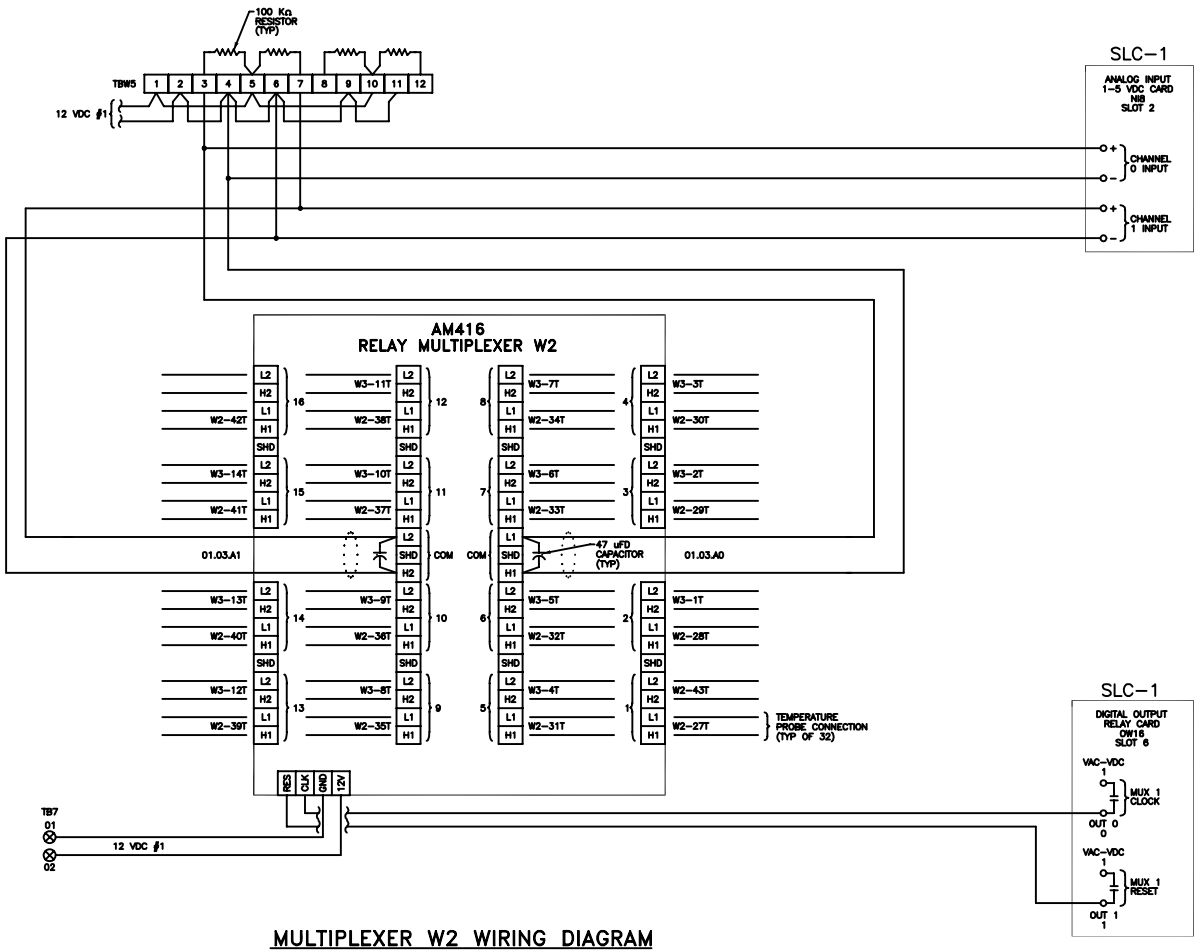
PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER W1 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5125 BROADWAY
SACRAMENTO, CA. 95817
916-457-5144

SHEET: 3 OF 6

DRAWING NO.	REV.
E3	0



MULTIPLEXER W2 WIRING DIAGRAM

FILE: 0209DE04

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KIVLIN NO. 15698 Exp. 12-31-2009 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: TEMPERATURE MULTIPLEXER W2 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5125 BROADWAY
SACRAMENTO, CA. 95817
916-457-8144

SHEET: 4 OF 6

DRAWING NO.	REV.
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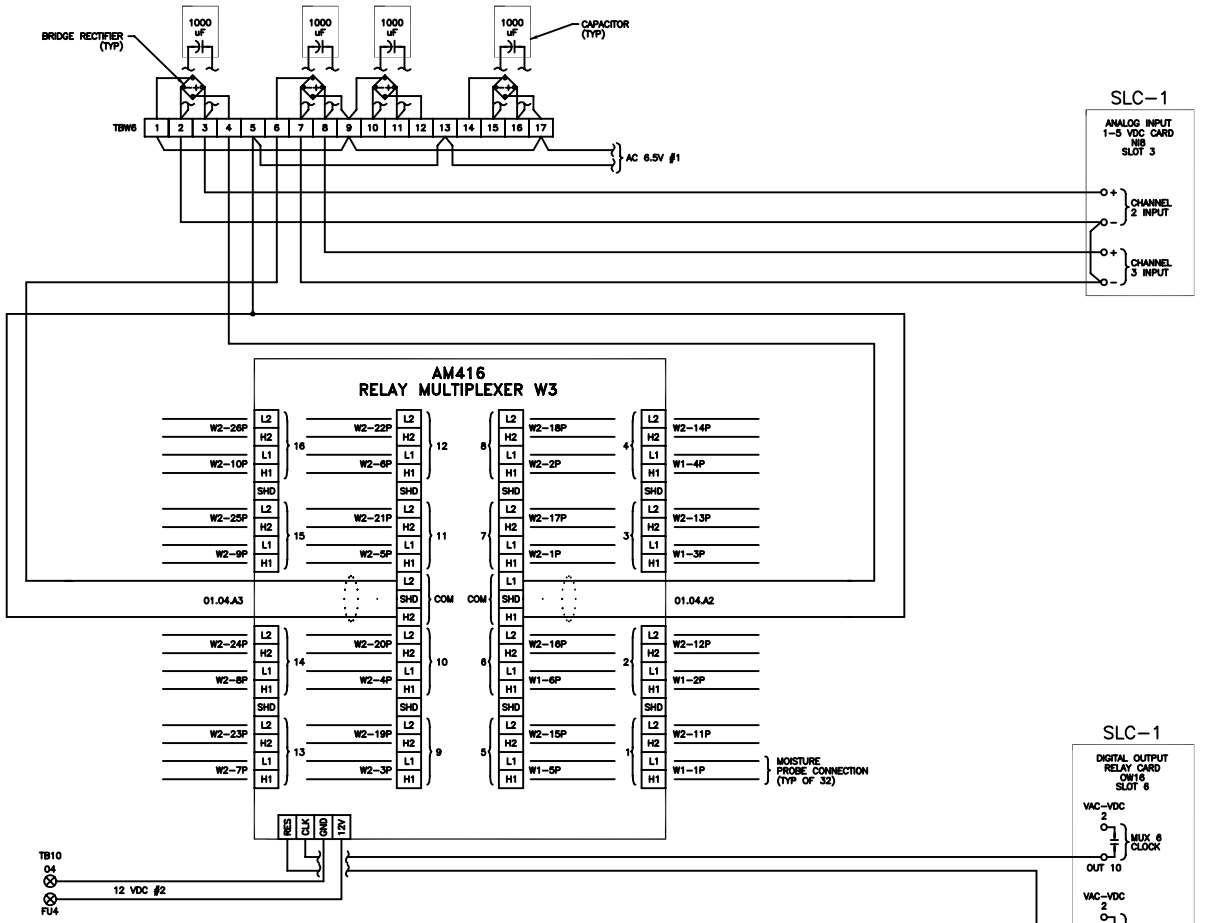

MULTIPLEXER W3 WIRING DIAGRAM

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REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15698 Exp. 12-31-2006 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: MOISTURE MULTIPLEXER W3 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5125 BROADWAY SACRAMENTO, CA. 95817
916-457-8144

SHEET: 5 OF 6

DRAWING NO.	REV.
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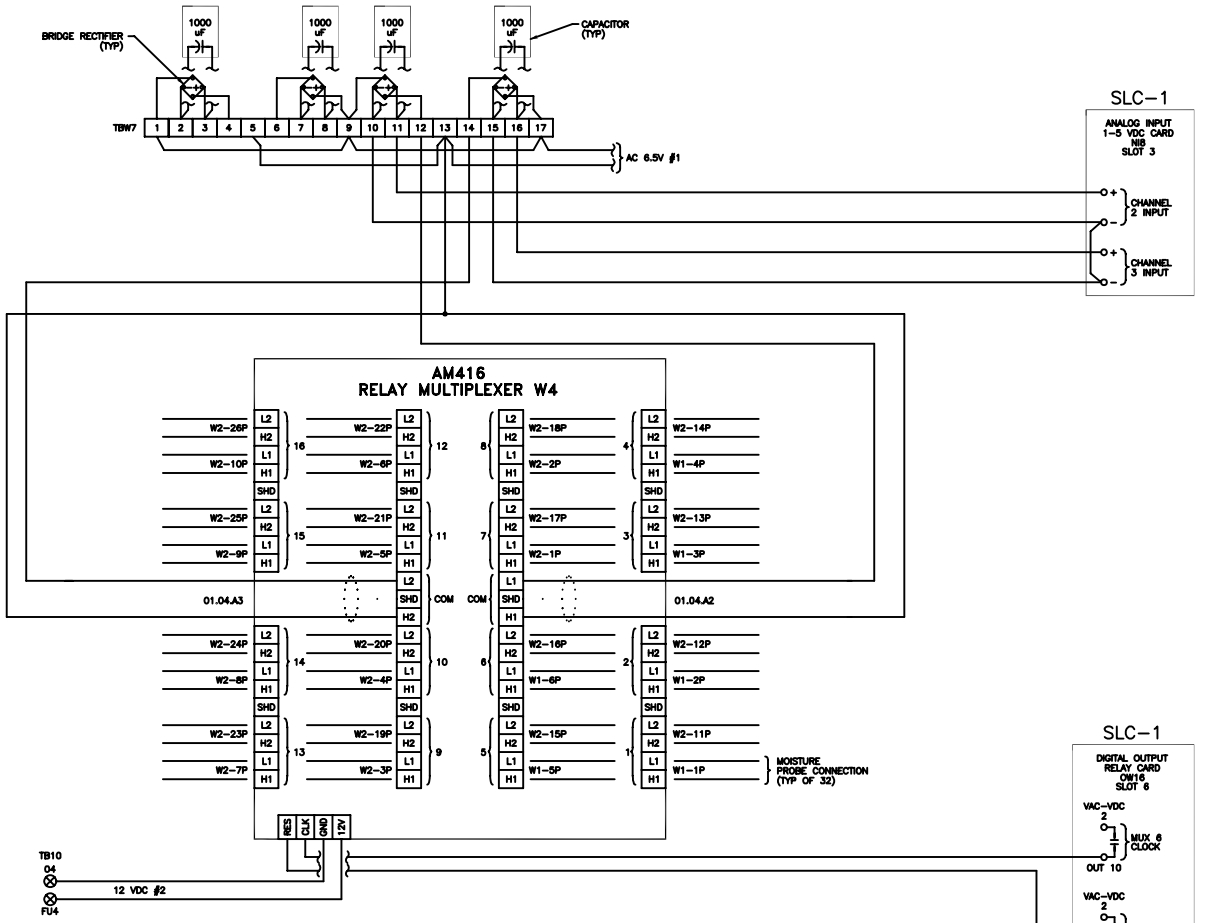

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FILE: 0007JE08

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
292 West Beamer Street Woodland, California 95695

ASSISTANT DIRECTOR OF PUBLIC WORKS

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R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KRITZMAN NO. 15698 Exp. 12-31-2002 ELECTRICAL STATE OF CALIFORNIA

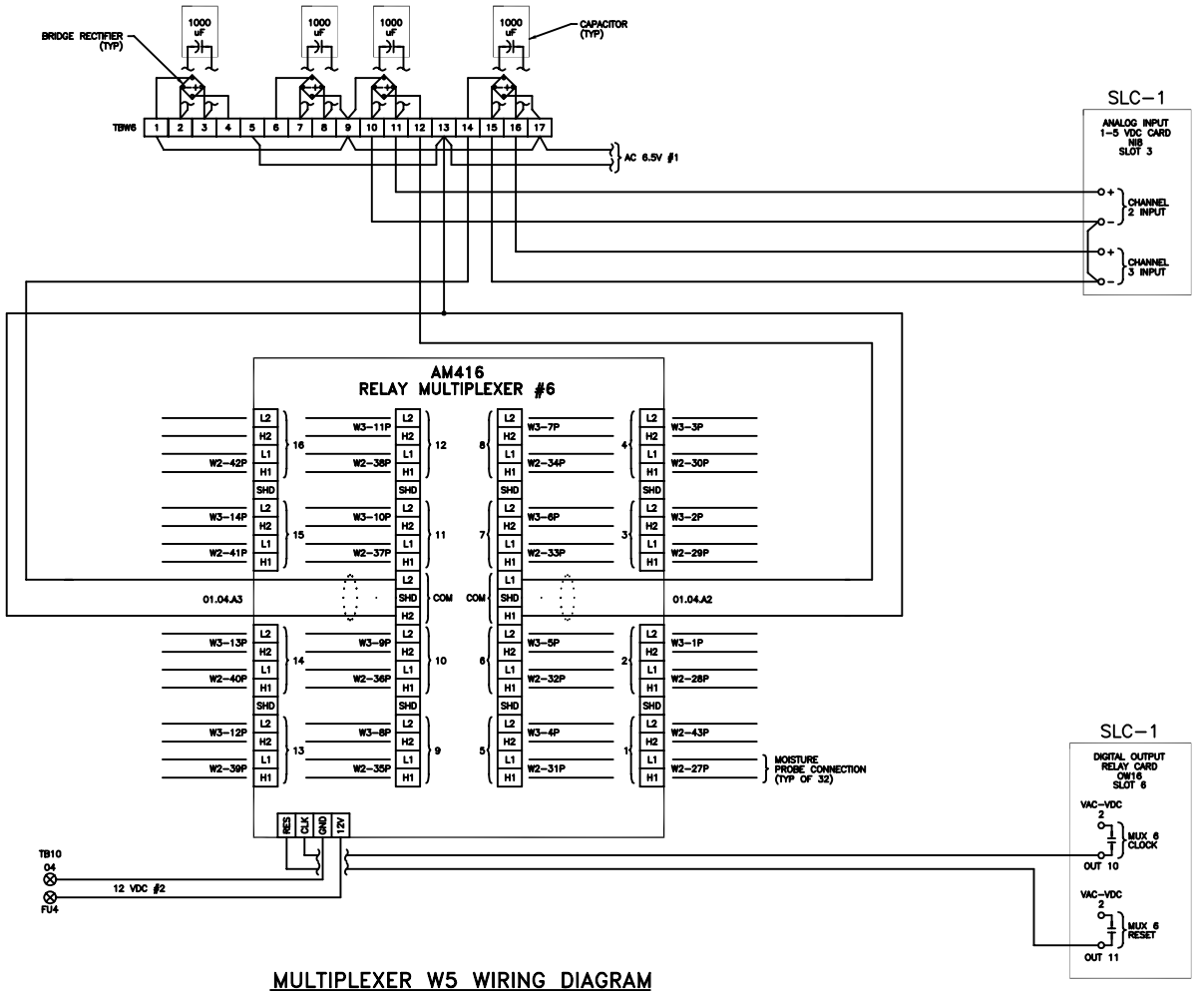
SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: MOISTURE MULTIPLEXER W4 WIRING DIAGRAM

A TEAM for ELECTRICAL ENGINEERING & MANAGEMENT
5125 BROADWAY SACRAMENTO, CA. 95817
916-457-8144

SHEET: 5 OF 24 | DRAWING NO.: E5 | REV.: 0



MULTIPLEXER W5 WIRING DIAGRAM

FILE: 0007JE08

REV.	DATE	DESCRIPTION	DRN BY	RVW BY

YOLO COUNTY
PLANNING AND PUBLIC WORKS DEPARTMENT
DIVISION OF INTEGRATED WASTE MANAGEMENT
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APPROVED _____ 20 ____

R. E. NO.

REGISTERED PROFESSIONAL ENGINEER SHARON M. KINTZLER NO. 15698 Exp. 12-31-2005 ELECTRICAL STATE OF CALIFORNIA

SCALE: AS SHOWN | PROJECT NO.: - | TASK NO.: -

PROJECT: YOLO COUNTY EPA PROJECT XL BIOREACTOR

SHEET TITLE: MOISTURE MULTIPLEXER W5 WIRING DIAGRAM

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SHEET: 5 OF 24

DRAWING NO.	REV.
E5	0

APPENDIX E – SURFACE LINER DESIGN REPORT

DESIGN REPORT
for the
SURFACE LINERS
of the
MODULE D PHASE 1 BIOREACTOR
at the
YOLO COUNTY CENTRAL LANDFILL

prepared for:

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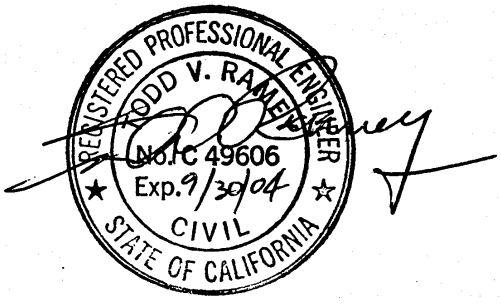

Job No. 931010.18
October 2001

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APPENDICES

1.0 INTRODUCTION

This report is being provided to summarize the design work performed by Vector Engineering, Inc. (Vector) for the surface liners for the aerobic and northeast anaerobic bioreactor cells and aerobic cell biofilter for Phase 1 of Module D at the Yolo County Central Landfill. The scope of our services was originally outlined in our proposal to Yolo County (County) dated May 14, 2001. This work has been further modified to include additional drawing preparation for the external piping systems for the referenced bioreactor cells. The design tasks that are specifically discussed in this report are:

- the selection of the surface liner materials;
- the anchorage design for wind uplift;
- the stability of the road surface materials on the access ramps;
- the design of the surface water drainage structures; and
- the design of the passive biofilter for the aerobic cell.

2.0 SELECTION OF THE SURFACE LINER MATERIALS

Based on information provided by the County, the surface liner materials will be exposed for at least 5 years. It was determined that the selected liner material must be able to withstand ultra violet (UV) exposure as well as other climatic and operational conditions such as wind uplift, rain, temperature fluctuations, foot traffic, and billowing of off-gases. Based on these criteria, two options were considered for use in the bioreactor surface liners: 1) high density polyethylene; and 2) reinforced polypropylene.

Vector and its subconsultant, Rick Thiel, P.E., reviewed available literature to examine the issues related to selection of the surface liner. The articles, text books, and other literature reviewed discussed UV exposure, damage by outside forces such as animals, and focused heavily on the effects of wind uplift and the resulting forces. Mr. Thiel was tasked with the primary selection of the materials with concurrence by Vector and the County. The results of his document review and recommendations for material selection are presented in the report entitled "Design Report: Geomembrane Material Selection and Wind Uplift Calculations, Yolo County Central Landfill Exposed Surface Liner, Yolo County, California", dated September 5, 2001 (Appendix A).

In summary, Mr. Thiel recommended that the County use reinforced 30-mil polypropylene (RPP) for its durability, functionality, and ease of maintenance. He went on to state that heavier (thicker) RPP such as 36-mil could be used if it was not cost prohibitive to the County or if there were an availability problem with the thinner material. A 36-mil RPP was selected by the County as the final surface liner material due to its more common availability within the industry.

3.0 ANCHORAGE DESIGN FOR WIND UPLIFT

As with the liner selection, Mr. Thiel was asked to perform the necessary calculations and make recommendations with respect to the anchorage design for wind uplift of the bioreactor surface liners. His design approach followed a standard method described by Giroud et al. (1995) to evaluate the forces acting on the geomembrane and the anchor trench due to wind uplift. Mr. Thiel selected a wind velocity of 90 miles per hour to represent an extreme design event that may occur at the site. Details of the design, assumptions, and results are provided in his report, Appendix A.

Design recommendations were provided as a result of the calculations, relative to the geometry shown in the design drawings produced by Vector. The following bullet items are excerpted from the recommendations section of the report prepared by Mr. Thiel.

ANAEROBIC CELL

- The anchor trench at the crest of the slope should be a minimum of 3 feet deep and 8 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf).
- The weld connecting the geomembrane on the slope to the geomembrane on the top-deck should be placed either within the anchor trench, or on the side of the anchor trench going towards the middle of the top-deck to avoid having the weld experience peel forces. In general, all welds should be constructed to avoid peel forces when the geomembrane is uplifted due to wind.
- The anchor trench at the toe of the slope should be a minimum of 3 feet deep and 7 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf).

- To provide additional hold-down force during construction and operations, a grid of 40-50 lb sandbags is recommended to be installed over the entire liner surface at a spacing of 8-feet on-center each-way. The sandbag locations should be maintained by securing the sandbags to a polypropylene rope grid. The vertical ropes should be ¾" diameter, the horizontal ropes should be 3/8" diameter. Supplemental ropes should be added at corner hinge points. All the ropes on the top-deck should be ¾" diameter. The sandbags should be tied at each grid node using electrical zip-ties threaded through the strands of both intersecting ropes. Additional sandbags are recommended around each pipe penetration through the liner to help reduce the amount of stress that would occur on the pipe boot.

- Vents were recommended at the crest of the slope at a 50' spacing. Special-order mechanical vents were specified that would open when the pressure below the geomembrane relative to the pressure above the geomembrane would be greater than 0.85-inch of water column. Although there is no specific design methodology for crest vents, vents have been observed to reduce the effects of strong wind uplift (Giroud et al. 1995). Ultimately the Yolo County staff decided to leave the vents out, at least initially, and install a manually-operated header vent to reduce excess gas pressure in the event the active gas collection system went down. The vents could be installed at a later date if deemed necessary by the County staff.

- To the extent possible, Thiel Engineering recommended that pipe penetrations be reduced or eliminated because experience has shown that these locations will provide the most operational problems over time. The nature of the Yolo County test cells, however, is such that numerous penetrations will exist for purposes of instrumentation and operation of the test cells. Because of the potentially high magnitude of forces that might be exerted on the penetrations due to wind uplift, Thiel Engineering recommended that the penetration boots be fabricated from reinforced material rather than using the vacuum-formed non-reinforced boots. Thiel Engineering notes that problems and repairs at the penetration points are to be expected over time due to wind uplift. The nature of the problems might include ripped cover material, ripped boots, and broken pipes. As problem areas become identified and repaired, it is possible that additional cover ballast could be added at those locations to reduce the chances of repeat failures at the same locations.

AEROBIC CELL

- The anchor trench at the crest of the slope should be a minimum of 3 feet deep and 6 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf). This will occur near the biofilter on the top-deck.

- The bench near the lower third of the slope should have a prism of soil encapsulated in the liner material to provide a mid-slope anchor. The best design would be to have the primary surface liner run continuously through the bench, and the soil prism cap-stripped by a separate piece of liner material. The cross-sectional area of the soil prism should be a minimum of 12 ft^2 (e.g. 6' wide by 2' thick as shown on the Vector drawings).

- The anchor trench at the toe of the slope should be a minimum of 2 feet deep and 6 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf).

- To provide additional hold-down force during construction and operations, a grid of 40-50 lb sandbags was recommended to be installed over the entire liner surface at a spacing of 8-feet on-center each-way. The sandbag locations would be maintained by securing the sandbags to a polypropylene rope grid. The vertical ropes would be ¾" diameter, the horizontal ropes would be 3/8" diameter. Supplemental ropes would be added at corner hinge points. All the ropes on the topdeck would be ¾" diameter. The sandbags would be tied at each grid node using electrical zip-ties threaded through the strands of both intersecting ropes. Additional sandbags were recommended around each pipe penetration through the liner to help reduce the amount of stress that would occur on the pipe boot.

- Additional continuous anchorage should be provided in the hip-valleys on the south-facing slope. This anchorage could be provided by an encapsulated soil prism or sandbags to provide a weight of 200 lbs per lineal foot from crest to toe.

- The same cautions, related to surface liner penetrations, which were described for the anaerobic cell, apply to the aerobic cell.

- Relative to the operational durability of the surface liner on the aerobic cell, Thiel Engineering advises against blowing air into the aerobic cell as this will have the potential of creating a positive pressure on the surface liner, thus exacerbating any potential wind uplift problems. If fresh air is desired to be introduced into the cell, Thiel Engineering recommends that a means be designed to suck the air in, rather than blow it in.

In addition to the design recommendations provided above, Mr. Thiel also provided recommendations with respect to the operations of the surface liner and bioreactor system. He recommended that the County make a concerted effort to observe the liner performance during high winds to note areas that may need more sandbag ballasting. Mr. Thiel also recommended that the County retain extra supplies of all the liner and ballast materials and equipment so that quick repairs could be made as needed. Finally, a telemetry system was suggested for installation to notify the County of problems with the landfill gas extraction system such that the cover could be vented in the case of a system shut-down. Further details regarding these recommendations are provided in Appendix A.

Due to the fast-track nature of the project, bidding and construction began before completion of this design report. Details of the construction and potential design options were also discussed on a periodic basis. With regard to the liner system, the selected contractor requested several design and specification changes that were considered and accepted. These changes are described below.

- The design of the anchor trench required that the top surface liner and the side slope liner to be seamed in the bottom of the crest anchor trench. The design was changed at the request of the contractor to bring the side slope liner all the way through the trench and seam it to top surface liner approximately 3 feet away from the trench. Installing the liner in this fashion allowed the contractor to backfill the anchor trench before the top surface liner was installed, minimizing potentially damaging traffic over the surface liner.
- Thiel Engineering recommended that the penetration boots be fabricated from reinforced material rather than using the vacuum-formed non-reinforced boots. After further consideration, Vector approved the use of the vacuum-formed non-reinforced boots because of their flexibility, ease of installation, and ease of repair.

4.0 STABILITY OF THE ROAD SURFACE MATERIALS

Access roads up to the top of the aerobic and anaerobic bioreactors will be constructed as shown on the project drawings with a maximum grade of approximately 25 percent, or 4H:1V. The access roads will be constructed by overlaying the surface liner with a geotextile and 12 inches of aggregate base rock. The stability was evaluated for both wet and dry conditions, and for loading conditions from heavy equipment.

The shear strength parameters used in the stability analyses were based on estimated values from Vector's experience with geomembrane liners and previous laboratory testing of geomembrane materials. A friction angle of 20 degrees was used in the stability analyses for the interface between the reinforced polypropylene (RPP) geomembrane and the non-woven geotextile cushion. Although this interface was not specifically tested for the project, for comparison, the shear strength between a polyvinylchloride (PVC) geomembrane, with similar hardness characteristics to the RPP, and a non-woven geotextile is approximately 21 degrees. This value is based on laboratory testing performed by Vector for design of the aerobic cell bottom liner system. Similar values are reported by others in the industry (Koerner, 1998). It should be noted that these values are based on testing performed on the materials in a saturated condition. The friction between the aggregate road base and the geotextile would be higher than the interface between the geosynthetic materials, and therefore would not be the critical surface in the stability analyses.

The stability of the final cover was analyzed using both a conventional infinite slope method to determine the factor of safety of the aggregate sliding above the liner, and with Spencer's method of slices. For the infinite slope analysis, it is assumed that the shear surface parallels the slope along the weakest interface within the surface liner system. A spread sheet was developed with Microsoft Excel that

calculates the resisting and driving forces under infinite slope conditions for the access road above the bioreactor cover. The calculations for the factor of safety included water head buildup during rainfall, using formulas developed by Thiel and Stewart (1993). Spencer's method of slices was performed using the computer program UTEXAS3 (Wright, 1991). The method of slices was used for evaluating the stability of the road when the surface is dynamically loaded with wheeled equipment. The results of the infinite slope analysis and the UTEXAS3 computer output files are provided in Appendix B.

The resulting static factors of safety for wet and dry soil conditions, and with loading from equipment, are summarized in Table 1. The wet conditions assume that a head of 3 inches exists above the geomembrane cover. It was estimated that 3 inches of head could develop during a storm intensity of approximately 1 inch per hour, with infiltration into the aggregate base. The loading from braking of the front-end loader was calculated based on a speed of 5 miles per hour and a braking distance of 4 feet. The braking force was assumed to be distributed beneath a CAT 966E front end loader.

Table 1
Summary of Stability Results for Access Road on Bioreactor Cover

Description	Factors of Safety
Failure along RPP/Geotextile interface, dry conditions	1.5
Failure along geosynthetic/soil interface, wet conditions with 3" of water head	1.3
Dry conditions, 966E Wheel Loader Braking on Slope	1.1

The results of the analyses were verbally transmitted to the County near the completion of the design stage. Based on our discussions with the County, it was their opinion that the potential existed where they would need to access the top of the cell during wet weather conditions. Given this information, perforated collection pipes were also added to the design to improve the drainage of aggregate base materials and to provide an added factor of safety against sliding during rainy weather with vehicular traffic.

5.0 DESIGN OF THE SURFACE WATER DRAINAGE STRUCTURES

Surface water hydrology calculations were performed to determine the peak discharge into the drainage channels around the perimeter of the bioreactor cells. The surface water analysis was performed for a 10-year, 24-hour storm event of 3.2 inches as determined from the NOAA Atlas 2 of California published in 1973 (Western Regional Climate Center, 2001). Peak discharge was determined using the TR-55 computer program (USDA, 1986).

At the time that the analysis was performed and based on the proposed drainage plans for the site, it was presumed that all of the run-off from the subareas of the watershed would drain to the central channel running between the west side anaerobic cell and the east side cells of Module D Phase 1. This central drainage channel would discharge into the main site drainage channel, south of Module D. The watershed area included the eastern slope of the west side anaerobic cell, a portion of the south side of Module C, and all of the northeast anaerobic and aerobic cells except for their east sides. For this analysis, the runoff for the east sides of the northeast anaerobic and aerobic cells was assumed to flow directly into the existing excavation for the future Module D Phase 2 landfill. The total watershed area modeled was approximately 11 acres.

Because of low hydraulic conductivity of the native clays used for interim cover of Module C and the fact that a geomembrane cover is being placed over the bioreactor cells, a high runoff curve number (CN) of 98 was assumed for all the calculations. From the TR-55 analysis, the peak discharge was determined to be 26 cubic feet per second (cfs) at the proposed discharge of the central drainage channel. During on-going discussions with the County, it was decided that the surface runoff from the southern portion of Module C and the north side of the northeast anaerobic cell would be discharged to the east toward the Module D Phase 2 excavation. This runoff would then be routed south through a temporary

channel to the main site drainage channel, south of Module D. With this change, it was estimated from the TR-55 output that approximately 5 cfs would be diverted into this temporary channel, leaving a peak flow of 21 cfs for the central drainage.

The central channel was sized using Manning's equation as provided within the computer model FlowMaster v5.15 (Heasted, 1997). Because of the configuration of the base liner, the channel was designed to flow at a minimum of 0.5% from north to south. It was decided that the channel would be constructed in a wide v-notch shape until it reached the south end of the aerobic cell where it would transition to a confined trapezoidal configuration.

Based on the calculations performed, the v-notch channel was designed with 10 to 1 slopes and a top width of 20 feet. The trapezoidal channel has a 6-foot bottom width with 2 to 1 side slopes. The transition to the trapezoidal channel will be created by constructing two berms 1.5 foot high berms that converge from the 20-foot width down to the 6-foot width approximately 40 feet from the southern berm of Module D Phase 1.

To ensure that ponding does not occur at the lower end of the channel, the trapezoidal section was designed with an increased flow slope of 1%. The maximum depth of flow for the design storm event will be about 1 foot for both channels. The flow velocity is estimated to be between 2 feet per second and 4 feet per second for the main section and outlet, respectively. Erosion protection of the outlet will be provided by installing a rock-filled, open-formed geosynthetic (geoweb) erosion mat. The calculations for the surface hydrology analysis are provided in Appendix C.

6.0 DESIGN OF THE PASSIVE BIOFILTER FOR THE AEROBIC CELL

Based on discussions with the County, it was decided that they would design a system to force (rather than draw) air into the aerobic cell. Given the chemical reactions of the waste and air (oxygen), the primary decomposition product is expected to be carbon dioxide, which is essentially odorless and benign to the environment in its pure state. However, based on other aerobic systems such as composting facilities, other odorous gases are present. Given this fact, the aerobic cell would need a filter to reduce odors and further treat methane or other landfill gases that may emanate from the decomposing refuse caused by the forced-air system. Some initial research had been performed by the County to the extent that they elected to go with a passive "biofilter" that would be installed at the highest point of the cell where gases were expected to migrate.

Vector reviewed the literature provided by the County and also other available literature provided on internet wed sites to examine the issues related to the design and material selection of the passive biofilter for the aerobic cell. Based on the literature (Singhal et al, undated), it was decided that a biofilter consisting of yard and wood waste compost would be the easiest to obtain, install, and replace in the future, if necessary. A compost material consisting of yard waste, refuse mixed with foliage, bark, paper, heather, and municipal sludge that has been composted for a minimum of 3 months was specified for the project.

The size or amount of biofilter required for the aerobic cell is based on the flow rate of gases or air through the system. Estimates of the potential forced-air injection quantity were determined by the County. Based on their calculations, the amount of air required could range from 1,300 cubic feet per minute (cfm) to a maximum of 4,500 cfm. Richard (1997) states that "Literature values for biofilter airflows range from 0.005 to 0.0025 m/s (1 to 5 cfm/ft^2) and are typically 0.015 to 0.02 m/s (3 to 4 cfm/ft^2). Using an average air injection flow rate of 2,900 cfm and airflow of 3

cfm/ft^2, the minimum area required was estimated to be 967 ft^2. Due to potential variables, it was decided that a factor of safety of 2 would be applied so that there was less potential for gases to build-up under the proposed geosynthetic cover. Therefore, the design area was increased to a minimum of 1,933 ft^2 (or a rectangular area of 24 feet by 81 feet).

Based on Singhal and others, the height or thickness of the biofilter "should be at least 0.5 m and depending on the flow rate, it can range from 0.5 – 1 m." For this project, it was decided that the biofilter would have a thickness of at least 3 feet (just under 1 m). To distribute the gases across the bottom (inlet) of the biofilter, a 1-foot thick gravel pack layer was incorporated into the design. This gravel layer consists of the same gravel-filled, geoweb discussed is Section 5 for erosion protection of the drainage channel outlet. The geoweb was added to the system to provide structural support for the gravel creating a firm base for placement and removal (in the future if needed) of the overlying compost filter material.

The biofilter would be installed by excavating the existing soil cover over the waste, constructing a perimeter berm, installing the gravel distribution layer, then backfilling the area to the top of the berm with the compost. At the request of the County, a geosynthetic cover, pipe manifold venting system, and sampling pipes were later added to the design drawings.

7.0 LIMITATIONS

The assumptions presented in this report are based upon our experience at the site, past field investigations, laboratory testing, a review of previous reports, and a review of other literature. Not withstanding this, if the County's scope of work changes from that described herein, our analyses should be reviewed and modified, if necessary.

This report was prepared in accordance with generally accepted soils, geosynthetics, and foundation engineering practices applicable at the time the report was prepared and for the project location. Vector makes no other warranties, either expressed or implied, as to the professional advice provided under the terms of this agreement, and as presented in this report. Our recommendations consist of professional opinions and conclusions, based on the scope of work outlined herein and that adequate follow-up engineering and construction quality assurance are provided. It is recommended that Vector be provided the opportunity for a general review of any final construction documents in order that our recommendations may be properly interpreted and implemented.

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APPENDIX A
THIEL ENGINEERING DESIGN REPORT

DESIGN REPORT: GEOMEMBRANE MATERIAL SELECTION AND WIND UPLIFT CALCULATIONS

YOLO COUNTY CENTRAL LANDFILL EXPOSED SURFACE LINER

YOLO COUNTY, CALIFORNIA

Prepared for

Vector Engineering, Inc.

September 5, 2001

Prepared by

Thiel Engineering
P.O. Box 1010
Oregon House, CA 95962

Contents

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

These calculations were prepared by Thiel Engineering in a subcontract to Vector Engineering, Inc. (Vector) to support the design of the exposed geomembrane surface liners at the Yolo County Central Landfill experimental anaerobic and aerobic bioreactor cells. The scope of the calculations was limited to geomembrane material selection, anchorage design, and light ballast design. These calculations did not include design of surface drainage systems, gas relief (anaerobic cell) or air supply (aerobic cell), or design of penetrations through the cover.

1.2 BACKGROUND

Yolo County has implemented a research project to study the performance of anaerobic and aerobic bioreactor landfill cells. The anaerobic cell is approximately 2.9 acres in area, and is filled with external 2(H):1(V) side slopes to approximately 47' above the perimeter grade (plus some amount of landfill below grade). The aerobic cell is smaller with a footprint of approximately 1.6 acres, and is filled with external 2:1 and 3:1 slopes approximately 28' above the perimeter grade.

Both of these small cells will eventually be incorporated into a larger future cell. In the meantime, however, these cells will be individually filled, operated, and monitored by Yolo County. The County requested that both cells be temporarily covered with an exposed geomembrane surface liner. A temporary geomembrane material was selected over a temporary soil cover to provide a tighter seal against uncontrolled gas escaping and rainwater intruding. An *exposed* geomembrane surface liner was selected over a *soil-covered* geomembrane because of the steep temporary slopes and to reduce cost.

The key issues evaluated by Thiel Engineering were a) to recommend a geomembrane material that would provide adequate durability and ease of maintenance for up to 10-year exposure, and b) design the anchorage and ballasting of the cover system to resist wind uplift.

2. SURFACE LINER MATERIAL SELECTION

This chapter presents alternatives and a recommendation for a surface liner material to use on the anaerobic and aerobic experimental bioreactor landfill cells at the Yolo County Central Landfill. The surface liner is intended to be an exposed geomembrane.

2.1 WHAT HAS BEEN USED SUCCESSFULLY ON OTHER PROJECTS?

Examples of some successful exposed geomembrane projects are listed below.

- Landfill cover for Delaware Solid Waste Authority. This is perhaps the most well documented case of all (Gleason et al. 1998, 1999, and 2001; and Germain et al. 2001). The area of exposed geomembrane is approximately 42 acres, is covered with a 36-mil reinforced polypropylene geomembrane, has a maximum height of 130 ft, has maximum slopes of 4:1, and anchors the geomembrane at vertical intervals of 40 ft (equivalent to 160 ft of exposed slope distance between anchorages). Anchorage was provided solely by ballasted drainage benches. Gleason et al. (1999) describe numerous problems with penetrations becoming points of high stress, and several of the structures were damaged during construction. No effective method was identified during construction to adequately and effectively anchor the geomembrane around the penetrations in that design, and penetrations were subsequently eliminated to the extent possible. Once the landfill gas collection system began operating, however, the problems around penetrations greatly decreased. They also discuss a problem with peeling of certain welds, and the subsequent design solution by altering the geometry of a certain bench detail.

- Waste Management Crossroads Landfill, Norridgewock, MA. (Gleason et al. 2001) Approximate area of 5 acres, 26 ft high, covered with 40-mil HDPE, ballasted solely by UV-resistant sandbags on approximate 10'×10' grid.

- WMI Naples Landfill, Naples, FL. (Gleason at al. 2001) Area approximately 22 acres, covered with 60-mil HDPE. Anchored only by trenches at top and toe of slopes. No information on slope length or height.

- WMI Sabine Parish Landfill, Many, LA. (Gleason et al. 2001) Area 15 acres, average slope inclination 2.8:1, height of 80 ft without benches, covered with 60-mil HDPE. The cover was anchored in trenches leaving slope distances of 115-130 ft between anchorages. Passive gas flaps were used to vent LFG.

- "Other projects" mentioned by Richardson (2000a) with photo of hazardous waste cover made from HDPE.

- Coffin Butte Landfill, Corvallis, OR, and numerous other sites in Pacific NW. Sites commonly operate with 6-mil Griffolyn as an interim cover over 10+ acres exposed, ballasted

only by sandbags. Some areas have been exposed up to 5 years. Seams typically have back-to-back sandbags. The rest of the area typically has a roped 8'×10' grid with 40-lb sandbags at each node. When no shortcuts are taken with regard to sandbagging and cross-linking the rope grid, there have not been failures due to under-ballasting. Note, however, these temporary tarps were not intended to provide any guaranteed level of barrier containment, and would never be suggested for a quasi-permanent installation. They are mentioned here only in the context of the ballast method that was used.

- Numerous floating covers and inflated covers have performed under exposed conditions, although the design conditions are not quite the same as those for landfill covers.

Based on the literature search described above there are two materials that have successfully been used for exposed geomembrane covers: reinforced polypropylene and HDPE. This track record matches Thiel's experience in evaluating materials for an inflated pond cover. Although the forces and anchoring for the inflated pond cover are different than for an exposed geomembrane cover laying on a subgrade, many of the selection criteria are similar. Thiel eventually recommended a reinforced polypropylene for the inflated pond cover, which has proven to be a very successful selection (Thiel, 2001).

2.2 MATERIAL EVALUATION CRITERIA

The thickness of HDPE used on projects described in the literature is mostly 60-mil, with one project using 40-mil. If HDPE were selected for the Yolo County project, Thiel would recommend 60-mil material because of its higher tear strength.

The thickness of reinforced polypropylene used on the one large project in Delaware was 36 mils, which is the industry standard for this type of material. It is available in other thickness as well, ranging from 20-45 mils. The same scrim reinforcement is generally used for all the thicknesses; with heavier polymer coatings providing increased thicknesses for increased UV durability. Generally for 36-mil material and greater, an industry standard 20-year warranty can be obtained against material degradation due to exposure. For thinner gages, the warranty period may be reduced. For a recent inflated cover project, Thiel selected 30-mil material as providing a good balance between durability (15-year warranty), material weight (cover is pulled on and off every year), and cost.

Table 1 presents a list of criteria that would be used to evaluate a potential exposed geomembrane cover material.

Table 1. Evaluation Criteria

CRITERIA	TEXTURED HDPE	REINFORCED POLYPROPYLENE
Exposure to UV and temperature extremes	Excellent (backed by warranty)	Excellent (backed by warranty)
Exposure to physical impact	Reasonably good	Excellent because of dense reinforcement
Resistance to down-slope creep	Poor. High expansion and contraction will result in progressive wrinkles occurring at toe.	Good. Low expansion and contraction coefficient
Resistance to wind-related uplift damage and tear resistance	Moderately good	Excellent because of high strength in both tension and tear modes
Ease of Maintenance	Good, but need specialized welding equipment, extrusion rod, and trained welder	Very good, can do with minimal training with a hot-air gun, not requiring extrudate
Demonstrated performance	Several projects	At least one large project, plus Thiel inflated cover experience
Surface texture	Available with textured surface to allow easier slope access by foot	Surface not available textured, but softer polymer and scrim provides fair traction for access by foot
Availability and cost	The most available of all products and probably the lowest cost	Good availability, but requires potentially more lead time than HDPE; material costs more than HDPE

2.3 UNIQUE ASPECTS OF YOLO COUNTY APPLICATION

Relative to the list of projects described above, the Yolo County application does not appear to be particularly unique. There is one significant concern, however, and that is regard to the number of penetrations that are expected to occur. The one reference by Gleason et al. (1999) cautions against penetrations, and recommends that penetrations through the geomembrane be eliminated to the extent possible, and that where penetrations occur, they be located next to geomembrane anchors. If it is possible for the Yolo County design to bring the pipe and instrumentation penetrations down the slope, under the cover, and create the penetrations at the toe, that would be preferable because the toe will have a continuous soil anchor. If that is not possible, the Yolo County operations staff should be aware that all penetrations are points of possible damage to either the pipes or the geomembrane, or both, and these points should be regularly inspected, especially after wind storms.

Other noteworthy recommendations from Gleason et al. (1999) are:

- Concave areas of the slope should be filled so that the geomembrane does not have a tendency to bridge over these areas. Yolo County should make an effort in the filling process to have all the slope surfaces be flat to convex.

- Geomembrane seams that might be subject to peel forces during wind uplift should receive extra ballast.

- An active gas collection system greatly benefits the exposed cover during strong winds. Relative to this point, Thiel strongly recommends that the air flow through the aerobic cells be created by suction, and not by blowing air into the landfill. The positive pressure that would be caused by blowing air into the landfill would exacerbate all potential problems with an exposed geomembrane cover, especially at the locations of penetrations.

- During construction, the installer needs to take great care in leaving exposed edges. Gleason et al. reported losing 5 acres of material in a windstorm during construction. A sequencing plan should be developed by prospective bidders.

2.4 CONCLUSIONS AND RECOMMENDATIONS REGARDING MATERIAL SELECTION

Research was performed regarding geosynthetic materials that are available that will provide good durability and performance for the surface liner application at Yolo County Central Landfill. The research indicates that HDPE and reinforced polypropylene are the two types of materials successfully being used for this type of application.

For durability, functionality, and ease of maintenance, Thiel recommends that Yolo County select reinforced 30-mil polypropylene. The selection of 30-mil is based on Thiel's judgement of the County's needs for the bioreactor application. A heavier material (namely 36-mil) is probably not needed, although would be acceptable if there was no extra cost compared to obtaining a 30-mil material, or if availability was an issue.

3. WIND UPLIFT DESIGN

This chapter describes the approach used for designing the exposed geomembrane cover system to survive wind uplift, and presents the calculations used to make design recommendations.

3.1 DESIGN APPROACH

The design approach used follows the method described by Giroud et al. (1995) to evaluate the forces acting on the geomembrane and the anchor trench due to wind uplift. The design steps and associated assumptions are described as follows (note that the calculations are generally performed in metric units):

1. The design wind velocity was selected as 90 miles per hour (40.2 m/s). This represents a fairly extreme wind velocity commonly used for safe design of buildings and other structures.

2. The uplift suction pressure, S, is calculated as follows:

$$S = (0.05)\lambda v_w^2 \qquad (1)$$

Where S = suction (Pa); λ = dimensionless suction factor; and v_w = design wind speed (km/hr). Conservative suction factors used in the analysis were $\lambda = 0.7$ for slopes, and $\lambda = 1.0$ for horizontal surfaces.

3. The factor of safety against the geomembrane failing by rupture due to the uplift suction pressure is

$$FS_r = \varepsilon_a/\varepsilon_c \qquad (2)$$

Where FS_r = factor of safety against tensile rupture; ε_a = maximum tensile strain before rupture; and ε_c = calculated tensile strain due to the wind uplift. For the reinforced polypropylene geomembrane, a maximum tensile strain of $\varepsilon_a = 27\%$ was selected for the design based on published material properties. The calculation of ε_c is performed by calculating the value of the normalized stiffness of the geomembrane, $J/(SL)$, and selecting the value of ε_c by referring to Table 4 in the paper by Giroud et al. (1995). The variables in the calculation of the normalized stiffness are defined as follows: J = the tensile stiffness of the geomembrane such as measured in a wide-width tensile test (kN/m), and L = the slope length of the exposed geomembrane from anchor point to anchor point. For this design, the tensile of stiffness of the reinforced polypropylene was estimated as 165 kN/m.

4. Using the value of the calculated strain, ε_c, the values for the uplift distance (u), uplift angle (θ), and the normalized tension (T/SL), can be found by referring to Table 2 of Giroud et al. (1995).

5. The tensile force, T, in the geomembrane can also be calculated and checked against the value found in Table 2 of Giroud et al. (1995) as follows:

$$T = J\varepsilon_c \text{ (kN/m)} \qquad (3)$$

6. Knowing the tensile force (T) in the geomembrane, and the uplift angle (θ), the horizontal and vertical forces acting on the anchor trenches can be calculated. The anchor trenches can then be designed to resist sliding, pulling, and/or uplift as appropriate.

3.2 RESULTS OF CALCULATIONS

The calculations were coded into a spreadsheet and checked against examples published in the literature (e.g. Gleason et al., 1998). The spreadsheet calculations are presented in Tables 2-6 for the Anaerobic Slope, Anaerobic Top-deck, Aerobic Slope Above the Bench (both 2:1 and 3:1 slopes), and the Aerobic Slope Below the Bench, respectively. Design recommendations were provided as a result of the calculations, relative to the geometry shown in the design drawings produced by Vector Engineering, and are described in the following paragraphs.

ANAEROBIC CELL

- The anchor trench at the crest of the slope should be a minimum of 3 feet deep and 8 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf).

- The weld connecting the geomembrane on the slope to the geomembrane on the top-deck should be placed either within the anchor trench, or on the side of the anchor trench going towards the middle of the top-deck to avoid having the weld experience peel forces. In general, all welds should be constructed to avoid peel forces when the geomembrane is uplifted due to wind.

- The anchor trench at the toe of the slope should be a minimum of 3 feet deep and 7 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf).

- To provide additional hold-down force during construction and operations, a grid of 40-50 lb sandbags is recommended to be installed over the entire liner surface at a spacing of 8-feet on-center each-way. The sandbag locations should be maintained by securing the sandbags to a polypropylene rope grid. The vertical ropes should be ¾" diameter, the horizontal ropes should be 3/8" diameter. Supplemental ropes should be added at corner hinge points. All the ropes on the top-deck should be ¾" diameter. The sandbags should be tied at each grid node using electrical zip-ties threaded through the strands of both intersecting ropes. Additional sandbags are recommended around each pipe penetration through the liner to help reduce the amount of stress that would occur on the pipe boot.

- Vents were recommended at the crest of the slope at a 50' spacing. Special-order mechanical vents were specified that would open when the pressure below the geomembrane relative to the pressure above the geomembrane would be greater than 0.85-inch of water column. Although there is no specific design methodology for crest vents, vents have been observed to reduce the effects of strong wind uplift (Giroud et al. 1995). Ultimately the Yolo County staff decided to leave the vents out, at least initially, and install a manually-operated header vent to reduce excess gas pressure in the event the active gas collection system went down. The vents could be installed at a later date if deemed necessary by the County staff.

- To the extent possible, Thiel Engineering recommended that pipe penetrations be reduced or eliminated because experience has shown that these locations will provide the most operational problems over time. The nature of the Yolo County test cells, however, is such that numerous penetrations will exist for purposes of instrumentation and operation of the test cells. Because of the potentially high magnitude of forces that might be exerted on the penetrations due to wind uplift, Thiel Engineering recommended that the penetration boots be fabricated from reinforced material rather than using the vacuum-formed non-reinforced boots. Thiel Engineering notes that problems and repairs at the penetration points are to be expected over time due to wind uplift. The nature of the problems might include ripped cover material, ripped boots, and broken pipes. As problem areas become identified and repaired, it is possible that additional cover ballast could be added at those locations to reduce the chances of repeat failures at the same locations.

AEROBIC CELL

- The anchor trench at the crest of the slope should be a minimum of 3 feet deep and 6 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf). This will occur near the biofilter on the top-deck.

- The bench near the lower third of the slope should have a prism of soil encapsulated in the liner material to provide a mid-slope anchor. The best design would be to have the primary surface liner run continuously through the bench, and the soil prism cap-stripped by a separate piece of liner material. The cross-sectional area of the soil prism should be a minimum of 12 ft^2 (e.g. 6' wide by 2' thick as shown on the Vector drawings).

- The anchor trench at the toe of the slope should be a minimum of 2 feet deep and 6 feet wide, filled with soil having a minimum density of 100 pounds per cubic foot (pcf).

- To provide additional hold-down force during construction and operations, a grid of 40-50 lb sandbags was recommended to be installed over the entire liner surface at a spacing of 8-feet on-center each-way. The sandbag locations would be maintained by securing the sandbags to a polypropylene rope grid. The vertical ropes would be ¾" diameter, the horizontal ropes would be 3/8" diameter. Supplemental ropes would be added at corner hinge points. All the ropes on the topdeck would be ¾" diameter. The sandbags would be tied at each grid node using electrical zip-ties threaded through the strands of both intersecting ropes. Additional sandbags were recommended around each pipe penetration through the liner to help reduce the amount of stress that would occur on the pipe boot.

- Additional continuous anchorage should be provided in the hip-valleys on the south-facing slope. This anchorage could be provided by an encapsulated soil prism or sandbags to provide a weight of 200 lbs per lineal foot from crest to toe.

- The same cautions, related to surface liner penetrations, which were described for the anaerobic cell, apply to the aerobic cell.

- Relative to the operational durability of the surface liner on the aerobic cell, Thiel Engineering advises against blowing air into the aerobic cell as this will have the potential of creating a positive pressure on the surface liner, thus exacerbating any potential wind uplift problems. If fresh air is desired to be introduced into the cell, Thiel Engineering recommends that a means be designed to suck the air in, rather than blow it in.

3.3 OPERATIONAL ISSUES

The most significant operational issue associated with the exposed surface liners will be damage due to wind uplift. Although the geomembrane and anchorages have been designed to withstand the very severe case of a 90 mph wind, the stresses and forces exerted at the numerous points of liner penetration by pipes are bound to cause some problems. Thiel Engineering recommends that Yolo County staff make an extra effort to be present and observe the surface liner performance during initial high wind events. Areas that are suspected to be vulnerable to wind damage as a result of these observations should receive extra sandbag ballast. Extra supplies of pre-made sandbags, rope, zip-ties, liner repair patches, a heat gun (e.g. Lyster machine) for welding, and a brayer should be on-hand to respond to damage during a windstorm.

Additionally, a telemetry system should be installed to auto-dial an alarm if the gas blower system goes down in the anaerobic cell. When the active gas collection system is working, it will be very beneficial to the performance of the geomembrane surface liner. When the gas collection blower is down, however, buildup of gas pressures beneath the liner can be very detrimental to the wind-uplift performance of the liner. In that case, the manual vent at the crest of the landfill should be opened.

4. REFERENCES

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Table 2. Spreadsheet for Calculation of Forces on Surface Liner for Anaerobic Cell Side Slopes

Project:	YOLO COUNTY CENTRAL LANDFILL TEST CELLS - ANAEROBIC SLOPES						
GEOMEMBRANE TENSION AND UPLIFT							
Design wind speed	90	mph					
	40.23	m/s					
Slope height	47	ft					
	14.32	m					
Slope angle	21.8	deg	Cos (b)=	0.9285			
Slope length	38.57	m					
GM mass/area (30 mil)	0.864	kg/m2					
Sandbag mass/area	3.05	kg/m2	Assumes 40-lb sandbag @ 8' o.c., e.w.				
suction factor lamda	0.7						
Effective suction Se	696.77	Pa					
Stiffnes J	165	kN/m					
Normalized tensile stiffness J/SeL	6.14						
Calc strain (Table 4 - Giroud et al)	11.4%						
Break strain	27%						
FS	2.4						
T/SeL (Table 2 - Giroud et al 1995)	0.7						
Tension T	18.81	kN/m					
check on T	18.81	kN/m =	1,288.84	lb/ft =	107.40	lb/in	
Max uplift u (Table 2 - Giroud et al)	8.10	m =	26.58	ft			
Theta (Table 2 - Giroud et al)	45.6	deg					
CHECK FOR UPLIFT AND PULLOUT OF ANCHOR TRENCH							
Vertical uplift on upper anchor	7.59	kN/m =	520.10	lb/ft =	43.34	lb/in	
Horizontal force	17.21	kN/m =	1,179.23	lb/ft =	98.27	lb/in	
A.T. setback from slope	1.00	m	3.28	ft			
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf			
Assumed anchor trench width	2.44	m	8.01	ft			
Assumed depth of anchor trench	0.91	m =	2.99	ft			
Assumed GM/soil friction angle top	18.00	deg					
Assumed GM/soil friction angle bottom	18.00	deg					
Assumed soil friction angle	30.00	deg					
Pullout force must be > T	25.90	kN/m					
FS against pullout	1.38	OK when combined with topdeck					
FS against uplift	4.97						
FS against horiz. Sliding	1.23						
Vertical uplift on lower anchor (TOE)	17.37	kN/m =	1,189.87	lb/ft =	99.16	lb/in	
Horizontal force	7.23	kN/m =	495.29	lb/ft =	41.27	lb/in	
A.T. setback from slope	-	m	-	ft			
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf			
Assumed anchor trench width	**2.10**	**m**	**6.89**	**ft**			
Assumed depth of anchor trench	**0.91**	**m =**	**2.99**	**ft**	**Cross sectional area of AT**		**20.57**
Assumed GM/soil friction angle top	18.00	deg					
Assumed GM/soil friction angle bottom	18.00	deg					
Assumed soil friction angle	30.00	deg					
Pullout force must be > T	22.48	kN/m					
FS against pullout	1.20	(Note: FS even greater because it works against topdeck)					
FS against uplift	1.87						
FS against horiz. Sliding	1.46	(Note: FS even greater because it works against topdeck)					

Table 3. Spreadsheet for Calculation of Forces on Surface Liner for Anaerobic Cell Topdeck

Project: **ANAEROBIC CELL**	YOLO COUNTY CENTRAL LANDFILL TEST CELLS - **TOPDECK**						
GEOMEMBRANE TENSION AND UPLIFT							
Design wind speed	90	mph					
	40.23	m/s					
Slope height	0	ft					
	-	m					
Slope angle	0	deg	Cos (b)=	1			
Slope length	30.00	m	98.43	ft			
GM mass/area (30 mil)	0.864	kg/m2					
Sandbag mass/area	3.05	kg/m2	Assumes 40-lb sandbag @ 8' o.c., e.w.				
suction factor lamda	1						
Effective suction Se	1,007.92	Pa					
Stiffnes J	165	kN/m					
Normalized tensile stiffness J/SeL	5.46						
Calc strain (Table 4 - Giroud et al)	12.4%						
Break strain	27%						
FS	2.2						
T/SeL (Table 2 - Giroud et al 1995)	0.68						
Tension T	20.56	kN/m					
check on T	20.46	kN/m =	1,401.89	lb/ft =	116.82	lb/in	
Max uplift u (Table 2 - Giroud et al)	6.60	m =	21.65	ft			
Theta (Table 2 - Giroud et al)	47.5	deg					
CHECK FOR UPLIFT AND PULLOUT OF ANCHOR TRENCH							
Vertical uplift on upper anchor	15.08	kN/m =	1,033.58	lb/ft =	86.13	lb/in	
Horizontal force	13.82	kN/m =	947.11	lb/ft =	78.93	lb/in	
A.T. setback from slope	1.00	m	3.28	ft			
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf			
Assumed anchor trench width	2.44	m	8.01	ft			
Assumed depth of anchor trench	0.91	m =	2.99	ft			
Assumed GM/soil friction angle top	18.00	deg					
Assumed GM/soil friction angle bottom	18.00	deg					
Assumed soil friction angle	30.00	deg					
Pullout force must be > T	25.90	kN/m					
FS against pullout	1.26	(Note: FS even greater because it works against slope liner)					
FS against uplift	2.50						
FS against horiz. Sliding	1.53	(Note: FS even greater because it works against slope liner)					

Table 4. Spreadsheet for Calculation of Forces on Surface Liner for Aerobic Cell 2:1 Side Slopes

Project: YOLO COUNTY CENTRAL LANDFILL TEST CELLS - AEROBIC 2:1 CELLSLOPE							
GEOMEMBRANE TENSION AND UPLIFT							
Design wind speed	90	mph					
	40.23	m/s					
Slope height	28	ft					
	8.53	m					
Slope angle	26.6	deg	Cos (b)=	0.8942			
Slope length	19.06	m =	62.53	ft			
GM mass/area (30 mil)	0.864	kg/m2					
Sandbag mass/area	3.05	kg/m2	Assumes 40-lb sandbag @ 8' o.c., e.w.				
suction factor lamda	0.7						
Effective suction Se	698.09	Pa					
Stiffnes J	165	kN/m					
Normalized tensile stiffness J/SeL	12.40						
Calc strain (Table 4 - Giroud et al)	6.9%						
Break strain	27%						
FS	3.9						
T/SeL (Table 2 - Giroud et al 1995)	0.854						
Tension T	11.36	kN/m					
check on T	11.42	kN/m =	782.35	lb/ft =	65.20	lb/in	
Max uplift u (Table 2 - Giroud et al)	3.55	m =	11.64	ft			
Theta (Table 2 - Giroud et al)	40.9	deg					
CHECK FOR UPLIFT AND PULLOUT OF ANCHOR TRENCH							
Vertical uplift on upper anchor	2.82	kN/m =	193.24	lb/ft =	16.10	lb/in	
Horizontal force	11.06	kN/m =	758.11	lb/ft =	63.18	lb/in	
A.T. setback from slope	1.00	m	3.28	ft			
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf			
Assumed anchor trench width	**1.80**	**m**	**5.91**	**ft**			
Assumed depth of anchor trench	**0.91**	**m =**	**2.99**	**ft**			
Assumed GM/soil friction angle top	18.00	deg					
Assumed GM/soil friction angle bottom	18.00	deg		Tear strength=		55	lb
Assumed soil friction angle	30.00	deg					
Pullout force must be > T	19.47	kN/m =	1,333.90	lb/ft =			
FS against pullout	1.71						
FS against uplift	9.87						
FS against horiz. Sliding	1.62						
CHECK FORCES ON LOWER BENCH							
Vertical uplift on lower anchor	10.55	kN/m =	722.79	lb/ft =	60.23	lb/in	
Horizontal force	4.37	kN/m =	299.39	lb/ft =	24.95	lb/in	
A.T. setback from slope	-	m	-	ft			
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf			
Assumed anchor trench width	1.83	m	**6.00**	ft			
Assumed depth of anchor trench	0.61	m =	**2.00**	ft			
Assumed GM/soil friction angle top	18.00	deg					
Assumed GM/soil friction angle bottom	10.00	deg					
Assumed soil friction angle	30.00	deg					
Pullout force must be > T	9.51	kN/m					
FS against pullout	0.84	(OK because it works against lower slope liner)					
FS against uplift	1.80						
FS against horiz. Sliding	0.77	(OK because it works against lower slope liner)					

Table 5. Spreadsheet for Calculation of Forces on Surface Liner for Aerobic Cell 3:1 Side Slopes

Project: YOLO COUNTY CENTRAL LANDFILL TEST CELLS - **AEROBIC 3:1 CELLSLOPE**							
GEOMEMBRANE TENSION AND UPLIFT							
Design wind speed	90	mph					
	40.23	m/s					
Slope height	28	ft					
	8.53	m					
Slope angle	18.4	deg	Cos (b)=	0.9489			
Slope length	27.04	m =	88.71	ft			
GM mass/area (30 mil)	0.864	kg/m2					
Sandbag mass/area	3.05	kg/m2	Assumes 40-lb sandbag @ 8' o.c., e.w.				
suction factor lamda	0.7						
Effective suction Se	695.99	Pa					
Stiffnes J	165	kN/m					
Normalized tensile stiffness J/SeL	8.77						
Calc strain (Table 4 - Giroud et al)	8.8%						
Break strain	27%						
FS	3.1						
T/SeL (Table 2 - Giroud et al 1995)	0.77						
Tension T	14.49	kN/m					
check on T	14.52	kN/m =	994.89	lb/ft =	82.91	lb/in	
Max uplift u (Table 2 - Giroud et al)	5.03	m =	16.52	ft			
Theta (Table 2 - Giroud et al)	40.9	deg					
CHECK FOR UPLIFT AND PULLOUT OF ANCHOR TRENCH							
Vertical uplift on upper anchor	5.56	kN/m =	380.73	lb/ft =	31.73	lb/in	
Horizontal force	13.41	kN/m =	919.16	lb/ft =	76.60	lb/in	
A.T. setback from slope	1.00	m	3.28	ft			
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf			
Assumed anchor trench width	**1.80**	**m**	**5.91**	**ft**			
Assumed depth of anchor trench	**0.91**	**m =**	**2.99**	**ft**			
Assumed GM/soil friction angle top	18.00	deg					
Assumed GM/soil friction angle bottom	18.00	deg		Tear strength=	55	lb	
Assumed soil friction angle	30.00	deg					
Pullout force must be > T	19.47	kN/m =	1,333.90	lb/ft =			
FS against pullout	1.34						
FS against uplift	5.01						
FS against horiz. Sliding	1.34						
CHECK FORCES ON LOWER BENCH							
Vertical uplift on lower anchor	12.49	kN/m =	855.46	lb/ft =	71.29	lb/in	
Horizontal force	7.41	kN/m =	507.94	lb/ft =	42.33	lb/in	
A.T. setback from slope	-	m	-	ft			
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf			
Assumed anchor trench width	1.83	m	**6.00**	ft			
Assumed depth of anchor trench	0.61	m =	**2.00**	ft			
Assumed GM/soil friction angle top	18.00	deg					
Assumed GM/soil friction angle bottom	10.00	deg					
Assumed soil friction angle	30.00	deg					
Pullout force must be > T	9.51	kN/m					
FS against pullout	0.66	(OK because it works against lower slope liner)					
FS against uplift	1.52						
FS against horiz. Sliding	0.45	(OK because it works against lower slope liner)					

Table 6. Spreadsheet for Calculation of Forces on Surface Liner for Aerobic Cell Side Slopes Below the Intermediate Bench

Project: **AEROBIC CELL**	YOLO COUNTY CENTRAL LANDFILL TEST CELLS - **BERM SLOPE**					
GEOMEMBRANE TENSION AND UPLIFT						
Design wind speed	90	mph				
	40.23	m/s				
Slope height	12	ft				
	3.66	m				
Slope angle	21.8	deg	Cos (b)=	0.9285		
Slope length	9.85	m				
GM mass/area (30 mil)	0.864	kg/m2				
Sandbag mass/area	3.05	kg/m2	Assumes 40-lb sandbag @ 8' o.c., e.w.			
suction factor lamda	0.7					
Effective suction Se	696.77	Pa				
Stiffnes J	165	kN/m				
Normalized tensile stiffness J/SeL	24.04					
Calc strain (Table 4 - Giroud et al)	4.3%					
Break strain	27%					
FS	6.3					
T/SeL (Table 2 - Giroud et al 1995)	1.07					
Tension T	7.34	kN/m				
check on T	7.13	kN/m =	488.40	lb/ft =	40.70	lb/in
Max uplift u (Table 2 - Giroud et al)	1.23	m =	4.04	ft		
Theta (Table 2 - Giroud et al)	27.8	deg				
CHECK FOR UPLIFT AND PULLOUT OF ANCHOR TRENCH						
Vertical uplift on upper anchor	0.75	kN/m =	51.05	lb/ft =	4.25	lb/in
Horizontal force	7.09	kN/m =	485.73	lb/ft =	40.48	lb/in
A.T. setback from slope	1.00	m	3.28	ft		
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf		
Assumed anchor trench width	1.83	m	6.00	ft		
Assumed depth of anchor trench	0.61	m =	2.00	ft		
Assumed GM/soil friction angle top	18.00	deg				
Assumed GM/soil friction angle bottom	18.00	deg				
Assumed soil friction angle	30.00	deg				
Pullout force must be > T	12.33	kN/m				
FS against pullout	1.68					
FS against uplift	25.47					
FS against horiz. Sliding	1.71					
CHECK FORCES ON LOWER BENCH						
Vertical uplift on lower anchor	5.43	kN/m =	371.94	lb/ft =	30.99	lb/in
Horizontal force	4.62	kN/m =	316.54	lb/ft =	26.38	lb/in
A.T. setback from slope	NA	m	#VALUE!	ft		
Unit wt of upper anchor trench backfill	17.00	kN/m3 =	108.28	pcf		
Assumed anchor trench width	1.83	m	6.00	ft		
Assumed depth of anchor trench	0.61	m =	2.00	ft		
Assumed GM/soil friction angle top	18.00	deg				
Assumed GM/soil friction angle bottom	10.00	deg				
Assumed soil friction angle	30.00	deg				
Pullout force must be > T	9.51	kN/m				
FS against pullout	1.30	(Conservative - did not count side forces)				
FS against uplift	3.50					
FS against horiz. Sliding	#VALUE!	(Actually NA in this case - sliding not an issue.)				

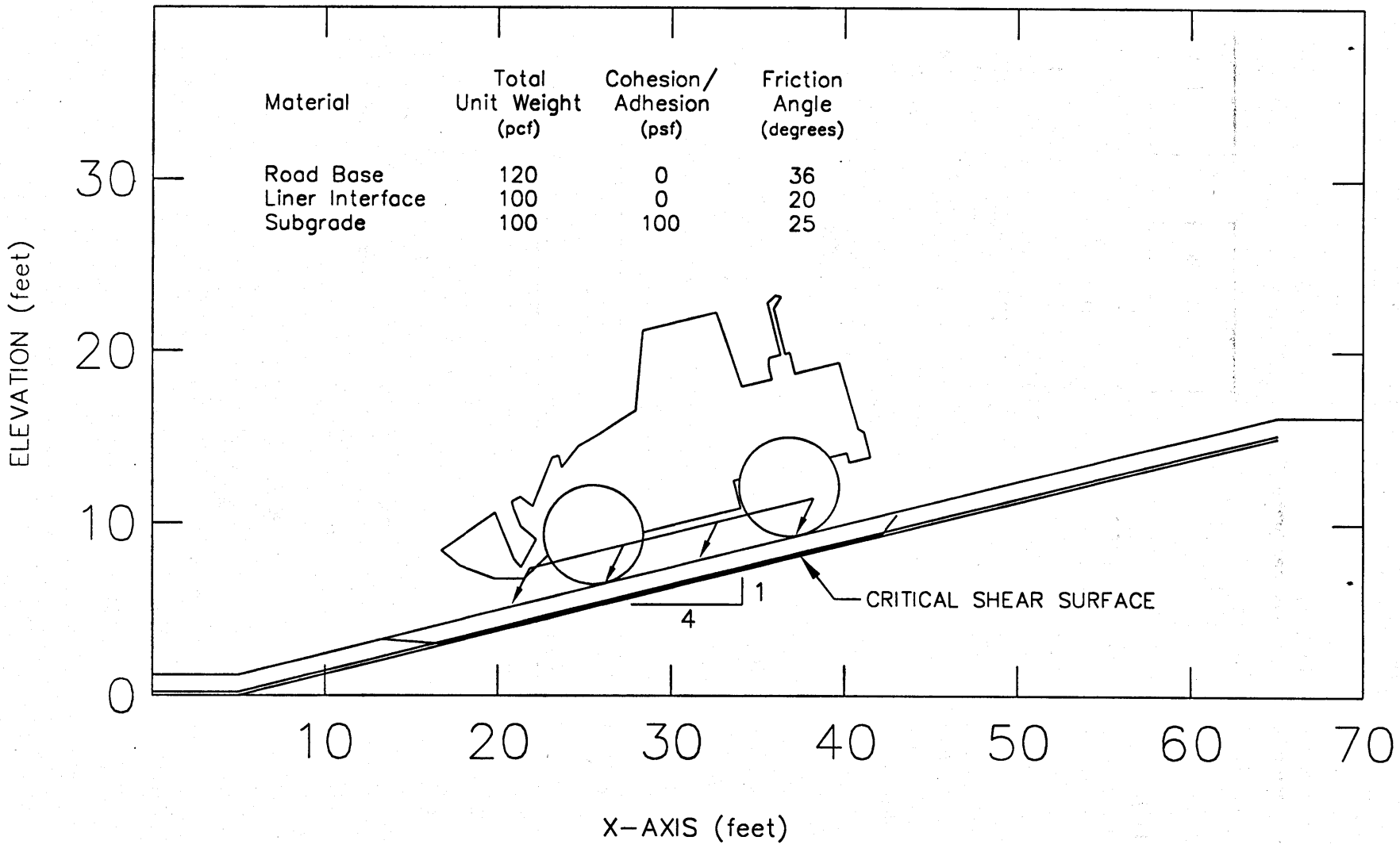
APPENDIX B
RESULTS OF STABILITY ANALYSES

Yolo County Landfill, 4:1 Access Road Stability
Infinite Slope Method of Cover Slope Stability Analysis
Reference Thiel and Stewart (1993)
Interface between geotextile and geomembrane (RPP)

	Normal Conditions	During Heavy Rainfall
Slope Angle, B, (degrees)	14	14
Ave. Depth of Solution in Cover Layer (ft.)	0	0.25
Topsoil Thickness, (ft.)	0	0
Cover Soil Layer Thickness, (ft.)	1	1
Topsoil Saturated Unit Weight, (pcf)	135	135
Cover Layer Total Unit Wt., (pcf)	125	125
Cover Layer Saturated Unit Weight., (pcf)	135	135
Solution Unit Wt. (pcf)	62.4	62.4
Interface Friction, phi, (degrees)	20	20
Interface Adhesion (psf)	0	0
Sin B	0.2419	0.2419
Cos B	0.9703	0.9703
Tan phi	0.3640	0.3640
Tan B	0.2493	0.2493

STATIC		
Resisting Strength (psf)	44.1	39.5
Driving Stress (psf)	30.2	30.8
Factor of Safety	**1.46**	**1.28**

UTEXAS3 – SPENCER'S METHOD OF SLICES



Job No.	931010.18
Date:	11/08/01
User:	MRT
CRITICAL FACTOR OF SAFETY:	1.10

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FILENAME: yolobrk4.out

Yolo County Landfill
Access Road Stability
4:1, with braking equipment

```
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        TABLE NO. 1
        ****************************************
        * COMPUTER PROGRAM DESIGNATION - UTEXAS3 *
        * Originally Coded By Stephen G. Wright  *
        * Version No. 1.209                      *
        * Last Revision Date  2/28/98            *
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        * All Rights Reserved                    *
        ****************************************

        ************************************************************
        *                                                          *
        *      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
        * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
        * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
        * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
        * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
        * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
        * PROGRAM BEFORE ATTEMPTING ITS USE.                         *
        *                                                          *
        *      NEITHER SHINOAK SOFTWARE NOR STEPHEN G. WRIGHT        *
        * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
        * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
        * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
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        Failure above liner, 4:1, with braking equipment


        TABLE NO.  2
        *************************
        * NEW PROFILE LINE DATA *
        *************************

        PROFILE LINE  1 - MATERIAL TYPE =  1
        OVERLINER MOIST

             Point      X             Y

               1          .000         1.200
               2         5.000         1.200
               3        65.000        16.200
               4        70.000        16.200

        PROFILE LINE  2 - MATERIAL TYPE =  2
        LINER INTERFACE

             Point      X             Y

               1          .000          .200
               2         5.000          .200
               3        65.000        15.200

        PROFILE LINE  3 - MATERIAL TYPE =  3
        SUBGRADE

             Point      X             Y

               1          .000          .000
               2         5.000          .000
               3        65.000        15.000
```

All new profile lines defined - No old lines retained
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TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
****

DATA FOR MATERIAL TYPE 1
OVERLINER

Unit weight of material = 120.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - .000
Friction angle - - - - - 36.000 degrees

No (or zero) pore water pressures

DATA FOR MATERIAL TYPE 2
Liner INterface

Unit weight of material = 100.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - .000
Friction angle - - - - - 20.000 degrees

No (or zero) pore water pressures

DATA FOR MATERIAL TYPE 3
Subgrade

Unit weight of material = 100.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 100.000
Friction angle - - - - - 25.000 degrees

No (or zero) pore water pressures

All new material properties defined - No old data retained
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TABLE NO. 10
****
* NEW SURFACE PRESSURE DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
****

ALL NEW DATA INPUT - NO OLD DATA RETAINED

Surface Pressures -

Point	X	Y	Normal Pressure	Shear Stress
1	17.000	4.200	116.400	-54.000
2	43.200	10.750	116.400	-54.000

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TABLE NO. 15
****
* NEW ANALYSIS/COMPUTATION DATA *
****

Noncircular Shear Surface(s)

Automatic Search Performed

Coordinates of points on shear surface which are to be shifted -

Point	X	Y	Shift Angle	
1	13.000	3.200	14.04	- moveable
2	17.000	3.100	14.04	- moveable
3	45.000	10.100	14.04	- moveable
4	49.000	12.000	14.04	- moveable

Initial distance for shifting points on shear surface = 5.000
Maximum steepness permitted for toe of shear surface = 50.00 degrees

Short form of output will be used for search

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Initial trial estimate for side force inclination = 15.000 degrees
(Applicable to Spencer's procedure only)

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Initial trial values for factor of safety (and side force inclination
for Spencer's procedure) will be kept constant during search

Number of increments for slice subdivision = 30

Depth of water in crack = .000

Unit weight of water in crack = 62.400

Seismic coefficient = .000

Conventional (single-stage) computations to be performed

Procedure used to compute the factor of safety: SPENCER

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TABLE NO. 16
****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA
WERE GENERATED BY THE PROGRAM

Slope Coordinates -

Point	X	Y
1	.000	1.200
2	5.000	1.200
3	65.000	16.200
4	70.000	16.200

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TABLE NO. 24
****
* SHORT-FORM TABLE FOR SEARCH WITH NONCIRCULAR SHEAR SURFACES *
****
1-Stage

Trial	Shear Surface Coordinates X	Y	X	Y	Factor of Safety	Side Force Inclin.
0	13.00	3.20	17.00	3.10	1.165	25.40
	45.00	10.10	49.00	12.00		
1	13.00	3.20	17.00	3.10	1.153	23.55
	45.00	10.10	49.00	12.00		
2	12.03	2.96	16.89	3.07	1.167	24.70
	46.80	10.55	47.20	11.55		
3	12.03	2.96	16.89	3.07	1.163	23.50
	46.80	10.55	47.20	11.55		
4	12.03	2.96	16.89	3.07	1.174	22.60
	46.80	10.55	47.20	11.55		
5	12.03	2.96	16.89	3.07	1.147	23.48
	46.80	10.55	47.20	11.55		
6	12.51	3.08	16.41	2.95	1.145	23.56
	46.31	10.43	47.69	11.67		
7	13.00	3.20	16.45	2.96	1.144	23.72
	46.31	10.43	47.20	11.55		
8	12.94	3.19	16.94	3.08	1.142	23.67
	45.83	10.31	47.30	11.57		
9	13.43	3.31	16.72	3.03	1.142	23.62
	45.94	10.33	46.81	11.45		
10	13.22	3.26	16.73	3.03	1.141	23.51
	45.45	10.21	46.92	11.48		
11	13.22	3.25	16.67	3.02	1.140	23.47
	45.55	10.24	46.43	11.36		
12	13.16	3.24	16.67	3.02	1.139	23.39
	45.07	10.12	46.53	11.38		

13	13.17	3.24	16.65	3.01	1.138	23.36
	45.17	10.14	46.05	11.26		
14	13.15	3.24	16.66	3.01	1.137	23.29
	44.69	10.02	46.15	11.29		
15	13.16	3.24	16.65	3.01	1.137	23.26
	44.79	10.05	45.66	11.17		
16	13.16	3.24	16.66	3.01	1.135	23.20
	44.30	9.93	45.76	11.19		
17	13.17	3.24	16.66	3.01	1.135	23.17
	44.40	9.95	45.28	11.07		
18	13.17	3.24	16.66	3.01	1.134	23.14
	43.91	9.83	45.38	11.09		
19	13.18	3.24	16.66	3.01	1.133	23.08
	44.01	9.85	44.89	10.97		
20	13.18	3.24	16.66	3.01	1.126	22.76
	43.53	9.73	44.99	11.00		
21	13.18	3.25	16.66	3.02	1.118	22.36
	43.04	9.61	44.51	10.88		
22	13.21	3.25	16.66	3.02	1.110	22.04
	42.56	9.49	44.02	10.76		
23	13.23	3.26	16.67	3.02	1.104	21.84
	42.34	9.44	43.54	10.63		
24	13.27	3.27	16.67	3.02	1.104	21.85
	42.14	9.39	43.05	10.51		

TABLE NO. 25

****

* FINAL CRITICAL SHEAR SURFACE (FOUND AFTER 24 TRIAL POSITIONS) *

****

X	Y
13.27	3.27
16.67	3.02
42.14	9.39
43.05	10.51

1-Stage Factor of Safety = 1.104

Side Force Inclination = 21.84

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Failure above liner, 4:1, with braking equipment

TABLE NO. 26
****
* Coordinate, Weight, Strength and Pore Water Pressure *
* Information for Individual Slices for Conventional *
* Computations or First Stage of Multi-Stage Computations. *
* (Information is for the Critical Shear Surface in the *
* Case of an Automatic Search.) *
****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	13.3	3.3					
1	13.7	3.2	11.6	1	.00	36.00	.0
	14.0	3.2					
2	14.4	3.2	34.8	1	.00	36.00	.0
	14.8	3.2					
3	15.2	3.1	58.1	1	.00	36.00	.0
	15.6	3.1					
4	16.0	3.1	81.3	1	.00	36.00	.0
	16.4	3.0					
5	16.5	3.0	38.7	2	.00	20.00	.0
	16.7	3.0					
6	16.8	3.1	42.4	2	.00	20.00	.0
	17.0	3.1					
7	17.5	3.2	121.1	2	.00	20.00	.0
	17.9	3.3					
8	18.4	3.4	121.1	2	.00	20.00	.0
	18.9	3.6					
9	19.3	3.7	121.1	2	.00	20.00	.0
	19.8	3.8					
10	20.3	3.9	121.1	2	.00	20.00	.0
	20.7	4.0					
11	21.2	4.1	121.1	2	.00	20.00	.0
	21.7	4.3					
12	22.1	4.4	121.1	2	.00	20.00	.0
	22.6	4.5					
13	23.1	4.6	121.1	2	.00	20.00	.0
	23.5	4.7					
14	24.0	4.8	121.1	2	.00	20.00	.0
	24.4	5.0					
15	24.9	5.1	121.1	2	.00	20.00	.0
	25.4	5.2					
16	25.8	5.3	121.1	2	.00	20.00	.0
	26.3	5.4					
17	26.8	5.5	121.1	2	.00	20.00	.0
	27.2	5.7					
18	27.7	5.8	121.1	2	.00	20.00	.0
	28.2	5.9					
19	28.6	6.0	121.1	2	.00	20.00	.0
	29.1	6.1					
20	29.6	6.2	121.1	2	.00	20.00	.0
	30.0	6.4					

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TABLE NO. 26
****
* Coordinate, Weight, Strength and Pore Water Pressure *
* Information for Individual Slices for Conventional *

```
*  Computations or First Stage of Multi-Stage Computations.  *
*  (Information is for the Critical Shear Surface in the     *
*  Case of an Automatic Search.)                             *
*************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	30.0	6.4					
21	30.5	6.5	121.1	2	.00	20.00	.0
	31.0	6.6					
22	31.4	6.7	121.1	2	.00	20.00	.0
	31.9	6.8					
23	32.4	6.9	121.1	2	.00	20.00	.0
	32.8	7.1					
24	33.3	7.2	121.1	2	.00	20.00	.0
	33.8	7.3					
25	34.2	7.4	121.1	2	.00	20.00	.0
	34.7	7.5					
26	35.2	7.6	121.1	2	.00	20.00	.0
	35.6	7.8					
27	36.1	7.9	121.1	2	.00	20.00	.0
	36.6	8.0					
28	37.0	8.1	121.1	2	.00	20.00	.0
	37.5	8.2					
29	38.0	8.3	121.1	2	.00	20.00	.0
	38.4	8.5					
30	38.9	8.6	121.1	2	.00	20.00	.0
	39.3	8.7					
31	39.8	8.8	121.1	2	.00	20.00	.0
	40.3	8.9					
32	40.7	9.0	121.1	2	.00	20.00	.0
	41.2	9.2					
33	41.7	9.3	121.1	2	.00	20.00	.0
	42.1	9.4					
34	42.2	9.4	12.6	2	.00	20.00	.0
	42.2	9.5					
35	42.4	9.8	38.7	1	.00	36.00	.0
	42.6	10.0					
36	42.8	10.3	19.4	1	.00	36.00	.0
	43.1	10.5					

```
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```

TABLE NO. 27

```
*************************************************************
*  Seismic Forces and Forces Due to Surface Pressures for   *
*  Individual Slices for Conventional  Computations or the  *
*  First Stage of Multi-Stage Computations.                 *
*  (Information is for the Critical Shear Surface in the    *
*  Case of an Automatic Search.)                            *
*************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	13.7	0.	3.3	0.	0.	13.7	3.4
2	14.4	0.	3.4	0.	0.	14.4	3.6
3	15.2	0.	3.4	0.	0.	15.2	3.8
4	16.0	0.	3.5	0.	0.	16.0	3.9
5	16.5	0.	3.6	0.	0.	16.5	4.1
6	16.8	0.	3.6	0.	0.	16.8	4.2
7	17.5	0.	3.8	112.	-52.	17.5	4.3
8	18.4	0.	4.0	112.	-52.	18.4	4.5
9	19.3	0.	4.2	112.	-52.	19.3	4.8

10	20.3	0.	4.5	112.	-52.	20.3	5.0
11	21.2	0.	4.7	112.	-52.	21.2	5.2
12	22.1	0.	4.9	112.	-52.	22.1	5.5
13	23.1	0.	5.2	112.	-52.	23.1	5.7
14	24.0	0.	5.4	112.	-52.	24.0	5.9
15	24.9	0.	5.6	112.	-52.	24.9	6.2
16	25.8	0.	5.9	112.	-52.	25.8	6.4
17	26.8	0.	6.1	112.	-52.	26.8	6.6
18	27.7	0.	6.3	112.	-52.	27.7	6.9
19	28.6	0.	6.6	112.	-52.	28.6	7.1
20	29.6	0.	6.8	112.	-52.	29.6	7.3
21	30.5	0.	7.0	112.	-52.	30.5	7.6
22	31.4	0.	7.3	112.	-52.	31.4	7.8
23	32.4	0.	7.5	112.	-52.	32.4	8.0
24	33.3	0.	7.7	112.	-52.	33.3	8.3
25	34.2	0.	8.0	112.	-52.	34.2	8.5
26	35.2	0.	8.2	112.	-52.	35.2	8.7
27	36.1	0.	8.4	112.	-52.	36.1	9.0
28	37.0	0.	8.7	112.	-52.	37.0	9.2
29	38.0	0.	8.9	112.	-52.	38.0	9.4
30	38.9	0.	9.1	112.	-52.	38.9	9.7
31	39.8	0.	9.4	112.	-52.	39.8	9.9
32	40.7	0.	9.6	112.	-52.	40.7	10.1
33	41.7	0.	9.8	112.	-52.	41.7	10.4
34	42.2	0.	10.0	12.	-6.	42.2	10.5
35	42.4	0.	10.2	48.	-22.	42.4	10.6
36	42.8	0.	10.5	48.	-22.	42.8	10.7

1 UTEXAS3 - VER. 1.209 - 2/28/98 - (C) 1985-2000 S. G. WRIGHT
One (1) copy licensed to Vector Engin., Inc., Grass Valley, CA
Date: 11: 7:2001 Time: 17:48:16 Input file: yolobrk4.dat
Yolo Bioreactor, PP liner, 1ft road rock
Failure above liner, 4:1, with braking equipment

TABLE NO. 29

```
**********************************************************************
*  Information Generated During Iterative Solution for the Factor  *
*  of Safety and Side Force Inclination by Spencer's Procedure     *
**********************************************************************
```

Iteration	Trial Factor of Safety	Trial Side Force Inclination (degrees)	Force Imbalance (lbs.)	Moment Imbalance (ft.-lbs.)	Delta-F	Delta Theta (degrees)
1	3.00000	15.0000	.1522E+04	.1788E+04		
First-order corrections to F and THETA					-.530E+01	.693E+00
Values factored by .944E-01 - Deltas too large					-.500E+00	.655E-01
2	2.50000	15.0655	.1349E+04	.1568E+04		
First-order corrections to F and THETA					-.326E+01	.766E+00
Values factored by .153E+00 - Deltas too large					-.500E+00	.118E+00
3	2.00000	15.1830	.1090E+04	.1229E+04		
First-order corrections to F and THETA					-.168E+01	.911E+00
Values factored by .297E+00 - Deltas too large					-.500E+00	.271E+00
4	1.50000	15.4536	.6570E+03	.6239E+03		
First-order corrections to F and THETA					-.567E+00	.134E+01
Values factored by .882E+00 - Deltas too large					-.500E+00	.119E+01
5	1.00000	16.6395	-.2277E+03	-.9955E+03		
First-order corrections to F and THETA					.512E-01	-.135E+02
Values factored by .639E+00 - Deltas too large					.327E-01	-.859E+01
6	1.03268	8.0452	-.1029E+03	-.8600E+03		
First-order corrections to F and THETA					.199E+00	.968E+02
Values factored by .888E-01 - Deltas too large					.176E-01	.859E+01
7	1.05032	16.6395	-.9898E+02	-.6904E+03		
First-order corrections to F and THETA					.733E-01	.150E+02

32	40.7	9.0	237.9	237.9	78.4
33	41.7	9.3	237.9	237.9	78.4
34	42.2	9.4	138.0	138.0	45.5
35	42.4	9.8	105.3	105.3	69.3
36	42.8	10.3	81.9	81.9	53.9

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .00 (= .129E-03)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .00 (= .122E-03)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = -.42 (= -.425E+00)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .651E-04)
SHOULD NOT EXCEED .100E+03
1
UTEXAS3 - VER. 1.209 - 2/28/98 - (C) 1985-2000 S. G. WRIGHT
One (1) copy licensed to Vector Engin., Inc., Grass Valley, CA
Date: 11: 7:2001 Time: 17:48:16 Input file: yolobrk4.dat
Yolo Bioreactor, PP liner, 1ft road rock
Failure above liner, 4:1, with braking equipment 1

TABLE NO. 39
****
* Final Results for Side Forces and Stresses Between Slices. *
* (Results for Critical Shear Surface in Case of a Search.) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.104 Side Force Inclination = 21.84 Degrees

---------- VALUES AT RIGHT SIDE OF SLICE ----------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	14.0	14.	3.4	.734	123.8	-20.7
2	14.8	56.	3.4	.550	134.1	72.0
3	15.6	125.	3.5	.516	169.7	139.6
4	16.4	222.	3.5	.504	211.5	200.8
5	16.7	243.	3.6	.547	262.9	146.7
6	17.0	246.	3.7	.584	312.4	103.1
7	17.9	240.	4.0	.624	353.2	52.2
8	18.9	234.	4.3	.662	390.2	5.2
9	19.8	228.	4.6	.700	423.3	-38.0
10	20.7	222.	4.8	.735	452.6	-77.4
11	21.7	216.	5.1	.770	478.1	-112.8
12	22.6	210.	5.4	.802	499.7	-144.5
13	23.5	205.	5.6	.833	517.4	-172.3
14	24.4	199.	5.9	.862	531.3	-196.2
15	25.4	193.	6.2	.888	541.4	-216.3
16	26.3	187.	6.4	.913	547.6	-232.6
17	27.2	181.	6.7	.934	549.9	-245.0
18	28.2	175.	6.9	.953	548.4	-253.5
19	29.1	169.	7.2	.969	543.1	-258.2
20	30.0	163.	7.4	.981	533.9	-259.1
21	31.0	157.	7.7	.989	520.9	-256.1
22	31.9	151.	7.9	.993	504.0	-249.2
23	32.8	145.	8.1	.992	483.2	-238.5
24	33.8	139.	8.4	.985	458.6	-224.0
25	34.7	133.	8.6	.972	430.2	-205.6
26	35.6	127.	8.8	.952	397.9	-183.3
27	36.6	121.	9.0	.923	361.8	-157.3
28	37.5	115.	9.2	.885	321.8	-127.3
29	38.4	109.	9.4	.836	278.0	-93.5
30	39.3	103.	9.5	.773	230.3	-55.9
31	40.3	97.	9.7	.696	178.7	-14.4
32	41.2	91.	9.8	.600	123.4	30.9
33	42.1	85.	9.9	.482	64.1	80.1

34	42.2	69.	10.0	.519	71.6	56.7
35	42.6	32.	10.3	.536	59.3	38.4
36	43.1	0.	597.0	ABOVE	64.5	-64.5

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .00 (= .129E-03)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .00 (= .122E-03)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = -.42 (= -.425E+00)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .651E-04)
SHOULD NOT EXCEED .100E+03

THE PROGRAM WAS ATTEMPTING TO READ A COMMAND WORD AND ENCOUNTERED
AN UNRECOGNIZABLE CHARACTER STRING FOR THE COMMAND WORD

THE LINE OF INPUT =

FIRST THREE CHARACTERS INTERPRETED AS ' '

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

Job No. 931010.18 Job Name: Yolo. Co. L.F.
Sheet No. 1 of
Calculated By: MRT Date: 6-12-01
Checked By: Date:
Scale: N.T.S.

VECTOR ENGINEERING, INC.
Grass Valley, CA • Houston, TX • Chile • Argentina • Perú • Philippines
12438 Loma Rica Drive, Suite C, Grass Valley, CA 95945 tel: (530) 272-2448 fax: (530) 272-8533

Access Road on bioreactor slope

- Road Base over geotextile and geomembrane
- 10 year, 6 hr. storm = 1.8 inches = 0.3 in/hr. average
- To be conservative, assume 1.0 inches/hr. intensity
- 1800 ft² on slope, 150 feet long
- Check Infiltration

$$\text{void ratio, } e = \frac{G_s \gamma_w}{\gamma_d} - 1 = \frac{2.7(62.4\ pcf)}{125\ pcf} - 1 = 0.35$$

$$\text{saturated water content, } w_{sat} = \frac{Se}{G_s} = \frac{0.35}{2.7} = 13\%$$

$$\frac{V_v}{V} = \frac{e}{e+1} = \frac{0.35}{1.35} \Rightarrow V_v = 0.26\ \frac{ft^3}{ft^3}$$

To Fill Voids, $V_w = V_v$

Depth of water = $(0.26\ ft^3/ft^3)(12\ in/ft) = 3.1$ inches of infiltration for full saturation

- Check collection of flow, time of concentration

$$k = 0.1\ ft/s \quad ; \quad i = \sin\beta = \frac{\Delta h}{\ell} = \sin 14^\circ = 0.24$$

$$V = ki = 0.1\ ft/s\,(0.24) = 0.024\ ft/s$$

$$t_c = \frac{150\ ft}{0.024\ ft/s}\left(\frac{hr.}{3600\ s}\right) = 1.74\ hrs.$$

⇒ Approx. 3 inches of head above liner appears reasonable for an average

Job No. 931010.18 Job Name: Yard

Sheet No. of

Calculated By: MRT Date: 6-13-01

Checked By: Date:

Scale:

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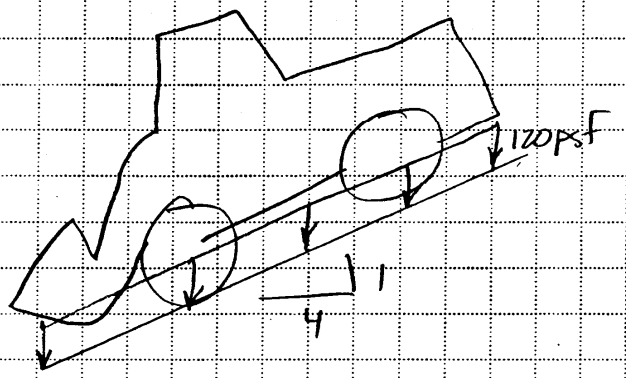

966E Wheel Loader

Total Weight = 16 tons ; 10 feet x 27 feet

Average Pressure = $\frac{32000\ lb}{270\ ft^2} \approx 120\ psf$

Braking Force, $F_b = ma$

Velocity in 2nd Gear ≈ 4 to 7 mph, use 5 mph = $V_{initial}$

Assume a stopping distance of 4 feet

$V_f^2 = V_i^2 + 2aL$

$a = \frac{V_f^2 - V_i^2}{2L} \approx -\frac{(7.3\ ft/s)^2}{8\ ft.} = -6.66\ ft/s^2$

$m = \frac{32,000\ lb}{32.2\ ft/s} \approx 1000\ slug$

$F_b = 1000\ slug\ (-6.66\ ft/s^2) = 6660\ lb$

For unit width pressure $\Rightarrow \frac{6660\ lb}{270\ ft^2} \approx 25\ psf$

Normal $W\cos\beta = 120 \cos 14^\circ = 116\ psf$

Shear = 25 psf + $W\sin\beta = 25 + 120\sin 14^\circ = 54\ psf$

APPENDIX C
SURFACE HYDROLOGY CALCULATIONS

TABULAR HYDROGRAPH METHOD Version 2.00

Project : MODULE D BIOREACTOR User: NCL Date: 06/05/2101

County : YOLO COUNTY State: CA Checked: TVR Date: 6/10/01

Subtitle:

Total watershed area: 0.017 sq mi Rainfall type: I Frequency: 10 years

	Subareas						
	S1	S2	S3	S4	S5	S6	S7
Area(sq mi)	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
Rainfall(in)	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Curve number	98*	98*	98*	98*	98*	98*	98*
Runoff(in)	2.97	2.97	2.97	2.97	2.97	2.97	2.97
Tc (hrs)	0.09*	0.04*	0.11*	0.04*	0.04*	0.06*	0.06*
(Used)	0.10	0.10	0.10	0.10	0.10	0.10	0.10
TimeToOutlet	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ia/P	0.01	0.01	0.01	0.01	0.01	0.01	0.01
(Used)	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Time	Total	Subarea Contribution to Total Flow (cfs)						
(hr)	Flow	S1	S2	S3	S4	S5	S6	S7
9.0	0	0	0	0	0	0	0	0
9.3	1	1	0	0	0	0	0	0
9.6	1	1	0	0	0	0	0	0
9.9	10	3	1	2	1	1	1	1
10.0	18	5	2	3	2	1	3	2
10.1	26P	7P	3P	4P	3P	2P	4P	3P
10.2	17	5	2	3	2	1	2	2
10.3	8	2	1	1	1	1	1	1
10.4	7	2	1	1	1	0	1	1
10.5	7	2	1	1	1	0	1	1
10.6	6	1	1	1	1	0	1	1
10.7	3	1	0	1	0	0	1	0
10.8	3	1	0	1	0	0	1	0
11.0	3	1	0	1	0	0	1	0
11.2	1	1	0	0	0	0	0	0
11.4	1	1	0	0	0	0	0	0
11.6	1	1	0	0	0	0	0	0
11.8	1	1	0	0	0	0	0	0
12.0	1	1	0	0	0	0	0	0
12.3	1	1	0	0	0	0	0	0
12.6	1	1	0	0	0	0	0	0
13.0	1	1	0	0	0	0	0	0
13.5	1	1	0	0	0	0	0	0
14.0	0	0	0	0	0	0	0	0
14.5	0	0	0	0	0	0	0	0
15.0	0	0	0	0	0	0	0	0
15.5	0	0	0	0	0	0	0	0
16.0	0	0	0	0	0	0	0	0
17.0	0	0	0	0	0	0	0	0
18.0	0	0	0	0	0	0	0	0
20.0	0	0	0	0	0	0	0	0
24.0	0	0	0	0	0	0	0	0

V-Notch Channel
Worksheet for Triangular Channel

Project Description	
Project File	k:\haestad\fmw\yolo1.fm2
Worksheet	Central Drainage Channel V-Notch
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Channel Slope	0.005000	ft/ft
Left Side Slope	10.000000	H : V
Right Side Slope	10.000000	H : V
Discharge	21.00	cfs

Results		
Depth	0.98	ft
Flow Area	9.66	ft²
Wetted Perimeter	19.76	ft
Top Width	19.66	ft
Critical Depth	0.77	ft
Critical Slope	0.018133	ft/ft
Velocity	2.17	ft/s
Velocity Head	0.07	ft
Specific Energy	1.06	ft
Froude Number	0.55	
Flow is subcritical.		

Yolo Drainage Calculations
Worksheet for Trapezoidal Channel

Project Description	
Project File	k:\haestad\fmw\yolo1.fm2
Worksheet	Central Drainage Channel
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Channel Slope	0.005000	ft/ft
Left Side Slope	2.000000	H : V
Right Side Slope	2.000000	H : V
Bottom Width	6.00	ft
Discharge	21.00	cfs

Results		
Depth	0.94	ft
Flow Area	7.42	ft²
Wetted Perimeter	10.21	ft
Top Width	9.76	ft
Critical Depth	0.67	ft
Critical Slope	0.016623	ft/ft
Velocity	2.83	ft/s
Velocity Head	0.12	ft
Specific Energy	1.07	ft
Froude Number	0.57	
Flow is subcritical.		

Yolo Drainage Calculations
Worksheet for Trapezoidal Channel

Project Description	
Project File	k:\haestad\fmw\yolo1.fm2
Worksheet	Central Drainage Channel
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Channel Slope	0.010000	ft/ft
Left Side Slope	2.000000	H : V
Right Side Slope	2.000000	H : V
Bottom Width	6.00	ft
Discharge	21.00	cfs

Results		
Depth	0.77	ft
Flow Area	5.85	ft²
Wetted Perimeter	9.46	ft
Top Width	9.10	ft
Critical Depth	0.67	ft
Critical Slope	0.016623	ft/ft
Velocity	3.59	ft/s
Velocity Head	0.20	ft
Specific Energy	0.97	ft
Froude Number	0.79	
Flow is subcritical.		

APPENDIX F – FINAL PROJECT AGREEMENT

EPA PROJECT XL
Final Project Agreement for the Yolo County Accelerated Anaerobic & Aerobic Composting (Bioreactor) Project

September 14, 2000
Submitted by:

County of Yolo
Planning and Public Works Department
Division of Integrated Waste Management
292 West Beamer Street
Woodland, CA 95695
Ramin Yazdani, Assistant Director
Phone: (530) 666-8775
Fax: (530) 666-8728
Email: Ramin.Yazdani@ccm.yolocounty.org
Co-sponsors of the project with Yolo County are:
Institute for Environmental Management (IEM, Inc.)
Don Augenstein
Phone: (650) 856-2850
Email: Iemdon@aol.com
and
Solid Waste Association of North America (SWANA)
John Pacey
Phone: (925) 288-9898
Email: JPacey@theitgroup.com

EPA United States Environmental Protection Agency
"...to protect human health and to safeguard the natural environment..."

Table of Contents for the Final Project Agreement

Figures

Tables

I. Introduction to the Agreement

A. Description of the Project and Its Purpose

The County of Yolo Planning and Public Works Department (Yolo County), proposes to operate its next 20-acre landfill module near Davis, California as a controlled bioreactor landfill to attain a number of superior environmental and cost savings benefits. In the first phase of this 20-acre project, a 12-acre module has been constructed. This 12-acre module contains one 9.5-acre cell, which will be operated anaerobically, and a 2.5-acre cell aerobically. The County will construct the second phase of Module D in two years and depending on the results of the first phase of Module D, County may operate the second phase either anaerobically or aerobically. The second phase of Module D is not discussed in this proposal since the County intends to seek revision of the FPA in two years, to address any regulatory flexibility necessary for the second phase of Module D, when more data becomes available from phase one of this project. If, at that point, Yolo wishes to proceed with the 2nd phase of module D, then the parties will need to negotiate and sign a second FPA or addendum.

Co-sponsors of the project with Yolo County are the Solid Waste Association of North America (SWANA) and Institute for Environmental Management (IEM, Inc.). As part of this proposal, Yolo County is requesting that U.S. EPA grant site-specific regulatory flexibility from the prohibition in 40 CFR 258.28 Liquid Restrictions, which may preclude addition of useful bulk or non-containerized liquid amendments. The County is proposing to supplement the liquid addition with ground water, but would like to obtain the flexibility to possibly utilize other liquids such as gray-water from a waste water treatment plant, septic waste, gray water, and food-processing wastes that are currently land applied. Liquid wastes such as these, that normally have no beneficial use, may instead beneficially enhance the biodegradation of solid waste in a landfill for this project. The County intends to use leachate and groundwater first but if not enough liquid is available then other liquids will be used.

Yolo County also requests similar flexibility on liquid amendments from California and local regulatory entities. Several sections of the California Code of Regulations (CCR), Title 27, Environmental Protection, address the recirculation of liquids in lined municipal waste landfills. While the regulations do not specifically endorse bioreactors, regulatory flexibility is provided by the State of California for Management of Liquids at Landfills, and Leachate Handling. This regulatory flexibility is further discussed in this FPA in Section IV A.

B. Description of the Facility and Facility Operations/Community/Geographic Area

The Yolo County Central Landfill (YCCL) is an existing Class III non-hazardous municipal landfill with two Class II surface impoundments for disposal of selected non-hazardous liquid wastes. This site encompasses 722 acres and is owned and operated by Yolo County. It is located at the intersection of Road 104 and Road 28H, 2 miles northeast of the City of Davis. The YCCL was opened in 1975 for the disposal of non-hazardous solid waste, construction debris, and non-hazardous liquid waste. Existing on-site operations include an eleven-year old landfill methane gas recovery and energy generation facility, a drop-off area for recyclables, a metal recovery facility, a wood and yard waste recovery and processing area, and a concrete recycling area.

The City of Davis Wastewater Treatment Plant lagoons located immediately east and south of the landfill, which will be continuing in operation. The Willow Slough By-pass runs parallel to the southern boundary of the site. The remainder of land uses adjacent to the site are agricultural (row crops).

There are approximately 28 residences scattered within a 2-mile radius of the landfill. The closest residence is located 1,600 feet south of the landfill and city treatment plant lagoons, on the West Side of Road 105 south of the Willow Slough By-pass.

Groundwater levels at the facility fluctuate 8 to 10 feet during the year, rising from lowest in September to highest around March. Water level data indicate that the water table level is typically 4 to 10 feet below ground surface during winter and spring months. During summer and fall months, the water table is typically 5 to 15 feet below ground surface. In January 1989, the County of Yolo constructed a soil/bentonite slurry cutoff wall to retard groundwater flow to the landfill site from the north. The cutoff wall was constructed along portions of the northern and western boundaries of the site to a maximum depth of 44 feet and has a total length of 3,680 feet, 2,880 feet along the north side and 800 feet along the west. In the fall of 1990, irrigation practices to the north of the landfill site were altered to minimize the infiltration of water.

Additionally, sixteen groundwater extraction wells were also installed south of the cutoff wall in order to lower the water table south and east of the wall. The purpose was to depress the water table to provide vertical separation between the base of the landfill and groundwater.

Prior to placement of the slurry wall and dewatering system, the groundwater flow direction was generally to the southeast. Under current dewatering conditions, the apparent groundwater flow paths are towards the extraction wells located along the western portion of the northern site boundary. In essence, a capture zone is created by the cone of depression created by the ground water extraction system, minimizing the possibility of off-site migration of contamination.

C. Purpose of the Agreement

This Final Project Agreement (" the Agreement") is a joint statement of the plans, intentions and commitments of the U.S. Environmental Protection Agency ("EPA"), the state of California, and Yolo County to carry out this project approved for implementation at the County's solid waste landfill site near Davis, California. This Project will be part of EPA's Project XL program to develop innovative approaches while providing superior environmental protection.

The Agreement does not create legal rights or obligations and is not an enforceable contract or a regulatory action such as a permit or a rule. This applies to both the substantive and the procedural provisions of this Agreement. While the parties to the Agreement fully intend to follow these procedures, they are not legally obligated to do so. For more detail, please refer to Section VI (Legal Basis for the Agreement).

Federal and State flexibility and enforceable commitments described in this Agreement will be implemented and become effective through a legal implementing mechanism (e.g. site-specific rule, rule or permit modification).

All parties to this Agreement will strive for a high level of cooperation, communication, and coordination to assure successful, effective, and efficient implementation of the Agreement and the Project.

D. List of the Parties that Will Sign the Agreement

The Parties to this Final Project XL Agreement are the United States Environmental Protection Agency (EPA), County of Yolo Planning and Public Works Department, and the State of California.

E. List of the Project Contacts

County of Yolo
Planning and Public Works Department
Division of Integrated Waste Management
292 West Beamer Street
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II. Detailed Description of the Project

A. Summary of the Project

Sanitary landfilling is the dominant method of solid waste disposal in the United States, accounting for about 217 million tons of waste annually (U.S. EPA, 1997). The annual production of municipal solid waste in the United States has more than doubled since 1960. In spite of increasing rates of reuse and recycling, population and economic growth will continue to render landfilling as an important and necessary component of solid waste management.

In a Bioreactor Landfill, controlled quantities of liquid are added, and circulated through waste as appropriate. The purpose is to accelerate the natural biodegradation and composting of solid

waste components. This process significantly increases the biodegradation rate of waste and thus decreases the waste stabilization and composting time (5 to 10 years) relative to what would occur within a conventional landfill (30 to 50 years or more). If the waste decomposes (i. e., is composted) in the absence of oxygen (anaerobically), it produces landfill gas (biogas). Biogas is primarily a mixture of methane, a potent greenhouse gas, carbon dioxide, and VOC's, which are local air pollutants. Methane is also a fuel. This by-product of anaerobic landfill waste composting can be a substantial renewable energy resource that can be recovered for electricity or other uses. Other benefits of a bioreactor landfill composting operation include increased landfill waste settlement and therefore increase in capacity and landfill life, improved opportunities for treatment of leachate liquid that may drain from fractions of the waste, possible reduction of landfill post-closure management time and activities, landfill mining, and abatement of greenhouse gases through highly efficient methane capture over a much shorter period of time than is typical of waste management through conventional landfilling.

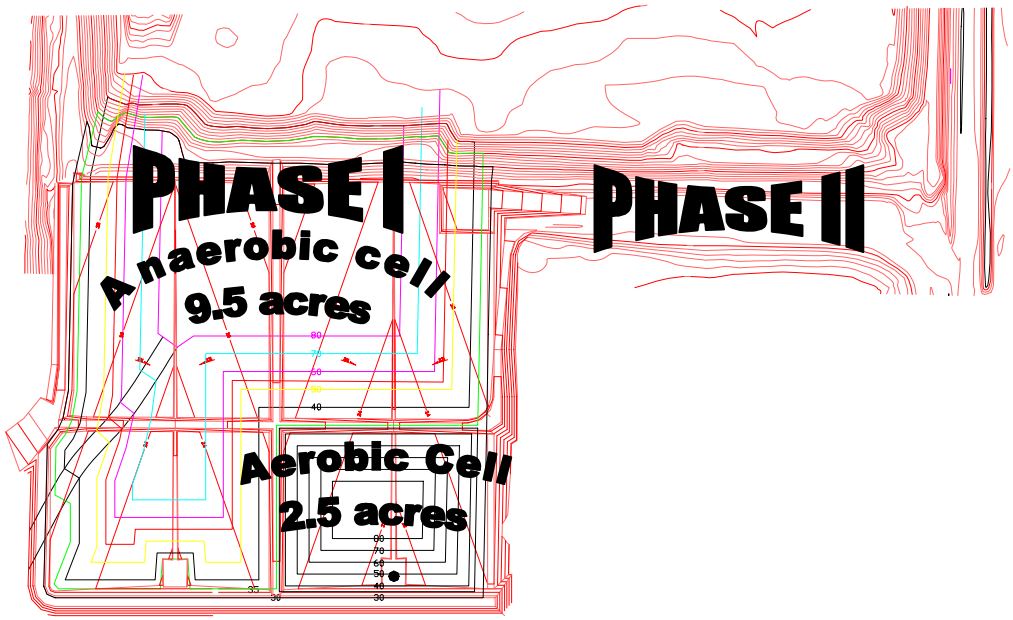
B. Description of the specific project elements

Yolo County proposes to operate its next full-scale 20-acre landfill module (Module D) with both anaerobic and aerobic bioreactor areas (also termed modules below). In the first phase of this 20-acre project, a 12-acre module has been constructed. One 9.5-acre cell will be operated anaerobically and the other 2.5-acre cell aerobically. The anaerobic and aerobic design and operations are summarized below:

DESIGN AND OPERATIONS OF PROPOSED MODULE D BIOREACTOR

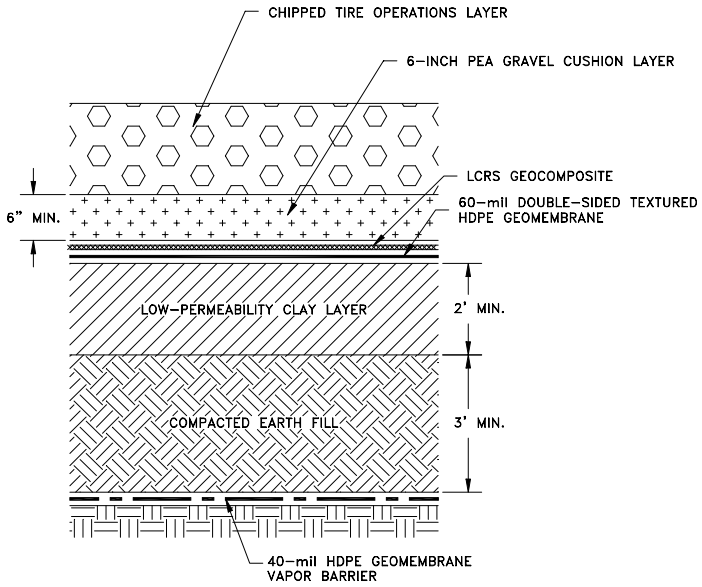
The bottom liner system was designed to exceed the requirements of Title 27 of CCR and Subtitle D of the Federal guidelines and was upgraded from other liner systems used previously at the site. The County believes that given the constructed configuration discussed herein and the stringent monitoring and operational requirements proposed for Module D, the proposed liner system will be suitable for use in the bioreactor operations.

Figure 1- Module D Expansion, Phase 1 & 2



Under current plans, the first phase of Module D will be further subdivided into the two independent bioreactor systems, the aerobic system and the anaerobic system. Module D was designed and constructed in a ridge and swale configuration to optimize landfill space and to maintain good drainage for the collection system. The blanket drainage layer slopes at 2% inward to two central collection v-notch trenches. Each of the trenches drain at 1% to their prospective leachate collection sumps located at the south side of the module. This grading configuration is an upgrade from previous designs at the site because it is steeper, thus, maintaining better drainage throughout its design life. Phase 2 of Module D will also be constructed in a similar manner as Phase 1 of Module D.

Figure 2- Module D Bottom Liner Cross-section



1. Liner and Leachate Collection and Removal System (LCRS) Components

The prescriptive liner for Class III landfills consists, from top to bottom, of an operations/drainage layer capable of maintaining less than one foot of head over the liner, a 60-mil high density polyethylene (HDPE) liner, and 2 feet of compacted clay ($k < 1 \times 10^{-7}$ cm/sec).

The Module D liner and leachate collection system consists, from top to bottom, of a 2 foot thick chipped tire operations/drainage layer ($k > 1$ cm/sec), over 6 inches of pea gravel, a blanket geocomposite drainage layer, a 60-mil HDPE liner, 2 feet of compacted clay ($k < 6 \times 10^{-9}$ cm/sec), 3 feet of compacted earth fill ($k < 1 \times 10^{-8}$ cm/sec), and a 40 mil HDPE vapor barrier layer[1] (see Figure 2). The chipped tire operations layer was not placed during construction but will be placed immediately before waste placement.

As shown, the permeability of the clay liner, as constructed, was on the average about 6×10^{-9} cm/sec and the earth fill averaged about 1×10^{-8} cm/s. These two layers in effect provide a 5

[1] Golder Associates, "Final Report, Construction Quality Assurance, Yolo County Central Landfill, WMU 6, Module D, Phase 1 Expansion", December 1999.

foot thick composite liner. This fact, coupled with the lower permeability, will result in a significantly more effective barrier to leachate migration than the prescriptive liner system.

The liner system within the collection trenches and sump areas was upgraded further to a double composite liner to account for infringement on the 5 foot groundwater offset and to minimize potential leakage in these critical collection areas where head on the primary liner will be at its greatest. The liner and leachate collection system in the collection trenches and sumps consists from top to bottom of a minimum of 2 feet of gravel drainage material, a protective geotextile, a blanket geocomposite drainage layer, a primary 60-mil HDPE liner, a geosynthetic clay liner (GCL) ($k < 5 \times 10^{-9}$ cm/sec), a secondary 60-mil HDPE liner, 2 feet of compacted clay ($k < 6 \times 10^{-9}$ cm/sec), a minimum of 0.5 feet of compacted earth fill ($k < 1 \times 10^{-8}$ cm/sec), and a 40-mil HDPE vapor barrier layer (see Figure 3). The thickness of the compacted earth fill actually varies from a minimum at the south end of the trench of 0.5 feet to a maximum of about 2.5 feet at the upper, north end of the leachate collection trench. Leachate collection pipes were also placed in the collection trench and at other locations on top of the primary liner to transport leachate immediately to the sumps for recovery, removal, and recirculation, as needed.

2. LCRS and Liner Performance

As described above, the more rigorous Module D LCRS and liner system will intended to outperform the Title 27 and Subtitle D prescriptive liner. The leachate collection and recovery system (LCRS) has been designed and constructed to be free-draining throughout the life of the module and will maintain less head over the primary liner system than prescribed by Title 27 and Subtitle D.

The LCRS system has been constructed with a geocomposite layer, which has over 10 times the required capacity and will maintain the head over the liner system to less than 0.3 inches during liquid application periods. In addition, the chipped tire layer will provide a level of redundancy in the event that the geocomposite becomes clogged or otherwise nonfunctional.

For the anaerobic operation, it is estimated that the peak liquid addition, up to 10 gallons per minute (gpm) of liquid per 10,000 square feet (44 gpm per acre) of disposal area will be typically delivered to the waste once the module has reached its design height. Based on the demonstration cell performance the amount of liquid added would be in the range of 30 to 50 gallons per ton of waste. According to results of the bioreactor demonstration project by Moore et al[2], the average leachate generated during liquid introduction peaked at about 47% of the liquid delivery rate, which would equate to approximately 20 gpm per acre for the proposed program. Given a 6-acre drainage area, the total anticipated flow into any given sump would be approximately 120 gpm (173,000 gallons per day).

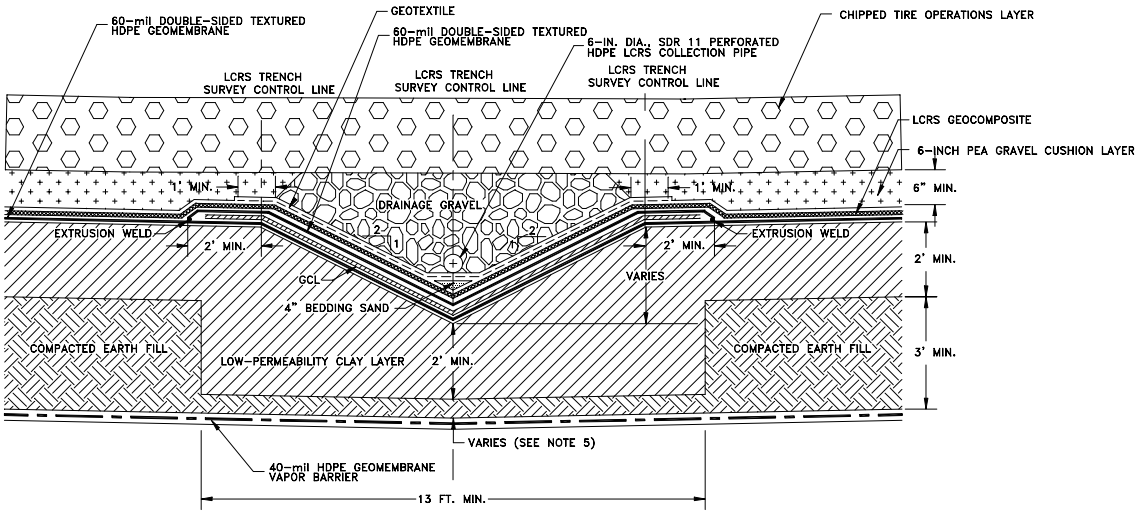
For the aerobic operation, liquid will be added to waste at a faster rate since the aerobic reaction uses much of the water in the evaporation of liquid added. It is estimated that the total water evaporated will range between 200 to 400 gallons of water per ton of waste.

Based on the estimated leachate production, drainage into the leachate collection layer will be about 4.6×10^{-4} gpm per square foot of disposal area. It is approximately 200 feet between the ridge and collection trench. Using these values, the peak flow through the geocomposite will be

[2] Moore et al, "Hydraulic Characteristics of Municipal Solid Waste Findings of the Yolo County Bioreactor Landfill Project.", Thirteenth International Conference on Solid Waste Technology and Management, Philadelphia, PA, November 1997.

about 0.09 gpm per linear foot of trench. The geocomposite for Module D has a measured capacity of 1.0 gpm per foot[3]. Therefore, the geocomposite has over 10 times the capacity required under peak flow conditions.

Figure 3- Module D Bottom Liner and Leachate Collection Trench Cross-Section



Although clogging of the geocomposite layer is not anticipated, the LCRS has been designed under the conservative assumption that geotextile clogging may occur. In the event that the geocomposite were to become clogged or otherwise nonfunctional, the proposed chipped tire operations layer with its high porosity will provide adequate drainage. Due to the large particle size of the chipped tires (>6 inches), the calculated effective permeability of the tire layer at the drainage slope of 0.02 is estimated to be well over 1.0 cm/sec. Given this value, it has a flow rate capacity on the order of 0.025 gpm per inch of thickness per one foot width. Therefore, at the calculated maximum inflow rate of 0.09 gpm per foot width, the head over the liner would not exceed 4 inches. Typically, collection systems are designed to maintain less than one foot of head over the liner. Therefore, this system has over three times the required flow capacity at the allowable prescriptive level of one foot.

In addition to the upgraded LCRS, the primary composite liner is better than the Title 27 prescriptive system. This is based on the reduced permeability (k) of the clay soil used during construction of the module. The permeability of the clay soil used in construction of the Module D liner is significantly lower than the prescriptive 1×10^{-7} cm/sec. Based on the results of the laboratory testing performed during construction of Module D, the clay liner has an average permeability on the order of 6×10^{-9} cm/sec. Using standard leakage rate analyses by Giroud and Bonaparte[4], the leakage from the Title 27 system (with one foot of head over a HDPE geomembrane and 1×10^{-7} cm/sec clay liner) would be 1×10^{-4} gpm from a standard 1 cm^2 hole

[3] Golder Associates, "Final Report, Construction Quality Assurance, Yolo County Central Landfill, WMU 6, Module D, Phase 1 Expansion", December 1999.

[4] Giroud, J.P. and Bonaparte, R., "Leakage Through Liners Constructed With Geomembranes – Part I. Geomembrane Liners." Geotextile and Geomembranes, Eslvier Science Publishers Ltd., England, 1989.

in the liner. With the Module D liner (4 inches of head over a HDPE geomembrane and 6 x 10^{-9} cm/sec clay liner), the leakage would be 5 x 10^{-6} gpm; less than 1/20 of the flow.

In the event that leakage were to occur through the 5-foot thick primary composite liner, the 40-mil vapor barrier would provide a secondary containment. Secondary containment is not required by Title 27 or Subtitle D for conventional landfilling operations. As constructed, the vapor barrier will minimize further downward migration and aid in detection of migrating leachate. The 40-mil HDPE vapor barrier was sloped to mirror the primary liner. Geocomposite strip drains were also installed diagonally across the top of the vapor barrier to act as drainage pathways to the southern portion of the cell located immediately beneath each of the leachate collection sumps. This will act as a vadose zone monitoring system for early detection of leakage across the entire Module D disposal area. This added feature provides another level of protection to the groundwater that standard Title 27 systems do not have.

In addition, the County hired Leak Location Services (LLC) to locate any pinholes that could have been in the leachate collection trenches on the primary liner system. LLC uses a high sensitive method using electrical charge to locate pinhole leaks very accurately. Using specialized equipment designed and built for locating liner leakage, LLC uses to verify integrity of liner system after completion of liner construction. Several small holes were found and repaired after this leak testing was done.

3. Specialized Design Considerations During Operation

Liquid will be applied during strategic periods to temporarily raise the moisture content of the waste to provide optimum conditions for rapid degradation and improved gas production. The duration of liquid addition will depend on when the optimum condition for rapid degradation has reached. The field data collected during the project will assist the County in determining the duration of liquid addition and recirculation. The total amount of liquid to be added will be measured and monitored as part of the liquid management program. This liquid will initially consist of a mixture of leachate and condensate from other WMUs and ground water delivered through a series of pipes after an interim cover and gas collection system has been constructed to control landfill gas generated.

Early gas collection and control is necessary at bioreactor landfills because the site in essence is rapidly degrades the waste so that it "behaves" as if it is much older. The result of this rapid "aging" is more complete biodegradation of the waste resulting in the generation of a larger quantity of landfill gas at a more rapid rate (sooner after waste placement in the landfill). To be at least as protective of human health and the environment as the new source performance standards for municipal solid waste landfills (40 CFR, part 60, subpart WWW) (the MSW Landfills NSPS), the site needs to: i) perform the same monitoring required in that rule, at the same frequency; ii) begin that monitoring sooner than the rule requires since bioreactor waste at 2 months of age behaves likes conventional waste of 2+ years of age; and, iii) continue the specified monitoring for the duration of the bioreactor project.

A typical gas collection system in a conventional landfill is constructed after the final elevation of the waste has reached. Vertical gas collection wells are installed to collect landfill gas. These wells are typically constructed at about 200 feet radius on center. In the bioreactor landfill the gas collection system will be installed during the waste filling phase of the landfill. The gas collection system will consist of a horizontal trench with 4-inch perforated pipe and shredded tires. The spacing of the horizontal trench gas collection system in the anaerobic cell will be 100 feet on center and 50 feet on center in the aerobic cell. In the anaerobic cell, after every 30 feet

waste lift is placed a horizontal gas collection pipes will be installed. In the aerobic cell, this will occur after every 15 feet of waste is placed. At every gas collection line, a valve will be installed to control and adjust the gas flow rate. The 4-inch gas collection lines in each lift of waste will be connected to an 8-inch lateral line. Each of the lateral lines will be connected to a 12-inch header line which will be connected directly to the main line that is connected to the existing flare and/or engines at the methane power facility on site. Accurate positive displacement gas meters will be used to measure the volume of landfill gas continuously. Each of the 4-inch gas collection lines will be constructed such that gas pressure, temperature, methane, carbon dioxide, and oxygen could be sampled and measured. The valves at each line will be used to adjust the system for optimum performance. The initial gas collection will be by horizontal wells, operated and tuned as are conventional wells, for earliest practical gas recovery. This essentially consists of extracting gas at the maximum rate consistent with keeping methane concentration near 50%. Recovery efficiency will be increased and surface emissions limited by a synthetic liner covering as much waste surface as possible during the filling phase, except the working face. After filling phase has been completed the entire surface will be covered with synthetic liner. Some fraction of the gas monitoring will be by gas chromatography to quantify the methane, nitrogen, carbon dioxide, oxygen, and other gaseous compounds of interest.

The typical chemical composition of potential liquid amendments are listed below in Table 1. The water will continually be introduced (as needed) to raise the moisture content within the waste to slightly above its equilibrated field capacity (estimated to be about 40% to 45% by wet weight basis). The liquid application system will be constructed such that liquid additions can be applied or discontinued at designated locations to control the moisture condition within the waste.

Moisture content will be monitored throughout the life of the module through the use of a network of moisture sensors to be installed during waste placement. The moisture sensor system used during the bioreactor demonstration project in Module B proved to be very effective and will be the basis for the layout in Module D. At this time, the moisture sensors are planned to be installed at 15-foot increments of depth at a spacing of about 75 feet on center. Using these sensors, the County can determine where liquid application should be increased or decreased to optimize the effectiveness of the system and to prevent build-up of head over the liner.

The quantity of leachate and additional liquids will be measured throughout the life of the landfill. Once leachate is produced, it will be re-circulated; thereby, either reducing the amount of subsequent liquid additions or serving to supply future cells. Liquid will be quantified using flow sensors installed on the leachate discharge line, re-circulation line, and liquid application line. These sensors will provide direct flow readout for determining flow rates in the pipelines and flow totalizing to quantify all of the liquid used and leachate produced.

The head over the liner will also be monitored shortly after the first lift of waste has been placed using a network of pressure transducers and bubbler gages. These devices will be installed on the primary liner, immediately before waste placement, to provide measurements of the leachate depth.

Table 1- Yolo County's Typical Chemical Composition of Potential Liquid Amendments

Inorganics and Metals	Leachate & Condensate	Groundwater
Potassium (mg/L)	69.3	2.7
Nitrate/Nitrite as Nitrogen (mg/L)	<0.05	3.9
Chloride (mg/L)	785	427
Sulfate (mg/L)	190	278
Total Alkalinity as $CaCO_3$ (mg/L)	1920	950
Temperature	20.9	18.6
pH	7.10	8.26
Electrical Conductivity	5370	2070
Dissolved Oxygen (mg/L)	3.21	8.61
Bicarbonate (mg/L)	2340	628
Total Dissolved Solids (mg/L)	3365	1233
Ammonia (mg/L)	17	0.02
Total Kjeldahl Nitrogen (mg/L)	140	0.19
Cobalt (µg/L)	<50	<3.2
Copper (µg/L)	<2.1	<4.9
Iron (µg/L)	4950	<14
Manganese (µg/L)	1175	9.4
Nickel (µg/L)	77	20.1
Lead (µg/L)	50	5.0
Vanadium (µg/L)	20	8.3
Zinc (µg/L)	323	10.8

In the event that the transducers indicate that the head is going to exceed the allowable value, the system will automatically start pumps to reduce the liquid level and shut-off valves to reduce the liquid application rate. A computerized control and monitoring system will be used to accomplish this task. This system which originated in the utility and petroleum industries, is often referred to as Supervisory Control and Data Acquisition Control (SCADA), such systems are now widely used in many different applications such as waste water treatment systems. These measures would be used to either reduce the liquid application rate across the entire module or specifically, in the area of head build-up. Generally, application of the liquid will only be continued until the gas generation phase of the unit has fallen to a low level and it has stabilized. At that time leachate production and recirculation may already have stopped and the leachate should have stabilized some time earlier. The quantity and quality of the leachate will also be closely monitored to evaluate the system performance and management. Leachate will be monitored in accordance with the requirements already established under the County's Waste Discharge Requirements with the State of California.

In addition to liquid delivery to the waste, air will be delivered to the aerobic portion of the bioreactor cell area. The aerobic decomposition of the waste and gas generation also requires the moisture condition be maintained slightly above equilibrated field capacity. However, the aerobic process is accomplished at a higher temperature and is more aggressive in the biodegradation activity. This requires a significant increase in the quantity of water necessary to achieve optimum biodegradation, as compared with the anaerobic process.

The degradation and gas generation of the waste is also related to the temperature within the decomposing waste. The effectiveness of both aerobic and anaerobic bioreactors is dependent on keeping the system within optimum temperatures; therefore, temperature gauges will also be installed to aid in the operation of the system. As with the moisture sensors, temperature gauges were also placed in the waste of the demonstration bioreactor and proved to be very effective. The temperature gauge network will be placed in a similar pattern to the moisture sensors at designated intervals throughout the waste mass.

In the aerobic cell, during filling, horizontal gas conduits will be installed in similar manner to those of the anaerobic bioreactor. However conduit spacing may be closer. After filling, chipped tires and conduits will be used to pull or push atmospheric air through the waste under a impermeable cover. It is expected that this will increase the rate of degradation but inhibit methane formation. Large-scale positive gas displacement meters, similar to meters used for the demonstration cells will monitor the gas quantity.

Gas will also be extracted from the base LCRS layer via the conduit collection pipe as filling proceeds. The purpose of this extraction system design is to lower methane emissions that would normally occur to the atmosphere during filling.

Separation of the two bioreactor systems will be performed using a low permeability clay liner constructed below the aerobic cell and on top of the first lift of waste in the anaerobic cell. This layer may include but would not be limited to a compacted clay liner, or geomembrane. The leachate and gas collection system will be separated from the anaerobic cell. Final selection will be based on its ability to appropriately isolate each cell, ability to accommodate settlement, ease of installation, and cost.

Daily cover operations will be performed in a similar fashion to the methods currently employed at the landfill. This includes the use of alternative daily covers such as green waste and tarps. The cover will consist of a gas piping collection system within a layer of chipped tires in lieu of gravel. The liquid injection system will also be placed within this layer to facilitate delivery of liquid to the waste. This layer will be overlain with a flexible geomembrane cover to control moisture conditions, control gas emissions, and satisfy regulatory requirements to control vectors, fires, odors, blowing litter, and scavenging.

As areas of the module reach their design grade, monuments will be installed to monitor settlement caused by degradation of the waste. These monuments will be checked bi-monthly at first and less often as the rate of settlement slows. Annual aerial topographic surveys will also be performed to aid in the evaluation of settlement and the effectiveness of the bioreactor system.

4. Contingency Plan for Failure of the Primary Liner System

The primary liner system is contained by a secondary liner system that serves as a leak detection system. A sump is located at the low point of this system and the sump will be monitored for

presence of liquid monthly. If any liquid is collected, samples will be tested to determine if there are any leaks in the primary liner system. If the test results from the sampled liquid indicates that there is a leak in the primary liner system then a pump will be installed in the sump to control liquid accumulation in the sump. The liquid level in the primary liner system will be evaluated and monitored to minimize liquid depth above the primary liner. The liner leakage rate and the leachate injection rate will be evaluated and reduced if necessary to control the rate of leakage.

5. Contingency Plan for Landfill Fire

At least 220 total temperature sensors will be installed in the aerobic or anaerobic bioreactor landfill to monitor and record landfill temperature continuously. Both cells will be brought to field capacity as an initial step to control and preclude landfill fire. The Supervisory Control And Data Acquisition (SCADA) system will be used to record any significant temperature fluctuations within the waste that is more than 2 degrees per day. If such temperature fluctuations are recorded the SCADA system will notify the operator that the system must be tested for CO presence. Gas samples will be collected and tested in the field for presence of CO, which will indicate possible internal fire. The location of the possible internal fire in the bioreactor will be determined from the recorded temperature by SCADA system. The rate of liquid injection in that area will be increased to reduce waste temperature. In the aerobic bioreactor the SCADA system will automatically turn off the air injection system to control the internal fire. If the liquid injection rate is not sufficient to reduce the temperature or it's not functioning properly, then a liquid injection well will be drilled from above. This well will be used to inject liquid in the area where possible fire is expected. The SCADA system will be used to continue monitoring the waste temperature after this treatment for an increase or decrease in waste temperature.

On top of the primary liner system, for the anaerobic bioreactor, four 600 feet long 3-inch perforated pipes will be installed to deliver cool water in order to reduce the liner temperature and protect the liner from damage, if needed. The leachate pump sumps for the anaerobic bioreactor have been designed to handle twice the volume of the anticipated liquid addition, without any significant liquid head build up over the liner. If necessary, for a short periods the pumps could be turned off so that liquid would build head over the liner and protect the primary liner system from excess heat. This method is not preferred over the other methods mentioned earlier. For the aerobic bioreactor, the bottom elevation of the cell is about seven feet from the primary liner system. Before any waste is place in the aerobic cell a low permeability clay liner will be constructed to separate the aerobic cell from the anaerobic cell and measure liquid and gas volumes accurately. This will also serve as a firebreak between the two cells. Portions of the clay liner within the leachate trench liner will be lined with a synthetic liner to reduce saturation of the clay liner. Similar method mentioned above for the anaerobic cell will be used in the aerobic cell to control fire in addition to stopping the air injection in the cell.

With all of these operational systems in place, the performance of the bioreactor and effectiveness of the LCRS and gas collection system can be thoroughly monitored. These operational systems far exceed the requirements of Title 27 and Subtitle D; thus, providing another basis for allowance of the Module D bioreactor project.

The instrumentation and monitoring frequency of the bioreactor project are listed in Table 2 and Table 3 respectively.

Table 2- Instrumentation Type and Location for the Bioreactor Project

Type of Instrumentation	Location/Quantity/Spacing	Description
• Pressure transducers • Pressure transducers	• **Anaerobic Bioreactor:** 1. Eight over the primary liner near the LCRS trench at 200 spacing 2. Two over the primary liner within the leachate collection sump • **Aerobic Bioreactor:** 1. Two over the primary liner at 200 feet spacing 2. One within the leachate sump	A series of pressure transducers and bubbler gages will be installed on top of the primary liner and near the LCRS trench in both the aerobic and anaerobic landfill cells to measure the head or depth of leachate above the liner. A gas pressure transducer in each cell will be used to correct the liquid head for gas pressure. Pressure transducers will be continuously monitored through a SCADA system which will control the liquid injection system to maintain less than four inches of head over the liner.
• Bubbler Gage for Liquid/Gas Pressure Measurement and Liquid/Gas Sampling	• **Anaerobic Bioreactor:** 1. Top of primary bottom liner-66 gages at 75 feet spacing 2. Top of the first lift of waste- 55 gages 3. Top of the second lift of waste-40 gages 4. Top of the third lift of waste-30 gages 5. Top of the final lift of waste-20 gages TOTAL= 211 gages	Bubbler gages will be installed to measure liquid and gas pressure directly on top of the liner and at different depths within the waste. The tubes will also be used to measure gas pressure and sample gas and/or leachate from a specific location within the waste. The data from the leachate levels within the waste will assist the County in the operation of the cell as well as provide valuable data on waste stability and pore pressure within the waste during liquid injection and recirculation.
• Bubbler Gage for Liquid/Gas Pressure Measurement and Liquid/Gas Sampling	• **Aerobic Bioreactor:** 1. Top of the aerobic bottom liner-48 gages at 50 feet spacing 2. Top of the first lift of waste- 24 gages 3. Top of the second lift of waste-20 gages 4. Top of the final lift of waste-20 gages TOTAL= 112 gages	A compacted clay liner and a synthetic liner will be constructed 5 to 7 feet above the primary liner system over compacted waste for the bottom liner in the aerobic bioreactor. The leachate from the aerobic cell will be collected and removed into a separate manhole for recirculation and measurement. This will isolate the primary HDPE liner under the aerobic cell and protect this liner from higher temperature seen in the aerobic cell.
• Moisture and Temperature Sensors	• **Anaerobic Bioreactor:** 1. Top of primary bottom liner-66 temperature	In both anaerobic and aerobic cells series of moisture and temperature sensors will be

• Moisture and Temperature Sensors	sensors at 75 feet spacing and 12 moisture sensors 2. Top of the first lift of waste-55 temperature and moisture sensors 3. Top of the second lift of waste-40 temperature and moisture sensors 4. Top of the third lift of waste-30 temperature and moisture sensors 5. Top of the final lift of waste-20 temperature sensors TOTAL= 211 temperature sensors and 137 moisture sensors • **Aerobic Bioreactor:** 1. Top of the aerobic bottom liner-48 temperature and 12 moisture sensors 2. Top of the first lift of waste- 24 gages 3. Top of the second lift of waste-20 gages 4. Top of the final lift of waste-20 gages TOTAL= 112 temperature sensors and 76 moisture sensors	installed within the waste mass to monitor the biological activity of each cell. Temperature and moisture sensors will be continuously monitored through a SCADA system. Temperature alarm will be set in the SCADA system to warn operator via telemetry when temperature change is 24 hours is greater than 2 degrees. This early warning system will enable the County to investigate the cause and reduce air injection or shout down the air injection system in the aerobic bioreactor.
• Gas Composition, Gas Pressure, and Gas Flow Rate	• **Anaerobic Bioreactor & Aerobic Bioreactor:** 1. Two gas pressure transducers under the final cover 2. Two gas flow meters in parallel to measure gas flow rate continuously 3. Temperature sensors to measure gas temperature at flow meters continuously 4. Gas composition will be monitored as listed in Table 3	Horizontal gas collection system will be constructed at 100 feet in the anaerobic bioreactor and 50 feet interval in the aerobic bioreactor. Four and six inch PVC pipes and chipped tire will be used to construct the gas collection system. This will be installed at every lift to either collect landfill gas or inject air in the landfill. Gas will be sampled from either the main collection pipe or each individual lift of waste to determine gas composition or measure gas pressure. The gas pressure and temperature will also be measured at the well heads when taking reading for gas composition weekly. Gas flow rate will be measured automatically continuously. If additional funding becomes available the County will

		investigate automation of CH_4, CO_2, O_2, and N_2 .
• Leachate Flow Measurement & Other Leachate Parameters	• **Anaerobic Bioreactor & Aerobic Bioreactor:** 1. Leachate input and output volumes 2. Leachate pH, dissolve oxygen, conductivity	The quality of leachate added or collected from the LCRS is measured by flow meters from each cell. The SCADA system will be used to monitor and control quantities of leachate added and collected. Some of the leachate parameters will be automated for continuous measurement such as pH, dissolved oxygen, and conductivity.

Table 3- Monitoring Parameters and Frequency for the Bioreactor Project

Monitoring Parameter	Frequency	Description
Leachate: • pH • Conductivity • Dissolved Oxygen • Dissolved Solids • Biochemical Oxygen Demand • Chemical Oxygen Demand • Organic Carbon • Nutrients(NH_3, TKN, TP) • Common Ions • Heavy Metals • Organic Priority Pollutants • Flow rate	• Monthly • Monthly • Monthly, Quarterly • Monthly, Quarterly • Monthly, Quarterly • Monthly, Quarterly • Monthly, Quarterly • Monthly, Quarterly • Monthly, Quarterly • Monthly, Quarterly • Monthly, Quarterly • Monthly	Leachate samples will be collected from each cell (aerobic or anaerobic) sump and tested. For the first six months tests will be done monthly and the next six months will be done quarterly. After the first year, tests will be done semi-annually (with the exception of pH, conductivity, and flow rate which will continue to be monitored on a monthly basis as required by the State of California's amended Waste Discharge Requirements for the County in Order 5-00-134. In some cases, leachate monitoring may be done on a more frequent basis, depending on the level of funding available for the project.
Landfill Gas: • CH_4, CO_2, O_2, and N_2 • Gas temperature at well head • Hydrogen sulfide • NMOCs, VOCs • Surface test for methane concentration • N_2O (for aerobic) • Flow rate	• Weekly • Weekly • Quarterly, Semi-annually • Quarterly, Semi-annually • Quarterly • Quarterly, Semi-annually • Continuously	Landfill gas will be tested routinely from both the aerobic and anaerobic cell. For the first year, tests will be done quarterly and for the following years some test frequencies will be changed to semi-annually as required in the FESOP with the local air district for early gas collection, control,

		and monitoring. The surface test for methane concentration which is used to determine collection efficiency and surface integrity will be conducted according to MSW NSPS surface monitoring requirements in 40 CFR section 60.755 (c).
Solid Waste Stabilization and decomposition: • Landfill surface topographic survey • Moisture Content • Biochemical Methane Potential • Cellulose • Lignin • Hemi-cellulose	 • Annually • Annually • Annually • Annually • Annually • Annually	To determine the total percent change in volume over time, an annual topographic survey will be done on the top surface of each cell. If funding is available solid waste samples may be collected to determine the degree of stabilization. Samples of waste may also be tested for heavy metals and organic pollutants.

The full-scale Yolo County Bioreactor project will combine two key elements:

a) Acceleration of waste decomposition and leachate treatment, via liquid amendments and recirculation through pipe network serving the waste mass. This is to accomplish rapid completion of composting, stabilization and generation of methane to the maximum practical yield.

b) Efficient capture of nearly all generated methane, withdrawn at slight vacuum from a freely gas-permeable shredded tire collection layer beneath low-permeability cover. The shredded tire collection layer has gas permeability from 3 to 5 orders of magnitude higher than overlying cover. Near-complete extraction with this approach has already been demonstrated in the 9000-ton test cell at the Yolo County Bioreactor Demonstration Project.

The planned anaerobic cell proposes a larger-scale replication of the 9000-ton anaerobic controlled bioreactor landfill demonstration at Yolo. This demonstration has now operated for over three years. Some of the data from the demonstration project are summarized below:

(a) Enhanced methane/ gas recovery (an index of anaerobic composting) at a rate of an order of magnitude greater than that of the current landfill unit production. Based on the collected data to date, the anaerobic bioreactor stabilization time may be reduced by more than 30 years less than the current landfills expectations. Table 4 below summarizes some of the landfill gas data for the enhanced and control cell.

Table 4- Landfill Gas Data for the 9000-ton Bioreactor Demonstration Project

YEAR	1997	1998	1999
ENHANCED CELL LFG VOLUME (Million SCF)	12.2	24.8	30.7
CONTROL CELL LFG VOLUME (Million SCF)	9	14.9	15.2
ENHANCED CELL AVERAGE FLOWRATE (SCFM)	35	22	7
CONTROL CELL AVERAGE FLOWRATE (SCFM)	22	5	1
ENHANCED CELL AVERAGE METHANE CONTENT	53%	54%	53%
CONTROL CELL AVERAGE METHANE CONTENT	47%	45%	47%

(b) Collection is by extraction from a freely gas-permeable surface layer, kept at slight vacuum, overlying the waste and beneath a very low-permeability surface cover. This approach allows recovery of all gas generated beneath the permeable layer.

(c) With the same collection approach, reductions in emissions of local air pollutants in landfill gas by at least the same fraction that landfill methane is reduced.

Figure 4- Percent Settlement versus Time for the 9000-ton Bioreactor Demonstration Project

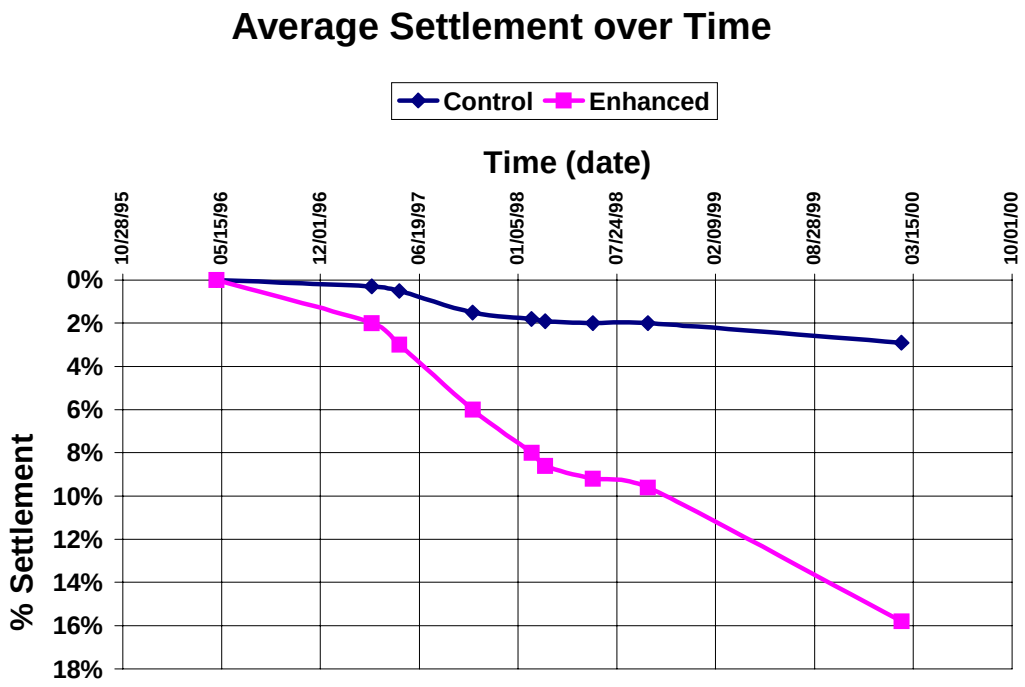
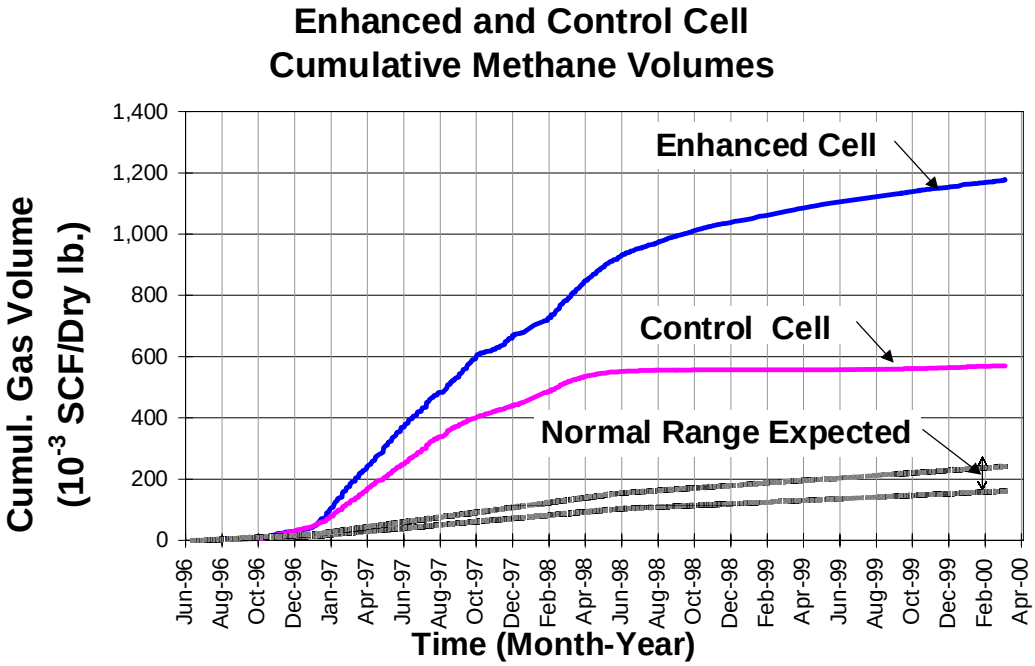


Figure 5- Cumulative Methane Volumes for the 9000-ton Bioreactor Demonstration Project



(d) Volume and waste mass loss of over 18% in the first 3 years of the enhanced operation, as compared to 3% for the control cell (see Figure 4). This suggests a difference of landfill life extension of over 15% possible by taking advantage of the extra air space made available.

(e) Bioreactor liquid additions can be slow and very carefully managed while still attaining excellent methane enhancement. In the Yolo anaerobic cell demonstration project liquid was carefully added at a slow rate. The highest liquid injection rate of 10 gpm resulted in an output leachate flow rate of less than 3 gpm for short periods, less than three days. Careful liquid injection rates resulted in liquid outflow rate that rapidly decreased and was easily controlled.

(f) No measurable leakage in the primary liner system of the enhanced cell. This is consistent with data from Othman et al showing primary composite liner leakage rates of 0 to 5 gallons per acre-day. Most values in Othman et al are consistent with negligible or no leakage (below detection limits, less than 0.2 gallons per acre-day) for monitoring periods within the first few years after base composite clay-geomembrane lining construction.

(g) Leachate pollutants stabilize rapidly, usually in under a year to concentrations well beneath those typifying the surrounding conventional landfill at the same site. Table 5 below shows typical leachate chemistry data over the past four years.

Table 5- Landfill Leachate Data for the 9000-ton Bioreactor Demonstration Project

YEAR	1996	1997	1998	1999
pH	5.8	7.0	7.2	7.2
BOD (mg O/L)	5,020	820	140	80
COD (mg O/L)	20,300	2,860	3,130	2,650
TDS (mg/L)	19,800	7,600	7,500	7,250
TOC (mg/L)	9,830	611	1,130	1,080
Iron (mg/L)	152,000	933	504	206
Manganese (µg/L)	41,900	4,000	1,170	1,060
Calcium (mg/L)	1,400	480	220	198
Lead (µg/L)	ND	ND	ND	ND
Toluene (µg/L)	160	75	24	15

The aerobic bioreactor differs from the anaerobic, only by introducing air to the landfill. Recent representative references on aerobic bioreactor processes include Johnson and Baker, 1999 and Bernreuter and Stessel. 1999.

Results indicate that "in-landfill" aerobic composting is feasible. Advantages include the desired waste destruction as well as suppression of landfill methane generation by heat and oxygen. In contrast to anaerobic operation, significant waste fractions such as lignin and ligneous materials,

and leachate COD components, not degradable anaerobically, are degradable aerobically. Thus it should be possible to achieve somewhat greater waste and leachate organics reduction by aerobic processing compared to anaerobic. These advantages of aerobic bioreactors are expected based on well-established fundamental scientific knowledge, but large-scale data to confirm advantages are limited. There are fewer key measurements to date on aerobic processes, and even basic data such as on material balances and flows are limited. However lysimeter tests, such as Stessel and Murphy, 1992 and other citations of Bernreuter and Stessel, 1999 summarizing ongoing field operations show that landfilled waste is degraded aerobically by passing air and liquid through landfills. Remaining questions include how fast and completely landfilled waste can be composted aerobically. Information for VOC and other emissions are not well established.

III. How the Project Will Meet the XL Acceptance Criteria

A. Anticipated Superior Environmental Performance

1. Tier 1: Is the Project Equivalent?

The existing information on the Yolo County demonstration project identifies no significant adverse environmental impacts, that is, worsening of environmental impacts relative to conventional practice. Although leachate may be recovered in quantities at times greater than that with conventional practice it can be well controlled; further, all recovered leachate can be re-used, being re-imbibed by waste, in the process. The liner not only meets, but exceeds, the design specifications required for leachate recirculation. The leachate collection system is also designed and constructed to maintain a head of less than the prescribed maximum of 30 cm. of leachate over the liner, as specified in the design criteria. The landfill was also constructed with a secondary liner (vapor barrier), which will act as a leak detection system, will provide protection if the primary liner does leak and will allow Yolo to reduce or cease liquids addition if necessary to control leakage. The landfill gas will be collected and controlled through Internal Combustion (IC) engines and a flare. Implementation of the project will result in an increase in the volume of landfill gas produced. As a consequence, there may be an increase in NOx emissions from the IC engines and the flare. NOx emissions will not, however, exceed the limits specified in Yolo County's existing air permit. Implementation of the project will result in a significant reduction in emissions of methane and nonmethane organic compounds. We, believe that these factors taken as a whole mean that the environmental impacts associated with the project will not be any greater, and in fact may be less, than those that would be experienced in the absence of the project.

2. Tier 2: Superior Environmental Performance

For convenience the various aspects of superior environmental performance are summarized in Table 6. The benefits to Yolo County are potentially greater energy revenue from the anaerobic operation, which could result from more electricity generation or other energy uses, and landfill life extension. Present landfill capacity is sufficient until the year 2040, and the County would like to see its ability to landfill waste extended farther into the future. The County is also very interested in reducing the anticipated post-closure expenses and liabilities that are presently associated with conventional landfilling in addition to cost of leachate treatment system.

With a Bioreactor Landfill, superior environmental results include: a) Maximizing landfill gas control and capture of fugitive emissions. b) Landfill life extension and/or reduced landfill use, and c) Leachate treatment and disposal benefits. These are summarized in Table 6 and discussed further below.

a. Maximizing landfill gas control and minimizing fugitive methane and VOC emissions. Landfill gas as generated contains 55% to 60% methane, a potent greenhouse gas. In terms of climate effects methane is second in importance only to carbon dioxide. Landfill gas is a transporter of volatile organic compounds (VOC's) that are air pollutants. Landfill gas capture is maximized by a subsurface permeable gas collection layer overlain by a cover of soil with embedded membrane. Gas is withdrawn to maintain this permeable layer beneath surface containment under a slight vacuum. The capture of methane is further facilitated and eased by a shortened generation interval, from 30 to 50 years to between 5 to10 years through enhanced decomposition. A horizontal gas collection system will be installed as waste is placed and collection of gas will begin as soon as waste begins to generate landfill gas. In addition, the final synthetic cover liner will improve the overall collection efficiency of the landfill gas system. With this gas capture approach, it is expected that fugitive landfill gas emissions will be reduced for reasons that include:

- Reduction in emissions through installation and operation of gas collection system before the final fill height has reached and before it's required by Clean Air Act NSPS regulations.

- Collection efficiency improvements with the proposed horizontal gas extraction method over vertical gas well efficiency.

- Reduction in long term emissions, from landfill gas generation occurring slowly beyond 30 years post-closure.

The demonstration project has already shown close to a tenfold increase in methane recovery rate compared to conventional landfills, which suggest a tenfold reduction in interval of methane generation. Available indications as well as basic physical principles suggest that capture effectiveness approaches 100% so long as slight vacuum is maintained within the permeable layer.

A recently completed study for the Federal Energy Technology Center (FETC) (now the National Energy Technology Laboratory, NETL) of the U. S. Department of Energy indicates that wide application of controlled landfilling could reduce US greenhouse gas emissions by 50-100 million tons of CO_2 equivalent when both emission prevention and fossil CO_2 offsets are taken into account. This major reduction in CO2 (equivalent) emissions is also cost-effective. In the analysis for FETC (IEM, 1999), over a range of representative landfill conditions, greenhouse gas abatement was estimated as attainable at a cost of \$1-5/ton CO_2 equivalent which represents extremely low (by more than tenfold) cost compared to most other options presented in the recent EIA Report (USDOE Energy Information Agency. 1998)

b. Landfill life extension and/or reduced landfill use. The more rapid conversion of greater quantities of solid waste to gas reduces the volume of the waste. Settlement in the Yolo test cell is already over 18% in three years. Volume reduction translates into either landfill life extension and/or less landfill use. Thus bioreactor landfills are able to accept more waste over their

working lifetime. Alternatively, fewer landfills are needed to accommodate the same inflows of waste from a given population

c. Leachate treatment and disposal benefits: Bioreactors promise more rapid leachate stabilization in terms of pollutant load, reduced leachate environmental impact, and elimination of need for most discharges to treatment facilities. The bioreactor processes, both anaerobic and aerobic, have been shown in studies at many scales to reduce the content of many leachate pollutants. These include organic acids and other soluble organic pollutants. Since a bioreactor operation brings pH to near-neutral conditions, metals of concern are largely precipitated and sequestered/ immobilized in waste. Thus free liquid concentrations and mobility of metals of concern are reduced compared to "conventional" landfill practice where more contaminated lower-pH leachate is often observed to be generated slowly for years. For example, in the Yolo test cell demonstration leachate reached near-neutral (pH 7) conditions within four months after liquid additions and recirculation commenced.

Although not a direct environmental benefit, a need for offsite leachate treatment should be avoidable altogether as long as waste landfilling continues concurrently with bioreactor operation. The additional leachate that would have to be treated at a wastewater treatment facility expansion could be avoided. Because bioreactors almost invariably require extra liquid for optimum performance, and leachate and condensate reintroduction are permissible (40 CFR 258.28), continuing operation of a landfill as a bioreactor allows generated leachate and condensate to be reintroduced so long as new dry waste continues to flow into the landfill. Additionally, calculations indicate that operation of even a small fraction of the landfill aerobically can consume leachate so long as generated, because of the high capacity of the aerobic reactions to evaporate liquid.

In addition, the following waste management benefits are discussed further below:

d. Lessened long-term risk and need for monitoring. The bioreactor approaches (anaerobic and aerobic) offer potential substantial reductions in postclosure care needs and costs. With present conventional practice, it is highly likely that gas management will be required for at least a mandated 30-year post-closure period. This entails all of the associated expense of continuing monitoring and gas well adjustment. Higher pollutant strength leachate must continue to be managed. A number of other management needs occur as waste continues to decompose, including dealing with subsidence, gas collection line breakage caused by subsidence, and the like.

e. Landfill Gas Energy Project Potential. Yolo County is considering several other alternatives for energy projects such as: (1) Self-wheeling of generated power, (2) Using increased generation at the landfill for sale to the grid (2MWe are being generated but the permit would allow up to 12 MWe), (3) Local boiler use of gas (4) Sale of power to the adjacent City of Davis Wastewater treatment facility, and (5) Sale of landfill gas to greenhouse farmer adjacent to the landfill. More predictable gas generation rate and higher collection efficiency will increase the economics of installing such projects and therefore would increase the number of projects that will be developed which would reduce the fugitive emissions from such sites.

f. Landfill Mining Potential: Although landfill mining is not listed in Table 6, the removal and re-use of waste for beneficial purposes, such as compost for alternative daily cover used on site in other landfill modules is a distinct possibility that County will be investigating in this project. If landfill mining were carried out, it would occur when sufficient stabilization has been

achieved. For the anaerobic cell this could be beyond the expected 5-year term of the XL agreement. However, landfill mining or other beneficial use of the waste could also qualify for credit as composting. County has discussed this with the state regulators and agencies and will be conducting a mining pilot project to mine waste from the older section of the landfill. Feasibility of this operation will be determined to estimate the cost for possibly mining the aerobic cell within the 5 year Project XL agreement period. If funds become available the County will explore mining the aerobic bioreactor to quantify the level of biodegradation and the amount decomposed matter that would be reclaimed from the landfill.

3. How We Will Measure the Superior Environmental Performance of our Proposal

A. Anticipated Superior Environmental Performance

Superior Environmental Performance will be measured using the baseline (Tier 1, without Project XL) against the actual results of the project (Tier 2, proposed Project XL). To determine specific bioreactor performance attributes of Table 6, monitoring plans are listed in Tables 2 and 3 and are discussed below:

a. Maximizing landfill gas control and minimizing fugitive methane /VOC emissions. Tests will be conducted to compare emission performance of the anaerobic and aerobic bioreactors to the conventional landfilling. An integrated combustible gas surface scan of the test cell versus the surrounding landfill will be employed , using the surrounding landfill as a control. NSPS emission guideline method (section 60.755 (c) 3) will be used to measure surface emission.

b. Life extension for a 20-year landfill. This will be based on annual topographical surveys. Total volume loss occurring within this time interval will be calculated.

c. Leachate contamination risk. One measurement of this, comparison of leachate from the bioreactor and surrounding areas, is straightforward. However there could also be an estimation of future risk from "entombed" waste. This could be inferred using generated gas data to indicate what fraction of waste remains undecomposed in the surrounding landfill vs. the bioreactor (i. e. greater normalized gas generation means more complete decomposition and less future risk).

B. Flexibility and Other Benefits

As noted, project results (to date) from smaller-scale demonstration projects are very encouraging and have demonstrated a tenfold increase in landfill gas generation, increased landfill settlement, improved leachate chemistry, and highly cost-effective abatement of greenhouse gases. Economic analysis of the project shows that implementing bioreactor landfilling operations can have significant cost savings and environmental benefits for the Yolo County Central Landfill.

Table 6- Superior Environmental Performance

			Conventional Landfill (Yolo without XL)	Proposed Bioreactor Project (with XL)	
				Anaerobic bioreactor	**Aerobic bioreactor**
A	Expedited methane generation and recovery to control fugitive emission such as "greenhouse" methane and VOC's.	Fugitive gases due to emissions before gas collection system is in operation. Recovery of 55-80% of total gas generated because of slow gas generation over very long term (25-70 years). Less than 100% collection efficiency after installation of gas collection system.		Higher gas recovery efficiency than conventional gas collection system. Capture begins early in filling phase. Efficient recovery from permeable layers ongoing through entire gas generation cycle of 5-10 years. High generation rate over short period (5 to 10 years) allows near-maximum recovery	N/A- (little or no methane expected)
B	Life extension for 20 year landfill	0 years gained		For a 20-year "conventional" design, ca. 5 years additional life obtained	Over 7 years life extension expected.
C	Future Leachate Contamination Risks	Medium to high (organics and metals) over long term		Lower organics and lower metals for shorter term	Lower organics and lower metals for shorter term.

C. Stakeholder Involvement and Support

Stakeholder involvement and support for this concept has already been demonstrated by previous federal, state, and local support of this bioreactor concept. For example, in 1994, the Yolo County Planning and Public Works Department, initiated a bioreactor landfill demonstration project to evaluate the Bioreactor Landfill concept for its Central Landfill near Davis, California. The construction phase of the project was funded by Yolo and Sacramento Counties ($125,000 each), the California Energy Commission ($250,000), and the California Integrated Waste Management Board ($63,000). More recent grant funding for the monitoring phase of the project has been received from the U. S. Department of Energy through the Urban Consortium Energy Task Force ($110,000), and the Western Regional Biomass Energy Program ($50,000). Greenhouse gas and emission abatement cost-effectiveness studies have recently been completed with $48,000 in support from the Federal Energy Technology Center/National Energy Technology Laboratory (hereafter, NETL). Further support, $462,000 recently committed by NETL, is enabling operation of the test cells for approximately 2 more years as well as helping prepare for larger module operation.

On January 26, 2000 the California Integrated Waste Management Board committed Yolo County $400,000 for the construction and testing of the full-scale bioreactor demonstration project.

Concerning local support for this XL project, Yolo County has held several public meetings for the full-scale demonstration project. These meeting have been held during the regular Waste Advisory Committee meetings to locate potential members of the local stakeholder group. The County will convene periodic meetings of the stakeholder group to obtain comments on this proposal, as well as to brief the group on their progress during the duration of the XL agreement.

Yolo County has recognized the following as a list of potential stakeholders:

Direct Participants:

County of Yolo, Planning and Public Works Department
U. S. Environmental Protection Agency
Solid Waste Association of North America (SWANA)
Institute for Environmental Management (IEM)
California State Regional Water Quality Control Board, Central Valley Region 5
Yolo County Department of Environmental Health
Yolo-Solano Air Quality Management District

Commentors:

California Integrated Waste Management Board
California State Water Resources Control Board
California Air Resources Board
National Energy Technology Laboratory (NETL, previously FETC), U. S. Department of Energy
SWANA–California Gold Rush Chapter and Southern California Chapter
Yolo County Waste Advisory Committee
University of California at Davis
Geosynthetic Institute, Drexel University
Yolo County Citizens

D. Innovation and Pollution Prevention and Multi-media Pollution Prevention

Yolo County intends, as part of this project, to continue our ongoing pollution prevention efforts. Regardless of whether a particular component is directly regulated as part of an XL agreement, the County will continue our process of reviewing all pollution prevention opportunities and will report on our pollution prevention progress.

E. Transferability of the Approach to Other Entities or Sectors

Yolo County believes that with the approval of this proposed bioreactor landfilling concept by Federal EPA and the state, many other public and private landfill owners and operators should be able to implement this type of technology. The technology is expected to yield substantial economic and environmental benefits for-nearly all regions of the U. S., and as noted, worldwide. Results from Yolo County's Bioreactor Landfill pilot project have already been shared among many other jurisdictions as well as the private sector throughout the U.S. and internationally. Results of the project have been published in technical and trade journals and magazines worldwide.

Following an evaluation of this XL Project by EPA, and the first progress report by the County, and assuming the overall success of the Project, the bioreactor landfill technology used in this project could be transferable to the large subset of landfills where conditions are favorable for actively managing the decomposition process and where groundwater protection and gas control are ensured. Based on early inquiries, application is likely outside as well as within the US.

F. Feasibility of the Project

The project sponsor, co-sponsors, and regulatory agencies as designated in the Final Project Agreement, agree to support the project, subject to any review procedures necessary to implement the legal mechanism for this project. Further, each XL participant has the financial capability, personnel and senior management commitment necessary to implement the elements of this Bioreactor Landfill XL Project.

G. Monitoring, Reporting, Accountability, and Evaluation Methods to be Used

The parties intend to implement as enforceable commitments, federal and state regulatory flexibility, monitoring, record-keeping, and reporting provisions of this FPA through a site-specific rule and a Federally Enforceable State Operating Permit (FESOP). Tables 2 and 3 identify the Monitoring Parameters and Frequency for Monitoring for this project.

The legal mechanisms that would apply to this project include a Federally Enforceable State Operating Permit for gas collection and monitoring, and a site-specific rule for liquid additions. The Yolo- Solano Air Quality Management District is the regulatory agency that has permitting authority for the Yolo County landfill. The FESOP would contain enforceable parameters and requirements with respect to NSPS-compliant gas collection and monitoring prior to liquid additions and/or leachate recirculation, whichever occurs first. It would require a public notice and comment period. In addition, EPA will be issuing a proposed rule for liquid additions at

Yolo County landfill. It would also require a public comment period. Either the FESOP or the site-specific rule (as appropriate) would contain the enforceable project monitoring requirements listed in Tables 2 and 3, and would require that Yolo County provide semi-annual reporting of the monitoring to project stakeholders and regulators in order to facilitate project evaluation.

EPA, the State, and other appropriate regulatory agencies will assess the project annually based on all information submitted. EPA will post Yolo County's project data on its Project XL web page semi-annually.

H. Avoidance of Shifting of Risk Burden to Other Areas or Media

Under the site specific Waste Discharge Requirement, the County is required to measure and monitor hydraulic head over the liner in addition to monitor liquid from the leak detection sumps and the underlying groundwater monitoring system. This will ensure that no shifting of risk burden to other environmental media associated with this project. The 40-mil HDPE liner covers the entire 12-acre base liner and will transmit any leakage from upper 60-mil HDPE composite liner system through the geonet/geotextile strips above the 40-mil HDPE liner to the lowest point sumps for early detection of leakage before it can reach the underlying groundwater. In addition, through the site-specific rule-making, the County will measure surface emission monitoring to determine the surface collection efficiency of the top liner and gas collection system. Test methods will be in accordance to NSPS CFR 40 Part 60 Subchapter WWW of the Clean Air Act.

IV. Description of the Requested Flexibility and Implementing Mechanisms

A. Requested Flexibility

This section is primarily intended to describe federal flexibility needed for this XL project. It also discusses State and local flexibility believed to be necessary to authorize this project. To the extent such action is necessary and appropriate, it will be provided as part of this project and subject to public notice and comment.

In general, Yolo County proposes to be able to undertake a proposed bioreactor landfill project that falls within the limitations established in the XL agreement. Yolo County is requesting specific flexibility under the current state and/or federal regulations requirements for liquid addition as described below.

Liquids Addition:

Yolo County is requesting that U.S. EPA grant site-specific regulatory flexibility from the prohibition in 40 CFR 258.28 Liquid Restrictions, which may preclude addition of useful bulk or non-containerized liquid amendments. The County is proposing to supplement the liquid addition with ground water, but would like to obtain the flexibility to possibly utilize other liquids such as gray waters from wastewater treatment plant, septic waste, gray water, and food-processing wastes that is currently land applied. Liquid wastes such as these that normally have no beneficial use, may instead beneficially enhance the biodegradation of solid waste in a landfill for this project.

Yolo County also requests similar flexibility on liquid amendments from California and local regulatory entities. Several sections of the California Code of Regulations (CCR), Title 27,

Environmental Protection, address the recirculation of liquids in lined municipal waste landfills. While the regulations do not specifically endorse bioreactors like the regulations in the State of Washington, regulatory flexibility is provided. This portion of the agreement will describe specific regulations in Title 27 regarding recirculation.

Title 27, Chapter 3, Subchapter 2, Article 2, Section 20200, Part (d)(3), *Management of liquids at Landfills and Waste Piles* states the following:

"Liquid or semi-solid waste (i. e. waste containing less than 50% solids, by weight), other than dewatered sewage or water treatment sludge as described in § 20220 (c), shall not be discharged to Class III landfills. Exceptions may be granted by the RWQCB if the discharger can demonstrate that such discharge will not exceed the moisture holding capacity of the waste either initially, or as the result of waste management operations, compaction, or settlement, so long as such discharge is not otherwise prohibited by applicable state or federal requirements".

The above regulation specifically allows the Regional Water Quality Control Board, Central Valley Region (RWQCB) the ability to grant an exception regarding the discharge of liquids into a Class III landfill providing the moisture holding capacity is not exceeded. The previous demonstration project at the Yolo County Central Landfill provided a working demonstration as to the feasibility of the proposed bioreactor project. Through monitoring, instrumentation, and testing, it was demonstrated that liquid could be added in such a way that the holding capacity of the refuse is not exceeded. The same equipment and procedures will be utilized for the Module D bioreactor. Specific sections of this agreement present plan details regarding the method of liquid recirculation.

It should be noted that the preceding Part in the regulations (Section 20200, Part (d)(2) addresses the discharge of waste containing free liquids and does not apply to this application. The County is not proposing to discharge wastes containing free liquids, but is instead proposing to add liquids or semi-solid waste to the refuse already in-place. While the regulations state that wastes containing free liquids must be discharged to a Class II waste pile, the addition of liquids to existing waste in a Class III landfill is allowed by the regulations if an exception is granted by the RWQCB.

Title 27, Chapter 3, Subchapter 2, Article 4, Section 20340, Part (g)(1,2,3), *Leachate Collection and Removal Systems* states the following:

"Leachate Handling – Except as otherwise provided under SWRCB Resolution No. 93-62 (for MSW landfills subject to 40CFR258.28), collected leachate shall be returned to the Unit(s) from which it came or discharged in another manner approved by the RWQCB. Collected leachate can be discharged to a different Unit only if:

1. *the receiving Unit has an LCRS, contains wastes which are similar in classification and characteristics to those in the Unit(s) from which leachate was extracted, and has at least the same classification (under Article 3 of this subchapter) as the Unit(s) from which leachate was extracted;*
2. *the discharge to a different Unit is approved by the RWQCB;*
3. *the discharge of leachate to a different Unit shall not exceed the moisture-holding capacity of the receiving unit, and shall comply with § 20200 (d)."*

The above section of Title 27 specifically allows the RWQCB to approve the discharge of leachate from other Units within a landfill to a receiving Unit as long as the wastes have similar classification and characteristics, the receiving Unit has a Leachate Collection and Removal System (LCRS), and the moisture-holding capacity of the refuse is not exceeded. These conditions are satisfied in that the wastes are similar throughout the landfill and Module D has a LCRS. Based on satisfying all of the conditions listed in the above regulatory requirement, the County is seeking approval from the RWQCB to discharge leachate generated from other Units within the Yolo County Central Landfill into Module D.

Title 27, Chapter 3, Subchapter 2, Article 5, Section 20937, Part (b)(4), *CIWMB – Control* states the following:

"A gas control system shall be designed to: Provide for the collection and treatment and/or disposal of landfill gas condensate produced at the surface. Condensate generated from gas control systems shall not be recirculated into the landfill unless analysis of the condensate demonstrates to the satisfaction of the EA, that it is acceptable to allow recirculation into landfills which have a liner and an operational leachate collection system and the RWQCB approves such discharge pursuant to § 20200 (d)."

Based on the design and operation of the Module D bioreactor, the LCRS and liner system are in place to allow for the recirculation of gas condensate. The County has submitted the analysis of constituents within the gas condensate in the site monitoring reports. Based on these factors, the County is seeking approval from the RWQCB to recirculate the condensate.

In reviewing the regulations regarding the recirculation of leachate and gas condensate, it appears that the County has satisfied all criteria enabling the RWQCB to grant approval for leachate/condensate recirculation in Module D. However, as previously discussed, the refuse deposited at the Yolo County Central Landfill is relatively dry. In order to have proper operation of a landfill bioreactor, the waste must attain its moisture holding capacity. This moisture level can not be reached with the addition of leachate and condensate alone but can be reached with other liquid supplements. Such flexibility in liquids additions is justified based on composting performance, available controls, and multiple environmental safeguards that have already been demonstrated in the smaller-scale 9000-ton test program at the Yolo County Central Landfill.

B. Legal Implementing Mechanisms

To implement this Project, the parties intend to take the following steps:

1. EPA will propose for public comment and promulgate a site-specific rule amending 40 CFR 258.28 (Liquid Restrictions) for Yolo County's facility. This site-specific rule will describe the project requirements and any other aspects of the rulemaking. It is expected that the site-specific rule will provide for Withdrawal or Termination and a Post-Project Compliance Period consistent with Section XI, and will address the Transfer procedures included in Section IX. The standards and reporting requirements set forth in Section III (and any attachments to this FPA) will be implemented in this site-specific rulemaking.

2. The State under its relevant authority expects to promulgate the appropriate rule changes, permit modifications, etc. to implement this FPA needed by Yolo County for this project. Except as provided in any rule(s), compliance order(s), permit provisions or other implementing mechanisms that may be adopted to implement the Project, the parties do not intend that this

FPA will modify or otherwise alter the applicability of existing or future laws or regulations to Yolo County's facility.

3. The Yolo-Solano Air Quality Management District under its relevant authority expects to modify any permits necessary to implement this FPA.

4. Except as provided in any rule(s), compliance order(s), permit provisions or other implementing mechanisms that may be adopted to implement the Project, the parties do not intend that this FPA will modify or otherwise alter the applicability of existing or future laws or regulations to Yolo County's Solid Waste Management Facility.

5. By signing this FPA, EPA, Yolo County, the State of California and its local authorities acknowledge and agree that they have the respective authorities and discretion to enter into this FPA and to implement the provisions of this project, to the extent appropriate.

V. Discussion of Intentions and Commitments for Implementing the Project

A. Yolo County's Intentions and Commitments

1. Enforceable

Yolo County will comply with all applicable environmental requirements during implementation of this Project.

The County will establish a record keeping system to ensure compliance, as well as accurate reporting of monitoring data from Tables 2 and 3.

Yolo County will submit an application to the Yolo-Solano Air Quality Management District requesting that the District issue, to Yolo County, a federally enforceable state operating permit (FESOP) which incorporates all of the landfill gas monitoring requirements specified in Table 3 of this agreement and contains adequate provisions to ensure that landfill gas is collected and controlled in accordance with the requirements of 40 CFR, part 60, Subpart WWW - Standards of Performance for Municipal Solid Waste Landfills. Yolo County will work diligently with the District to ensure that the FESOP is issued in a timely manner.

2. Voluntary

Yolo County intends to operate its next 20-acre landfill module near Davis, California as a controlled bioreactor landfill to attain a number of superior environmental and cost savings benefits.

The County is committed to working with federal, state, and local governments to demonstrate, with regulatory flexibility, how a bioreactor landfill can attain more desirable environmental results than a conventional landfill.

The County commits to exploring alternatives in their energy generation system which would minimize the amount of additional NOx generated.

Yolo County intends to provide accurate data for the proposed bioreactor landfill. This data should enable EPA and the State to develop or modify regulatory requirements for identified parameters, such as those identified in Table 2 and Table 3 of this FPA.

Yolo County intends to continue to provide resources to maintain the schedules set forth in this FPA.

B. EPA's, State of California, and other local regulatory agency's Intentions and Commitments

EPA intends to propose and issue (subject to applicable procedures and review of public comments) a site-specific rule, amending 40 CFR Part 258.28, that applies specifically to the Yolo County's solid waste landfill site in Davis. The site-specific rule will also provide for withdrawal or termination and a post-Project compliance period consistent with Section XI of this Agreement, and will address the transfer procedures included in Section IX. Monitoring, record keeping, and reporting requirements will be implemented in the site-specific rule. EPA will work with other parties, stakeholders and the appropriate local, regional, state and federal agencies to facilitate the process.

The State and other local governing regulatory agencies will assist the XL Project Team in understanding all applicable regulatory and/or permitting requirements for the Project, and evaluate any need for regulatory flexibility openly with the Team.

The Yolo-Solano Air Quality Management District under its relevant authority expects to modify any permits necessary to implement this FPA. The monitoring, record keeping, and reporting requirements will be implemented in the FESOP.

EPA and the other regulatory agencies will review and assess annual and periodic reports submitted by Yolo County.

EPA will review the Project to determine whether it results in superior environmental performance.

The State and other local regulatory agencies will assist EPA in reviewing the Project to determine whether it results in superior environmental performance.

C. Project XL Performance Targets

See Table 6, Superior Environmental Performance.

D. Proposed Schedule and Milestones

This project will be developed and implemented over a time period necessary to complete its desired major objectives, beginning from the date that the final legal mechanism becomes effective, unless it is terminated earlier or extended by agreement of all Project Signatories.
An expected timeline is shown in below, Table 7.

Table 7- Project XL Delivery Schedule

Project Task	Delivery Date
• RWQCB approved the revised Waste Discharge Requirement Permit	June 15, 2000
• Draft FPA circulated to stakeholders for comments	June 22, 2000
• Preliminary comments received for final Draft FPA • Begin instrumentation installation and waste filling in bioreactor	July 3, 2000
• Official public comment period for Draft FPA	August 25, 2000
• All parties sign FPA document	September 15, 2000
• Federal Register for Yolo County XL Project proposed rule begins	September 30 , 2000
• Federally-enforceable State Operating Permit in place	October 31, 2000
• First lift of waste in anaerobic bioreactor finished and begin waste placed in aerobic bioreactor	November 30, 2000
• Federal approval obtained for liquid addition	November 30, 2000
• Begin second lift of waste placement in anaerobic bioreactor • Monitor cell temperature and moisture • Place intermediate soil cover and start gas monitoring and collection	January 1, 2001
• Complete the following for the aerobic bioreactor: waste placement, instrumentation, data acquisition and control system, leachate injection system, air injection system, gas and leachate monitoring, and cover system	March 1, 2001
• Start liquid addition, air injection, and monitoring in aerobic bioreactor	April 1, 2001
• Complete placement of last lift of waste in anaerobic cell • Install gas collection and leachate injection in each lift of waste • Monitor cell for start of landfill gas generation and operate gas collection system as soon as landfill gas is produced • Complete instrumentation, data acquisition and control system, leachate injection system, gas collection and monitoring system, and cover system	November 1, 2001
• Begin liquid injection and continue gas collection in anaerobic bioreactor	December 1, 2001
• Data collection and reporting will continue	July 2000-July 2004

E. Project Tracking, Reporting and Evaluation

The project tracking, reporting and evaluation will be accomplished for project sponsors including EPA in accordance with, among other things, EPA requests. The County agrees to provide data to EPA and EPA has agreed to post this information on the EPA's web page. County will also make data from project available through publishing in professional journals and magazines.

The County will prepare semi-annual reports which will include all monitoring data commencing with the execution of the Final Project Agreement and deliver them to USEPA and the stakeholders. An annual meeting will be held to review the project progress and results to date for as long as Yolo County continues to add liquid and/or recirculate leachate at its site under the provisions of the site specific rule(s) promulgated to implement this XL project.

F. Periodic Review by the Parties to the Agreement

The Parties will hold periodic performance review conferences to assess their progress in implementing this Project. Unless they agree otherwise, the date for those conferences will be concurrent with annual Stakeholder Meetings. No later than thirty (30) days following a periodic performance review conference, Yolo County will provide a summary of the minutes of that conference to all Direct Stakeholders. Any additional comments of participating Stakeholders will be reported to EPA.

G. Duration of Project

This Agreement will remain in effect for 5 years after signing, unless the Project ends at an earlier date, as provided under Section VIII (Amendments or Modifications), Section XI (Withdrawal or Termination), or Section IX (Transfer of Project Benefits and Responsibilities). The implementing mechanism(s) will contain "sunset" provisions ending authorization for this Project 5 years after the effective date of the FPA. They will also address withdrawal or termination conditions and procedures (as described in Section XI). This Project will not extend past the agreed upon date, and Yolo County will comply with all applicable requirements following this date (as described in Section XII), unless all parties agree to an amendment to the Project term (as provided in Section VIII)."

VI. Legal Basis for the Project

A. Authority to Enter Into the Agreement

By signing this Agreement, all signatories acknowledge and agree that they have the respective authorities, discretion, and resources to enter into this Agreement and to implement all applicable provisions of this Project, as described in this Agreement.

B. Legal Effect of the Agreement

This Agreement states the intentions of the Parties with respect to Yolo County's XL Project. The Parties have stated their intentions seriously and in good faith, and expect to carry out their stated intentions. This Agreement in itself does not create or modify legal rights or obligations, is not a contract or a regulatory action, such as a permit or a rule, and is not legally binding or enforceable against any Party. Rather, it expresses the plans and intentions of the Parties without making those plans and intentions binding requirements. This applies to the provisions of this Agreement that concern procedural as well as substantive matters. Thus, for example, the Agreement establishes procedures that the parties intend to follow with respect to dispute resolution and termination (see Sections X and XI). However, while the parties fully intend to adhere to these procedures, they are not legally obligated to do so.

EPA intends to propose for public comment a site-specific rule making needed to implement this Project. Any rules, permit modifications or legal mechanisms that implement this Project will be effective and enforceable as provided under applicable law.

This Agreement is not a "final agency action" by EPA, because it does not create or modify legal rights or obligations and is not legally enforceable. This Agreement itself is not subject to judicial review or enforcement. Nothing any Party does or does not do that deviates from a provision of this Agreement, or that is alleged to deviate from a provision of this Agreement, can serve as a basis for any claim for damages, compensation or other relief against any Party.

C. Other Laws or Regulations That May Apply

Except as provided in the legal implementing mechanisms for this Project, the parties do not intend that this Final Project Agreement will modify any other existing or future laws or regulations.

D. Retention of Rights to Other Legal Remedies

Except as expressly provided in the legal implementing mechanisms described in Section IV, nothing in this Agreement affects or limits Yolo County's, EPA's, the State's, or any other signatory's legal rights. These rights may include legal, equitable, civil, criminal or administrative claims or other relief regarding the enforcement of present or future applicable federal and state laws, rules, regulations or permits with respect to the facility.

Although Yolo County does not intend to challenge agency actions implementing the Project (including any rule amendments or adoptions, permit actions, or other action) that are consistent with this Agreement, Yolo County reserves any right it may have to appeal or otherwise challenge any EPA, state of California, or local agency action to implement the Project. With regard to the legal implementing mechanisms, nothing in this Agreement is intended to limit Yolo County's right of to administrative or judicial appeal or review of those legal mechanisms, in accordance with the applicable procedures for such review.

VII. Unavoidable Delay During Project Implementation

"Unavoidable delay" (for purposes of this Agreement) means any event beyond the control of any Party that causes delays or prevents the implementation of the Project described in this Agreement, despite the Parties' best efforts to put their intentions into effect. An unavoidable delay can be caused by, for example, a fire or acts of war.

When any event occurs that may delay or prevent the implementation of this Project, whether or not it is avoidable, the Party to this Agreement who knows about it will immediately provide notice to the remaining Parties. Within ten (10) days after that initial notice, the Party should confirm the event in writing . The confirming notice should include: 1) the reason for the delay; 2) the anticipated duration; 3) all actions taken to prevent or minimize the delay; and 4) why the delay was considered unavoidable, accompanied by appropriate documentation.

If the Parties, agree that the delay is unavoidable, relevant parts of the Project schedule (see Section V.) will be extended to cover the time period lost due to the delay. If they agree, they will also document their agreement in a written amendment to this Agreement. If the Parties don't agree, then they will follow the provisions for Dispute Resolution outlined below.

This section applies only to provisions of this Agreement that are not implemented by legal implementing mechanisms. Legal mechanisms, such as permit provisions or rules, will be subject to modification or enforcement as provided under applicable law.

VIII. Amendments or Modifications to the Agreement

This Project is an experiment designed to test new approaches to environmental protection and there is a degree of uncertainty regarding the environmental benefits and costs associated with activities to be undertaken in this Project. Therefore, it may be appropriate to amend this Agreement at some point during its duration.

This Final Project Agreement may be amended by mutual agreement of all parties at any time during the duration of the Project. The parties recognize that amendments to this Agreement may also necessitate modification of legal implementation mechanisms or may require development of new implementation mechanisms. If the Agreement is amended, EPA and Yolo County expect to work together with other regulatory bodies and stakeholders to identify and pursue any necessary modifications or additions to the implementation mechanisms in accordance with applicable procedures (including public notice and comment). If the parties agree to make a substantial amendment to this Agreement, the general public will receive notice of the amendment and be given an opportunity to participate in the process, as appropriate.

In determining whether to amend the Agreement, the parties will evaluate whether the proposed amendment meets Project XL acceptance criteria and any other relevant considerations agreed on by the parties. All parties to the Agreement will meet within ninety (90) days following submission of any amendment proposal (or within a shorter or longer period if all parties agree) to discuss evaluation of the proposed amendment. If all parties support the proposed amendment, the parties will (after appropriate stakeholder involvement) amend the Agreement.

IX. Transfer of Project Benefits and Responsibilities to a New Owner

The parties expect that the implementing mechanisms will allow for a transfer of Yolo County's benefits and responsibilities under the Project to any future owner or operator upon request of Yolo County and the new owner or operator, provided that the following conditions are met:

A. Yolo County will provide written notice of any such proposed transfer to the EPA, the state of California, and all applicable local agencies at least ninety (90) days before the effective date of the transfer. The notice is expected to include identification of the proposed new owner or operator, a description of its financial and technical capability to assume the obligations associated with the Project, and a statement of the new owner or operator's intention to take over the responsibilities in the XL Project of the existing owner or operator.

B. Within forty-five (45) days of receipt of the written notice, the parties expect that EPA, the state of California, and all applicable local agencies in consultation with all stakeholders, will determine whether: 1) the new owner or operator has demonstrated adequate capability to meet EPA's requirements for carrying out the XL Project; 2) is willing to take over the responsibilities in the XL Project of the existing owner or operator; and 3) is otherwise an appropriate Project XL partner. Other relevant factors, including the new owner or operator's record of compliance with Federal, State and local environmental requirements, may be considered as well.

It will be necessary to modify the Agreement to reflect the new owner and it may also be necessary for EPA, the state of California, and all applicable local agencies to amend appropriate rules, permits, or other implementing mechanisms (subject to applicable public notice and comment) to transfer the legal rights and obligations of Yolo County under this Project to the proposed new owner or operator. The rights and obligations of this project remain with Yolo County prior to their final, legal transfer to the proposed transferee.

X. Process for Resolving Disputes

Any dispute which arises under or with respect to this Agreement will be subject to informal negotiations between the parties to the Agreement. The period of informal negotiations will not exceed twenty (20) calendar days from the time the dispute is first documented, unless that period is extended by a written agreement of the parties to the dispute. The dispute will be considered documented when one party sends a written Notice of Dispute to the other parties.

If the parties cannot resolve a dispute through informal negotiations, the parties may invoke non-binding mediation by describing the dispute with a proposal for resolution in a letter to the Regional Administrator for EPA Region 9, with a copy to all parties. The Regional Administrator will serve as the non-binding mediator and may request an informal mediation meeting to attempt to resolve the dispute. He or she will then issue a written opinion that will be non-binding and does not constitute a final EPA action. If this effort is not successful, the parties still have the option to terminate or withdraw from the Agreement, as set forth in Section XI below.

XI. Withdrawal From or Termination of the Agreement

A. Expectations

Although this Agreement is not legally binding and any party may withdraw from the Agreement at any time, it is the desire of the parties that it should remain in effect through the expected duration of 5 years, and be implemented as fully as possible unless one of the conditions below occurs:

1. Failure by any party to (a) comply with the provisions of the enforceable implementing mechanisms for this Project, or (b) act in accordance with the provisions of this Agreement. The assessment of the failure will take its nature and duration into account.

2. Failure of any party to disclose material facts during development of the Agreement.

3. Failure of the Project to provide superior environmental performance consistent with the provisions of this Agreement.

4. Enactment or promulgation of any environmental, health or safety law or regulation after execution of the Agreement, which renders the Project legally, technically or economically impracticable.

5. Decision by an agency to reject the transfer of the Project to a new owner or operator of the facility.

In addition, EPA, the state of California, and all applicable local agencies do not intend to withdraw from the Agreement if Yolo County does not act in accordance with this Agreement or its implementation mechanisms, unless the actions constitute a substantial failure to act consistently with intentions expressed in this Agreement and its implementing mechanisms. The decision to withdraw will, of course, take the failure's nature and duration into account.

Yolo County will be given notice and a reasonable opportunity to remedy any "substantial failure" before EPA's withdrawal. If there is a disagreement between the parties over whether a "substantial failure" exists, the parties will use the dispute resolution mechanism identified in Section X of this Agreement. EPA, the State of California, and all applicable local agencies retain their discretion to use existing enforcement authorities, including withdrawal or termination of this Project, as appropriate. Yolo County retains any existing rights or abilities to defend itself against any enforcement actions, in accordance with applicable procedures.

B. Procedures

The parties agree that the following procedures will be used to withdraw from or terminate the Project before expiration of the Project term. They also agree that the implementing mechanism(s) will provide for withdrawal or termination consistent with these procedures.

1. Any party that wants to terminate or withdraw from the Project is expected to provide written notice to the other parties at least sixty (60) days before the withdrawal or termination.

2. If requested by any party during the sixty (60) day period noted above, the dispute resolution proceedings described in this Agreement may be initiated to resolve any dispute relating to the intended withdrawal or termination. If, following any dispute resolution or informal discussion, a party still desires to withdraw or terminate, that party will provide written notice of final withdrawal or termination to the other parties.

If any agency withdraws or terminates its participation in the Agreement, the remaining agencies will consult with Yolo County to determine whether the Agreement should be continued in a modified form, consistent with applicable federal or State law, or whether it should be terminated.

3. The procedures described in this Section apply only to the decision to withdraw or terminate participation in this Agreement. Procedures to be used in modifying or rescinding any legal implementing mechanisms will be governed by the terms of those legal mechanisms and applicable law. It may be necessary to invoke the implementing mechanism's provisions that end authorization for the Project (called "sunset provisions") in the event of withdrawal or termination.

XII. Compliance After the Project is Over

The parties intend that there be an orderly return to compliance upon completion, withdrawal from, or termination of the Project, as follows:

A. Orderly Return to Compliance with Otherwise Applicable Regulations, if the Project Term is Completed

If, after an evaluation, the Project is terminated because the term has ended, Yolo County will return to compliance with all applicable requirements by the end of the Project term, unless the Project is amended or modified in accordance with Section VIII of this Agreement (Amendments or Modifications). Yolo County is expected to anticipate and plan for all activities to return to compliance sufficiently in advance of the end of the Project term. Yolo County may request a meeting with EPA, the state of California, and all applicable local agencies to discuss the timing and nature of any actions that they will be required to take. The parties should meet within thirty days of receipt of Yolo County's written request for such a discussion. At and following such a meeting, the parties should discuss in reasonable, good faith, which of the requirements deferred under this Project will apply after termination of the Project."

B. Orderly Return to Compliance with Otherwise Applicable Regulations in the Event of Early Withdrawal or Termination

In the event of a withdrawal or termination not based on the end of the Project term and where Yolo County has made efforts in good faith, the parties to the Agreement will determine an interim compliance period to provide sufficient time for Yolo County to return to compliance with any regulations deferred under the Project. The interim compliance period will extend from the date on which EPA, the state of California, and all applicable local agencies provides written notice of final withdrawal or termination of the Project, in accordance with Section XI of this Project Agreement. By the end of the interim compliance period, Yolo County will comply with the applicable deferred standards set forth in 40 CFR Part 258.28. During the interim compliance period, EPA, the state of California, and any applicable local agency may issue an order, permit, or other legally enforceable mechanism establishing a schedule for Yolo County to return to compliance with otherwise applicable regulations as soon as practicable. This schedule cannot extend beyond 6 months from the date of withdrawal or termination. Yolo County intends to be in compliance with all applicable Federal, State, and local requirements as soon as is practicable, as will be set forth in the new schedule.

XIII. Signatories and Effective Date

1. Felicia Marcus
Regional Administrator
U.S. Environmental Protection Agency, Region 9
Signature _____
Date _____

2. John Bencomo
Director
Yolo County Planning and Public Works
Signature _____
Date _____

3. Gary Carlton
Executive Officer
California Regional Water Quality Control Board
Signature _____
Date _____

4. Larry Greene
Air Pollution Control Officer
Yolo-Solano Air Quality Management District
Signature _____
Date _____

5.. John Pacey
Solid Waste Association of North America
Signature _____
Date _____

6. Don Augenstein
Institute for Environmental Management
Signature _____
Date _____

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APPENDIX G – SLOPE STABILITY REPORT

DESIGN REPORT
for the
MODULE D PHASE 1 BIOREACTOR
at the
YOLO COUNTY CENTRAL LANDFILL

prepared for:

YOLO COUNTY DEPARTMENT OF PUBLIC WORKS
Division of Integrated Waste Management
292 West Beamer Street
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Job No. 931010.17
October 2001

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APPENDICES

1.0 INTRODUCTION

This report is being provided to summarize the design work performed by Vector Engineering, Inc. (Vector) for the bioreactor for Phase 1 of Module D at the Yolo County Central Landfill. The scope of our services was originally outlined in our proposal to Yolo County (County) dated October 30, 2000. This work was further modified to include additional interface liner testing and specifications for the potential liner materials to be used at the project. The design tasks that are specifically discussed in this report are: 1) the associated testing performed for the design; 2) sliding stability of the bioreactor waste fill; and 3) calculations performed for the surface water runoff for sizing of a culvert adjacent to the bioreactor area.

2.0 LABORATORY TESTING

2.1 General

Laboratory testing for the bioreactor included moisture density relationships, sieve analyses, Atterberg limits, hydraulic conductivity, and small scale direct shears on soils used during construction of Module D. The testing also included large scale direct shears on the various interfaces for the liner system as well as two fixed-wall constant head hydraulic conductivity on the pea gravel used in the blanket leachate collection system for Module D. A laboratory evaluation of the geocomposite used for construction of the leachate collection system was also performed due to some concerns about the length of time it had been left exposed before placement of the overlying pea gravel.

The results of the testing performed by Vector were compared with past test results and used as input parameters for the stability analyses performed and summarized in Section 4. The laboratory test results for the project are presented in Appendix A and are summarized below.

2.2 Moisture Density and Classification Testing

Soil samples of materials used for construction of the Phase 1 Module D area and for the subgrade soils for the aerobic bioreactor were obtained by the County and provided to Vector for testing. One Modified Proctor test was performed in accordance with ASTM D-1557 on a composite of the soil samples to determine its moisture density relationships for compaction of the materials during testing and construction. The results of this testing indicate that the maximum dry density of the soil is approximately 118 pounds per cubic foot (pcf) with an optimum moisture content of 15%. The moisture density curve for the soil composite is presented in Appendix A.

Sieve analyses and Atterberg limits were performed on two soil samples in accordance with ASTM D422 and D4318, respectively, to classify the materials for comparison with previous test results. The measured sand content of the samples

was somewhat higher than previous test results performed for the on-site soil. Although there was more sand, the results of this testing still indicate that the soils used during construction Module D Phase 1 are classified as high plasticity (fat) clay. The graphs of the sieve analyses and plots of the Atterberg Limits are provided in Appendix A.

Additional sieve analyses were performed on two samples of pea gravel used during construction of the leachate collection layer placed over the drainage geocomposite within Module D Phase 1. These tests were performed in accordance with ASTM D422. Constant head hydraulic conductivity tests were also performed on the pea gravel to determine their drainage characteristics. Hydraulic conductivity was determined in accordance with ASTM D2434. Based on this testing, the pea gravel has a hydraulic conductivity in excess of 5 cm/sec. The results of the sieve analyses and hydraulic conductivity tests are also provided in Appendix A.

2.3 Small-Scale Direct Shear Testing

Small-scale direct shear tests were performed in accordance with ASTM D3080 on two soil samples. The results of these tests are shown in Table 1. Based on this testing, the results of the small scale soil direct shears indicate that the soil used during construction of Module D Phase 1 has a higher internal strength than previously reported (Vector 1994). Copies of the results of the small-scale direct shear tests are provided in Appendix A.

TABLE 1
Summary of the Results of the Small-Scale Direct Shear Testing

Test Description	Shear Strength Results			
	Peak Strength		Post-Peak Strength	
	Friction Angle - ϕ (degrees)	Cohesion – c (psf)	Friction Angle - ϕ' (degrees)	Cohesion - c' (psf)
Soil 422A	31.7	0	16.6	870
Soil 453B	18.5	950	18.8	550

2.4 Large-Scale Direct Shear Testing

Large-scale direct shear tests were performed in accordance with ASTM D5321 on various interfaces of geosynthetic and soil materials. Interface tests were performed on textured high density polyethylene (HDPE) in contact with the soil, textured linear low density polyethylene (LLDPE) in contact with the soil, polyvinyl chloride (PVC) liner in contact with the soil, and PVC in contact with geotextile. Three additional tests were performed on the textured HDPE in contact with the geocomposite materials used during construction of the Module D Phase 1 primary liner.

Tearing of the textured HDPE occurred during testing at several of the loading conditions of the interface with the geocomposite. Invalid data was dismissed and the remaining shear strength data were combined to obtain an average interface friction and adhesion value from the three tests. The results of the three geomembrane-soil interface tests, the PVC/geotextile test, and the calculated average value for the textured HDPE-geocomposite tests are summarized in Table 2. Copies of the test data sheets are provided in Appendix A.

TABLE 2
Summary of the Results of the Large-Scale Interface Testing

Test Description	Shear Strength Results			
	Peak Strength		Post-Peak Strength	
	Friction Angle - ϕ (degrees)	Adhesion – a (psf)	Friction Angle - ϕ' (degrees)	Adhesion - a' (psf)
Text. HDPE/Soil	22	550	20	700
Text. LLDPE/Soil	19	500	19	530
PVC/Soil	18	370	10	180
PVC/Geotextile	23	0	21	0
Text. HDPE/Geocomp.	26.7	470	17.5	143

2.5 Evaluation of Geocomposite

A laboratory evaluation of the geocomposite was performed to determine if its exposure to weather over the past year had any detrimental effects. Samples of the geocomposite drainage material were obtained from the existing liner system by the County. These samples were forwarded to Precision Laboratories for determination of their mass per unit area, grab tensile strength, puncture resistance, and permittivity. From these results, it was concluded that the exposure had no detrimental effects on the geocomposite. The results from Precision are provided in Appendix A.

3.0 SURFACE WATER HYDROLOGY

Surface water hydrology calculations were performed to determine the peak discharge into the drainage ditch adjacent to Waste Management Unit (WMU) 6 on the south side of the anaerobic cell for Module D. Peak discharge was determined using the TR-55 computer program. The results of the TR55 analysis, presented in Appendix B, were used to determine the size of the culvert needed for the south side access crossing into Module D.

The analysis was performed for a 100-year, 24-hour storm event of 4.5 inches. Based on the current and future drainage plans for the site, the watershed area included portions of WMUs 4, 5 and 6 for a total of 68 acres. Because of low hydraulic conductivity of the native clays used for interim cover at the site, a hydrologic soil group D was assumed for all the calculations. In addition, all of the areas within WMU 4 and 5 that drain to the ditch are covered with a heavy growth of native grasses. Modules A, B, and a portion of Module C are also covered with vegetation. For this analysis, approximately 56 acres was assumed to be classified as pasture, grassland, or range in good condition with a curve number (CN) value of 80. The remaining area (12 acres) was assumed to be fallow, bare soil with a CN value of 94. From the TR-55 analysis, the peak discharge was determined to be 50 cubic feet per second (cfs) at the proposed crossing location.

Based on the results, it was determined that a 42 inch diameter culvert or a bridge was needed for the south side access crossing into Module D (Handbook of Steel Drainage and Highway Construction Products, 1971). The County also requested that a determination be made as to whether the existing 36-inch culvert on the west side of Module D was adequate to handle the flow reporting to it. The peak discharge calculated using TR-55 was prorated for a smaller, separate drainage area (26.9 acres) reporting to the existing culvert. This calculation indicated that the flow to the culvert existing culvert is about 19.8 cfs and the culvert is adequate

in size. The calculations for the surface hydrology analysis are provided in Appendix B.

4.0 STABILITY ANALYSES

4.1 General

There are two liner systems beneath the anaerobic area and three liner systems beneath the aerobic cell. From bottom to top the lined area for the anaerobic cells consist of recompacted native clay overlain by a 40-mil double textured HDPE vapor barrier, overlain by 5 feet of compacted clay, overlain by a 60-mil double-textured HDPE overlain by a double-sided geocomposite, overlain by 6 inches of drainage gravel, overlain by 2 feet of chipped tires. For the aerobic cell, approximately 10 feet of waste and soil cover was placed prior to installing the third liner system which consists of a 40-mil double-textured LLDPE overlain by geotextile over lain by chipped tires. The selection of the LLDPE material was based on the interface shear testing described in Section 2.4 and is discussed in detail in Section 4.6.

Stability analyses were performed on three potential failure locations within Module D Phase 1. One along the south end of aerobic cell, one on the unbuttressed east side of the aerobic cell, and the last one on the unbuttressed east side of the anaerobic cell. The initial analyses were focused on the east side of the aerobic cell. In this area, multiple analyses were performed to examine the stability at three different unit weights and three different strengths of the waste. Failures along each of the three liner system interfaces of the aerobic cell (vapor barrier, Module D primary liner, and aerobic primary liner) were also examined. Once these initial results were obtained, additional analyses were performed for the other two failure cross section locations.

4.2 Aerobic Cell East Side

Thirty-nine (39) analyses were performed for the cross section along the east side of the aerobic cell. Thirty-six of these were performed with the waste slope configured at 2 to 1, horizontal to vertical, to a final elevation of 70 feet above mean sea level (amsl). For these analyses, the interface strengths of the aerobic

(top) liner and the vapor barrier (bottom) liner were assumed to be the same (based on the strength of a textured polyethylene liner against soil, the friction angle equals 19 degrees and adhesion equals 530 psf). These values were determined during Vector's laboratory testing program described in Section 2.4 of this report. The interface strength of the Module D primary (intermediate) liner was estimated based on previous testing (not specific to the Module D) by Vector for a textured polyethylene in contact with a geocomposite (friction angle equals 14 degrees and cohesion equals 0 psf).

Based on these parameters, the analyses showed that the lowest factor of safety against failure nearly always occurred as a block failure along the intermediate liner where the geocomposite interface is located. The only exceptions were cases when the shear strength of the waste had a high cohesion (1,500 psf), but low internal friction angle (3 degrees). In these cases, the failures with the lowest factors of safety were by circular failure mode through the waste and liner into the foundation soil and out the toe of the fill. However, with these waste strength conditions, the factors of safety were always higher than the other two waste strength conditions. The lowest factor of safety (1.2) occurred when the waste had a strength of 35 degrees and a cohesion of 50 psf, and its unit weight was highest at 85 pcf.

Based on the results of these analyses, three more analyses were performed (for a total of 39) along the east side of the aerobic cell. These were performed using a fill configuration of 2.5 to 1. Because the results showed that the high friction angle waste low cohesion shear strength was always the most critical, this option was used in each of the remaining analyses (only the waste density was changed). With the flatter (2.5 to 1) fill slope, the factor of safety increased by 0.2 for each case versus the 2 to 1 configuration (i.e. 1.4 for the block failure along the geocomposite at a density of 85 pcf).

4.3 Aerobic Cell South Side

Three analyses were performed for a 2 to 1 configuration along the south side of the aerobic cell. As with the east side 2.5 to 1 cases, these analyses were each performed with the waste strength remaining at 35 degrees and a cohesion of 50 psf. The only changes were to the waste density. The factors of safety for the south side were slightly (approximately 0.05) higher than the east side. Therefore, the analyses confirmed our assumption that the berm on the south side is providing an added factor of safety against failure.

4.4 Anaerobic Cell East Side

The remaining analyses were focused on the east side of the anaerobic cell where the depth of the waste is planned to extend to an elevation of 80 feet amsl. Initially, three analyses were performed under similar conditions to the critical surfaces for the aerobic cell (i.e. 35 degrees and 50 psf with varying waste densities). These results indicated that the added height of waste slightly decreased the factor of safety (compared to the aerobic cell). Again, the lowest factor of safety (1.2) was obtained for a block failure along the geocomposite interface given a density of 85 pcf.

Two additional analyses were performed on the anaerobic cell, one at 2.5 to 1 and the other at a final closed configuration of 3 to 1. The density and strength of the waste remained constant at 85 pcf and 35 degrees internal friction with 50 psf cohesion. Again, the factor of safety for the 2.5 to 1 configuration increased over the 2 to 1 by 0.2 to a value of 1.4. The factor of safety for the 3 to 1 configuration was 1.5.

4.5 Sensitivity to Changes in Geocomposite Interface Strength

Based on the results obtained for the aerobic cell, it was obvious that the cohesion of the waste had a significant effect on the factor of safety. Additional analyses were performed to examine the sensitivity of the factor of safety to

cohesion (adhesion) along the geocomposite interface. The results of these analyses showed that the factor of safety is very sensitive and increased dramatically with only minor variations in the adhesion. Based on these results, it was decided that additional, site-specific testing of the geocomposite HDPE interface was necessary.

As shown in Table 2 in Section 2, the results of the testing showed that the strength of the on-site materials was higher (17.5 degrees with 143 psf adhesion) than the value assumed for the initial stability analyses (14 degrees with 0 psf adhesion). Using a value of 17.5 degrees with a conservative cohesion of 100 psf, the factor of safety for the east side anaerobic cell increased from 1.2 to 1.4 under the 2 to 1 configuration. Increases similar to this value are expected for all other block failures along the geocomposite. Due to the excessive amount of output data for the various analyses performed, only the computer output files for this most critical configuration are provided in Appendix C.

4.6 Summary and Recommendations

The results show that the factor of safety of Module D decreases with an increase in density which is expected to occur as the fill area gets deeper (compressing the waste) and as the waste decomposes. The factor of safety decreases as the waste strength goes from a material with a low friction angle with high cohesion to a material with a high friction angle with low cohesion. Although, it is not understood fully whether the waste becomes more cohesive as time goes on or acts more like a high friction granular fill, it is known that as the waste decomposes and settles, the height of the landfill will decrease and the overall slope of the outer face of the fill will decrease (i.e. flatten out). This will result in an increase in the factor of safety over time.

The results presented in Section 4.5 indicate that filling the cells at 2 to 1 is feasible for the anaerobic area (the factor of safety is above 1.4 for the worst case waste density and strength conditions estimated based on the laboratory testing of

the liner systems for Module D). The County considered using a PVC liner within the aerobic cell. Additional testing was performed to determine the shear strength of this material with the native soils. The results of this testing (shown in Table 2) indicate that the relatively smooth PVC liner has a very low interface shear strength. Since this value was lower than the values used in the stability analyses, it was recommended that the PVC liner not be used. The County decided to use the textured LLDPE material as the primary liner for the aerobic cell. Based on this decision, the factors of safety for the aerobic cell would be similar to those of the anaerobic cell and therefore, filling the area with 2 to 1 slopes is feasible.

5.0 LIMITATIONS

The assumptions presented in this report are based upon our experience at the site, past field investigations, laboratory testing, a review of previous reports, and a review of other literature. Not withstanding this, if the County's scope of work changes from that described herein, our analyses should be reviewed and modified, if necessary.

This report was prepared in accordance with generally accepted soils and foundation engineering practices applicable at the time the report was prepared and for the project location. Vector makes no other warranties, either expressed or implied, as to the professional advice provided under the terms of this agreement, and as presented in this report. Our recommendations consist of professional opinions and conclusions, based on the scope of work outlined herein and that adequate follow-up engineering and construction quality assurance are provided. It is recommended that Vector be provided the opportunity for a general review of any final construction documents in order that our recommendations may be properly interpreted and implemented.

APPENDIX A
LABORATORY TEST RESULTS

Moisture Density, Classification And Hydraulic Conductivity

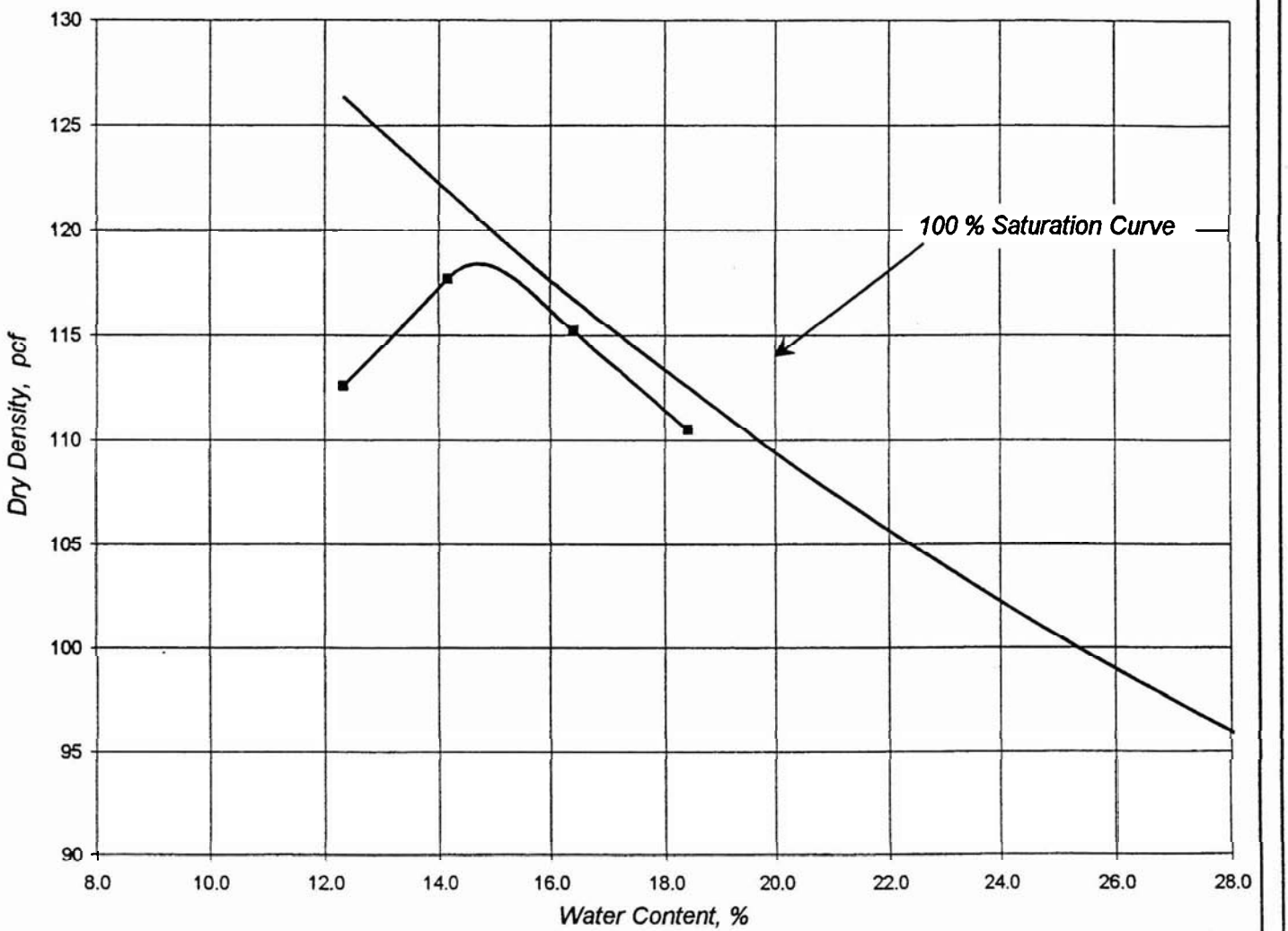
Vector Engineering Inc.
12438 Loma Rica, Grass Valley, CA 530-272-2448
LABORATORY SERVICES

MOISTURE / DENSITY RELATIONSHIPS

TEST REPORT

ASTM D - 1557

Client:	Project No.:	Lab Log No.:
Yolo County	931010.17	422A
Project Name:		**Report Date:**
Bioreactor Stability		October 19, 2000



Symbol	Lab No.	Sample Identification	Description	Maximum Dry Density pcf	Maximum Dry Density kg / m³	Optimum Water Content %
■	422A	Clay (rec'd 9/6/00)	Brown, Clay	118.4	1.90	14.7

Corrected Values For Oversized Particles, per ASTM D-4718

■	422A	0	Percent Gravel	118.4	14.7

Vector Engineering Inc.
12438 Loma Rica, Grass Valley, CA 530-272-2448
LABORATORY SERVICES

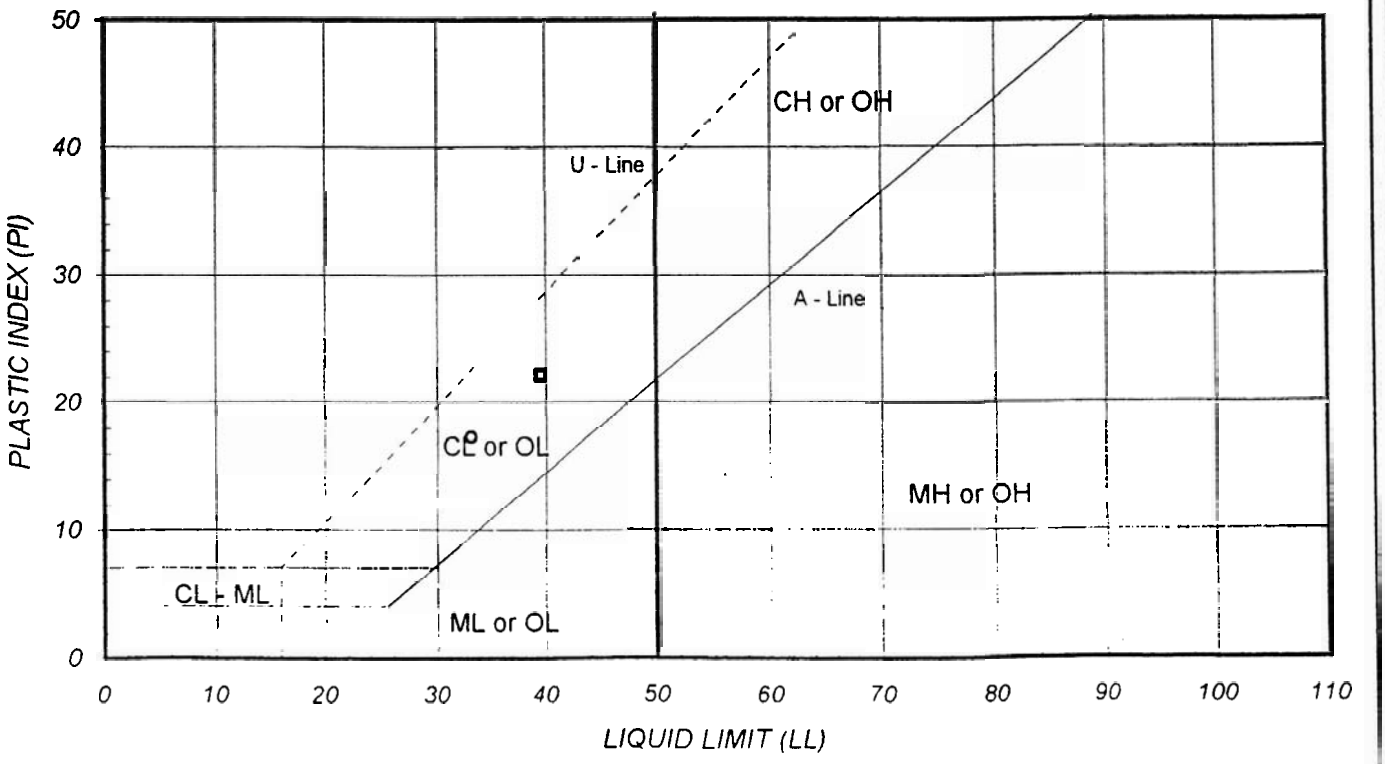
ATTERBERG LIMITS

SUMMARY REPORT
ASTM D-4318

Client: Yolo County
Project No: 931010.17
Lab Log: 453
Project Name: Bioreactor Stability
Description:
Report Date: November 3, 2000

LSN	SYMBOL	SAMPLE IDENTIFICATION		COLOR	UNIFIED SYMBOL	LIQUID LIMIT	PLASTIC LIMIT	PLASTIC INDEX
A	□	453A	Clay (LL # 422A)	Brown	CL or OL	40	17	22
B	○	453B	Clay	Brown	CL or OL	33	16	17

PLASTICITY CHART



Vector Engineering Inc.
12438 Loma Rica, Grass Valley, CA, 530-272-2448
LABORATORY SERVICES

PARTICLE SIZE ANALYSIS

TEST REPORT

ASTM D-422

Client: YOLO COUNTY

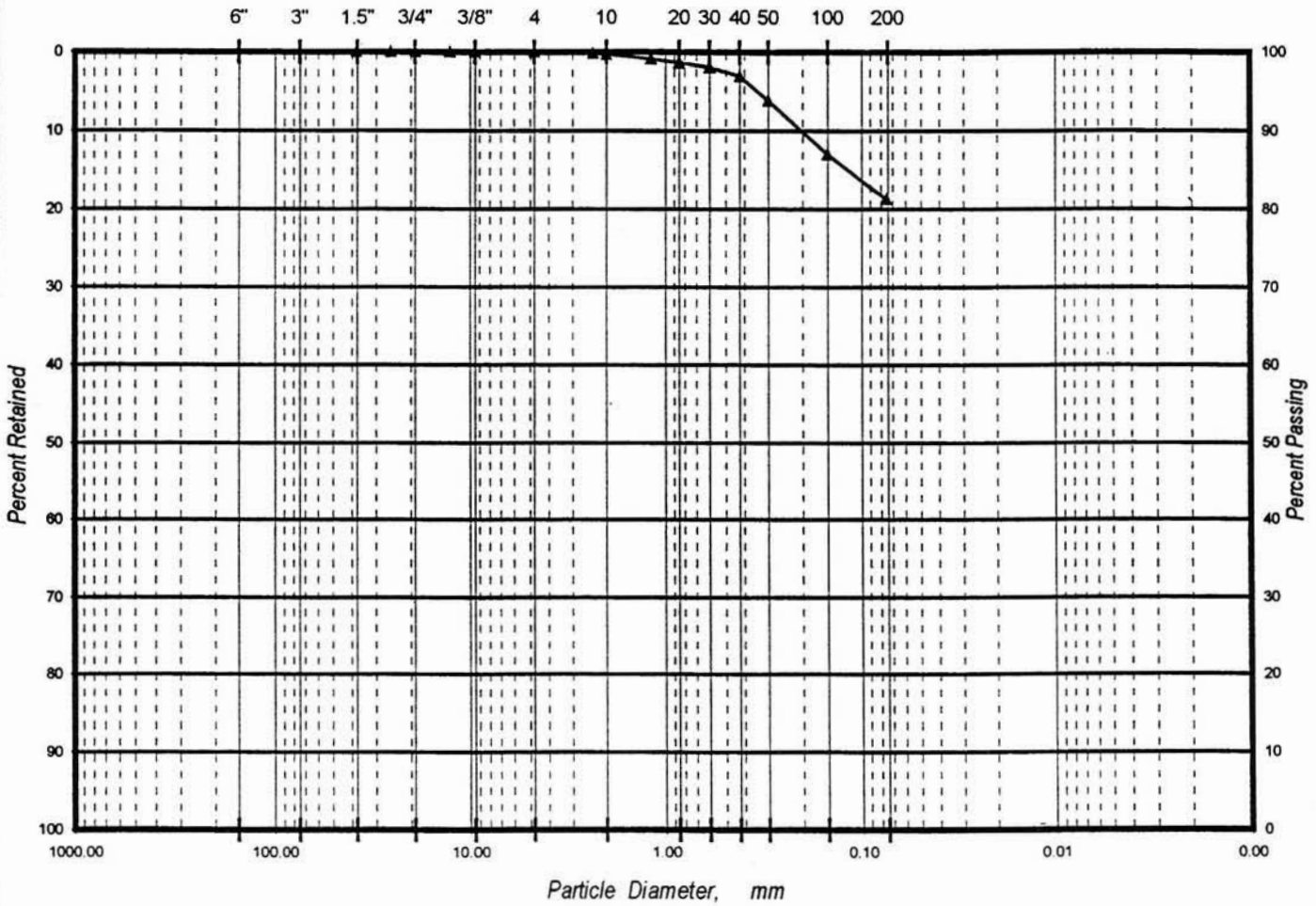
Project No: 931010.17

Lab Sample No: 453A

Project Name: BIOREACTOR STABILITY

Report Date: 10/30/00

BOLDERS	COBBLES	GRAVEL		SAND			SILT AND CLAY
		COARSE	FINE	COARSE	MEDIAN	FINE	
US SIEVE SIZE, INCHES				US STANDARD SIEVE SIZE No.			HYDROMETER



Symbol	Sample ID	Description	% Gravel	% Sand	% Silt - Clay
▲	Clay (LL #422A) (rec'd 9/6/00)	Brown, Lean Clay w/Sand	0.0	18.8	81.2

Vector Engineering Inc.

12438 Loma Rica, Grass Valley, CA, 530-272-2448

LABORATORY SERVICES

PARTICLE SIZE ANALYSIS

TEST REPORT

ASTM D-422

Client: YOLO COUNTY

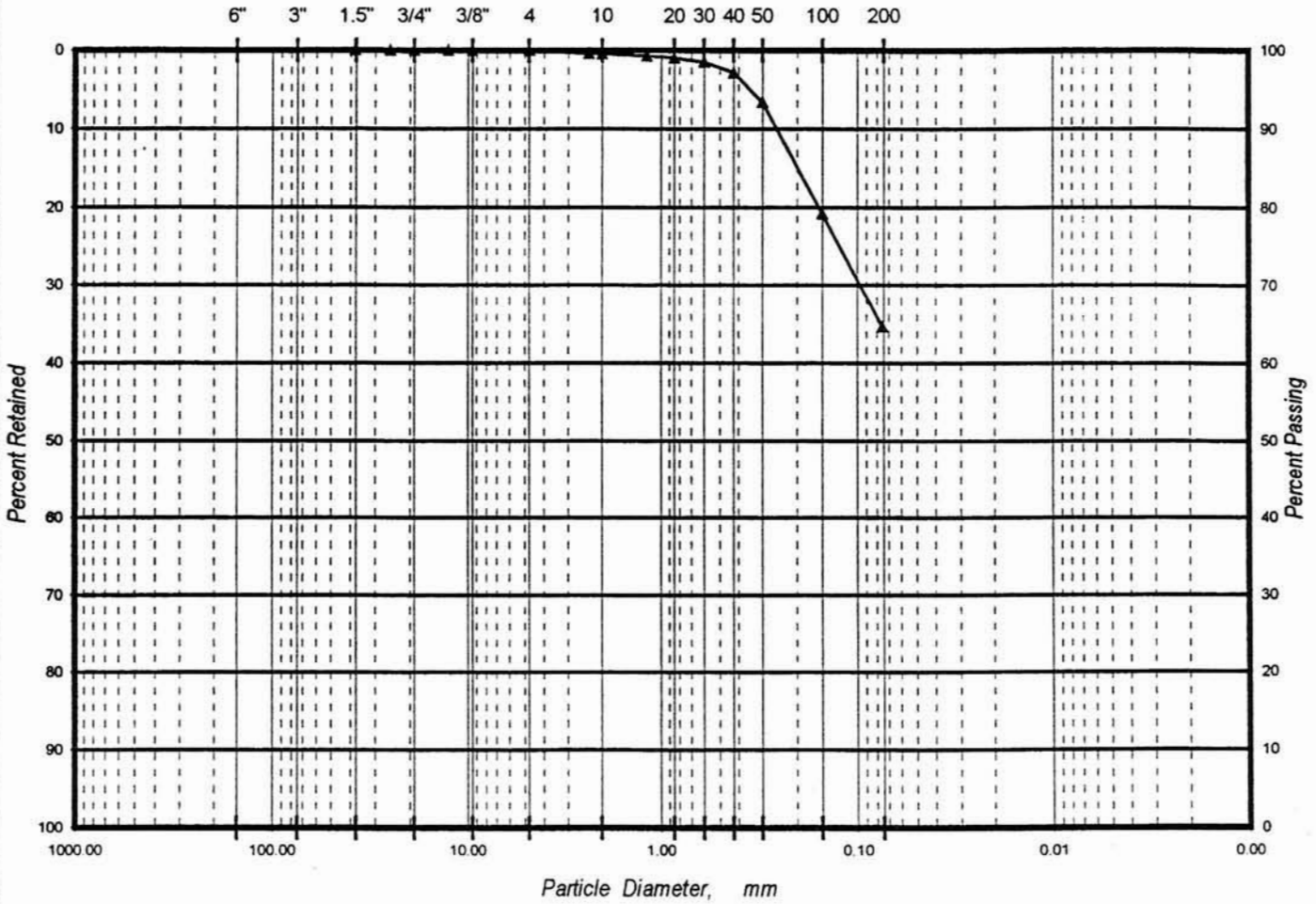
Project No: 931010.17

Lab Sample No: 453B

Project Name: BIOREACTOR STABILITY

Report Date: 11/1/00

BOLDERS	COBBLES	GRAVEL		SAND			SILT AND CLAY
		COARSE	FINE	COARSE	MEDIAN	FINE	
US SIEVE SIZE, INCHES				US STANDARD SIEVE SIZE No.			HYDROMETER



Symbol	Sample ID	Description	% Gravel	% Sand	% Silt - Clay
▲	Clay (rec'd 10/27/00)	Brown, Sandy Lean Clay	0.0	35.3	64.7

Vector Engineering Inc.

12438 Lome Rica, Grass Valley, CA, 530-272-2448
LABORATORY SERVICES

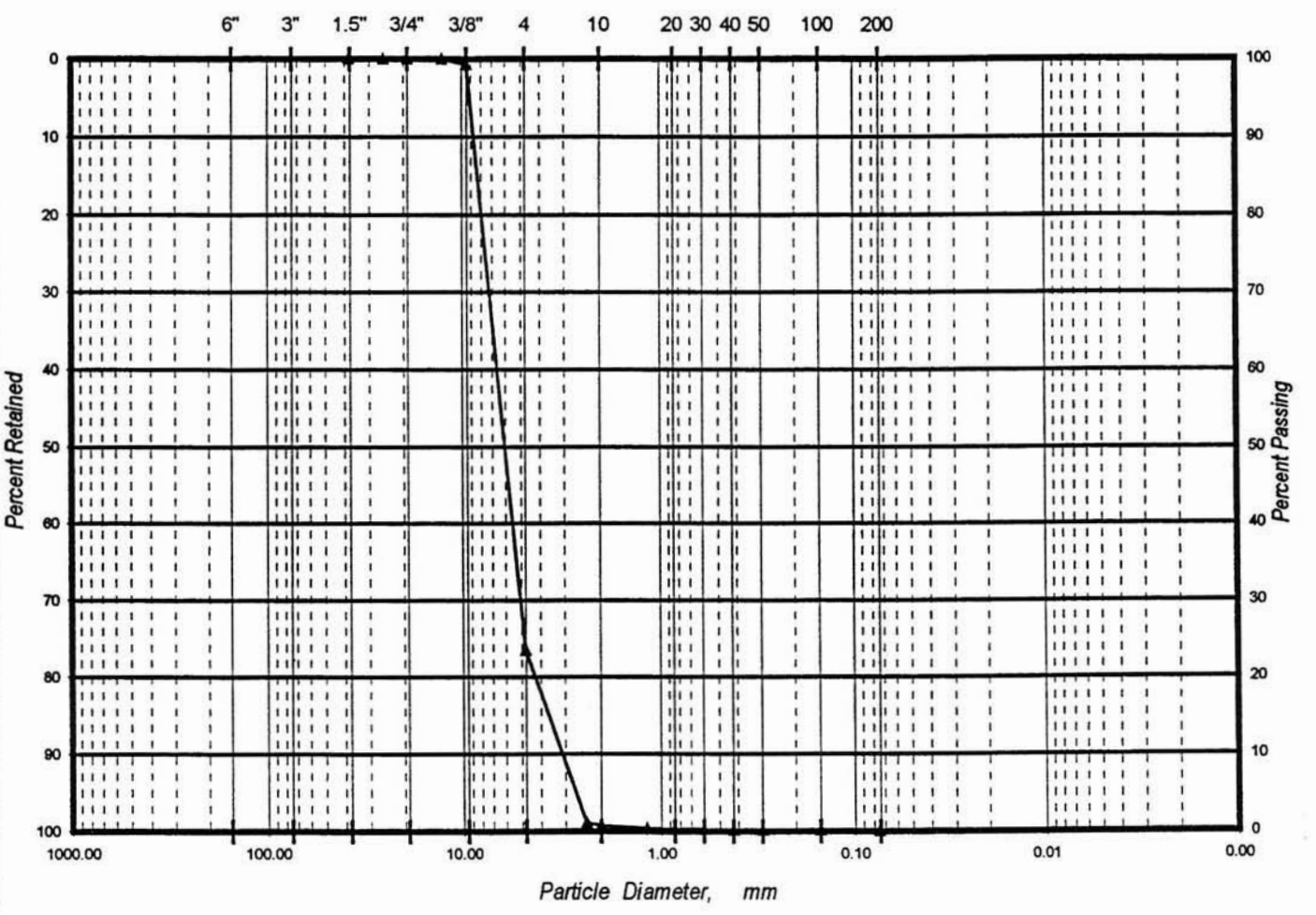
PARTICLE SIZE ANALYSIS

TEST REPORT

ASTM D-422

Client:	Project No:	Lab Sample No:
YOLO COUNTY	931010.17	422B

Project Name:	Report Date:
BIOREACTOR STABILITY	9/26/00



Symbol	Sample ID	Description	% Gravel	% Sand	% Silt - Clay
▲	3/8" Pea Gravel (rec'd 9/22/00)	Grey, Poorly Graded Gravel w/Sand	76.5	23.4	0.1

Vector Engineering Inc.
12438 Loma Rica, Grass Valley, CA, 530-272-2448
LABORATORY SERVICES

PARTICLE SIZE ANALYSIS

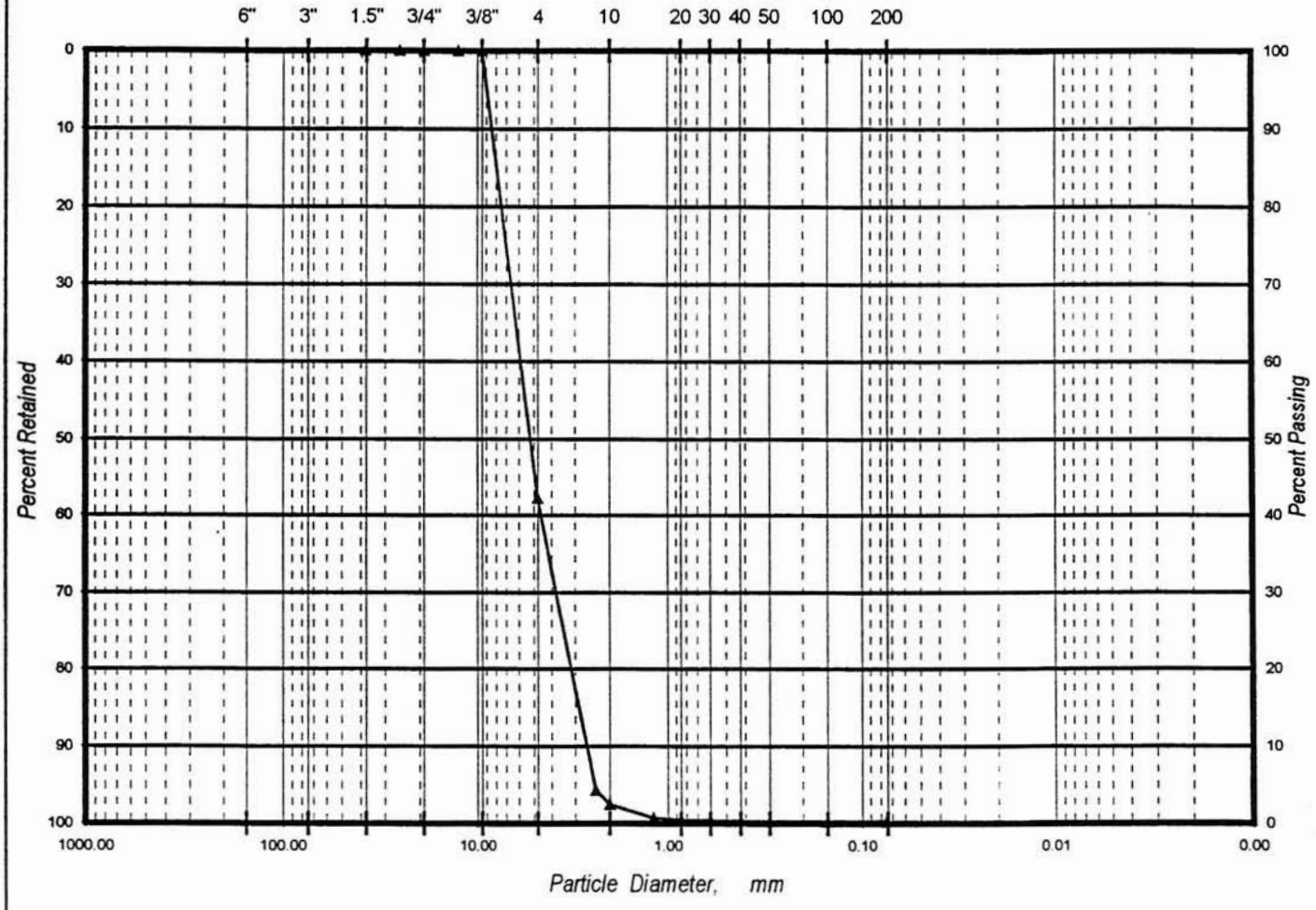
TEST REPORT

ASTM D-422

Client:	Project No:	Lab Sample No:
YOLO COUNTY	931010.17	453C

Project Name:	Report Date:
BIOREACTOR STABILITY	11/1/00

BOLDERS	COBBLES	GRAVEL		SAND			SILT AND CLAY
		COARSE	FINE	COARSE	MEDIAN	FINE	
US SIEVE SIZE, INCHES				US STANDARD SIEVE SIZE No.			HYDROMETER



Symbol	Sample ID	Description	% Gravel	% Sand	% Silt - Clay
▲	3/8" Pea Gravel (rec'd 10/27/00)	Grey, Poorly Graded Gravel w/Sand	57.8	42.0	0.2

Vector Engineering Inc.

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Laboratory Services

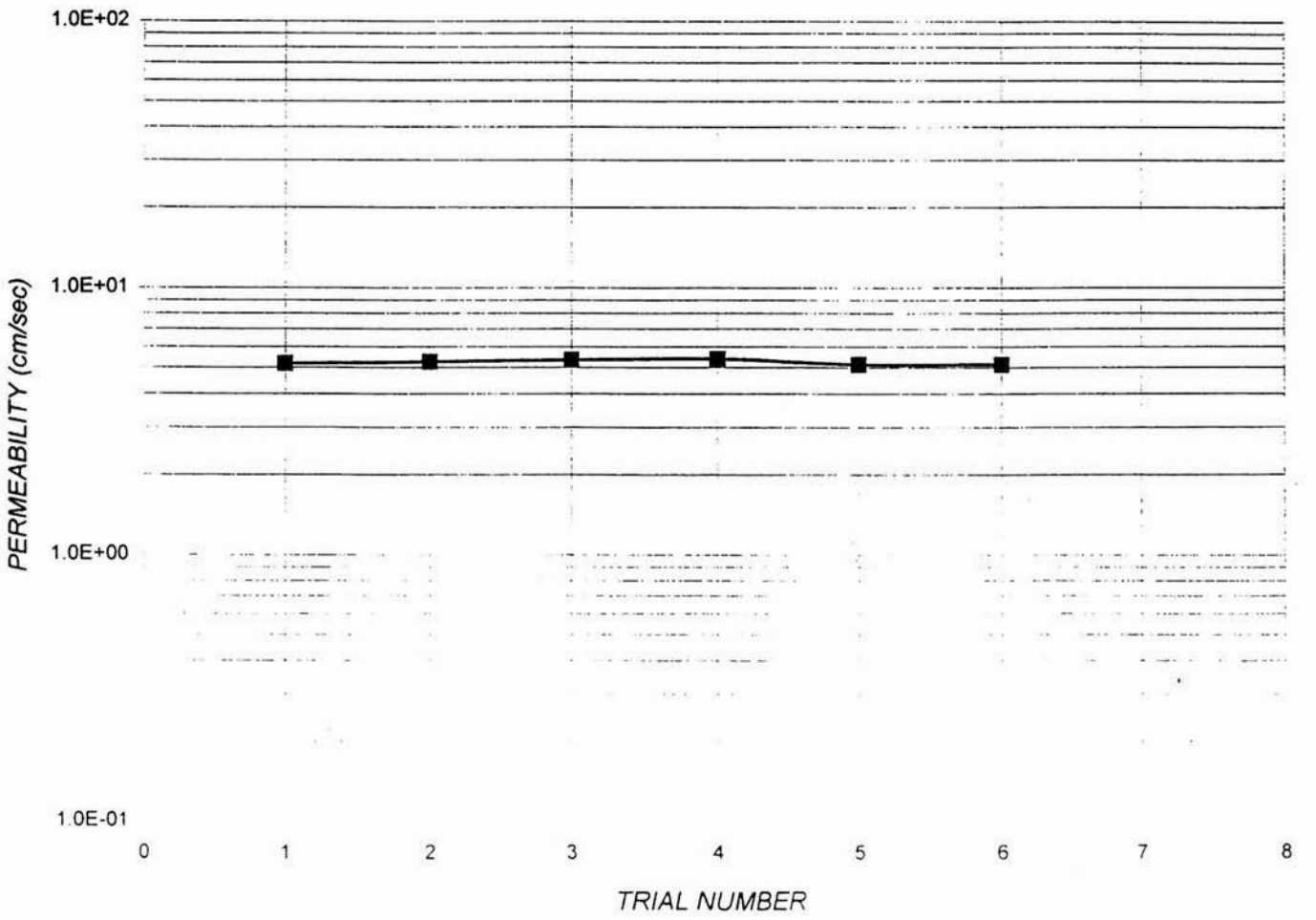
HYDRAULIC CONDUCTIVITY

FIXED WALL
ASTM D- 2434, Modified

Client Name:	Project Name:	Project No.:	Lab Log:
Yolo County	Bioreactor Stability	931010.17	463C

Sample I.D.:	Description:	Report Date:
3/8" Pea Gravel (rec'd 10/27/00)	Grey, Poorly Graded Gravel w/Sand	11/1/00

TRIAL NUMBER	WATER CONTENT %		DRY DENSITY pcf	DRY DENSITY kg/m^3		HYDRAULIC CONDUCTIVITY cm / sec
Initial	2.0		92.5	1.48		———
1						5.2E+00
2						5.3E+00
3						5.4E+00
4						5.4E+00
5						5.1E+00
6						5.1E+00
Final	4.5				AVERAGE:	**5.3E+00**



NOTES: 1) Test run using a 7.25" diameter fixed wall permeameter

2) Constant Head Test Average Head = 8.9 cm

Vector Engineering Inc.

12438 Lorna Rica, Grass Valley, CA, 530-272-2448
Laboratory Services

HYDRAULIC CONDUCTIVITY

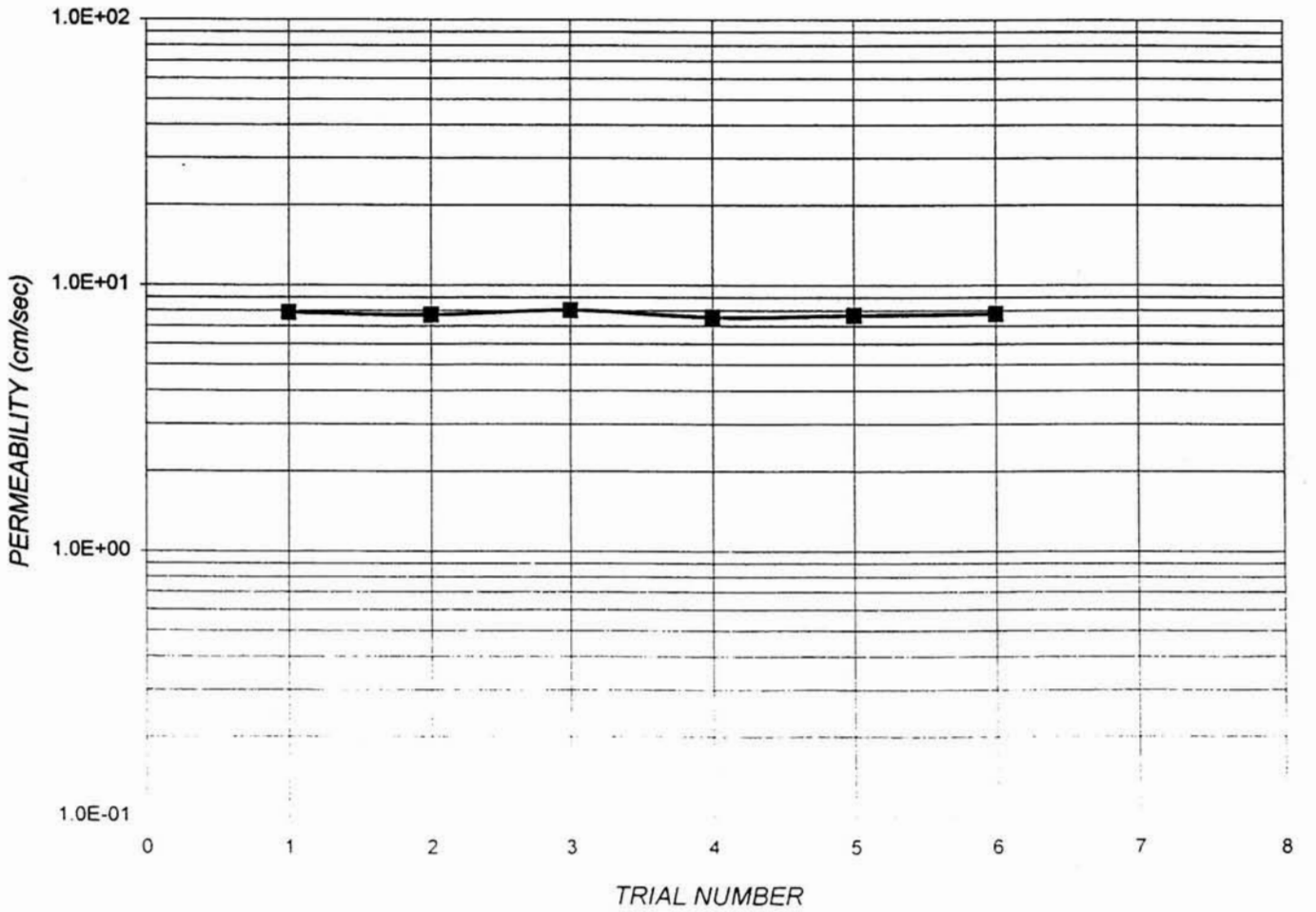
FIXED WALL

ASTM D- 2434, Modified

Client Name:	Project Name:	Project No.:	Lab Log:
Yolo County	Bioreactor Stability	931010.17	422B

Sample I.D.:	Description:	Report Date:
3/8" Pea Gravel (rec'd 9/22/00)	Grey, Poorly Graded Gravel w/Sand	10/19/00

TRIAL NUMBER	WATER CONTENT %		DRY DENSITY pcf	DRY DENSITY kg/m^3		HYDRAULIC CONDUCTIVITY cm / sec
Initial	0.6		104.6	1.67		———
1						7.9E+00
2						7.7E+00
3						8.0E+00
4						7.6E+00
5						7.7E+00
6						7.8E+00
					AVERAGE:	**7.8E+00**



NOTES: 1) Test run using a 7.25" diameter fixed wall permeameter

2) Constant Head Test Average Head = 10.1 cm

Small-Scale Direct Shear Results

Vector Engineering Inc.

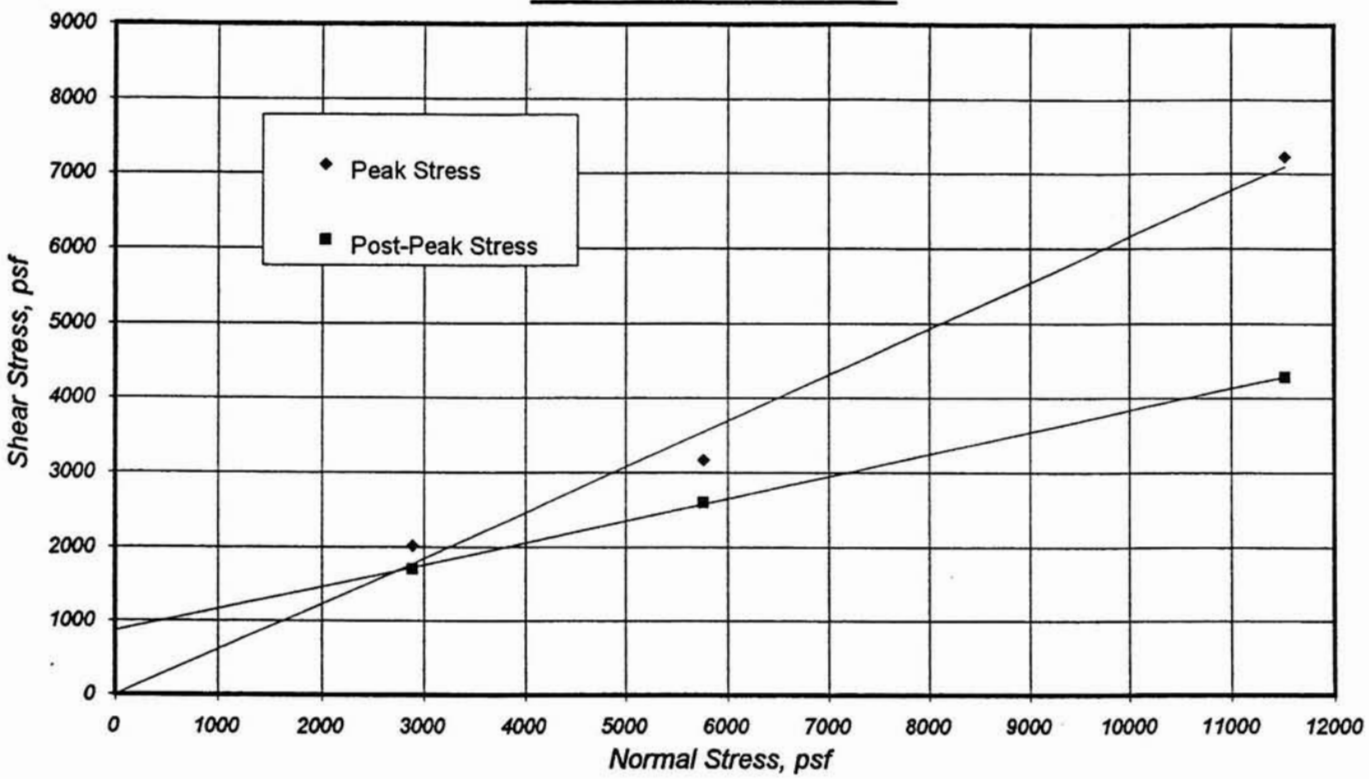
12438 LOMA RICA DR., GRASS VALLEY CA 95945, (530) 272-2448
Laboratory Services

DIRECT SHEAR REPORT

ASTM D- 3080, Consolidated - Drained Test

Client Name:	Project Name:	Project No. :	Lab Log:
Yolo County	Bioreactor Stability	931010.17	422A
Sample :	**Soil Description:**		**Report Date:**
Clay (rec'd 9/6/00)	Brown, Clay		10/19/00

STRENGTH ENVELOPE



		Peak	Post Peak
Coefficient of Friction	:	0.617	0.297
Friction Angle	:	31.7	16.6
Cohesion, psf:	:	0	870

Point No.	Normal Stress psf	Shear Stress Peak psf	Shear Stress Post-Peak psf		Initial Water Content %	Initial Dry Density pcf	Final Water Content %	Final Dry Density pcf
1	2880	2018	1708		17.5	105.5	21.8	104.3
2	5760	3167	2608		17.2	105.7	21.4	107.0
3	11520	7235	4285		17.1	105.7	21.3	113.1
4								
5								
6								

Horizontal Displacement Rate, in. / min. : 0.001 *Sample Diameter, in.:* 2.43

Vector Engineering Inc.

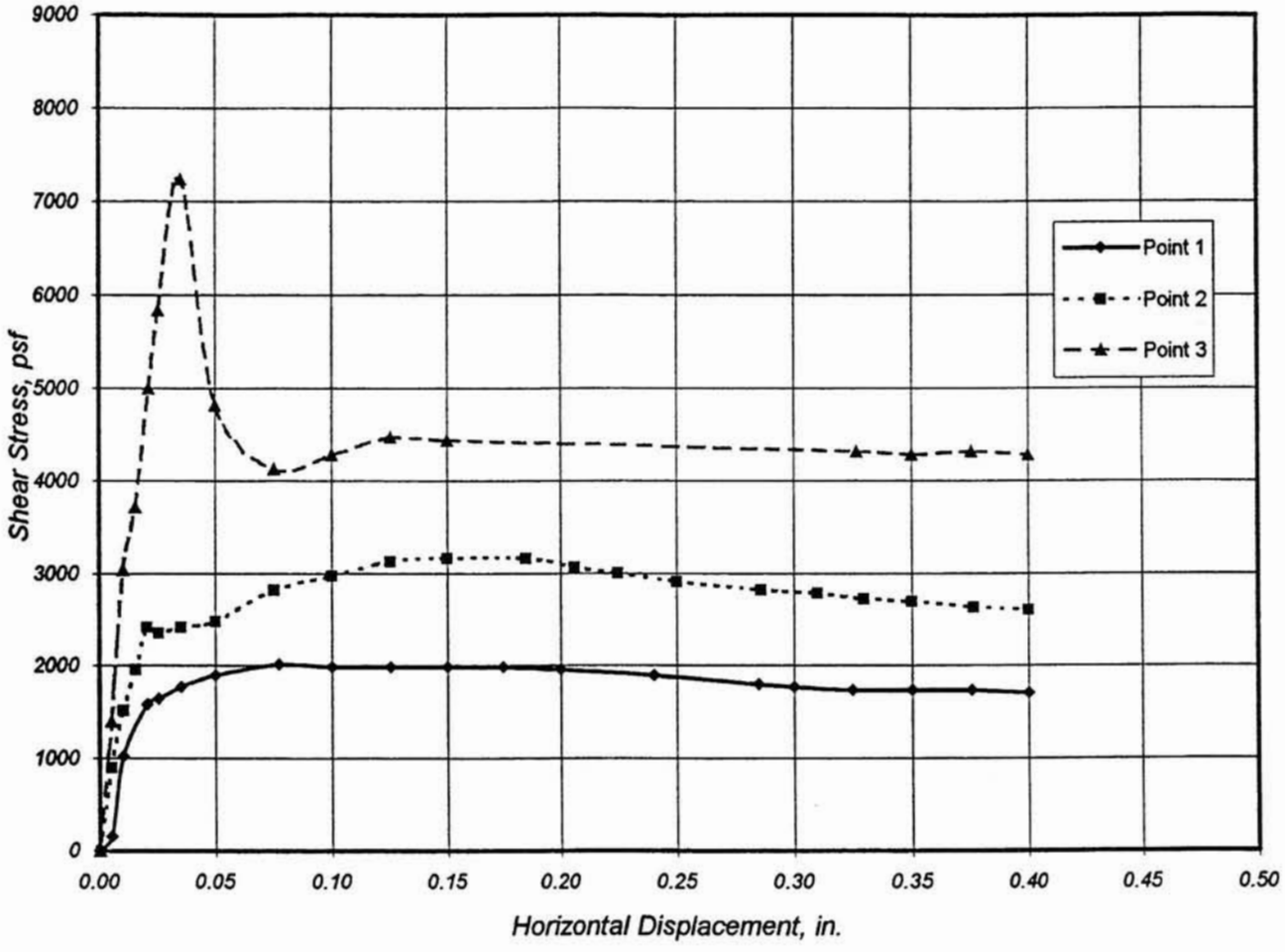
12438 LOMA RICA DR., GRASS VALLEY CA 95945, (530) 272-2448

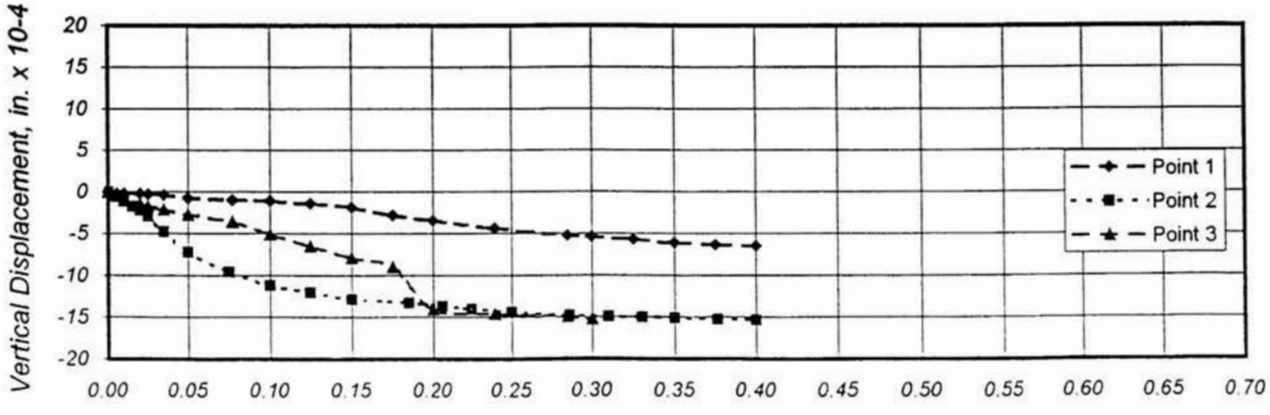
Laboratory Services

DIRECT SHEAR REPORT

ASTM D- 3080, Consolidated - Drained Test

Client Name:	Project Name:	Project No. :	Lab Log:
Yolo County	Bioreactor Stability	931010.17	422A
Sample :	**Soil Description:**		**Report Date:**
Clay (rec'd 9/6/00)	Brown, Clay		10/19/00





NORMAL STRESSES, psf :	Point - 1	2880	Point - 2	5760	Point - 3	11520

Entered By	Reviewed By	Lab Log
NCL	ML	

422A

Vector Engineering Inc.

12438 LOMA RICA DR., GRASS VALLEY CA 95945, (530) 272-2448

Laboratory Services

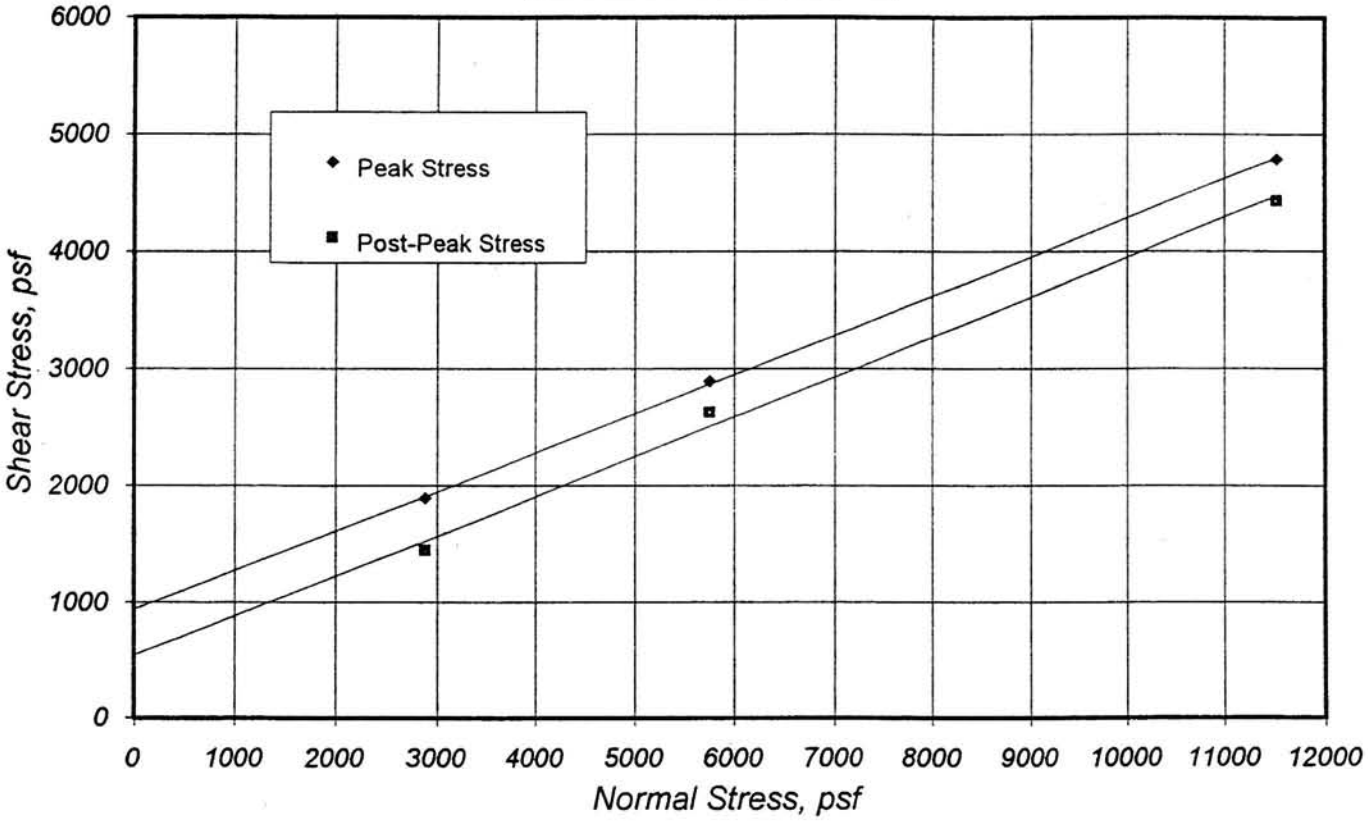
DIRECT SHEAR REPORT

ASTM D- 3080, Consolidated - Drained Test

Client Name:	Project Name:	Project No. :	Lab Log:
Yolo County	Bioreactor Stability	931010.17	453B

Sample :	Soil Description:	Report Date:
remold	Brown Sandy Lean Clay	12/11/00

STRENGTH ENVELOPE



		Peak	Post Peak
Coefficient of Friction	:	0.334	0.341
Friction Angle	:	18.5	18.8
Cohesion, psf:	:	950	550

Point No.	Normal Stress psf	Shear Stress Peak psf	Shear Stress Post-Peak psf		Initial Water Content %	Initial Dry Density pcf	Final Water Content %	Final Dry Density pcf
1	2880	1891	1448		19.9	115.4	23.0	117.5
2	5760	2896	2630		18.8	117.2	19.5	124.8
3	11520	4787	4432		18.7	113.3	18.3	127.6
4								
5								
6								

Horizontal Displacement Rate, in. / min 0.0007 *Sample Diameter, in.:* 2.49

The test results given here are based on a mathematically determined best fit line. Further interpretation should be conducted by a qualified professional experienced in geotechnical engineering.

Vector Engineering Inc.

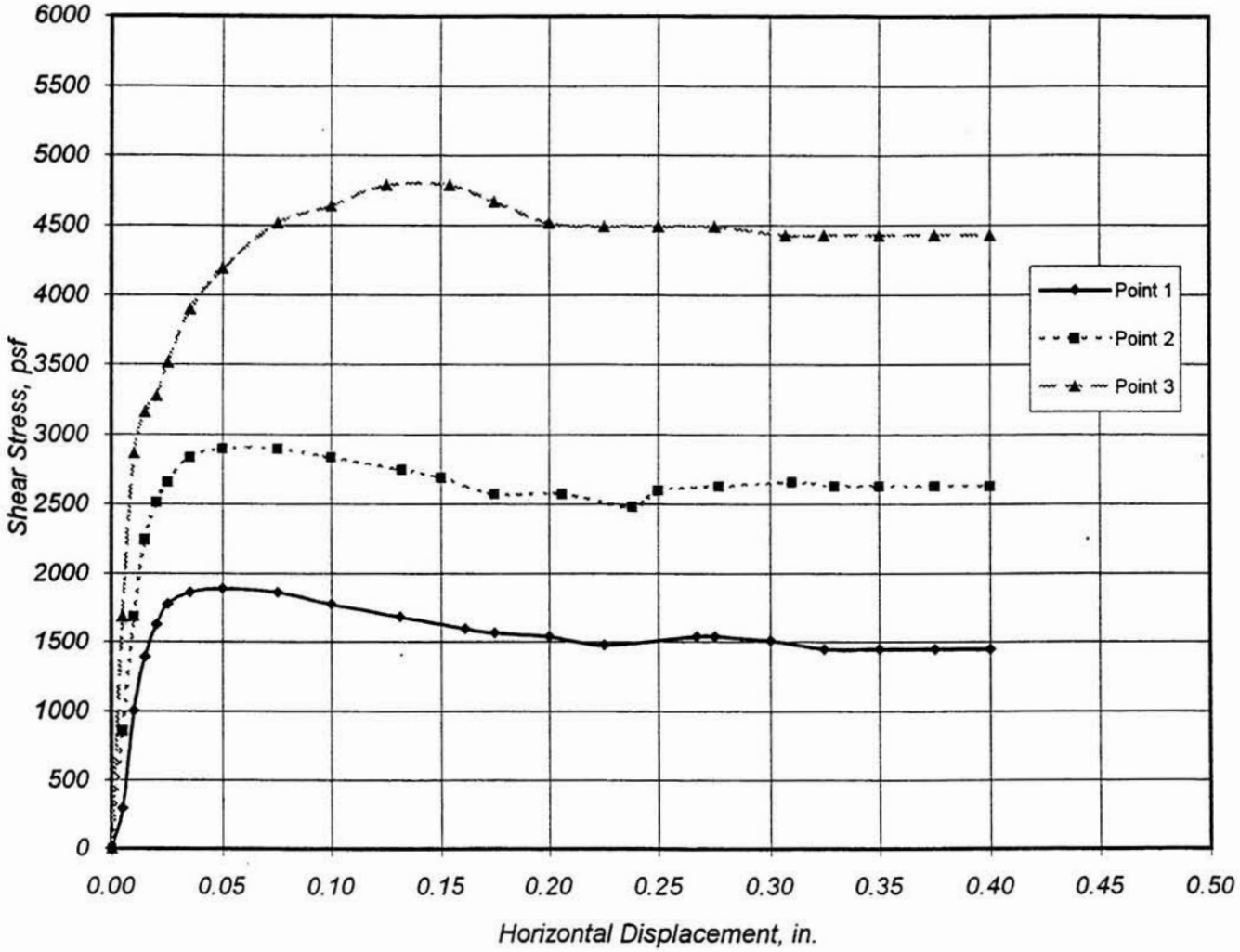
12438 LOMA RICA DR., GRASS VALLEY CA 95945, (530) 272-2448

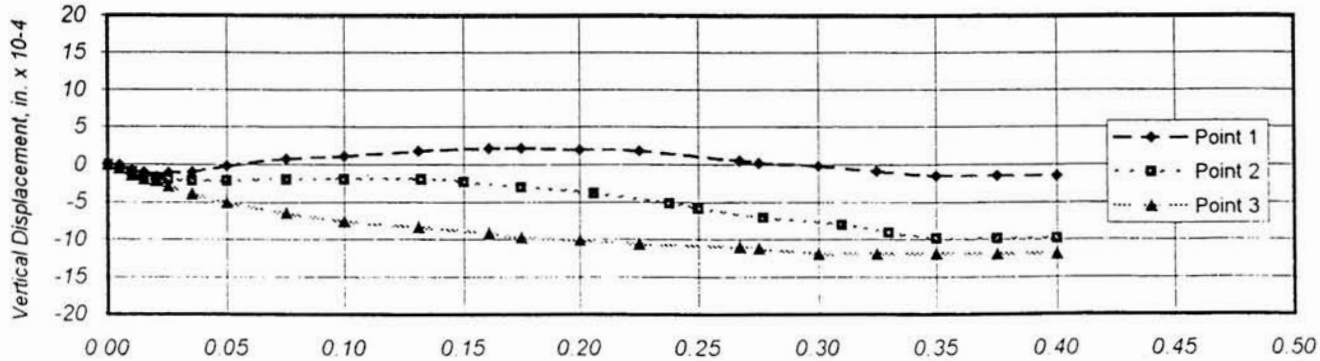
Laboratory Services

DIRECT SHEAR REPORT

ASTM D- 3080, Consolidated - Drained Test

Client Name:	Project Name:	Project No. :	Lab Log:
Yolo County	Bioreactor Stability	931010.17	453B
Sample :	**Soil Description:**		**Report Date:**
remold	Brown Sandy Lean Clay		12/11/00





NORMAL STRESSES, psf :	Point - 1	2880	Point - 2	5760	Point - 3	11520

Large-Scale Direct Shear Results

Vector Engineering Inc.

12438 Lorna Rica Drive., Suite C, Grass Valley, CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321-B

Client Name: YOLO COUNTY | Project Name: **BIOREACTOR STABILITY** | Project No: 931010.17

Superstrate: ⇦ Spacer Boards

Material 1: ⇦ Brown, Clay (rec'd 9/6/00) (clay vs. textured side of HDPE) LSN: 422A Remolded

Material 2: ⇨ Serrot 60 mil HDPE Geomembrane, Textured/Smooth Roll #3908129 LSN: BMK Clamped

Substrate: ⇨ Concrete Board Spacers

PEAK STRENGTH

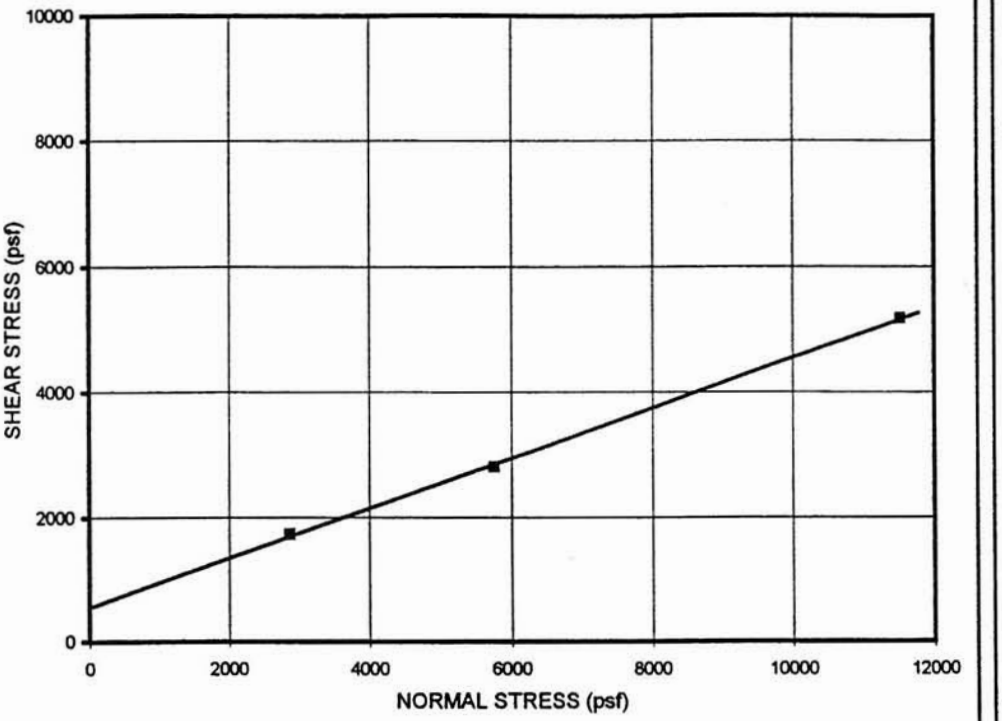
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	1730	31
2.	40.0	5760	2820	26
3.	80.0	11520	5180	24

Adhesion: 550 psf

Friction Angle: 22 degrees

Coefficient of Friction: 0.4

NOTE: GRAPH NOT TO SCALE



STRENGTH ENVELOPE

(at 2.5 in. displacement)

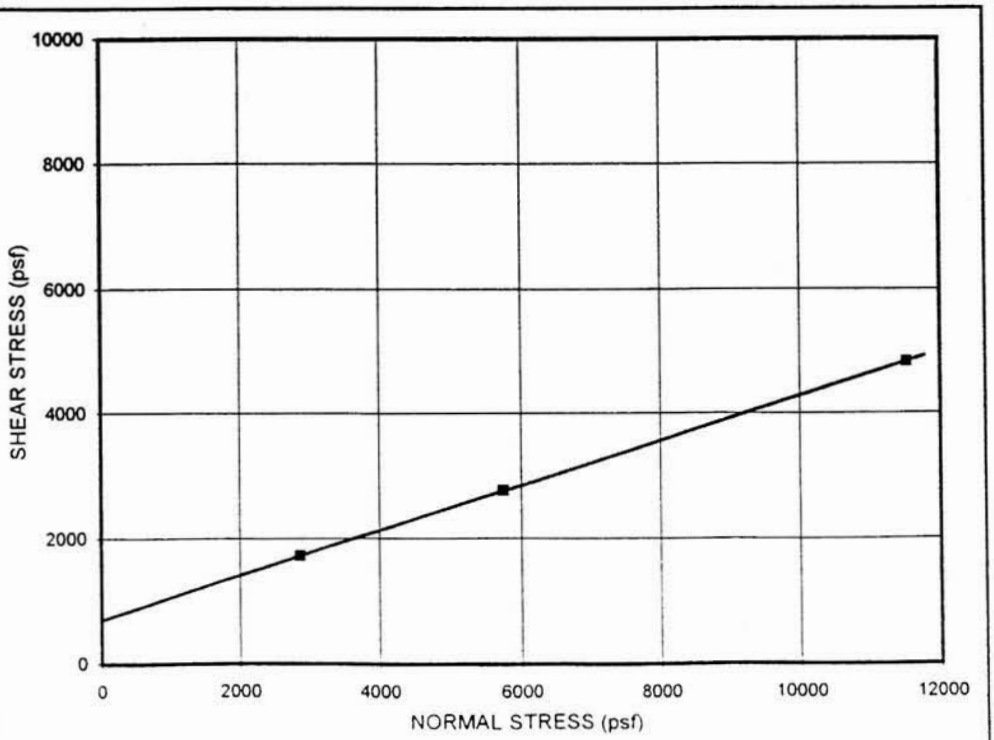
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	1730	31
2.	40.0	5760	2770	26
3.	80.0	11520	4830	23

Adhesion: 700 psf

Friction Angle: 20 degrees

Coefficient of Friction: 0.36

NOTE GRAPH NOT TO SCALE



Vector Engineering Inc.

12438 Lome Rica Drive., Suite C, Grass Valley, CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321-B

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ Spacer Boards

Material 1: ⇦ Brown, Clay (rec'd 9/6/00) (clay vs. textured side of HDPE) LSN: 422A Remolded

Material 2: ⇨ Serrot 60 mil HDPE Geomembrane, Textured/Smooth Roll #3908129 LSN: BMK Clamped

Substrate: ⇨ Concrete Board Spacers

DISPLACEMENT vs. SHEAR STRESS

Test Point	Normal Stress	
	psi	psf
1.	20.0	2880
2.	40.0	5760
3.	80.0	11520

MOISTURE DATA:

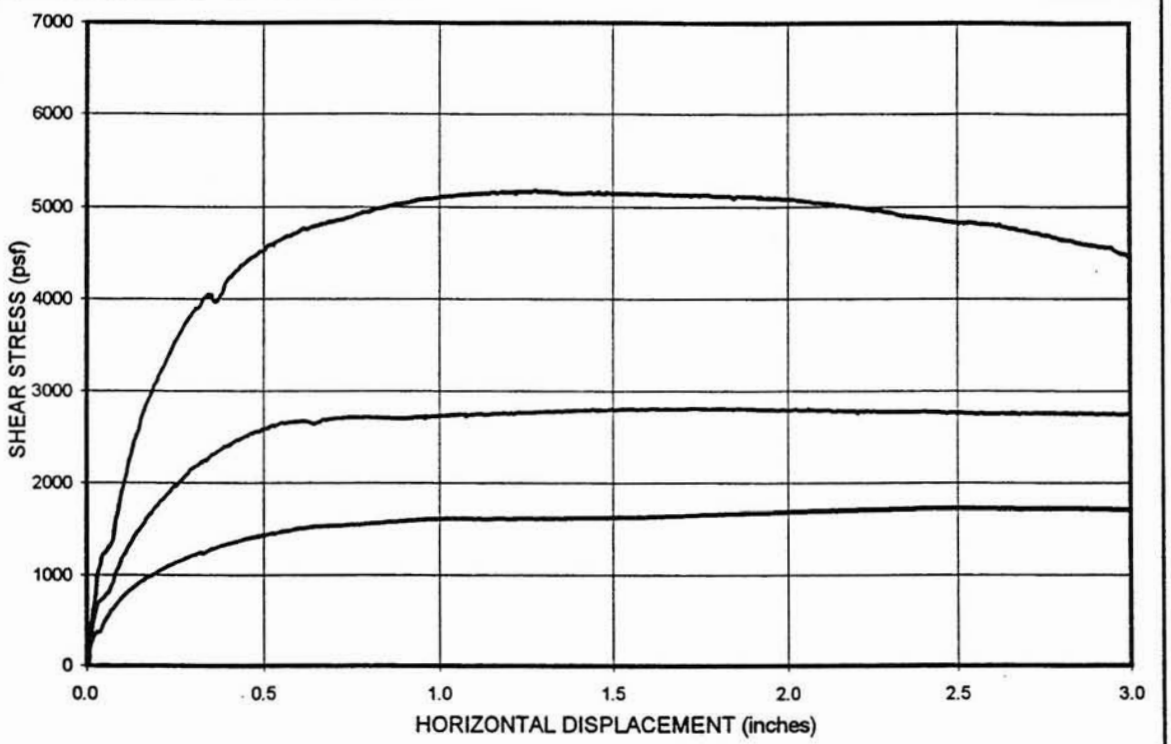
(Soil)

Initial Water Content: 16.7%

Initial Dry Density: 106.6 pcf

Final Water Content:(%)

1.	2.	3.
21.9	20.7	19.3

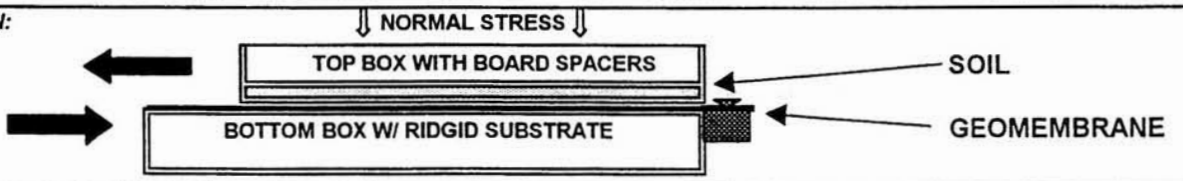


STANDARD CONDITIONS:

SHEAR DISPLACEMENT RATE: 0.006 in/min

1. The "gap" between shear boxes was set at 80 mil (2.0 mm)
2. The test specimens were flooded during testing unless otherwise noted.
3. High Normal Stresses, >5psi (35 kPa) was applied using air pressure.
4. Low Normal Stresses, <5psi (35 kPa) was applied using dead weights.
5. The tests were terminated after 3.0"(75 mm) of displacement unless otherwise noted.
6. Tests were performed in general accordance with ASTM procedure D-5321 using a Brainard-Killman LG-112 direct shear machine with an effective area of 12" x 12" (300 x300 mm).

TEST ORIENTATION:



SPECIAL TEST NOTES:

1. Each specimen of geomembrane was cut to 14" x 20" and clamped to the lower shear box.
2. The test soil was remolded in the upper shear box to 90% of 118.4 pcf at a water content of 16.7%.
3. Each soil/geomembrane specimen was consolidated for 24 hours at the specified normal stress, then sheared.
4. The test was performed in a "wet" or "flooded" condition.
5. Shearing occurred at the interface of the soil and geomembrane specimens.
6. No stretching, abrasion, or tearing was observed on the geomembrane specimens.
7. The Friction Angle and Adhesion (or Cohesion) results given here are based on a mathematically determined best fit line.
8. Further interpretation should be conducted by a qualified professional experienced in geosynthetic and geotechnical engineering.

Vector Engineering Inc.

12438 Loma Rica Drive, Suite C, Grass Valley, CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321-B

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ Spacer Boards

Material 1: ⇦ Brown, Clay (rec'd 9/6/00) (clay vs. textured side of HDPE) LSN: 422A Remolded

Material 2: ⇨ Serrot 40 mil LLDPE Geomembrane, Textured/Textured Roll #3904789 LSN: BML Clamped

Substrate: ⇨ Concrete Board Spacers

PEAK STRENGTH

(at 0.6 inch displacement)

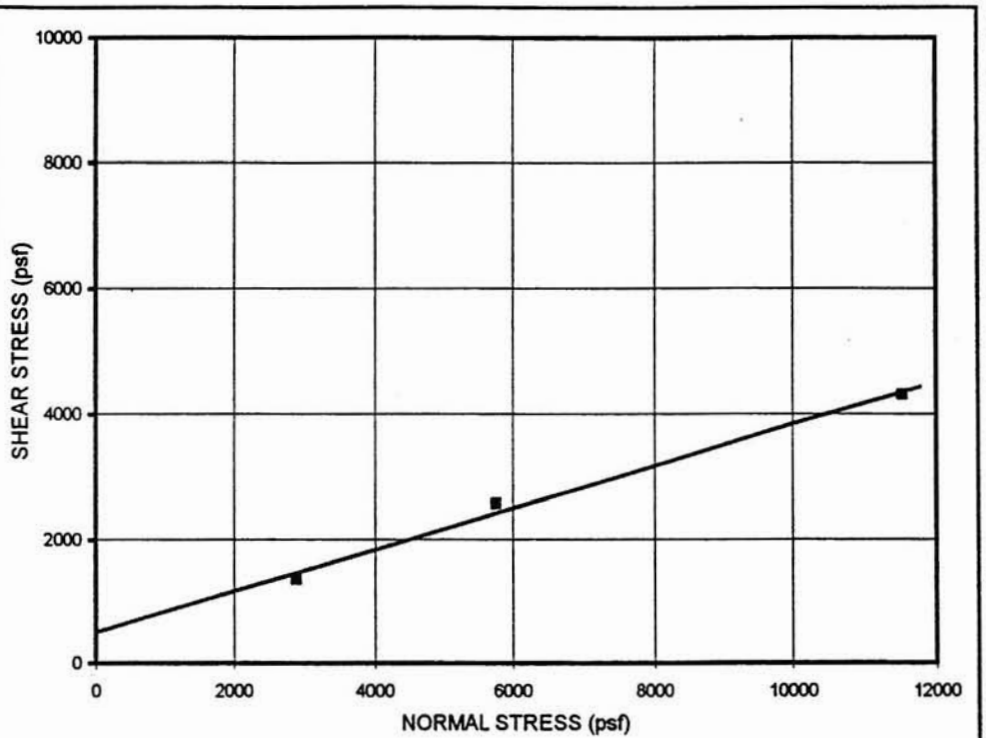
Test Point	Normal Stress psi	Normal Stress psf	Shear Stress psf	Secant Friction Angle
1.	20.0	2880	1370	25
2.	40.0	5760	2570	24
3.	80.0	11520	4310	21

Adhesion: 500 psf

Friction Angle: 19 degrees

Coefficient of Friction: 0.34

NOTE: GRAPH NOT TO SCALE



STRENGTH ENVELOPE

(at 2.5 in. displacement)

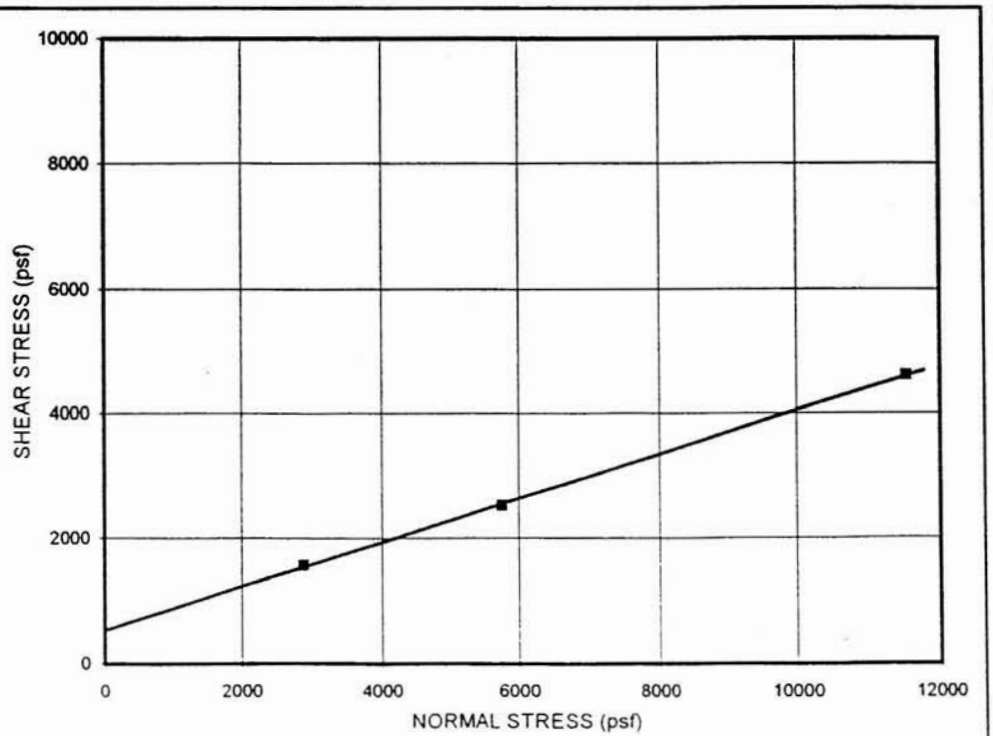
Test Point	Normal Stress psi	Normal Stress psf	Shear Stress psf	Secant Friction Angle
1.	20.0	2880	1570	29
2.	40.0	5760	2530	24
3.	80.0	11520	4610	22

Adhesion: 530 psf

Friction Angle: 19 degrees

Coefficient of Friction: 0.35

NOTE: GRAPH NOT TO SCALE



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LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321-B

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ Spacer Boards

Material 1: ⇦ Brown, Clay (rec'd 9/6/00) (clay vs. textured side of HDPE) LSN: 422A Remolded

Material 2: ⇨ Serrot 40 mil LLDPE Geomembrane, Textured/Textured Roll #3904789 LSN: BML Clamped

Substrate: ⇨ Concrete Board Spacers

DISPLACEMENT vs. SHEAR STRESS

Test Point	Normal Stress	
	psi	psf
1.	20.0	2880
2.	40.0	5760
3.	80.0	11520

MOISTURE DATA:

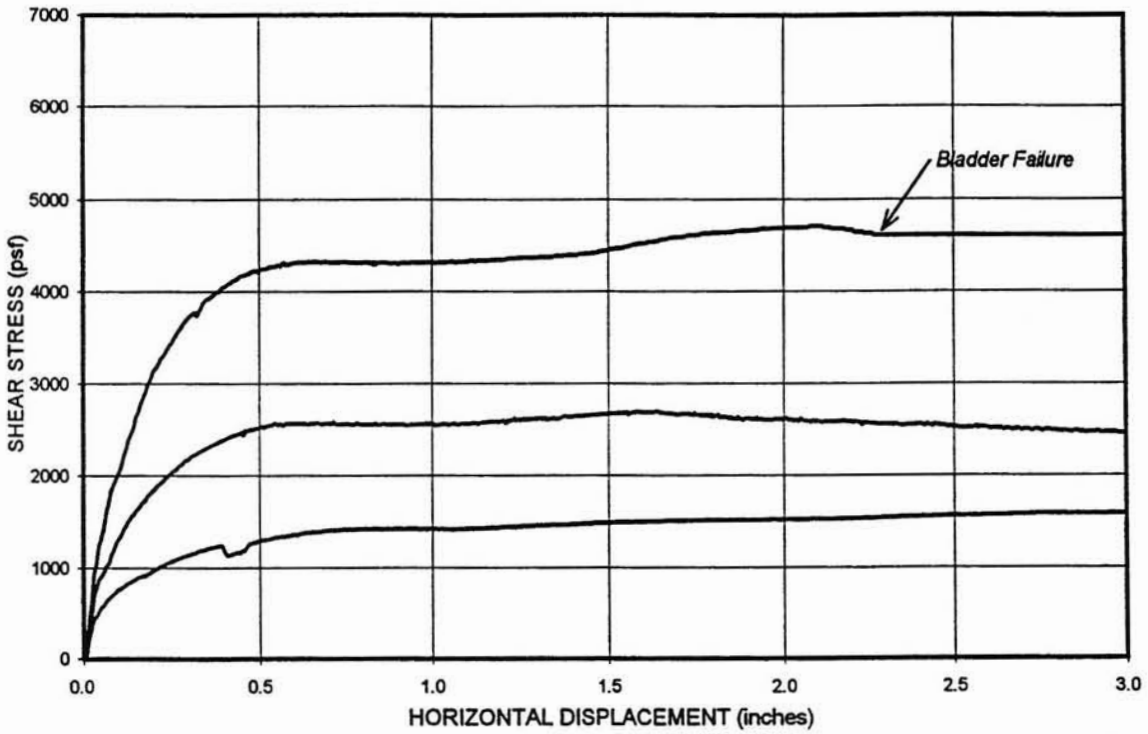
(Soil)

Initial Water Content: 16.7%

Initial Dry Density: 106.6 pcf

Final Water Content:(%)

1.	2.	3.
22.4	20.2	19.6

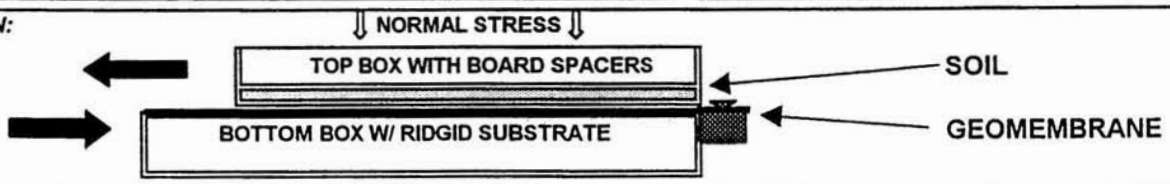


STANDARD CONDITIONS:

SHEAR DISPLACEMENT RATE: 0.006 in/min

1. The "gap" between shear boxes was set at 80 mil (2.0 mm)
2. The test specimens were flooded during testing unless otherwise noted.
3. High Normal Stresses, >5psi (35 kPa) was applied using air pressure.
4. Low Normal Stresses, <5psi (35 kPa) was applied using dead weights.
5. The tests were terminated after 3.0"(75 mm) of displacement unless otherwise noted.
6. Tests were performed in general accordance with ASTM procedure D-5321 using a Brainard-Kilman LG-112 direct shear machine with an effective area of 12" x 12" (300 x300 mm).

TEST ORIENTATION:



SPECIAL TEST NOTES:

1. Each specimen of geomembrane was cut to 14" x 20" and clamped to the lower shear box.
2. The test soil was remolded in the upper shear box to 90% of 118.4 pcf at a water content of 16.7%.
3. Each soil/geomembrane specimen was consolidated for 24 hours at the specified normal stress, then sheared.
4. The test was performed in a "wet" or "flooded" condition.
5. Shearing occurred at the interface of the soil and geomembrane specimens.
6. No stretching, abrasion, or tearing was observed on the geomembrane specimens.
7. The Friction Angle and Adhesion (or Cohesion) results given here are based on a mathematically determined best fit line.
8. Further interpretation should be conducted by a qualified professional experienced in geosynthetic and geotechnical engineering.

Vector Engineering Inc.

12438 Loma Rica Drive., Suite C, Grass Valley, CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A FORWARD DIRECTION

Client Name: YOLO COUNTY Project Name: STABILITY UPDATE RESEARCH Project No: 931010.17

Superstrate: ⇦ PVC Spacer Boards

Material 1: ⇦ Serrot 60 mil HDPE T/S (textured side tested) LSN: BMK Clamped

Material 2: ⇨ Geocomposite with 10 oz fabric on both sides LSN: BMJ Clamped

Substrate: ⇨ Concrete Board Spacers

PEAK STRENGTH

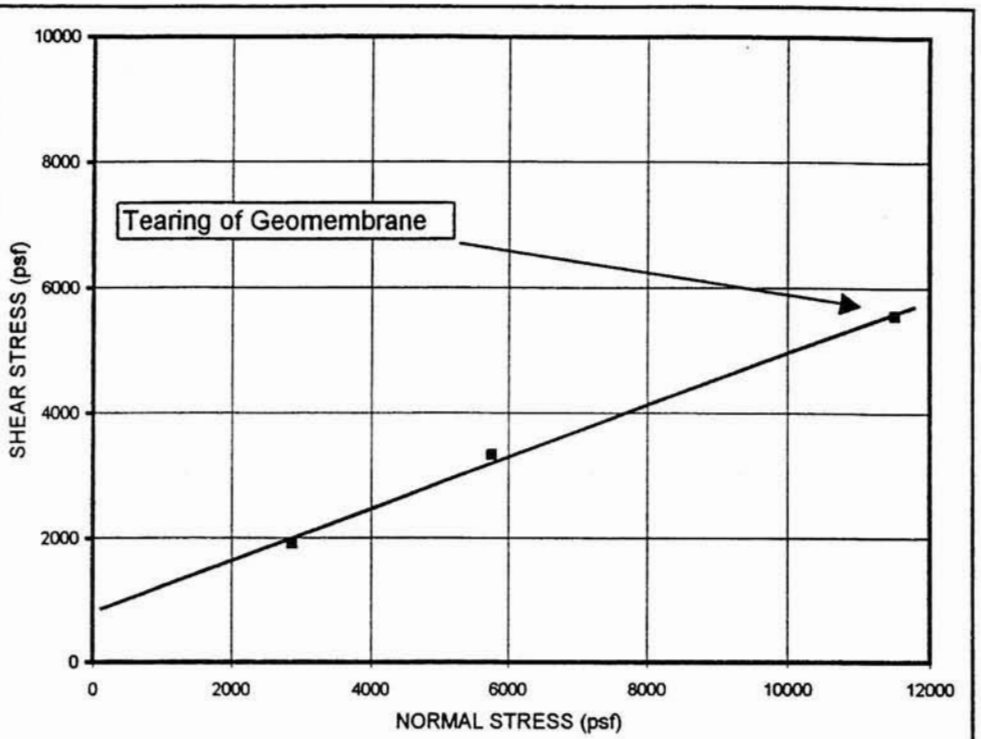
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	1920	34
2.	40.0	5760	3340	30
3.	80.0	11520	5560	26

Adhesion: 810 psf

Friction Angle: 23 degrees

Coefficient of Friction: 0.42

NOTE: GRAPH NOT TO SCALE



STRENGTH ENVELOPE

(at 2.5 in. displacement)

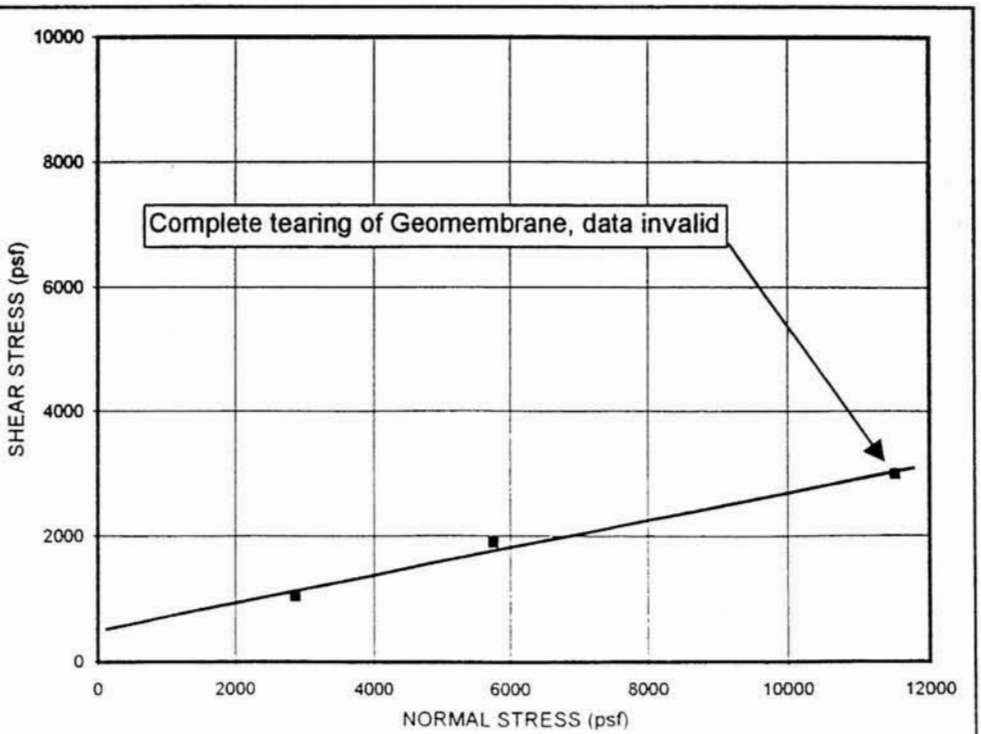
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	1040	20
2.	40.0	5760	1900	18
3.	80.0	11520	3000	15

Adhesion: 490 psf

Friction Angle: 13 degrees

Coefficient of Friction: 0.22

NOTE: GRAPH NOT TO SCALE



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LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A FORWARD DIRECTION

Client Name: YOLO COUNTY Project Name: STABILITY UPDATE RESEARCH Project No: 931010.17

Superstrate: ⇦ PVC Spacer Boards

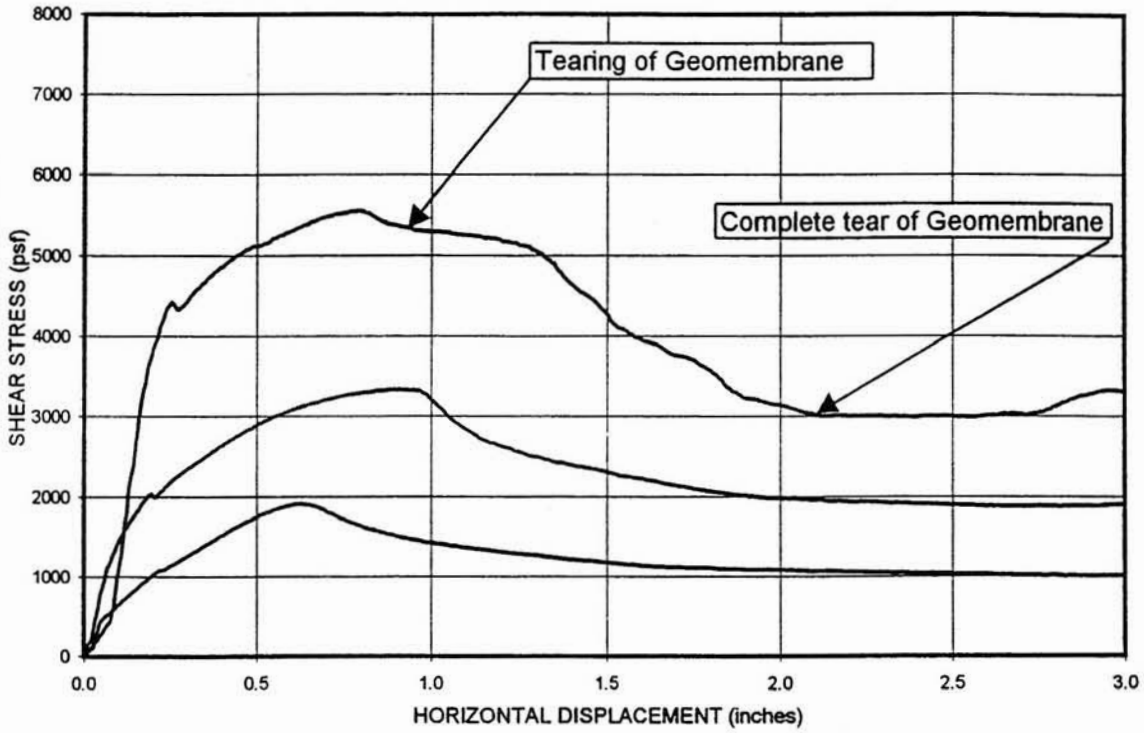
Material 1: ⇦ Serrot 60 mil HDPE T/S (textured side tested) LSN: BMK Clamped

Material 2: ⇨ Geocomposite with 10 oz fabric on both sides LSN: BMJ Clamped

Substrate: ⇨ Concrete Board Spacers

DISPLACEMENT vs. SHEAR STRESS

Test Point	Normal Stress	
	psi	psf
1.	20.0	2880
2.	40.0	5760
3.	80.0	11520

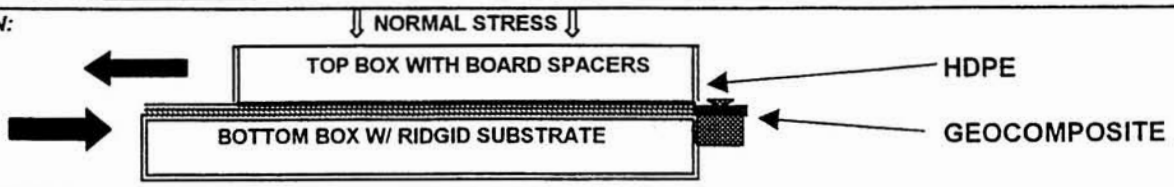


STANDARD CONDITIONS:

SHEAR DISPLACEMENT RATE: 0.04 in/min

1. The "gap" between shear boxes was set at 80 mil (2.0 mm)
2. The test specimens were flooded during testing unless otherwise noted.
3. High Normal Stresses, >5psi (35 kPa) was applied using air pressure.
4. Low Normal Stresses, <5psi (35 kPa) was applied using dead weights.
5. The tests were terminated after 3.0"(75 mm) of displacement unless otherwise noted.
6. Tests were performed in general accordance with ASTM procedure D-5321 using a Brainard-Killman LG-112 direct shear machine with an effective area of 12" x 12" (300 x300 mm).

TEST ORIENTATION:



SPECIAL TEST NOTES:

1. Each specimen of HDPE was cut to 14" x 20".
2. Each specimen of Geocomposite was cut to 14" x 20".
3. The HDPE specimen was bolted to the upper shear box with channel clamps.
4. The Geocomposite was bolted to the lower shear box with channel clamps.
5. Complete tearing of the geomembrane occurred at or slightly after the peak stress for point 3.
6. The post peak values for point 3 are suspect.
7. The Friction Angle and Adhesion (or Cohesion) results given here are based on a mathematically determined best fit line
8. Further interpretation should be conducted by a qualified professional experienced in geosynthetic and geotechnical engineering

Vector Engineering Inc.

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LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A REVERSE DIRECTION

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ PVC Spacer Boards

Material 1: ⇦ Serrot 60 mil HDPE T/S (textured side tested) LSN: BMK Clamped

Material 2: ⇨ Geocomposite with 10 oz fabric on both sides LSN: BMJ Clamped

Substrate: ⇨ Concrete Board Spacers

PEAK STRENGTH

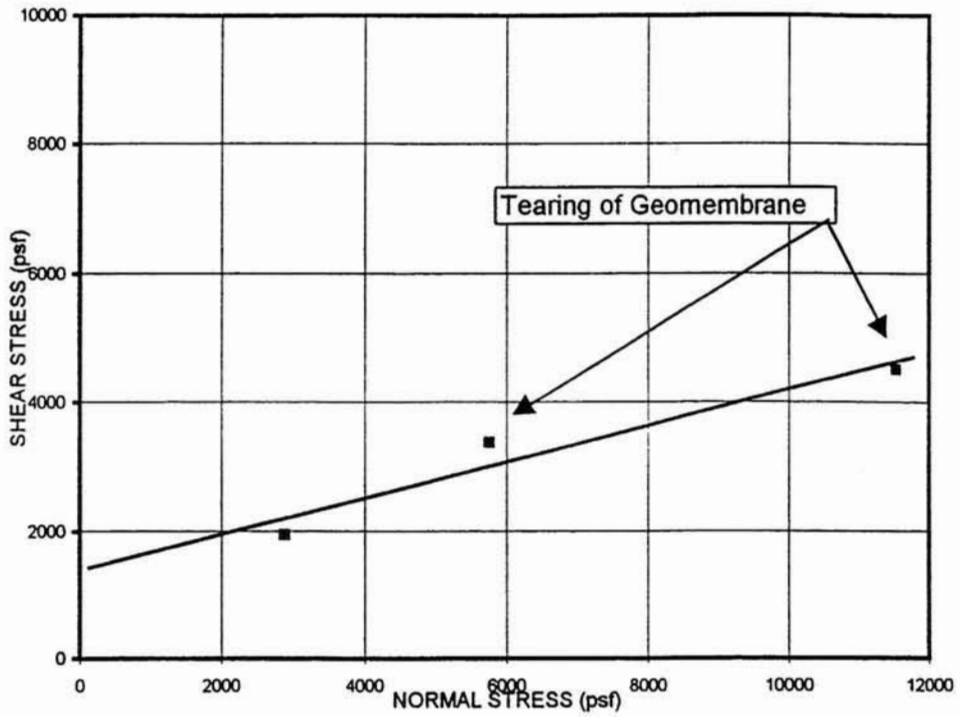
Test Point	Normal Stress		Shear Stress	Secant Friction Angle
	psi	psf	psf	
1.	20.0	2880	1950	34
2.	40.0	5760	3380	30
3.	80.0	11520	4510	21

Adhesion: 1380 psf

Friction Angle: 16 degrees

Coefficient of Friction: 0.28

NOTE: GRAPH NOT TO SCALE



STRENGTH ENVELOPE

(at 2.5 in. displacement)

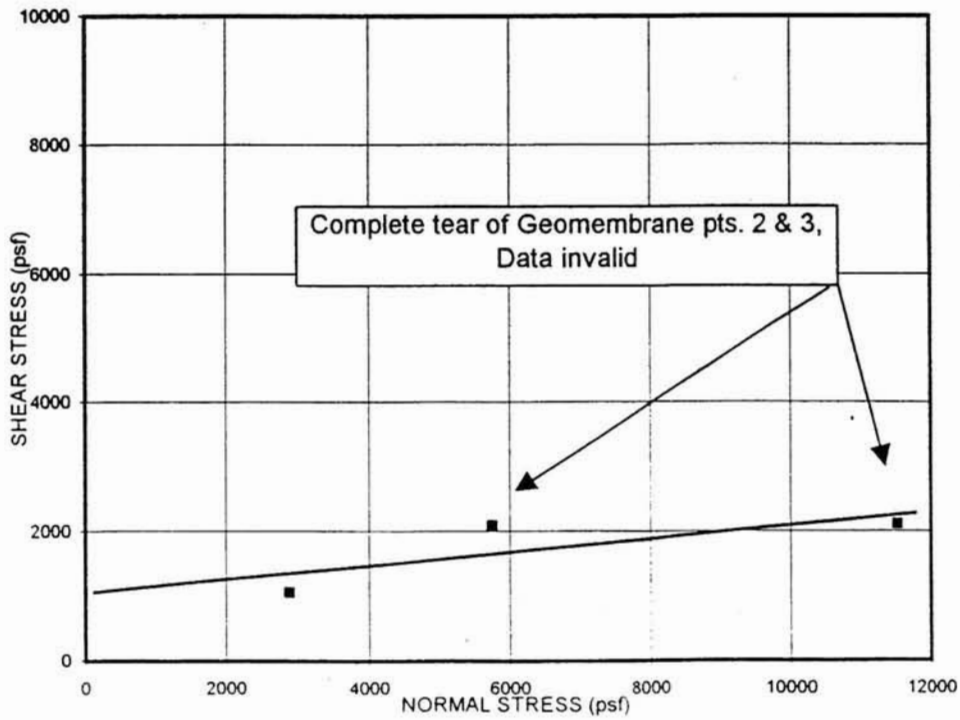
Test Point	Normal Stress		Shear Stress	Secant Friction Angle
	psi	psf	psf	
1.	20.0	2880	1060	20
2.	40.0	5760	2090	20
3.	80.0	11520	2110	10

Adhesion: 1050 psf

Friction Angle: 6 degrees

Coefficient of Friction: 0.11

NOTE: GRAPH NOT TO SCALE



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LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A REVERSE DIRECTION

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ PVC Spacer Boards

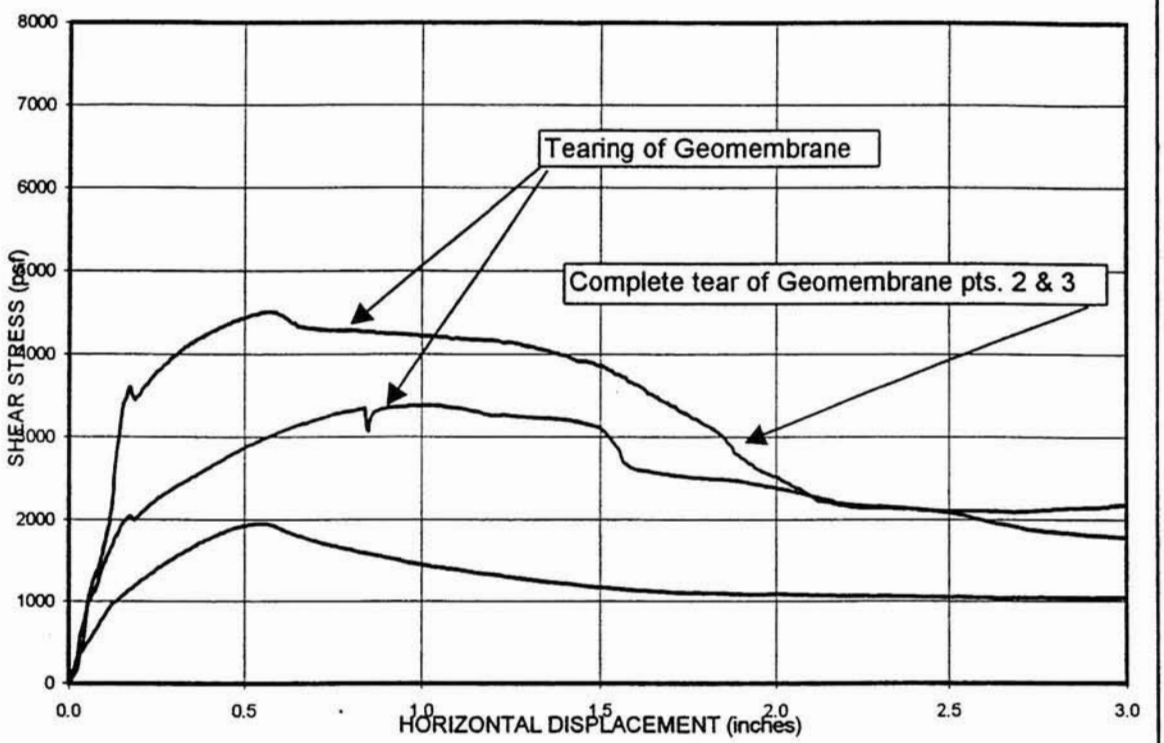
Material 1: ⇦ Serrot 60 mil HDPE T/S (textured side tested) LSN: BMK Clamped

Material 2: ⇨ Geocomposite with 10 oz fabric on both sides LSN: BMJ Clamped

Substrate: ⇨ Concrete Board Spacers

DISPLACEMENT vs. SHEAR STRESS

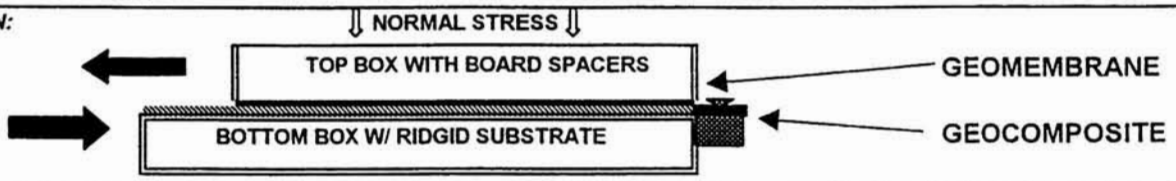
Test Point	Normal Stress	
	psi	psf
1.	20.0	2880
2.	40.0	5760
3.	80.0	11520



STANDARD CONDITIONS: **SHEAR DISPLACEMENT RATE: 0.04 in/min**

1. The "gap" between shear boxes was set at 80 mil (2.0 mm)
2. The test specimens were flooded during testing unless otherwise noted.
3. High Normal Stresses, >5psi (35 kPa) was applied using air pressure.
4. Low Normal Stresses, <5psi (35 kPa) was applied using dead weights.
5. The tests were terminated after 3.0"(75 mm) of displacement unless otherwise noted.
6. Tests were performed in general accordance with ASTM procedure D-5321 using a Brainard-Killman LG-112 direct shear machine with an effective area of 12" x 12" (300 x300 mm).

TEST ORIENTATION:



SPECIAL TEST NOTES:

1. Each specimen of geomembrane was cut to 14" x 20" and clamped to the upper shear box.
2. Each specimen of geocomposite was cut to 14" x 20" and clamped to the lower shear box.
3. Each specimen was consolidated at the specified normal stress approximately 1 hour, then sheared.
4. Shearing occurred at the interface between the geomembrane and geocomposite.
5. Complete tearing of the geomembrane samples occurred at points 2 and 3, post-peak data invalid. Peak data is suspect.
6. The Friction Angle and Adhesion (or Cohesion) results given here are based on a mathematically determined best fit line.
7. Further interpretation should be conducted by a qualified professional experienced in geosynthetic and geotechnical engineering.

Vector Engineering Inc.

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LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A TRANSVERSE

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ PVC Spacer Boards

Material 1: ⇦ Serrot 60 mil HDPE T/S (textured side tested) LSN: BMJ Clamped

Material 2: ⇨ Geocomposite with 10 oz fabric on both sides LSN: BMK Clamped

Substrate: ⇨ Concrete Board Spacers

PEAK STRENGTH

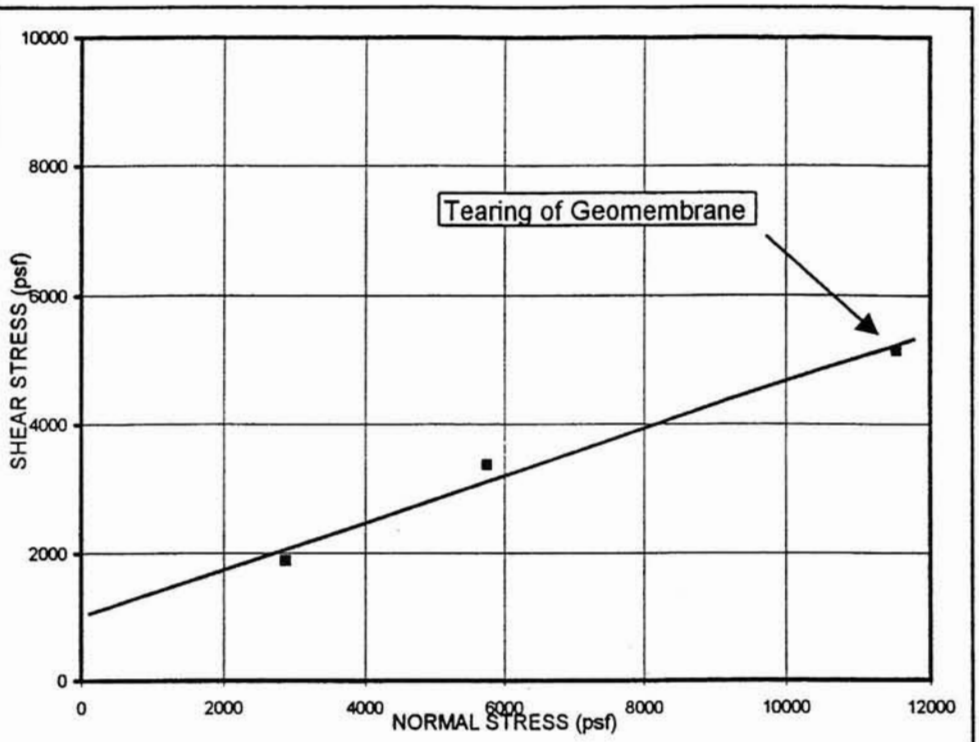
Test Point	Normal Stress		Shear Stress	Secant Friction Angle
	psi	psf	psf	
1.	20.0	2880	1880	33
2.	40.0	5760	3390	30
3.	80.0	11520	5150	24

Adhesion: 1000 psf

Friction Angle: 20 degrees

Coefficient of Friction: 0.37

NOTE: GRAPH NOT TO SCALE



STRENGTH ENVELOPE

(at 2.5 in. displacement)

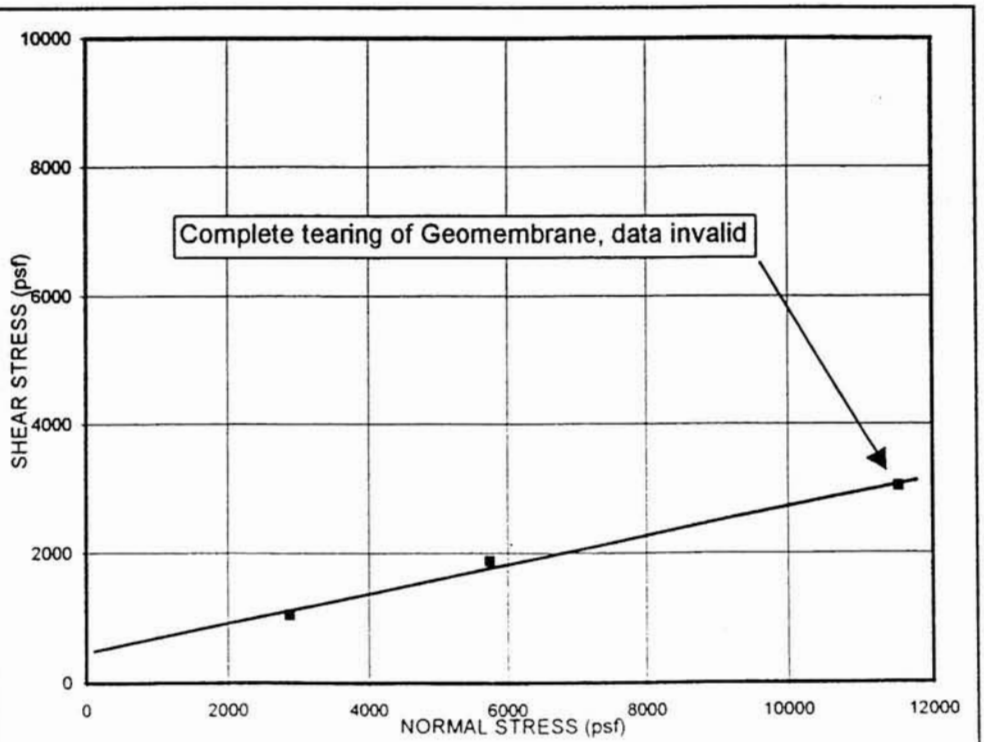
Test Point	Normal Stress		Shear Stress	Secant Friction Angle
	psi	psf	psf	
1.	20.0	2880	1050	20
2.	40.0	5760	1880	18
3.	80.0	11520	3040	15

Adhesion: 470 psf

Friction Angle: 13 degrees

Coefficient of Friction: 0.23

NOTE: GRAPH NOT TO SCALE



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LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A TRANSVERSE

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ PVC Spacer Boards

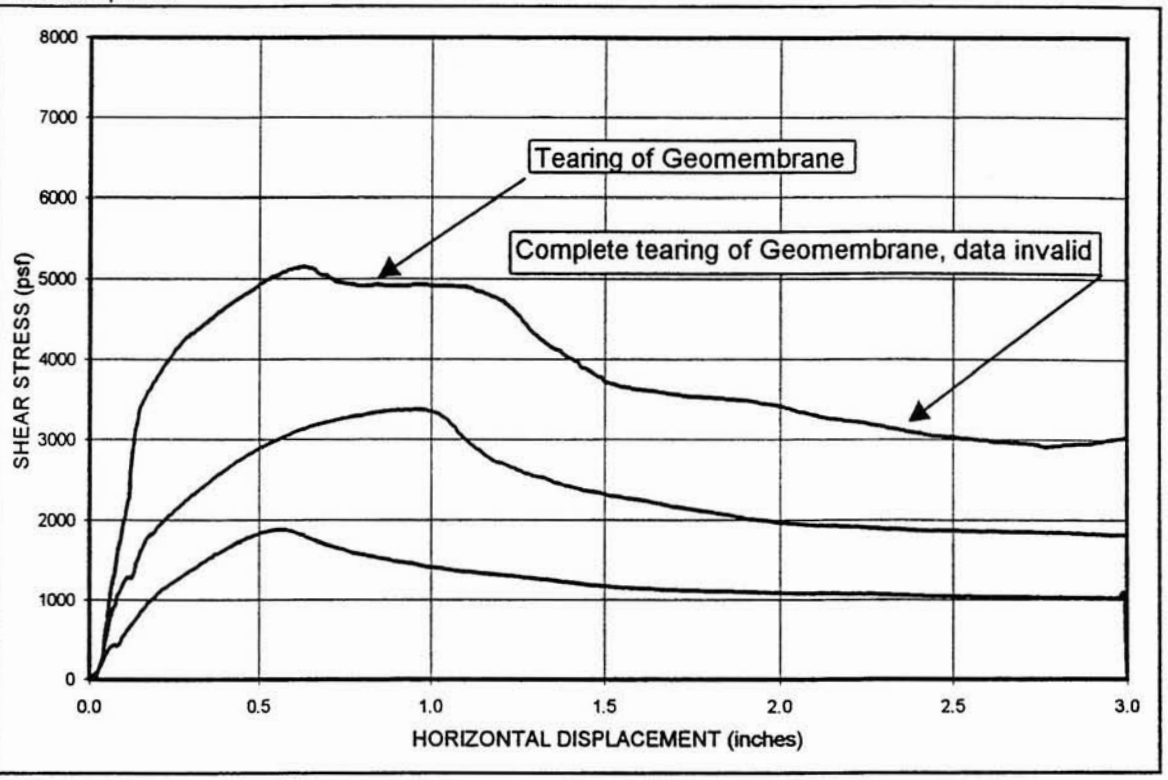
Material 1: ⇦ Serrot 60 mil HDPE T/S (textured side tested) LSN: BMJ Clamped

Material 2: ⇨ Geocomposite with 10 oz fabric on both sides LSN: BMK Clamped

Substrate: ⇨ Concrete Board Spacers

DISPLACEMENT vs. SHEAR STRESS

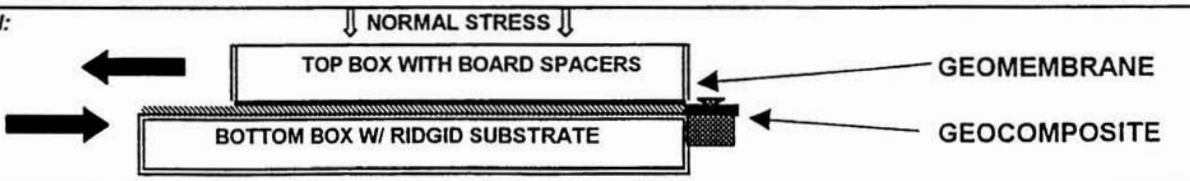
Test Point	Normal Stress	
	psi	psf
1.	20.0	2880
2.	40.0	5760
3.	80.0	11520



STANDARD CONDITIONS: **SHEAR DISPLACEMENT RATE: 0.04 in/min**

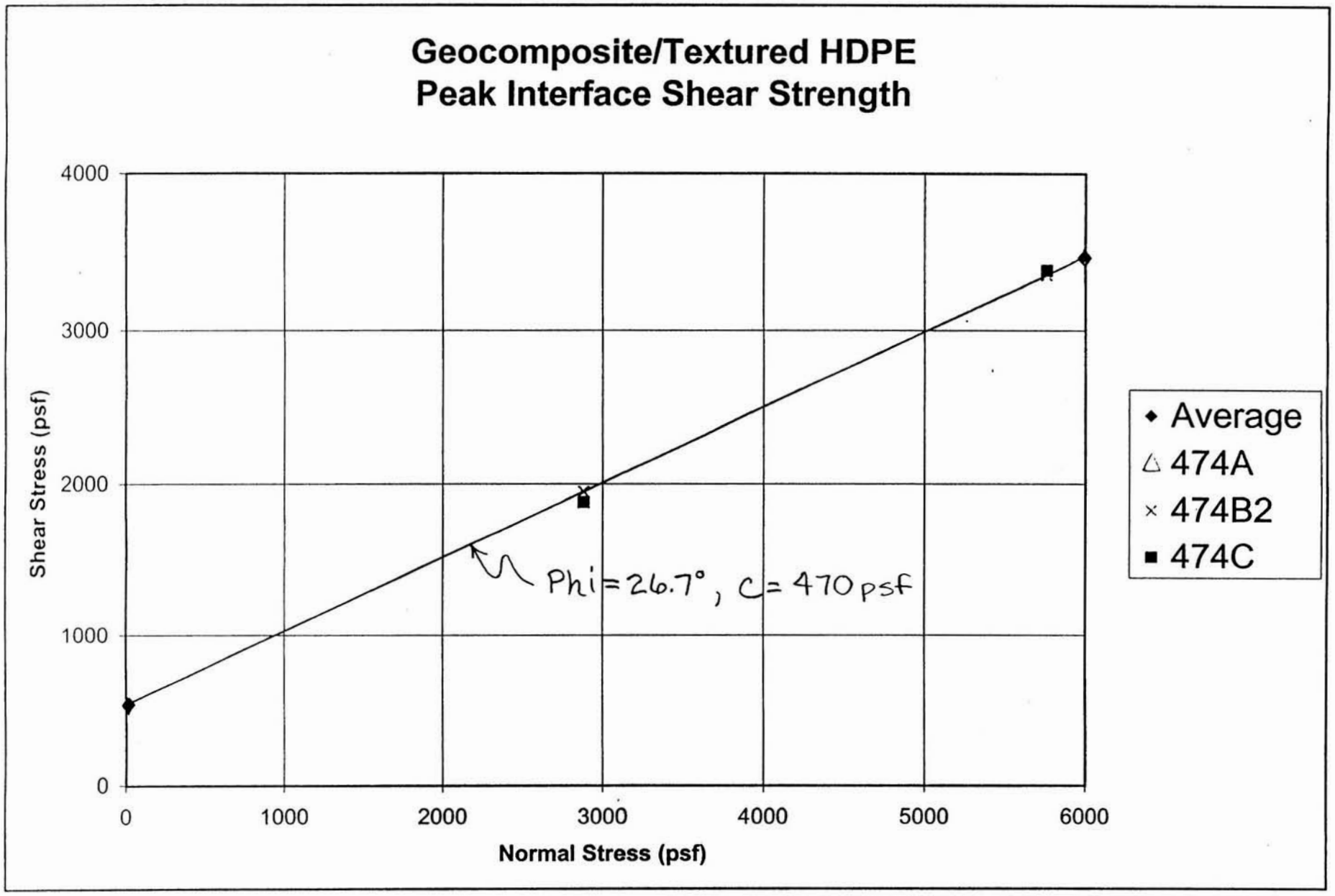
1. The "gap" between shear boxes was set at 80 mil (2.0 mm)
2. The test specimens were flooded during testing unless otherwise noted.
3. High Normal Stresses, >5psi (35 kPa) was applied using air pressure.
4. Low Normal Stresses, <5psi (35 kPa) was applied using dead weights.
5. The tests were terminated after 3.0"(75 mm) of displacement unless otherwise noted.
6. Tests were performed in general accordance with ASTM procedure D-5321 using a Brainard-Kilman LG-112 direct shear machine with an effective area of 12" x 12" (300 x300 mm).

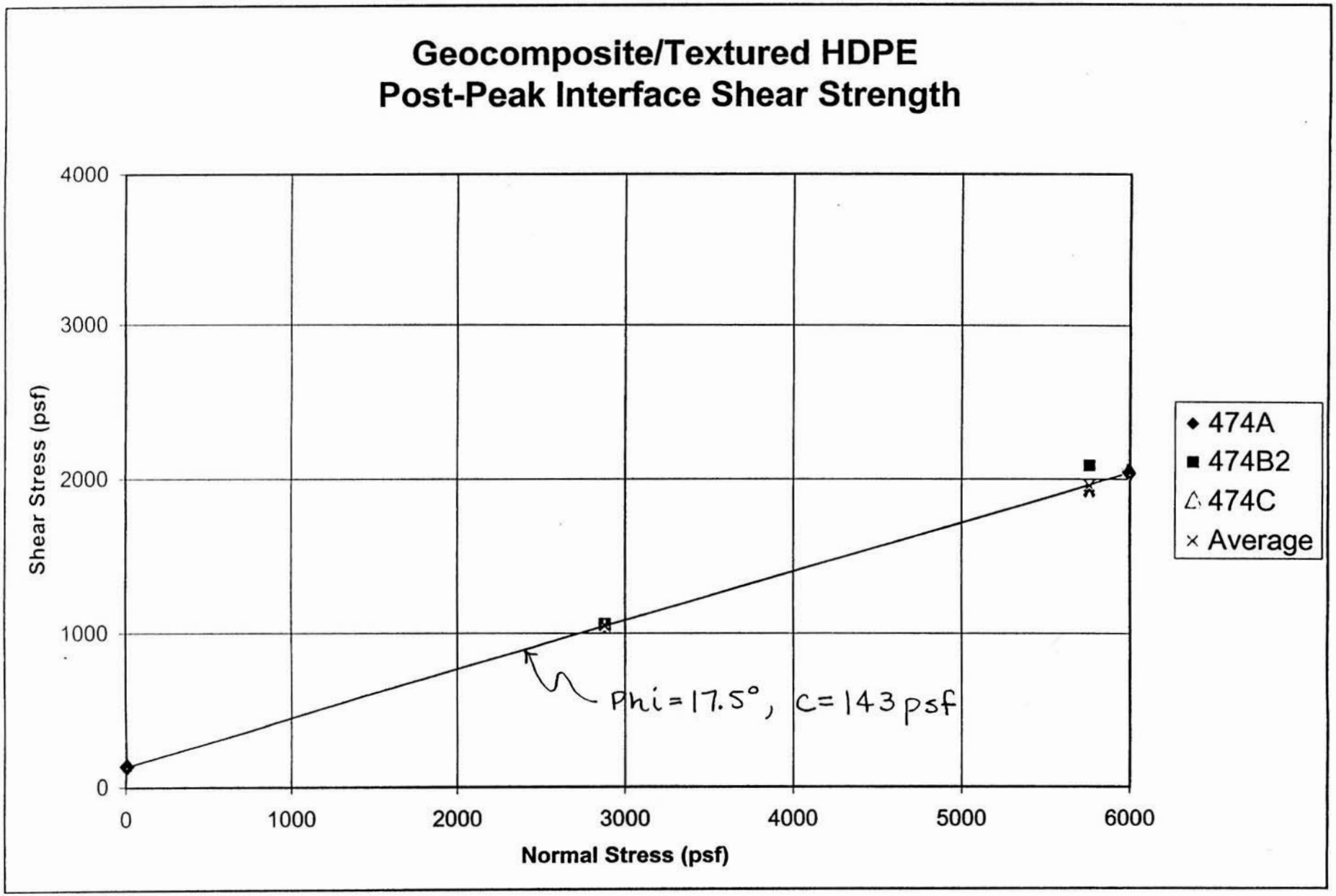
TEST ORIENTATION:



SPECIAL TEST NOTES:

1. Each specimen of HDPE was cut to 14" x 20".
2. Each specimen of Geocomposite was cut to 14" x 20".
3. The HDPE specimen was bolted to the upper shear box with standard clamps.
4. The Geocomposite was bolted to the lower shear box with "channel clamps."
5. Complete tearing of the geomembrane occurred at or slightly after the peak stress for point 3.
6. The post peak values for point 3 are invalid.
7. The Friction Angle and Adhesion (or Cohesion) results given here are based on a mathematically determined best fit line.
8. Further interpretation should be conducted by a qualified professional experienced in geosynthetic and geotechnical engineering.


Geocomposite/Textured HDPE
Peak Interface Shear Strength
Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
Phi=26.7°, C=470 psf
Average
474A
474B2
474C


Geocomposite/Textured HDPE
Post-Peak Interface Shear Strength
Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
474A
474B2
474C
Average
Phi = 17.5°, C = 143 psf

Vector Engineering Inc.

12438 Loma Rica Drive, Suite C, Grass Valley, CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321-B

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ Spacer Boards

Material 1: ⇦ Clay LSN: 422A Remolded

Material 2: ⇨ 40 mil PVC LSN: 531B Clamped

Substrate: ⇨ Concrete Board Spacers

PEAK STRENGTH

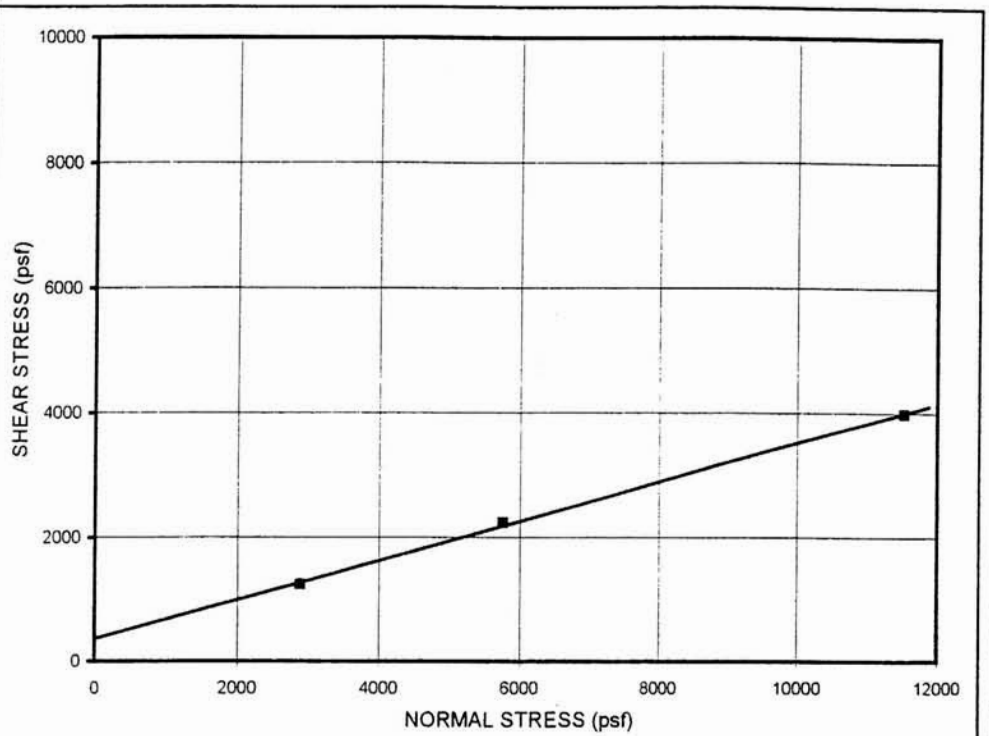
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	1250	23
2.	40.0	5760	2240	21
3.	80.0	11520	3990	19

Adhesion: 370 psf

Friction Angle: 18 degrees

Coefficient of Friction: 0.32

NOTE: GRAPH NOT TO SCALE



STRENGTH ENVELOPE

(at 2.5 in. displacement)

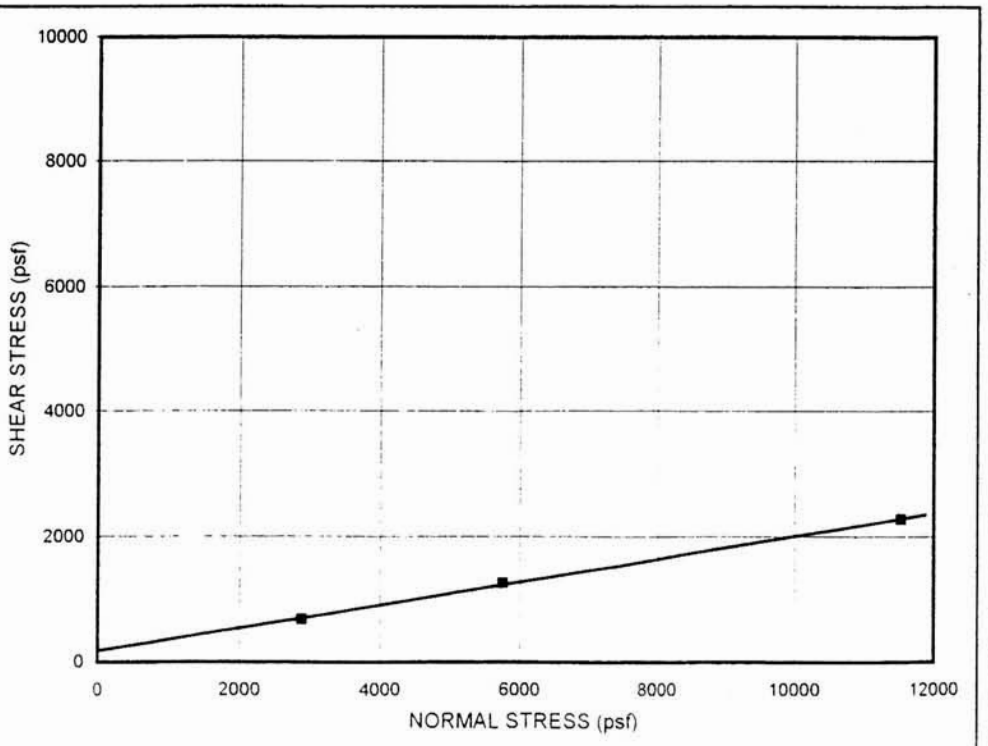
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	690	13
2.	40.0	5760	1260	12
3.	80.0	11520	2280	11

Adhesion: 180 psf

Friction Angle: 10 degrees

Coefficient of Friction: 0.18

NOTE: GRAPH NOT TO SCALE



Vector Engineering Inc.

12438 Loma Rica Drive, Suite C, Grass Valley CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321-B

Client Name: YOLO COUNTY Project Name: BIOREACTOR STABILITY Project No: 931010.17

Superstrate: ⇦ Spacer Boards

Material 1: ⇦ Clay LSN: 422A Remolded

Material 2: ⇨ 40 mil PVC LSN: 531B Clamped

Substrate: ⇨ Concrete Board Spacers

DISPLACEMENT vs. SHEAR STRESS

Test Point	Normal Stress	
	psi	psf
1.	20.0	2880
2.	40.0	5760
3.	80.0	11520

MOISTURE DATA:

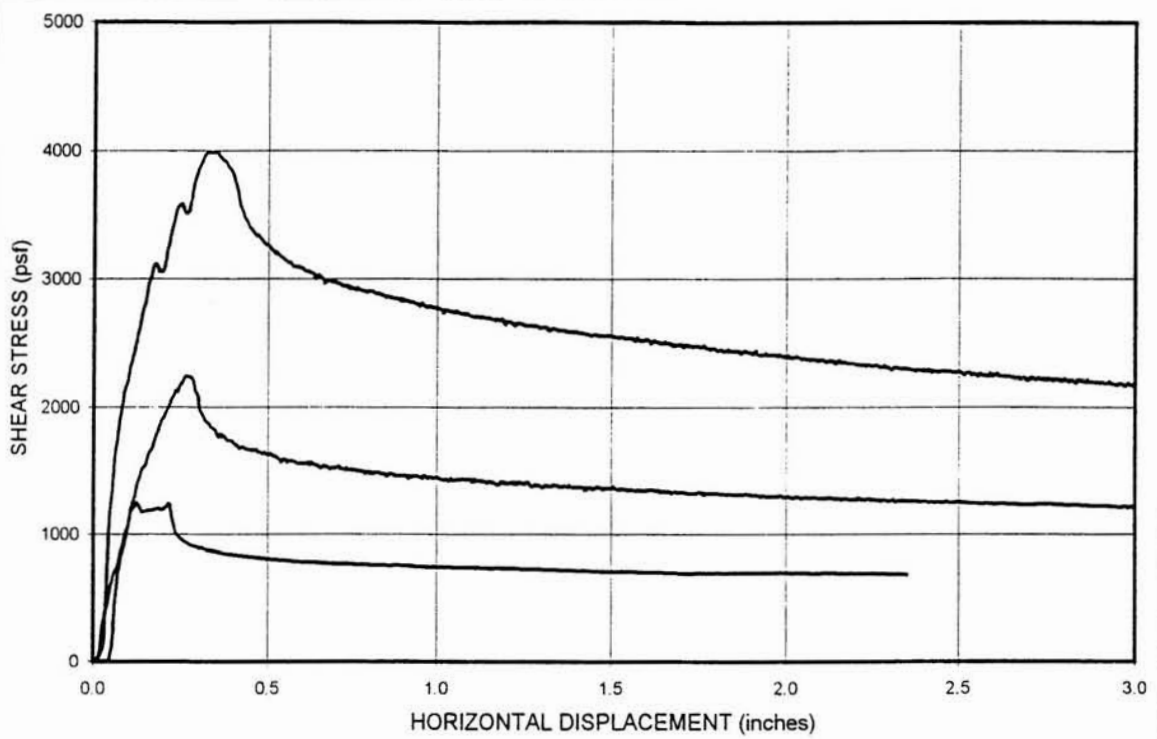
(Soil)

Initial Water Content: 16.7%

Initial Dry Density: 106.6 pcf

Final Water Content:(%)

1.	2.	3.
20.7	19.8	17.3

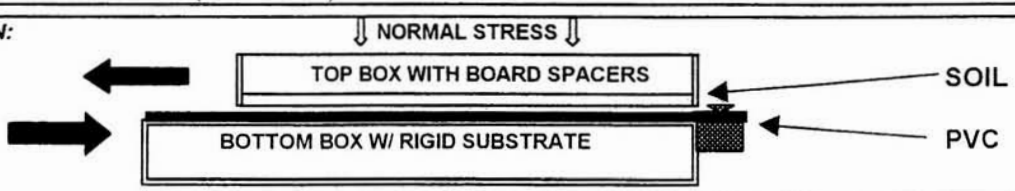


STANDARD CONDITIONS:

SHEAR DISPLACEMENT RATE: 0.006 in/min

1. The "gap" between shear boxes was set at 80 mil (2.0 mm)
2. The test specimens were flooded during testing unless otherwise noted.
3. High Normal Stresses, >5psi (35 kPa) was applied using air pressure.
4. Low Normal Stresses, <5psi (35 kPa) was applied using dead weights.
5. The tests were terminated after 3.0"(75 mm) of displacement unless otherwise noted.
6. Tests were performed in general accordance with ASTM procedure D-5321 using a Brainard-Killman LG-112 direct shear machine with an effective area of 12" x 12" (300 x300 mm).

TEST ORIENTATION:



SPECIAL TEST NOTES:

1. Each specimen of PVC was cut to 14" x 20" and clamped to the lower shear box.
2. The test soil was remolded in the upper shear box to the required dry density and water content.
3. Each soil specimen was consolidated for 24 hours at the specified normal stress, then sheared.
4. The test was performed in a "wet" or "flooded" condition.
5. Shearing occurred at the interface of the soil and PVC specimens.
6. The Friction Angle and Adhesion (or Cohesion) results given here are based on a mathematically determined best fit line.
7. Further interpretation should be conducted by a qualified professional experienced in geosynthetic and geotechnical engineering.

Vector Engineering Inc.

12438 Loma Rica Drive Suite C. Grass Valley, CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A

Client Name: YOLO COUNTY Project Name: **BIOREACTOR STABILITY** Project No. 931010.17

Superstrate: ⇦ Spacer Boards

Material 1: ⇦ 8 oz. Geotextile LSN 531D Clamped

Material 2: ⇨ 40 mil PVC LSN 531B Clamped

Substrate: ⇨ Concrete Board Spacers

PEAK STRENGTH

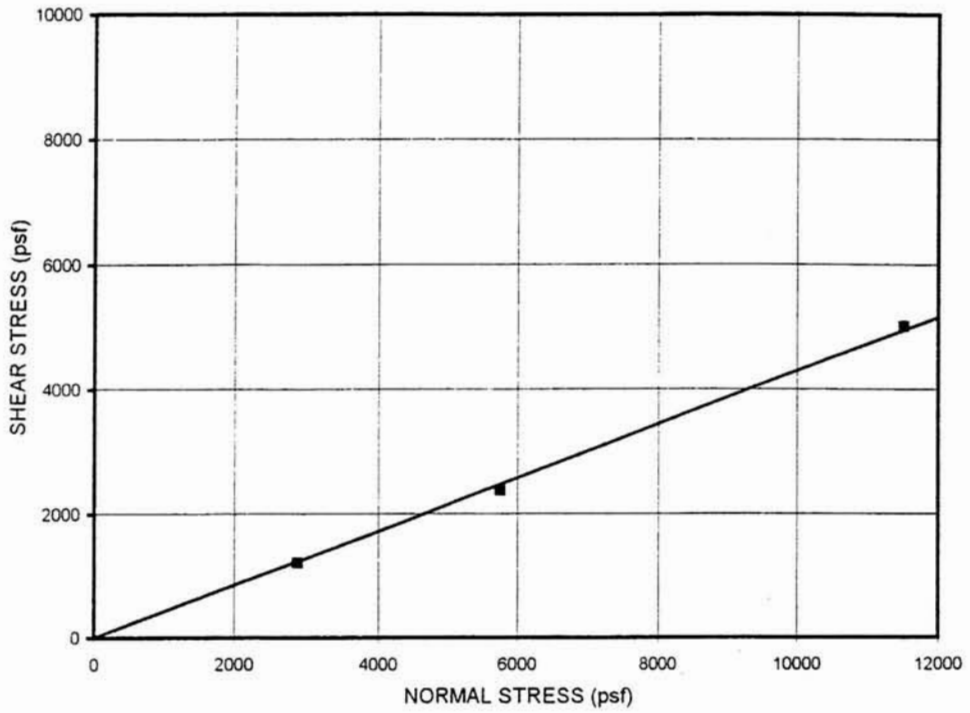
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	1210	23
2.	40.0	5760	2380	22
3.	80.0	11520	5020	24

Adhesion: 0 psf

Friction Angle: 23 degrees

Coefficient of Friction: 0.43

NOTE: GRAPH NOT TO SCALE



STRENGTH ENVELOPE

(at 2.5 in. displacement)

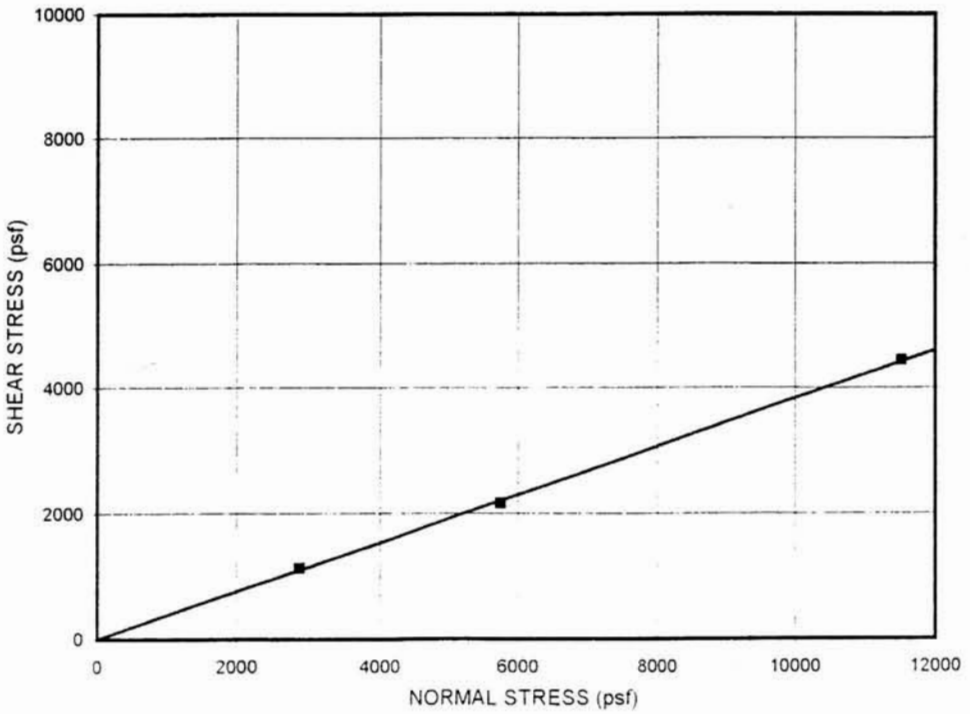
Test Point	Normal Stress		Shear Stress	Secant Friction
	psi	psf	psf	Angle
1.	20.0	2880	1130	21
2.	40.0	5760	2170	21
3.	80.0	11520	4450	21

Adhesion: 0 psf

Friction Angle: 21 degrees

Coefficient of Friction: 0.38

NOTE: GRAPH NOT TO SCALE



Vector Engineering Inc.

12438 Loma Rica Drive . Suite C Grass Valley CA 95945

LABORATORY SERVICES

LARGE SCALE DIRECT SHEAR REPORT

Test Method D-5321A

Client Name: YOLO COUNTY Project Name: **BIOREACTOR STABILITY** Project No: 931010.17

Superstrate: ⇦ Spacer Boards

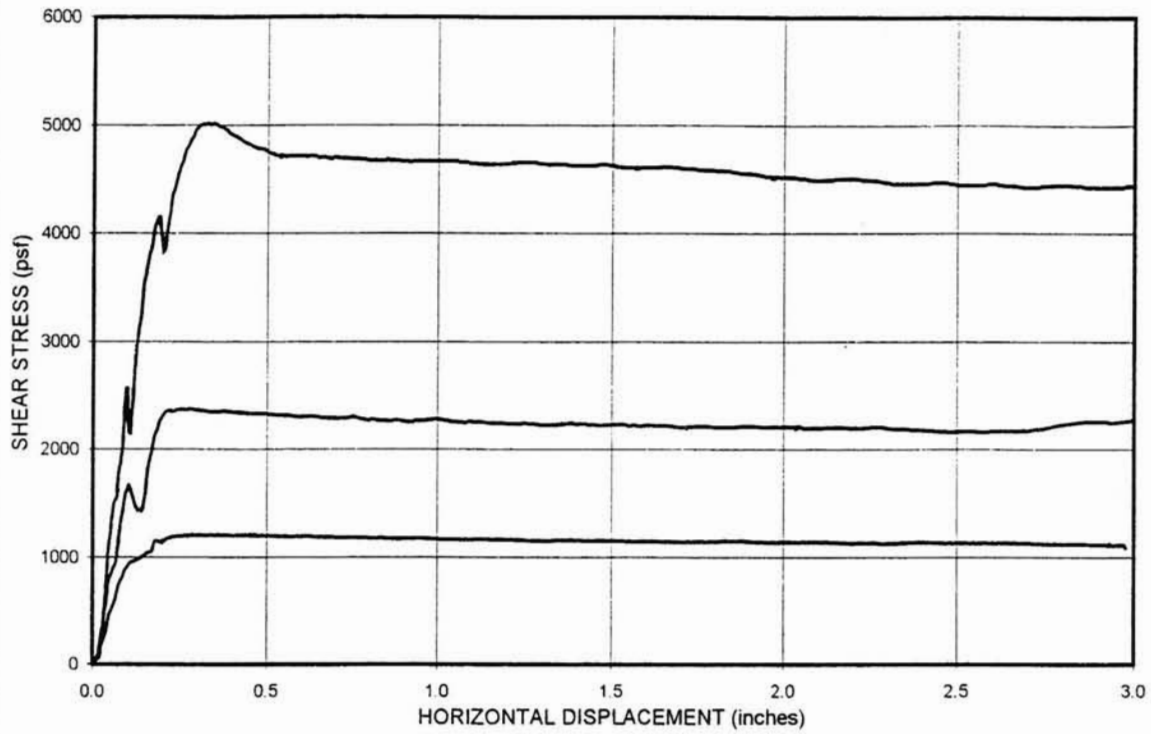
Material 1: ⇦ 8 oz. Geotextile LSN: 531D Clamped

Material 2: ⇨ 40 mil PVC LSN: 531B Clamped

Substrate: ⇨ Concrete Board Spacers

DISPLACEMENT vs. SHEAR STRESS

Test Point	Normal Stress	
	psi	psf
1.	20.0	2880
2.	40.0	5760
3.	80.0	11520

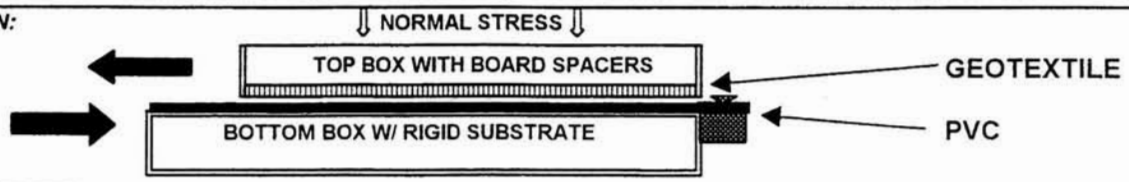


STANDARD CONDITIONS:

SHEAR DISPLACEMENT RATE: 0.04 in/min

1. The "gap" between shear boxes was set at 80 mil (2.0 mm)
2. The test specimens were flooded during testing unless otherwise noted.
3. High Normal Stresses, >5psi (35 kPa) was applied using air pressure.
4. Low Normal Stresses, <5psi (35 kPa) was applied using dead weights.
5. The tests were terminated after 3.0"(75 mm) of displacement unless otherwise noted.
6. Tests were performed in general accordance with ASTM procedure D-5321 using a Brainard-Killman LG-112 direct shear machine with an effective area of 12" x 12" (300 x300 mm).

TEST ORIENTATION:



SPECIAL TEST NOTES:

1. Each specimen of Geotextile was cut to 14" x 20".
2. The Geotextile specimen was bolted to the upper shear box with standard clamps.
3. Each specimen of PVC was cut to 14" x 20".
4. The PVC was bolted to the lower shear box with "channel clamps."
5. Each Geotextile and PVC specimen was consolidated for 1 hour at the specified normal stress, then sheared.
6. The test was performed in a "wet" or "flooded" condition.
7. Shearing occurred at the interface of the Geotextile and PVC specimens.
8. The Friction Angle and Adhesion (or Cohesion) results given here are based on a mathematically determined best fit line.

Precision Labs Geocomposite Test Results

Precision Geosynthetic Laboratories

September 28, 2000

Ms. Linda Sinderson
YOLO COUNTY DEPT. OF PUBLIC WORKS
600 A Street, Suite 158
Davis, CA 95616

Dear Ms. Sinderson:

Thank you for consulting Precision Geosynthetic Laboratories for your material testing needs.

It should be noted that the test specimen and test sample used for this report was believed to be representative of the material produced under the designation herein stated. However, these results are indicative of only the specimens that were actually tested. The testing herein is based upon accepted industry practice as well as the test method listed. Precision Geosynthetic Laboratories neither accepts responsibility for nor makes claims to the final use and purpose of the material.

By accepting the data and results represented on this report, Client agrees to limit the liability of Precision Geosynthetic Laboratories from Client and all other parties for claims arising out of the use of this data to the cost for the respective test(s) represented in this report, and Client agrees to indemnify and hold harmless Precision Geosynthetic Laboratories from and against all liability in excess of the aforementioned limit.

The test data and all associated project information shall be held in confidence and disclosed to other parties only with the authorization of Client or Precision Geosynthetic Laboratories.

It is a company policy to keep the physical records of each job for 2 years since the receipt of the samples and keep the electronic file for 7 years. ***Failed seam samples are kept for 7 years; good seam samples are disposed after 2 weeks and conformance samples are disposed after 1 month.*** Should you need us to keep them longer, please advise us in writing.

If you have any questions or if we may be of further service, please do not hesitate to call at 800-522-4599.

Sincerely,

PRECISION GEOSYNTHETIC LABORATORIES

Edith Pintor
Quality Assurance

Cora B. Queja
Vice President

Enclosure: (Job No. 001255)

1160 North Gilbert Street, Anaheim, CA 92801, Tel # 714-520-9631, Fax # 714-520-9637

Precision Geosynthetic Laboratories

CLIENT: YOLO COUNTY DEPT. OF PUBLIC WORKS

VERIFICATION OF MATERIAL PROPERTIES
(PGL Job No. 001255)

MATERIAL DESCRIPTION: Double Sided Geocomposite

SAMPLED BY: YOLO COUNTY DEPT. OF PUBLIC WORKS

DATE RECEIVED: September 27, 2000 **DATE REPORTED:** September 28, 2000

SAMPLE IDENTIFICATIONS:

SAMPLE ID	PRECISION CONTROL NUMBER
Double Sided Geocomposite	57182
Nonwoven Geotextile	57182-1

TESTS REQUIRED:

TEST METHOD	DESCRIPTION
ASTM D5261	Mass Per Unit Area
ASTM D4632	Grab Tensile
ASTM D4833	Puncture Resistance
ASTM D4491, *Constant Head*	Permittivity

TEST CONDITIONS: The sample was conditioned for a minimum one hour in the laboratory at 22 ± 2°C (71.6 ± 3.6°F) and at 60 ± 10% relative humidity prior to test.

TEST RESULTS:

The test results are summarized in Table 1. The units in which the data are reported are included on the table.

PRECISION GEOSYNTHETIC LABORATORIES

Edith Pintor
Quality Assurance

Cora B. Queja
Vice President

1160 North Gilbert Street, Anaheim, CA 92801, Tel # 714-520-9631, Fax # 714-520-9637

TABLE 1.

MATERIAL PROPERTIES

CLIENT: YOLO COUNTY DEPT. OF PUBLIC WORKS

Date Received: **9/27/00**
Date Reported: **9/28/00**
Client Sample ID: **Nonwoven Geotextile**
Material Description: **Double Sided Geocomposite, Nonwoven Geotextile Portion**

QC'd By: _____
PGL Job No.: **001255**
PGL Control No.: **57182-1**

		SPECIMENS												
		1	2	3	4	5	6	7	8	9	10	Avg.	Std. Dev.	Proj. Specs.
METHOD	**DESCRIPTION**													
ASTM D5261	Mass per Unit Area (oz./ yd.^{2})													
		24.4	24.3	23.6	24.1	23.3						23.9	0.5	
ASTM D4632	Grab Tensile													
	Tensile Strength (lbs)													
	MD	519	498	528	511	493	514	522	490	518	519	511	13	
	TD	467	464	475	515	472	465	491	482	532	428	479	29	
	Elongation at Peak (percent)													
	MD	77	74	77	73	76	80	72	73	83	75	76	3	
	TD	77	82	82	91	83	80	83	81	84	75	82	4	
ASTM D4833	Puncture Resistance (lbs)													
		226	235	225	220	211	212	235	218	213	216	225	11	
		250	224	232	219	237								
ASTM D4491	Permittivity (sec.$^{-1}$)													
Constant Head		1.28	1.28	1.24	1.23							1.26	0.03	
	Permeability (cm./ sec.)													
		0.59	0.59	0.58	0.57							0.58	0.01	
	Flow Rate (gal/ min./ ft.^{2})													
		96	95	93	92							94	2	

491

MD - MACHINE DIRECTION
TD - TRANSVERSE DIRECTION

Precision Geosynthetic Laboratories

APPENDIX B
SURFACE HYDROLOGY CALCULATIONS

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : Yolo County Central Landfill User: TVR Date:
County : Yolo State: CA Checked: ____ Date: _____
Subtitle: Waste Management Unit 6 drainage ditch
Subarea : 68

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
			Acres (CN)			
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	-	12(94)
OTHER AGRICULTURAL LANDS						
Pasture, grassland or range		good	-	-	-	56(80)
Total Area (by Hydrologic Soil Group)						68

SUBAREA: 68 TOTAL DRAINAGE AREA: 68 Acres WEIGHTED CURVE NUMBER:82

TR-55 Tc and Tt THRU SUBAREA COMPUTATION VERSION 1.11

Project : Yolo County Central Landfill User: TVR Date:
County : Yolo State: CA Checked: ____ Date: _____
Subtitle: Waste Management Unit 6 drainage ditch

Subarea #1 - 68

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.3	300	.05	F					0.468
Shallow Concent'd		300	.05	U					0.023
Shallow Concent'd		50	.25	U					0.002
Open Channel		2300						1	0.639
								Time of Concentration =	1.13*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : Yolo County Central Landfill User: TVR Date:
County : Yolo State: CA Checked: ____ Date: _____
Subtitle: Waste Management Unit 6 drainage ditch

Total watershed area: 0.106 sq mi Rainfall type: I Frequency: 100 years

	Subareas
	68
Area(sq mi)	0.11*
Rainfall(in)	4.5
Curve number	82*
Runoff(in)	2.64
Tc (hrs)	1.13*
(Used)	1.25
TimeToOutlet	0.00
Ia/P	0.10
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 68
9.0	3	3
9.3	4	4
9.6	6	6
9.9	8	8
10.0	9	9
10.1	11	11
10.2	13	13
10.3	17	17
10.4	22	22
10.5	29	29
10.6	36	36
10.7	42	42
10.8	46	46
11.0	50P	50P
11.2	46	46
11.4	39	39
11.6	32	32
11.8	27	27
12.0	24	24
12.3	20	20
12.6	17	17
13.0	15	15
13.5	13	13
14.0	11	11
14.5	10	10
15.0	9	9
15.5	9	9
16.0	8	8
17.0	8	8
18.0	7	7
20.0	6	6
24.0	4	4

P - Peak Flow * - value(s) provided from TR-55 system routines

Job No. 931010.17 Job Name: Yolo County
Sheet No. 1 of 1
Calculated By: TVR Date: 11/10/00
Checked By: Date:
Scale:

VECTOR ENGINEERING, INC.
Grass Valley, CA • Santiago, Chile • Mendoza & Buenos Aires, Argentina • Lima, Perú • Manila, Philippines
12438 Loma Rica Drive, Suite C, Grass Valley, CA 95945 tel: (530) 272-8533 fax: (530) 272-8533

Peak Discharge for West Side Culvert for Module D

Peak Discharge for Entire Watershed = 50cfs

Total Area of Entire Watershed = 68 acres

Area Watershed Reporting to West Side Culvert = 26.9ac

Prorated Peak Discharge for West Side Culvert = **19.8cfs**

Culvert Size per "Handbook of Steel Drainage & Highway Construction Products", 1971

West Side (19.8cfs) ⇒ **36 inch @ 3/4 full**

South Side (Entire Watershed-50cfs) ⇒ **42 inch @ Full Flow**

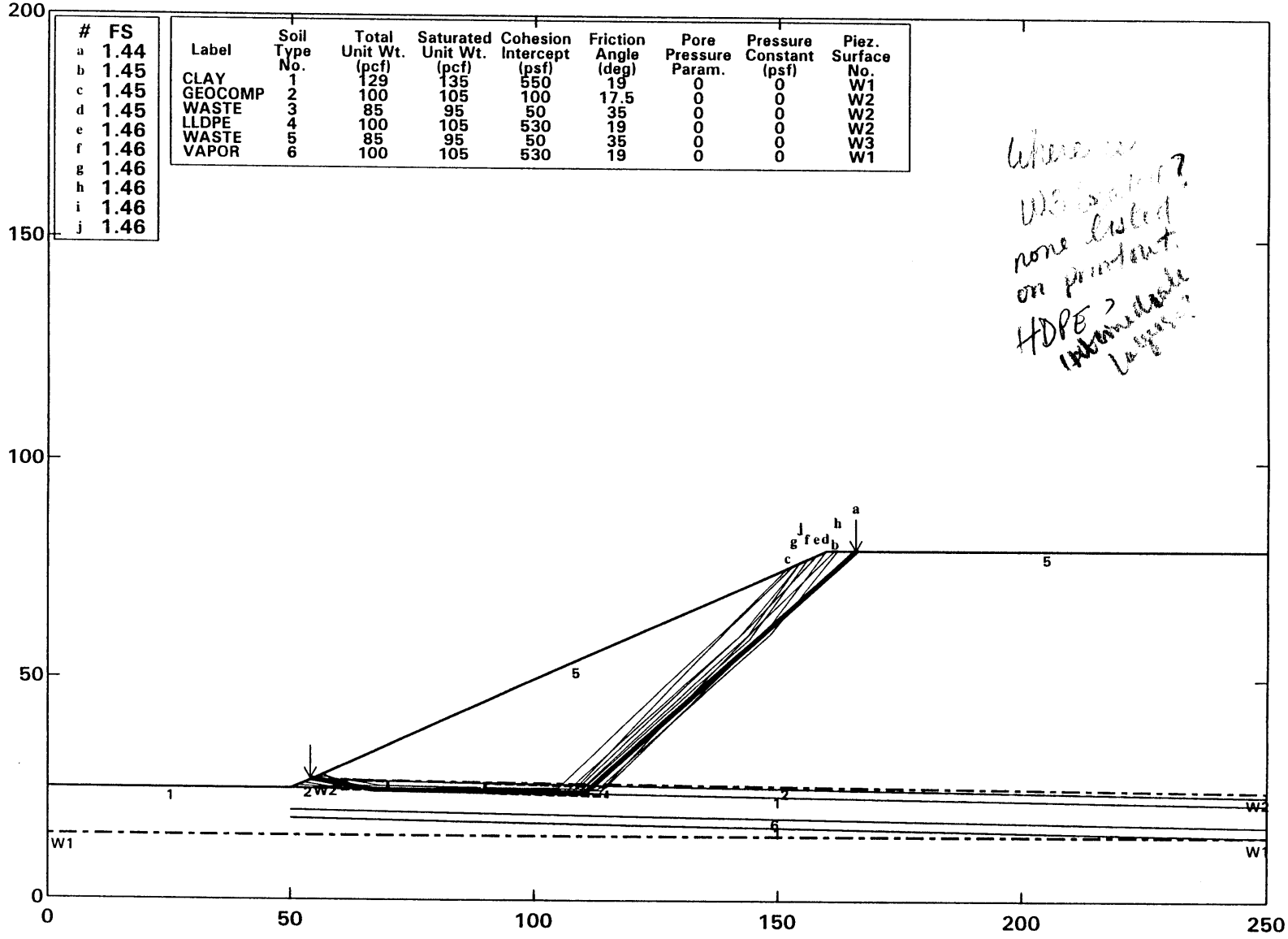
APPENDIX C
RESULTS OF STABILITYANALYSIS – CRITICAL SURFACE

YOLO COUNTY LANDFILL BIOREACTOR ANAEROBI C CELL, EAST SIDE, 2:1, PHI = 35, C = 50
Ten Most Critical. C:YOEAST42.PLT By: TODD RAMEY 3/09/2001 4:53pm

#	FS
a	1.44
b	1.45
c	1.45
d	1.45
e	1.46
f	1.46
g	1.46
h	1.46
i	1.46
j	1.46

Label	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
CLAY	1	129	135	550	19	0	0	W1
GEOCOMP	2	100	105	100	17.5	0	0	W2
WASTE	3	85	95	50	35	0	0	W2
LLDPE	4	100	105	530	19	0	0	W2
WASTE	5	85	95	50	35	0	0	W3
VAPOR	6	100	105	530	19	0	0	W1

Where is W3 water? none listed on printout. HDPE? Intermediate Layer?



PCSTABL5M FSmin = 1.44 X-Axis (ft)
Factors Of Safety Calculated By The Modified Janbu Method

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:	3/09/2001
Time of Run:	4:53pm
Run By:	TODD RAMEY
Input Data Filename:	C:YOEAST42
Output Filename:	C:YOEAST42.OUT
Plotted Output Filename:	C:YOEAST42.PLT

PROBLEM DESCRIPTION YOLO COUNTY LANDFILL BIOREACTOR ANAEROBI
C CELL, EAST SIDE, 2:1, PHI=35, C=50

BOUNDARY COORDINATES

4 Top Boundaries
8 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Below
1	.00	25.00	50.00	25.00	1
2	50.00	25.00	54.00	27.00	2
3	54.00	27.00	160.00	80.00	5
4	160.00	80.00	250.00	80.00	5
5	54.00	27.00	250.00	23.50	2
6	50.00	25.00	250.00	21.50	1
7	50.00	20.00	250.00	16.50	6
8	50.00	18.00	250.00	14.50	1

← why is this not 3 ?

1

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.

1	129.0	135.0	550.0	19.0	.00	.0	1
2	100.0	105.0	100.0	17.5	.00	.0	2
3	85.0	95.0	50.0	35.0	.00	.0	2
4	100.0	105.0	530.0	19.0	.00	.0	2
5	85.0	95.0	50.0	35.0	.00	.0	3
6	100.0	105.0	530.0	19.0	.00	.0	1

1

2 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	14.50
2	250.00	14.50

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	54.00	27.00
2	250.00	24.50

Janbus Empirical Coef is being used for the case of c & phi both > 0

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.

500 Trial Surfaces Have Been Generated.

2 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 50.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)

1	60.00	25.80	70.00	25.60	2.00
2	90.00	25.20	115.00	24.50	2.00

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	58.34	29.17
2	62.10	25.47
3	103.04	24.38
4	104.56	52.28

Factor Of Safety For The Preceding Specified Surface = 4.878

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	59.00	29.50
2	63.77	25.97
3	94.52	25.44
4	95.78	47.89

Factor Of Safety For The Preceding Specified Surface = 5.171

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	58.88	29.44
2	61.68	26.64
3	98.64	24.53
4	100.08	50.04

Factor Of Safety For The Preceding Specified Surface = 5.376

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.42	27.21
2	66.62	25.43
3	102.57	25.07
4	103.23	51.62

Factor Of Safety For The Preceding Specified Surface = 6.932

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

1	61.78	30.89
2	68.31	25.10
3	92.93	25.13
4	93.70	46.85

Factor Of Safety For The Preceding Specified Surface = 7.502

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	56.32	28.16
2	65.04	24.81
3	105.48	24.95
4	107.44	53.72

Factor Of Safety For The Preceding Specified Surface = 3.933

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	61.25	30.62
2	67.97	24.97
3	109.04	24.54
4	111.30	55.65

Factor Of Safety For The Preceding Specified Surface = 4.140

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	59.06	29.53
2	62.90	25.96
3	112.97	25.08
4	114.30	57.15

Factor Of Safety For The Preceding Specified Surface = 5.339

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	61.56	30.78
2	68.74	25.10
3	96.21	25.96
4	97.17	48.58

Factor Of Safety For The Preceding Specified Surface = 5.899

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined

By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	61.08	30.54
2	66.67	24.95
3	99.20	24.04
4	100.56	50.28

Factor Of Safety For The Preceding Specified Surface = 6.134

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	52.02	26.01
2	62.04	25.94
3	106.41	25.41
4	107.18	53.59

Factor Of Safety For The Preceding Specified Surface = 6.333

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	58.14	29.07
2	63.83	25.49
3	91.15	24.41

4	92.97	46.49

Factor Of Safety For The Preceding Specified Surface = 4.340

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	61.65	30.83
2	69.54	25.59
3	106.13	24.66
4	106.99	53.49

Factor Of Safety For The Preceding Specified Surface = 7.487

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	57.28	28.64
2	65.38	24.94
3	114.37	24.84
4	115.37	57.69

Factor Of Safety For The Preceding Specified Surface = 5.820

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	61.30	30.65
2	67.11	24.96
3	102.48	24.87
4	104.08	52.04

Factor Of Safety For The Preceding Specified Surface = 4.802

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	55.05	27.52
2	60.76	25.10
3	95.46	25.90
4	95.78	47.89

Factor Of Safety For The Preceding Specified Surface = 7.801

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	62.67	31.33
2	67.93	26.62
3	111.28	24.56
4	113.04	56.52

Factor Of Safety For The Preceding Specified Surface = 5.313

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	61.20	30.60
2	69.94	25.24
3	111.65	25.52
4	112.23	56.11

Factor Of Safety For The Preceding Specified Surface = 8.039

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	57.87	28.94
2	64.18	24.80
3	98.92	25.29
4	100.26	50.13

Factor Of Safety For The Preceding Specified Surface = 4.587

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	58.44	29.22
2	64.55	25.28
3	105.57	25.15
4	106.53	53.27

Factor Of Safety For The Preceding Specified Surface = 5.883

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.25	27.12
2	65.89	25.64
3	113.16	23.63
4	115.66	57.83

Factor Of Safety For The Preceding Specified Surface = 4.402

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	55.24	27.62
2	60.49	26.50
3	108.19	24.28
4	110.66	55.33

Factor Of Safety For The Preceding Specified Surface = 3.991

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	58.39	29.19
2	63.35	25.14
3	90.12	25.60
4	91.28	45.64

Factor Of Safety For The Preceding Specified Surface = 4.852

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

1	55.97	27.98
2	61.59	26.76
3	104.26	25.59
4	104.55	52.28

Factor Of Safety For The Preceding Specified Surface = 11.127

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	57.76	28.88
2	64.22	25.15
3	96.68	25.26
4	98.39	49.20

Factor Of Safety For The Preceding Specified Surface = 4.127

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	51.83	25.92
2	65.91	24.82
3	112.03	24.62
4	114.72	57.36

Factor Of Safety For The Preceding Specified Surface = 3.444

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	58.64	29.32
2	62.57	25.83
3	104.07	25.19
4	106.28	53.14

Factor Of Safety For The Preceding Specified Surface = 3.929

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	58.95	29.47
2	63.73	25.62
3	96.77	25.47
4	97.65	48.83

Factor Of Safety For The Preceding Specified Surface = 6.064

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.09	27.04
2	66.97	24.73
3	110.34	23.95
4	145.70	59.31
5	165.97	80.00

*** 1.436 ***

Individual data on the 9 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	.3	2.2	.0	.0	.0	.0	.0	.0	.0
2	.0	.2	.0	.0	.0	.0	.0	.0	.0
3	12.6	5046.1	.0	840.5	.0	.0	.0	.0	.0
4	43.4	75447.8	.0	5997.3	.0	.0	.0	.0	.0
5	2.0	5274.5	.0	232.2	.0	.0	.0	.0	.0
6	.3	753.1	.0	.0	.0	.0	.0	.0	.0
7	33.1	61264.0	.0	.0	.0	.0	.0	.0	.0
8	14.3	11935.7	.0	.0	.0	.0	.0	.0	.0
9	6.0	1547.4	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	52.50	26.25
2	60.06	24.94
3	113.87	24.80
4	146.16	62.98
5	161.43	80.00

*** 1.449 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	51.06	25.53
2	67.17	24.78
3	105.08	25.41
4	139.39	61.78
5	151.80	75.90

*** 1.451 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	55.39	27.69
2	62.02	25.06
3	113.50	24.00
4	147.27	60.87
5	159.64	79.82

*** 1.451 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	55.57	27.79
2	60.10	25.14
3	108.64	25.00
4	142.98	61.34
5	157.74	78.87

*** 1.458 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	56.67	28.34
2	60.53	25.00
3	108.93	24.04
4	144.18	59.50
5	155.87	77.94

*** 1.460 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.03	27.02
2	64.68	24.77
3	107.78	24.44
4	140.27	62.45
5	153.01	76.50

*** 1.463 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	55.38	27.69
2	68.44	25.47
3	113.05	25.13
4	148.31	60.59
5	162.22	80.00

*** 1.463 ***

1

Failure Surface Specified By 5 Coordinate Points

Point	X-Surf	Y-Surf

No.	(ft)	(ft)
1	54.55	27.27
2	63.06	25.51
3	106.97	24.77
4	142.25	60.20
5	154.83	77.42

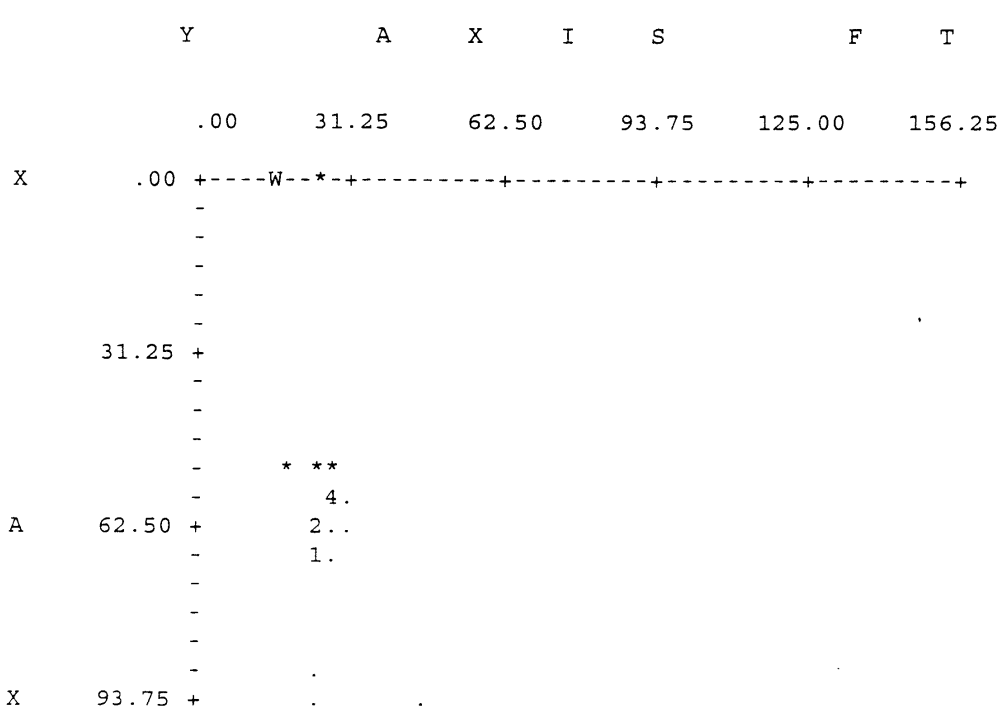
*** 1.464 ***

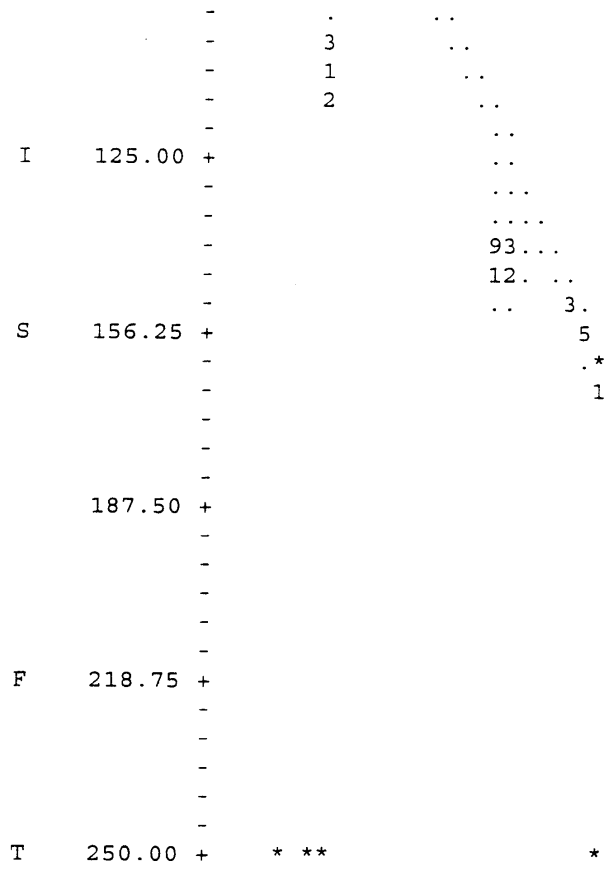
Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	56.28	28.14
2	65.58	24.98
3	109.11	24.30
4	143.65	60.45
5	154.34	77.17

*** 1.464 ***

1

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APPENDIX H – BIOFILTER EMISSION RESULTS

CE Schmidt, Ph.D.
Environmental Consultant

April 21, 2004

Mr. Ramin Yazdani
Yolo County Public Works Department
Division of Integrated Waste Management
292 West Beamer Street
Woodland, CA 95695

Dear Mr. Yazdani:

Enclosed please find (1) copy of the draft work plan for the flux chamber testing program at the Yolo County landfill and biofilter research site located in Woodland, California. This testing program involves conducting a baseline air emissions testing from two biofilters established for removal of constituents from the research landfill cells. The goal is to provide data that can assist in the research effort by assessing fugitive air emissions from the biofilter system.

Testing is scheduled for Friday, April 30, 2004, on site at 0900. Please send me a map where the site is located and an address/contact phone number. Mr. Rash will not be conducting testing with us on Friday.

Please call with any questions that you may have and thanks for your help.

19200 Live Oak Road Red Bluff, CA 96080 (530) 529-4256 FAX- 4878

CE Schmidt, Ph.D.
Environmental Consultant

Sincerely,

CE Schmidt, Ph.D.

SOURCE TEST PROTOCOL
BIOFILTER FACILITY BASELINE EMISSIONS TESTING AT THE YOLO COUNTY RESEARCH FACILITY LOCATED IN WOODLAND, CALIFORNIA USING THE USEPA FLUX CHAMBER FOR FUGITIVE EMISSIONS

DRAFT

Prepared for:

Mr. Ramin Yazdani
Yolo County Public Works Department
Division of Integrated Waste Management
292 West Beamer Street
Woodland, CA 95695

19200 Live Oak Road Red Bluff, CA 96080 (530) 529-4256 FAX- 4878

CE Schmidt, Ph.D.
Environmental Consultant

Prepared by:

CE Schmidt
19200 Live Oak Road
Red Bluff, California 96080

April 2004

CE Schmidt, Ph.D.
Environmental Consultant

TABLE OF CONTENTS

19200 Live Oak Road Red Bluff, CA 96080 (530) 529-4256 FAX- 4878

CE Schmidt, Ph.D.
Environmental Consultant

1.0 INTRODUCTION

This source test protocol describes the methodology and sampling procedure for using the USEPA surface emission isolation flux chamber to assess fugitive air emissions in support of a Yolo County Public Works Department, Division of Integrated Waste Management (DIWM) research project. A conceptual approach has been developed that uses the USEPA surface emission isolation flux chamber assessment technology to assess air emissions from the face of two biofilter units that may be operated at different feed rates. The proposed program can satisfy the objective of assessing actual air emissions from the biofilter units; the duct sample collection activity (needed to determine removal efficiency in the biofilters) and the analysis of samples collected from both the ductwork leading to the biofilters and the samples collected from the flux chamber are not included in this proposal and are the responsibility of the Yolo County DIWM.

A description of the history, background, and operation of the USEPA recommended surface emission isolation flux chamber (flux chamber) is provided along with sampling and analytical protocol, sampling strategy, quality control requirements, and sample management protocol.

This source-specific test protocol is intended to provide area source flux data representative of site-specific fugitive air emissions of hydrocarbon compounds including methane from the research biofilter unit treatment process. Data will be collected representing volatile organic compound (VOC0 flux and fixed gases including methane from representative surfaces on one or both biofilter units. The number of samples and test locations indicated below

represent a cost-effective strategy that will provide unique characterization data and are subject to change based on process operation and site conditions.

The testing scheduled for the site is summarized below. Testing will be conducted on the biofilter operated in a start-up condition and later throughout the remainder of the research program. The testing strategy includes a total of six field samples for the start-up testing and 1 media blank and 1 field replicate sample. Testing at other times will include the use of the testing protocols described herein and will vary in sampling effort based on the objective of each process-related activity or condition of the biofilter.

The technical effort includes: preparing and submitting a source test protocol for the collection of flux data; preparation of field test equipment including flux chamber equipment and expendable field supplies; field testing including flux chamber testing at up to 6 locations for the start-up condition test, chain-of-custody; sample shipping; sample analysis for VOCs and methane; laboratory reporting and review of laboratory data, reporting of the source test results.

2.0 HISTORY, BACKGROUND, AND OPERATION OF THE EPA RECOMMENDED SURFACE EMISSION ISOLATION FLUX CHAMBER

This section briefly describes the history, background, and operation of the US EPA-recommended surface emission isolation flux chamber. This device is used to measure the emission rates from surfaces emitting gas species. The primary reference for this section is the document entitled "Measurement of Gaseous Emission Rates from Land Surfaces Using

an Emission Isolation Flux Chamber, Users Guide," US EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, US EPA Contract No. 68-02-3889, Work Assignment No. 18, February 1986 [1].

2.1 History

Assessing the rate of emissions of gas phase species from area sources has been, and continues to be, a challenge for scientists and engineers. The interest in assessing emission rates from area or "fugitive" sources has been steadily increasing over the past 23 years, largely due to two factors:

1) Fugitive emission sources are contributing to the non-attainment of state and federal ambient air quality standards; and

2) Fugitive emissions from controlled and uncontrolled facilities are often toxic (air toxics) and the impact to receptors near these sources is an issue.

The later has been the primary driving force in the development of the current emission assessment methods, in particular, the flux chamber method. There are four basic assessment approaches for assessing air emissions rates: direct measurement technologies; indirect measurement technologies; fenceline monitoring and modeling technologies; and predictive emission modeling. The most promising of these approaches is the direct measurement approach[2]. One reason for this is that there is no modeling or estimation involved which reduces the uncertainty in the assessment. If emission rate data are to be used as input to exposure assessment and health risk assessment, it is important to use

measured versus modeled emission rate input data. This will reduce the uncertainty in the health risk assessment output.

Although the other three approaches have been used successfully, the direct approach is versatile, provides reproducible emission rate data, and is a cost-effective assessment approach. The other advantages include superior detection limit capabilities, the lack of upwind interferences, and the operation of the technology is not dependent upon meteorological conditions.

The use of enclosures for assessing emission rates was first reported in the literature by Zimmerman[3] (1977) and Adams[4] (1978). The basic approach uses an enclosure or chamber of some design to isolate a surface emitting gas species. The chamber must be well characterized and qualify as a continuously stirred reactor. Clean sweep air is added to the chamber at a controlled, fixed rate, and the contents are sampled and analyzed for species of concern. The emission rate of species, ERi (milligrams per minute per square meter), is calculated by knowing the sweep air flow rate, Q (cubic meters/minute), species concentration Yi (milligrams/cubic meters), and exposed (to the chamber) surface area A (square meters) as follows:

$$ERi = (Q, m3/min)\ (Yi, ug/m3) / (A, m2) \qquad \text{Equation 1}$$

This emission assessment approach has been used on a variety of solid and liquid surfaces and for a variety of species[5].

2.2 Background

The development of the current EPA-recommended flux chamber started with the need to assess the emissions of air toxics at an uncontrolled hazardous waste landfill (superfund site) as part of a Remedial Investigation effort. Literature on direct measurement technologies was used to develop flux chambers of different size, shape, and construction materials. After several site assessment reports where this technology was used at uncontrolled superfund sites, EPA became interested at using the approach to characterize fugitive emissions from controlled treatment, storage, and disposal facilities (TSDFs). This interest leads to a study where the most promising direct, indirect, and predictive modeling technologies were evaluated by conducting side-by-side emission rate assessments at TSDFs. The results of this study demonstrated the advantages of the flux chamber measurement technology when compared to the other assessment technologies. Further interest lead to the redesign and parametric evaluation of the flux chamber as described in the EPA Users Guide. This design represents the best compromise in design, construction materials, and suitability for different types of applications. EPA then funded the preparation of the Users Guide, which provides the results of the chamber evaluation and recommended operating protocols.

Test data indicate that the flux chamber is a reliable assessment technology. Precision is reported at $\pm$5 percent and accuracy is $\pm$30 percent. The recovery studies conducted on 40 hydrocarbon species (alkanes, alkenes, aromatics, halogenated, sulfur containing, cyclic) averaged 103 percent[1]. The sensitivity and range of the technology is a function of the analytical methods used, the selection of operating conditions, the level of the emission source, and, to some degree, the type of species encountered.

3.0 QUALITY CONTROL

Quality control procedures that are used to assure quality data are listed and described below. The flux chamber has no specific quality control requirements except that the flow meter used to introduce the sweep air at 5.0 liters per minute requires representative calibration (i.e., multipoint calibration using a primary standard current for the year). The rotometer used as part of the emission measurement test should not be used for other applications insuring the clean operation of the air introduction system. Operation of the chamber should follow the specific protocol for use described in the USEPA User's Guide. This includes using a 5.0 liters per minute sweep air flow rate and allowing for 5 residence times equilibration prior to sample collection. Other sampling quality control procedures are listed below.

System Blank Sample -- A system blank sample is obtained by operating the flux chamber as per protocol on a clean Teflon surface and filling the sample media as a sample, and submitting the blank sample for analysis. The frequency of blank samples is a minimum of 5% or one per batch. A system blank sample will be collected at the onset of testing.

Replicate Sample -- Determine sample precision by collecting a replicate sample immediately after a sample is collected. The frequency of replicate sample collection is 5% or one per mill. The criteria for acceptable field precision is ±50% relative percent difference (RPD).

Specific Method Performance -- Specific method quality control is conducted as per ASTM Method E-679-91 for olfactory odor analysis.

Sample Management -- Sample management is defined by the specific sampling method used to satisfy the program objectives. A summary of the sample management information for the field measurement activities is given in Table 1.

Data qualifiers that will be used to assist in data usage include: J- estimated value or below method detection limit; B- value found in blank sample and data may be baseline corrected; and E- value found at level that exceeds calibration range. Laboratory recovery and precision data, as well as field precision data, will be used to qualify data usage on data tables and in the text of the report.

3.1 FIELD QC SUMMARY

The field QC activities scheduled for the field testing are summarized in Table 2. Deviation in schedule or frequency in QC activities will require corrective action including documentation of corrective action in the field notebook and notifying Total Compliance Management of the deviation and corrective action.

3.2 SAMPLE MANAGEMENT SUMMARY

Sample management includes all activities involving the recording, preserving, storing, handling, and shipping of the field samples. These activities are summarized below by method in Table 1.

4.0 SAMPLING STRATEGY

The sampling strategy includes using the flux chamber to assess the area source emissions of project target compounds from the operating biofilter facilities. The data collection approach

will involve using the USEPA recommended surface emission isolation flux chamber. This approach will provide data of high quality (accuracy and precision) that will be representative of target compound emissions from unique components released as fugitive air emissions from the biofilter operations. The technical approach provided below will generate a minimum data set that can be used to estimate the emissions (species and flux rate) from the biofilters.

This source-specific test protocol is intended to provide area source flux data representative of the fugitive air emissions from the biofilter units. Data will be collected representing VOC emissions and fixed gases from the operating units. The number of samples and test locations indicated below are subject to change based on process operation and site conditions, and may be finalized after a site walk-through prior to the site assessment.

The goal of this technical approach is to provide a matrix of flux data on unique surface representing the emissions from the biofilter units as a start-up conditions emissions assessment. The matrix of representative flux data is used, along with detailed operations knowledge of the process and estimates of surface areas these sources, to generate the baseline emissions estimate.

All analytes will be tested for at all locations. The total sample count is up to 6 field samples and 2 QC samples. The technical effort includes: preparing and submitting a source test protocol for the collection of flux data; preparation of field test equipment including flux chamber equipment and expendable field supplies; field testing including the collection of up

to6 field samples (plus 2 QC samples); chain-of-custody; sample shipping; sample analysis for VOC/fixed gases; and reporting of the source test results.

The standard operating procedure using the flux chamber includes placing the chamber approximately 1/4"-to-1" into the surface emitting the target compounds (forming an air-tight seal) and adding clean, sweep gas (ultra high purity air) until the contents are at equilibrium. (Note- media materials will also be added to the outside wall of the chamber to assist in sealing the chamber to the surface preventing ambient air infiltration into the chamber from the bottom seal.) This occurs after about four or five residence times or about 30 minutes (following the USEPA flux chamber User's Guide). At equilibrium, the grab samples for VOC analysis and instrument measurements will be collected/conducted. The flux chamber testing in the field per location will require about one hour per sample. Site operations will need to be altered to create the test surfaces of interest.

The sample matrix shown in Table 3 will generate the minimum QC samples and field data from up to 6 locations. The total sample count for the start-up program is up to 8 samples. A summary of all sample collection is given below. All surface area data will be reported in flux units (ug/m2,min-1 or mg/m2,min-1) and these data, along with unit dimensions, will be used to calculate species emissions from the biofilters.

5.0 PROJECT INSTRUCTIONS

It is estimated that the start-up field testing will require one day of flux chamber testing using one flux chambers. This will require a crew of one person and one complete flux chamber system.

5.1 SCHEDULE

The project will be executed on the schedule given below. The project team will arrive the morning of testing. All equipment and field supplies will be inventoried and pre-testing calibrations will be performed. The first order of business will be to review health and safety issues (if necessary) and orient to the site. Then, locations for testing will be selected. After this, testing will be conducted the remainder of the day. It is anticipated that all testing will be completed within one day per facility. All field progress will be recorded in a project logbook and all chain-of-custody will be completed on the day of sample collection. All shipping records will be retained as part of the field data set and the person shipping samples is responsible for contacting the laboratory prior to sample receipt.

PROJECT SCHEDULE

Draft Work Plan	04/22/04
Final Work Plan	Within Five (5) Days of Receipt of Comments
Field Sampling	04/30/04
Draft Report	Ten (10) Working After Receipt of Lab Data
Final Report	Within 5 Days of Receipt of Comments from Contractor

5.2 EQUIPMENT LIST

The list of field equipment and expendable supplies for the proposed field testing is provided below. All sampling media (prepared as per method specifications) is to be provided by the laboratories, including tedlar bags. The laboratory typically provides the sampling media for this method and conducts blank testing to insure proper laboratory service. Dr. C.E. Schmidt will supply all other sampling equipment. CE Schmidt will supply the flux chamber system that will be required for this effort. The complete flux chamber system shall include the following:

1) Modified USEPA flux chamber as per USEPA design including stainless steel Swage-lock fittings,
2) Support cooler with a mounted rotometer (0-to-5 liter per minute) through the cooler walls,
3) Brass, 2-stage regulator for bottled air (CGA 590 fitting for air and 1/4" Swage-lock (male) adaptor fitting,
4) Ten foot, 1/4" Teflon line with female fittings,
5) Ten foot, 1/4" Teflon air inlet/outlet support line,
6) Large size plastic support cooler,
7) Set of miscellaneous hand-tools including an adjustable crescent wrench for the CGA 580 regulator fitting, small adjustable crescent wench for the 1/4" swage fittings, assorted medium and small size screw drivers,
8) Teflon sheet (1/32" or thicker) for blank system testing,
9) Type K thermocouple wires (2, 12') and temperature readout,
10) Rigid-wall shipping/storage crate for the flux chamber mounted on roller wheels,
11) Open-bed truck or van or sampling vehicle (rent vehicle),

12) Decontamination supplies including Alconox soap, paper towels, and wash water,

13) One (1) bottle of ultra high purity air (size 150) supplied by CE Schmidt,

14) Purge pump for sample line purging, and

15) Hand tools.

6.0 SAMPLING PROTOCOLS

6.1 US EPA RECOMMENDED SURFACE ISOLATION FLUX CHAMBER

The surface emission isolation flux chamber (flux chamber) can be used on any liquid surface and solid surface. The only requirement regarding application is that there must be access to the surface for testing. If the surface cannot support the chamber, the chamber must be suspended or equipped with a flotation devise or suspended from over-head. The most critical issue regarding application is that the location and number of locations for testing be sufficient so that these data can be used to calculate the total emissions from the emitting surface area.

Volumetric flow is assessed by either recovering a trace gas that is added to the sweep air, or by measuring the flow using a calibrated bag on the exhaust port of the chamber. Carbon monoxide is used as a tracer and the recovery of carbon monoxide, as compared to the added amount, is used to calculate an 'advective flow' correction factor for each measurement. If there is no measurable volumetric flow from a green material pile location, then the carbon monoxide level in the flux chamber will equal that of the QC response of the field carbon monoxide instrument on the sweep air from the standard gas bottle. Advective correction factors are commonly used to generate an accurate flux assessment from advective flow

surfaces and will be used for this baseline investigation. At a minimum, the volumetric flow calculated from process flow rates can be used to correct emission rates on this surface.

The operation of the flux chamber involves: 1) identifying the test area; 2) initiating sweep gas flow rate to the flux chamber; 3) operating the chamber for at least four residence times; 4) collecting exhaust gas for analysis and/or recording instrument response; 5) decontaminating the chamber; and 6) relocating the measurement equipment to the next test area. The specific operating protocol for soil surfaces is given below.

1) Locate the flux chamber, sweep gas, sample collection equipment, and field documents at the test location. Perform screening activities as needed to select the exact test location (i.e., venting, non-venting surface).

2) Document site information, location information, equipment information, name of sampler, date, and time on the Field Data Sheet.

3) Select the exact test location and place the chamber approx. 1/4"-to-1" into the test surface. Biofilter media should also be piled along the outside edge to insure sealing. The chamber should be sealed along the base preventing air infiltration. Thermocouples will be used to measure the media/air temperatures.

4) Initiate the sweep gas flow rate and set the rotometer at 5.0 liters per minute. Constant sweep gas flow rate is critical. Record time.

5) Collect instrument background data (gas analyzers, thermocouples) and record data if needed.

6) Operate the chamber sweep air flow rate at 5.0 liters per minute and record data every residence time (6 minutes) for four to five residence times or 24 to 30 minutes. Record data. The chamber is at steady-state.

7) Connect the purge pump. A total of 5.0 liters per minute is added to the chamber and the gas not sampled is exhausted out the pressure equalization port in the top of the chamber. The chamber is operated at near atmospheric pressure. Do not exceed an exhaust gas sample/purge rate of 2.5 liters per minute. This will prevent entraining of ambient air into the chamber and maintain an exhaust rate of at least 2.5 liters per minute out of the pressure equalization port. Ten plunges of the hand pump are adequate.

8) Interface the canister to the purged sample line and collect the grab sample by slowly filling the tedlar bag sample(s) and metering the collection rate. Do not exceed a collection rate of 2.5 liters per minute at any time. This will prevent unwanted dilution of chamber exhaust gas by ambient air.

9) Collect any field measurement data by interfacing the purged sample line to the measurement device (colorometric tube, micro-FID for total VOCs, CO analyzer for carbon monoxide tracer recovery, etc.), and collecting field data. Record the field data.

10) Discontinue the flux measurement, shut off the sweep air, remove chamber and secure equipment.

12) Decontaminate the chamber where contact was made with the green material using a clean paper towel and water (if needed) to remove any residual materials and condensation from the inside of the chamber. Purge the sample lines with sweep gas (5 lpm) for 2 minutes. Purging is accomplished by switching inlet and outlet lines at the cooler housing the rotometer.

13) Relocate equipment to the next test location and follow steps 1) through 14).

6.2 GRAB SAMPLING

Grab samples using tedlar bags will be collected from the purged exhaust line of the flux chamber at steady-state conditions for VOC analysis and fixed gas analysis. Sampling rate will be maintained at less than 2.5 lpm. Canister samples will collected by interfacing the canister to the sample line using the 1/4" Swage-lock fittings, drawing a vacuum on the sample line from the canister and filling the canister over the appropriate time period.

7.0 ANALYTICAL PROTOCOLS

This section describes the analytical protocols that will be used to analyze the field samples. Copies of all protocols used are available upon request.

7.1 TO-15 HYDROCARBON SPECIATION/FIXED GASES ANALYSIS

Flux chamber samples will be analyzed by USEPA Method TO-15 operated in the full scam mode. A copy of the analytical method is available on request. TO-15 retrieves whole air sample from a Summa polished, stainless-steel canister. Sample is transferred from the canister that is sampled at atmospheric pressure to the analytical system by pressurizing the canister with ultra-pure nitrogen. An aliquot of sample is retrieved by the pressurized canister to the sample loop and cryotrap. Calibrated volumes of sample are frozen in the trap and then desorbed via heating and transferred into the GC/MS. The project compound list was derived from historic groundwater data is represented below along with expected method detection limit (MDL) and reporting limit (RL) information.

The method detection limit (MDL) for EPA TO-15 utilizing gas chromatography/mass spectrometry (GC/MS) in the full scan mode is about 0.1 ppbv or less, or a flux of less than about 0.02 ug/m2,min-1 for VOCs.

Fixed gases can also be analyzed from the canister using a variety of methods.

7.2 DETECTOR TUBE AND INSTRUMENT SCREENING FOR VOCs, CARBON MONOXIDE, HYDROGEN SULFIDE, AND AMMONIA

Screening-level data may be collected for VOCs, carbon monoxide, or other compounds from the flux chamber using field instruments and measurement devices. Gas species emitted from the biofilters can be detected using instruments, including total VOCs and other compounds. Carbon monoxide can also be used as a tracer added to the sweep air and is also detected using a field instrument. Gas samples are withdrawn from the flux chamber (post

steady state conditions) by interfacing the instrument or colorometric tube of interest to the purged sample collection line, and collecting field readings until a stable or repeatable detection is recorded. These screening-level data are not critical to the program, but do provide useful information that can be obtained with minimal effort.

REFERENCES

1) US EPA, "Measurement of Gaseous Emission Rates from Land Surfaces Using an Emission Isolation Flux Chamber- User's Guide," EPA 600/8-86-008 (NTIS PB86-223161), February 1986.

2) US EPA, "Procedures for Conducting Air Pathway Analysis for Superfund Activities, Interim Final Documents, Volume 2- Estimation of Baseline Air Emissions at Superfund Sites, EPA-450/1-89-002a (NTIS PB90-270588), August 1990.

3) Zimmerman, Pat. "Procedures for Conducting Hydrocarbon Emission Inventories of Biogenic Sources and Some Results of Recent Investigations." Presented at the 1977 EPA Emissions Inventory/Factor Workshop, Raleigh, North Carolina, September 13-15, 1977.

4) Adams, D.T., et al, "Measurement of Biogenic Sulfur-Containing Gas Emissions from Soils and Vegetation." Presented at the 71st Annual Meeting of the APCA, Houston, Texas, June 25-30, 1978.

5) Winegar, E.D., L.H. Keith editors, Sampling and Analysis of Airborne Pollutants, C.E. Schmidt, Chapter 3, "Theory and Applications of the US EPA Recommended Surface Emission Isolation Flux Chamber for Measuring Emission Rates of Volatile and Semi-volatile Species." Lewis Publishers, Ann Arbor, Michigan, 1993.

Table 1. Summary of Sample Management Information.

Analytical Method	Sample Container	Hold Time	Preservation	Special Consider-ations	Comment
USEPA TO-15	Summa Canister	14-Days	Close Valve; Cap Port	Store sample in protective container	None

Table 2. Summary of Field Quality Control Information.

Sampling Method	Activity	Frequency	Criteria	Comment

Flux Chamber	Rotometer Single-Point Calib.	Once per year	Define Rotometer Setting	None
Field Blank	All media	5%	None	Use As Baseline Data
Replicate Sample	All media	5%	± 50 RPD	Qualify Exceedences

CE Schmidt, Ph.D.
Environmental Consultant

Table 3. Testing Schedule- Summary of Sampling Schedule- Start-up Test.

TEST CONDITION	VOC FLUX	COMMENT
Open Soil Flux on the Biofilter #1	3	Define the Range and Maximum Flux on the Biofilter Surface
Open Soil Flux on the Biofilter #2	3	Define the Range and Maximum Flux on the Biofilter Surface
Field Blank	1	1 Flux
Field Replicate	1	1 Flux
TOTAL FLUX	8	

19200 Live Oak Road Red Bluff, CA 96080 (530) 529-4256 Fax- 4878 ***ceschmidt.com*** ***schmidtce@aol.com***
CES#042004

SAMPLES		
TOTAL DUCT SAMPLES	3	12" Duct (main), Each 6" Duct (to Biofilter #1 and #2)
TOTAL CANISTER SAMPLES (TO-15; Fixed Gases)	12	

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SANTA CLARA OFFICE
May 24, 2004
Lab. No. 50748

YOLO COUNTY PLANNING AND PUBLIC WORKS
292 W. Beamer St.
Woodland, CA 95695

Attn: Ramin Yazdani

RE: BIOFILTER TEST-WOODLAND

BACKGROUND

The three samples received represent organic biofilter materials that are for use in a gas-cleaning project. Sample 1 and 2 are assumed to represent unused materials since only #3 was described as having been used.

The detailed analysis of the media is performed on just the smaller than 1/2" fraction since that is the portion that is biologically the most active. Since a substantial amount of each these materials exceeds 1/2" moisture content as a percentage of weight was determined first on the entire sample and is also included in the analysis of only that 1/2" minus fraction. Particle size results also reflect the entire sample with data entered for the percentage by weight retained on the 1" screen and on the 1/2".

ANALYTICAL RESULTS

BIOFILTER MEDIA 1 AND 2

Differences between 1 and 2 are slight. Sample 2 is just a little coarser than 1 and this is both with respect to more material in excess of 1/2" and a slightly more coarse texture of the fraction passing the 1/2". In both cases very little of the material passes a 1.0-mm screen. Organic content as a percentage of weight is high compare to mature compost.

Moisture content of the entire sample is a little lower as a percentage of weight than when just determined on the 1/2" minus fraction. Values for the unscreened 1 and 2 materials are 62.4 and 64.2% while the screened samples show 50.7 and 62.7%.

Total elemental makeup does not appear to be significantly different between the two materials. Sample 2 shows slightly lower level of nitrogen, potassium, calcium, magnesium, manganese and iron but it is doubtful that the variation is to a degree of significance. Total nitrogen levels are fairly low and are resulting in high estimated carbon to nitrogen levels. In order for the microbial population to have sufficient nitrogen to accommodate the utilization of the organic component the C/N ratio should be less than 35, while these are in the 45-51 range.

YOLO COUNTY PLANNING AND PUBLIC WORKS
May 24, 2004
Lab. No. 50748

Both materials are slightly alkaline and show low levels of qualitative lime. This is typical for compost. Salinity, sodium and chloride are very safely low. Boron levels would be considered very slightly high for plants but at this level would not interfere with biological activity. Typically, a compost derived from a wide range of greenwaste materials will have high potassium content and also substantial phosphorous. This is not at all the case with these materials as phosphorous and potassium are very deficient. Available nitrogen is also quite low as a reflection of the high C/N ratio. All of the other required nutrients are available at normal levels.

USED MEDIA #3

Particle size data show this a little finer than the others both with respect to amounts larger than 1/2" and the distribution of sizes finer than 1/2". Organic content as a percentage of weight is in a range more normally associated with mature compost.

Moisture content as 61% for the unscreened sample is again a bit higher than the 56.9% found on just the 1/2" minus fraction.

The most significant difference in chemistry is with respect to potassium. Both total and available potassium are much higher than found in the unused materials. Total nutrient levels are also moderately higher for nitrogen, phosphorous, calcium, sulfur, copper, zinc and iron. The estimated carbon to nitrogen ratio at 29 does show an appropriate balance to support active microbial activity. Available levels of phosphorous, copper and zinc are moderately higher with magnesium sharply lower. Nitrogen availability is still very low and the other nutrients are in sufficient supply.

Chemical characteristics such as pH, salinity and the soluble levels of sodium and chloride remain favorable and no different than in the other two materials. Boron is also at about the same level.

DISCUSSION

Please feel free to call should you have any questions regarding the evaluation of these data. If the intent of samples 1 and 2 is to have a very active microbial population, then this may be inhibited by the present lack of nitrogen, phosphorous and potassium. There might also be some benefit to increasing calcium a little to put it in better balance with magnesium. Magnesium is presently about 1.8 times the calcium level. With respect to plant nutrition this should be greater than 2 and more ideally 3 or above. I am not sure how this might affect microbial activity but in the used media it is 3.8.

JIM WEST

E-mail 8 pages.

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292 W. Beamer St.
Woodland, CA 95695

Santa Clara Office
Lab No. 50748
BIOFILTER TEST-WOODLAND

Samples Rec'd: 5/7/04

Sample #	Analysis Requested	Quantity	Units	Sample Description & Log Number
11	Moisture Percentage	62.4	% as rec'd	Biofilter #1 04-A9098 23
12	Moisture Percentage	64.2	% as rec'd	Biofilter #2 04-A9099 23
13	Moisture Percentage	61.0	% as rec'd	Biofilter Media #3 04-A9100 23

5/18/04

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COMPOST EVALUATION
(A91)

Santa Clara Office
Lab No. 50748
BIOFILTER TEST-WOODLAND

Samples Rec'd: 5/7/04

TOTAL NUTRIENT LEVELS

Sample #	Percent N	P	K	Ca	Mg	Na	S	Parts Per Million Cu	Zn	Mn	Fe	B	Sample Description	Log Number
1	0.88	0.10	0.10	0.88	0.44	0.06	0.24	52	92	256	6874	58	Biofilter #1	1.0004-A9095 23 4

5/18/04

AVAILABLE NUTRIENT LEVELS

Sample #	Half Sat%/ TEC	pH/ Qual Lime	ECe	Parts Per Million Parts Dry Soil NO_3 N	NH_4 N	PO_4 P	K	Ca	Mg	Cu	Zn	Mn	Fe	Sat Ext B ppm	Sat Ext SO_4 S	Sat Ext meq/l Na As % ECe	Sat Ext meq/l Cl As % of ECe	-dilute- acid Fe %
1	148	7.2	1.4	10	12	114	199	3821	2372	4.8	48	36	128	1.46	4.4	4.9	4.3	0.112
	376	Low		0.1		0.6	0.2	0.6	2.7	0.6	2.6	0.9	0.7		1.5	31.6	27.9	

PHYSICAL PROPERTIES

Sample #	Fraction of Sample Passing 1/2 Inch Screen — As Received: Wt Percent Retained 1"	Wt Percent Retained 1/2"	Bulk Density lbs/yd³	Water Moisture %	Water Fraction lbs/yd³	Dry Matter lbs/yd³	Organic Fraction lbs/yd³	Mineral Fraction lbs/yd³	Values Based upon dry weight: Organic %	percent passing: 9.51 mm	6.35 mm	4.75 mm	2.38 mm	1.00 mm	0.50 mm	Est. C/N Ratio
1	11.1	28.3	1146	59.7	684	462	330	132	71.4	78.2	61.7	50.2	31.7	12.3	4.5	45.1

Salinity (ECe (dS/m at 25 deg.C.)) by sat ext method. Available Major Nutrients by sodium chloride extraction. Phosphorus by sodium bicarbonate extraction. Micronutrients by DTPA extraction. Interpretation guide below each element (1.0=predicted sufficiency level for average fertility requiring crops). TEC(listed below Half Sat)=Est. Total Exchangeable Cations (meq/kg) Total Nutrient values expressed as element in oven dried sample ground to 40 mesh. Total N (corrected for moisture content) is determined on as received sample. N=nitrogen, P=phosphorus, K=potassium Ca=calcium, Mg=magnesium, Na=sodium, S=sulfur, Cl=chloride, Cu=copper, Zn=zinc, Mn=manganese, Fe=iron and B=boron.

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COMPOST EVALUATION
(A91)

Santa Clara Office
Lab No. 50748
BIOFILTER TEST-WOODLAND

Samples Rec'd: 5/7/04

Sample 1 - Biofilter #1 Log Number 04-A9095

ELEMENT OF INTEREST	AMOUNT PER CUBIC YARD TOTAL	AMOUNT PER CUBIC YARD AVAILABLE	AMOUNT PER TON, As Rec'd at 59.7% Moisture TOTAL	AMOUNT PER TON, As Rec'd at 59.7% Moisture AVAILABLE	AVAILABLE % OF TOTAL
Nitrogen	4.06 lbs	0.01 lbs	7.09 lbs	0.02 lbs	0.25
Phosphorus	0.48 lbs	0.05 lbs	0.84 lbs	0.09 lbs	10.98
Potassium	0.46 lbs	0.09 lbs	0.81 lbs	0.16 lbs	19.85
Calcium	4.06 lbs	1.76 lbs	7.09 lbs	3.08 lbs	43.42
Magnesium	2.04 lbs	1.10 lbs	3.56 lbs	1.91 lbs	53.67
Sulfur	1.11 lbs	0.09 lbs	1.93 lbs	0.16 lbs	8.25
Copper	0.38 ozs	0.04 ozs	0.67 ozs	0.06 ozs	9.23
Zinc	0.68 ozs	0.35 ozs	1.19 ozs	0.62 ozs	52.2
Manganese	1.89 ozs	0.27 ozs	3.30 ozs	0.46 ozs	14.1
Iron	50.8 ozs	0.95 ozs	88.65 ozs	1.65 ozs	1.86
Boron	0.43 ozs	0.0319 ozs	0.74 ozs	0.0557 ozs	7.50
Organic Matter	330. lbs		575. lbs		

The above results reflect only the fraction smaller than 1/2 inch. If a substantial portion of this sample is larger than 1/2 inch, the above values should be adjusted accordingly if further screening is not intended. The coarse fractions will react much slower with the soil and not have significant impact upon soil nutrition over the short term.

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Lab No. 50748
BIOFILTER TEST-WOODLAND

Samples Rec'd: 5/7/04

TOTAL NUTRIENT LEVELS

Sample #	Percent N	P	K	Ca	Mg	Na	S	Parts Per Million Cu	Zn	Mn	Fe	B	Sample Description	Log Number
2	0.80	0.09	0.08	0.72	0.37	0.08	0.24	46	96	200	5596	62	Biofilter #2	1.0004-A9096 23 4

5/18/04

AVAILABLE NUTRIENT LEVELS

Sample #	Half Sat%/ TEC	pH/ Qual Lime	ECe	Parts Per Million Parts Dry Soil NO_3 N	NH_4 N	PO_4 P	K	Ca	Mg	Cu	Zn	Mn	Fe	Sat Ext B ppm	Sat Ext SO_4	Sat Ext meq/l Na As % ECe	Sat Ext meq/l Cl As % of ECe	-dilute- acid Fe %
2	176	7.3	1.0	11	12	59	214	3539	1737	7.0	46	32	108	1.27	3.0	3.7	3.5	0.090
	314	Low		0.1		0.3	0.2	0.6	2.2	1.1	2.9	0.9	0.7		1.0	33.7	31.8	

PHYSICAL PROPERTIES

Sample #	As Received Wt Percent Retained 1"	1/2"	Bulk Density lbs/yd³	Moisture %	Water Fraction lbs/yd³	Dry Matter lbs/yd³	Organic Fraction lbs/yd³	Mineral Fraction lbs/yd³	Values Based upon dry weight Organic %	Fraction of Sample Passing 1/2 Inch Screen percent passing 9.51 mm	6.35 mm	4.75 mm	2.38 mm	1.00 mm	0.50 mm	Est. C/N Ratio
2	20.8	22.5	1000	62.7	627	373	276	97	74.1	63.6	50.0	39.9	22.5	7.4	2.7	51.5

Salinity (ECe (dS/m at 25 deg.C.)) by sat ext method. Available Major Nutrients by sodium chloride extraction. Phosphorus by sodium bicarbonate extraction. Micronutrients by DTPA extraction. Interpretation guide below each element (1.0=predicted sufficiency level for average fertility requiring crops). TEC(listed below Half Sat)=Est. Total Exchangeable Cations (meq/kg) Total Nutrient values expressed as element in oven dried sample ground to 40 mesh. Total N (corrected for moisture content) is determined on as received sample. N=nitrogen, P=phosphorus, K=potassium Ca=calcium, Mg=magnesium, Na=sodium, S=sulfur, Cl=chloride, Cu=copper, Zn=zinc, Mn=manganese, Fe=iron and B=boron.

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COMPOST EVALUATION
(A91)

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BIOFILTER TEST-WOODLAND

Samples Rec'd: 5/7/04

Sample 2 - Biofilter #2 Log Number 04-A9096

ELEMENT OF INTEREST	AMOUNT PER CUBIC YARD TOTAL	AMOUNT PER CUBIC YARD AVAILABLE	AMOUNT PER TON, As Rec'd at 62.7% Moisture TOTAL	AMOUNT PER TON, As Rec'd at 62.7% Moisture AVAILABLE	AVAILABLE % OF TOTAL
Nitrogen	2.98 lbs	0.01 lbs	5.97 lbs	0.02 lbs	0.28
Phosphorus	0.32 lbs	0.02 lbs	0.64 lbs	0.04 lbs	6.86
Potassium	0.30 lbs	0.08 lbs	0.60 lbs	0.16 lbs	26.81
Calcium	2.69 lbs	1.32 lbs	5.37 lbs	2.64 lbs	49.15
Magnesium	1.39 lbs	0.65 lbs	2.78 lbs	1.30 lbs	46.70
Sulfur	0.90 lbs	0.06 lbs	1.79 lbs	0.12 lbs	6.87
Copper	0.27 ozs	0.04 ozs	0.55 ozs	0.08 ozs	15.2
Zinc	0.57 ozs	0.27 ozs	1.15 ozs	0.55 ozs	47.9
Manganese	1.19 ozs	0.19 ozs	2.39 ozs	0.38 ozs	16.0
Iron	33.4 ozs	0.64 ozs	66.79 ozs	1.29 ozs	1.93
Boron	0.37 ozs	0.0267 ozs	0.74 ozs	0.0534 ozs	7.21
Organic Matter	276. lbs		553. lbs		

The above results reflect only the fraction smaller than 1/2 inch. If a substantial portion of this sample is larger than 1/2 inch, the above values should be adjusted accordingly if further screening is not intended. The coarse fractions will react much slower with the soil and not have significant impact upon soil nutrition over the short term.

Soil and Plant Laboratory, Inc.

www.soilandplantlaboratory.com

352 Mathew Street
Santa Clara, CA 95050
408-727-0330 phone
408-727-5125 fax

YOLO COUNTY PLANNING & PUBLIC WORKS
292 W. Beamer St
Woodland, CA 95695

COMPOST EVALUATION
(A91)

Santa Clara Office
Lab No. 50748
BIOFILTER TEST-WOODLAND

Samples Rec'd: 5/7/04

TOTAL NUTRIENT LEVELS

Sample #	Percent N	P	K	Ca	Mg	Na	S	Parts Per Million Cu	Zn	Mn	Fe	B	Sample Description	Log Number
3	1.13	0.13	0.32	1.12	0.43	0.06	0.36	70	152	308	9518	66	Biofilter Media Used #3	1.0004-A9097 23 4

5/18/04

AVAILABLE NUTRIENT LEVELS

Sample #	Half Sat%/ TEC	pH/ Qual Lime	ECe	Parts Per Million Parts Dry Soil NO_3 N	NH_4 N	PO_4 P	K	Ca	Mg	Cu	Zn	Mn	Fe	Sat Ext B ppm	Sat Ext meq/l SO_4	Sat Ext meq/l Na As % ECe	Sat Ext meq/l Cl As % of ECe	-dilute- acid Fe %
3	140	7.2	1.2	9	16	158	1717	3712	965	9.2	64	30	142	1.65	4.5	3.8	1.7	0.140
	284	Low		0.1		0.9	2.2	0.8	1.4	1.6	4.5	1.0	1.0		1.5	29.1	12.9	

PHYSICAL PROPERTIES

Sample #	Fraction of Sample Passing 1/2 Inch Screen: As Received Wt Percent Retained 1"	1/2"	Bulk Density lbs/yd³	Water Moisture %	Water Fraction lbs/yd³	Dry Matter lbs/yd³	Organic Fraction lbs/yd³	Mineral Fraction lbs/yd³	Values Based upon dry weight: Organic %	percent passing 9.51 mm	6.35 mm	4.75 mm	2.38 mm	1.00 mm	0.50 mm	Est. C/N Ratio
3	8.3	17.9	933	56.9	531	402	238	164	59.1	77.9	66.2	57.7	41.9	24.3	11.8	29.1

Salinity (ECe (dS/m at 25 deg.C.)) by sat ext method. Available Major Nutrients by sodium chloride extraction. Phosphorus by sodium bicarbonate extraction. Micronutrients by DTPA extraction. Interpretation guide below each element (1.0=predicted sufficiency level for average fertility requiring crops). TEC(listed below Half Sat)=Est. Total Exchangeable Cations (meq/kg) Total Nutrient values expressed as element in oven dried sample ground to 40 mesh. Total N (corrected for moisture content) is determined on as received sample. N=nitrogen, P=phosphorus, K=potassium Ca=calcium, Mg=magnesium, Na=sodium, S=sulfur, Cl=chloride, Cu=copper, Zn=zinc, Mn=manganese, Fe=iron and B=boron.

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408-727-5125 fax

YOLO COUNTY PLANNING & PUBLIC WORKS
292 W. Beamer St
Woodland, CA 95695

COMPOST EVALUATION
(A91)

Santa Clara Office
Lab No. 50748
BIOFILTER TEST-WOODLAND

Samples Rec'd: 5/7/04

Sample 3 - Biofilter Media Used #3 **Log Number 04-A9097**

ELEMENT OF INTEREST	AMOUNT PER CUBIC YARD TOTAL	AMOUNT PER CUBIC YARD AVAILABLE	AMOUNT PER TON, As Rec'd at 56.9% Moisture TOTAL	AMOUNT PER TON, As Rec'd at 56.9% Moisture AVAILABLE	AVAILABLE % OF TOTAL
Nitrogen	4.54 lbs	0.01 lbs	9.74 lbs	0.02 lbs	0.22
Phosphorus	0.52 lbs	0.06 lbs	1.12 lbs	0.14 lbs	12.14
Potassium	1.29 lbs	0.69 lbs	2.76 lbs	1.48 lbs	53.65
Calcium	4.50 lbs	1.49 lbs	9.65 lbs	3.20 lbs	33.15
Magnesium	1.72 lbs	0.39 lbs	3.69 lbs	0.83 lbs	22.55
Sulfur	1.45 lbs	0.08 lbs	3.10 lbs	0.17 lbs	5.39
Copper	0.45 ozs	0.06 ozs	0.97 ozs	0.13 ozs	13.1
Zinc	0.98 ozs	0.41 ozs	2.10 ozs	0.88 ozs	42.1
Manganese	1.98 ozs	0.19 ozs	4.25 ozs	0.41 ozs	9.74
Iron	61.2 ozs	0.91 ozs	131.3 ozs	1.96 ozs	1.49
Boron	0.42 ozs	0.0297 ozs	0.91 ozs	0.0637 ozs	7.00
Organic Matter	238. lbs		509. lbs		

The above results reflect only the fraction smaller than 1/2 inch. If a substantial portion of this sample is larger than 1/2 inch, the above values should be adjusted accordingly if further screening is not intended. The coarse fractions will react much slower with the soil and not have significant impact upon soil nutrition over the short term.

Excelchem Environmental Labs

500 Giuseppe Court, Suite 3
Roseville, CA 95678
(916) 773-3664 voice
(916) 773-4784 fax

FAX COVER SHEET

Date: 24 MAY 2004

To: Peter Janicki

Fax Number: 319-857369

From: SHANNON

Total Pages (including cover sheet): (6)

Comments: Here are Your results for project Name: YOLO LF. If You have any questions please call.

Thank You!

Excelchem
Environmental Labs

Excelchem Environmental Labs
500 Giuseppe Ct., Suite # 3
Roseville, CA 95678

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Peter Janicki

Company/Address: CIWMB

Fax #:

Project Number/P.O#:

Project Name: YOLO LF

Project Location: DAVIS, CA

Sampler Signature: Janicki

Electronic Data Deliverables Request:
Global I.D.#:
COC #:
Location I.D.#:
Email Address:

ANALYSIS REQUEST

Page ___ of ___

Bill#: N/A
Due Date: 05/07

Sample ID	Sampling Date	Sampling Time	Container: VOA	SLEEVE	1L GLASS	PLASTIC	SUMMA	Method Preserved: HCl	HNO3	ICE	NONE	Matrix: WATER	SOIL	AIR	BTEX/TPH as Gasoline (602/8020/8015)	MTBE (8020/8260B)	TPH as Diesel (8015m)	TPH as Oil (8015m)	Total Oil & Grease (SM-18th Ed 5520B,F)/166	Pesticides (608/8081A)	PCBs (8082)	VOC Full list (8260B)	5 Oxygenates (8260B)	Methanol/Ethanol (8015/8260)	Lead Scavengers DCA/EDB (8260B)	Semi VOC Full List (8270C)	CAM 17 Metals: Wet	CAM 17 Metals: Total	Lead	Cd, Cr, Pb, Zn, Ni (CAM 5)	TO-15	Fixed Gases EPA 15/16	EPA 25C Mod.		Requested TAT: 12hr/24hr/48hr/72hr/1wk	LAB USE ONLY:
BF-P1	4/30	12:50									X			X																	X	X	X	X			A0404828
BF-P2	4/30	13:00									X			X																	X	X	X	X			A0404829
BF-P4D	4/30	13:04									X			X																	X	X	X	X			A0404830

Relinquished by:	Date	Time	Received by:	Remarks/Condition of Sample:
Peter Janicki	4/30	14:41		
Relinquished by:	Date	Time	Received by:	
Relinquished by:	Date	Time	Received by Laboratory:	Bill To:
	4/30	1441		

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812

Project: Yolo LF

Method: EPA TO15

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/05/04

Client Sample I.D.	BF-P1		BF-P2		BF-HP	
LAB. NO.	A0404828		A0404829		A0404830	
ANALYTE	R/L	Results	R/L	Results	R/L	Results
Dichlorodifluoromethane	0.2	3.9	0.2	3.9	0.2	3.7
Chloromethane	0.2	0.4	0.2	0.3	0.2	0.3
Vinyl chloride	0.2	ND	0.2	ND	0.2	ND
Bromoethane	0.2	ND	0.2	ND	0.2	ND
Chloroethane	0.2	ND	0.2	ND	0.2	ND
Trichlorofluoromethane	0.2	0.5	0.2	0.5	0.2	0.5
1,1-Dichloroethene	0.2	ND	0.2	ND	0.2	ND
Carbon disulfide	0.2	2.0	0.2	1.9	0.2	2.0
Acetone	2.0	16	2.0	10	2.0	38
Methylene chloride	2.0	ND	2.0	ND	2.0	ND
trans-1,2-Dichloroethene	0.2	ND	0.2	ND	0.2	ND
1,1-Dichloroethene	0.2	ND	0.2	ND	0.2	ND
Vinyl acetate	0.2	ND	0.2	ND	0.2	ND
cis-1,2-Dichloroethene	0.2	0.8	0.2	0.6	0.2	1.0
2-Butanone	2.0	12	2.0	6.9	2.0	40
2,2-Dichlorophopane	0.2	ND	0.2	ND	0.2	ND
Chloroform	0.2	ND	0.2	ND	0.2	ND
1,1,1-trichloroethane	0.2	ND	0.2	ND	0.2	ND
Carbon Tetrachloride	0.2	ND	0.2	ND	0.2	ND
Benzene	0.2	0.5	0.2	0.4	0.2	0.6
1,2-Dichloroehane	0.2	ND	0.2	ND	0.2	ND
Trichloroethene	0.2	1.0	0.2	0.9	0.2	1.0
1,2-Dichloropropane	0.2	ND	0.2	ND	0.2	ND
Debromomethane	0.2	ND	0.2	ND	0.2	ND
Dibromomethane	0.2	ND	0.2	ND	0.2	ND
cis-1,3-Dichloropropene	0.2	ND	0.2	ND	0.2	ND
4-Methyl-2-pentanone	2.0	4.5	2.0	ND	2.0	11
Toluene	0.2	18	0.2	17	0.2	22
trans-1,3-Dichloropropene	0.2	ND	0.2	ND	0.2	ND
1,1,2-Trichloroethane	0.2	ND	0.2	ND	0.2	ND
Tetrachloroethene	0.2	4.4	0.2	4.7	0.2	5.1
2-Hexanone	2.0	ND	2.0	ND	2.0	ND
Dibromochloromethane	0.2	ND	0.2	ND	0.2	ND
1,2-Dibromoethane	0.2	ND	0.2	ND	0.2	ND
Chlorobenzene	0.2	ND	0.2	ND	0.2	ND

Laboratory Representative

05/21/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

1

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention:	Peter Janicki	Date Sampled:	04/30/04
	CIWMB	Date Received:	04/30/04
	P.O. Box 4025 / 1001 I Street	Date Analyzed:	05/05/04
	Sacramento, CA 95812		
Project:	Yolo LF		
Method:	TO15		

Client Sample I.D.	BF-P1		BF-P2		BF-HP	
LAB. NO.	A0404828		A0404829		A0404830	
ANALYTE	R/L	Results	R/L	Results	R/L	Results
Ethylbenzene	0.2	6.6	0.2	7.0	0.2	9.2
m,p-Xylene	0.2	17	0.2	18	0.2	25
o-Xylene	0.2	4.2	0.2	4.4	0.2	7.3
Styrene	0.2	1.0	0.2	1.0	0.2	2.2
Bromoform	0.2	ND	0.2	ND	0.2	ND
1,1,2,2-Tetrachloroethane	0.2	ND	0.2	ND	0.2	ND
1,3,5-Trimethylbenzene	0.2	0.8	0.2	1.1	0.2	1.6
1,2,4-Trimethylbenzene	0.2	1.3	0.2	1.7	0.2	3.1
1,3-Dichlorobenzene	0.2	ND	0.2	ND	0.2	ND
1,4-Dichlorobenzene	0.2	0.5	0.2	0.7	0.2	2.0
1,2-Dichlorobenzene	0.2	ND	0.2	ND	0.2	ND
1,2,4-Trichlorobenzene	0.2	ND	0.2	ND	0.2	ND
Hexachlorobutadiene	0.2	ND	0.2	ND	0.2	ND
SURROGATE %RECOVERY						
Dibromofluoromethane	100		100		101	
Tuluene-d8	102		104		103	
4-Bromofluorobenzene	99		101		100	

QA/QC %RECOVERY		
	LCS	LCSD
1,1-Dichloroethene	97	98
Benzene	95	97
Trichloroethene	96	98
Toluene	95	98
Chlorobenzene	96	101

QA/QC Analyzed: 05/05/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Air samples reported in mg/m3

Laboratory Representative

05/21/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
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(Certification No. 2119)

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812

Project: Yolo LF
TNMOC Method: EPA 25C
Fixed Gasses Method: EPA 3C

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/10/04

Client Sample I.D.			BF-P1		BF-P2		BF-HP	
LAB. NO.			A0404828		A0404829		A0404830	
ANALYTE	Units	PQL	R/L	Results	R/L	Results	R/L	Results
TNMOC	ppmv C	10	17	NA	18	NA	17	NA
TNMOC uncorr*	ppmv C	10	17	1500	18	1700	17	1700
Nitrigen	%v/v	1.0	1.7	80	1.8	81	1.7	79
Oxygen	%v/v	0.50	0.87	13	0.89	14	0.87	13
Carbon Dioxide	%v/v	0.010	0.017	7.4	0.018	7.5	0.017	7.3
Methane	%v/v	0.0010	0.0017	3.2	0.0018	3.2	0.0017	3.1

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
PQL = Practical Quantitation Limit
TNMOC = Total Non Methane Organic Carbon
TNMOC uncorr = TNMOC concentration in sample without nitrogen/moisture correction
NA = Nitrogen/moisture correction causes division by zero

Laboratory Representative

05/21/04
Date Reported

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention:	Peter Janicki	Date Sampled:	04/30/04
	CIWMB	Date Received:	04/30/04
	P.O. Box 4025 / 1001 I Street	Date Analyzed:	05/11/04
	Sacramento, CA 95812		
Project:	Yolo LF		
Method:	EPA 15/16		

Client Sample I.D.		BF-P1		BF-P2		BF-HP	
LAB. NO.		A0404828		A0404829		A0404830	
ANALYTE	PQL	R/L	Results	R/L	Results	R/L	Results
Hydrogen Sulfide	200	360	ND	370	ND	360	ND
Carbonyl Sulfide	200	360	690	370	710	360	680
Methyl Mercaptan	200	360	ND	370	ND	360	ND
Carbon Disulfide	200	360	570	370	600	360	560
Dimethyl Sulfide	200	360	1200	370	1300	360	1200
Dimethyl Disulfide	200	360	ND	370	ND	360	ND

QA/QC %RECOVERY		
	LCS	LCSD
Hydrogen Sulfide	99	100
Carbonyl Sulfide	98	99
Methyl Mercaptan	103	104
Carbon Disulfide	84	87
Dimethyl Sulfide	83	85
Dimethyl Disulfide	71	77

QA/QCAnalyzed: 05/11/04

PQL = Practical Quantitation Limit
ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit

Laboratory Representative

05/21/04
Date Reported

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Excelchem Environmental Labs

500 Giuseppe Court, Suite 3
Roseville, CA 95678
(916) 773-3664 voice
(916) 773-4784 fax

FAX COVER SHEET

Date: 8/1/04

To: Peter S.

Fax Number: 319 7369

From: Laura

Total Pages (including cover sheet): 19

Comments:

Excelchem
Environmental Labs
300 Broadway Street
Eureka, CA 95501
Ph: 707-444-0120 Fx: 707-444-0560

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Peter Janicki
Phone #: (916)341-6315
Company/Address: CIWMB
Fax #: (916)319-7369
Project Number/P.O#: YOLO LF
Project Name:
Project Location: Davis, CA
Sampler Signature: [signature]

Electronic Data Deliverables Request:
Global I.D.#:
Email Address:
COC #:
Location I.D.#:

ANALYSIS REQUEST Page ___ of ___

Bin# 53 / 0423B
Due Date: 5/7

Sample ID	Sampling Date	Sampling Time	Container: VOA	SLEEVE	1L GLASS	PLASTIC	Method Preserved: HCl	HNO3	ICE	NONE	Matrix: WATER	SOIL	AIR	BTEX/TPH as Gasoline (602/8020/8015)	MTBE (8020/8260B)	TPH as Diesel (8015m)	TPH as Oil (8015m)	Total Oil & Grease (SM-18th Ed 5520B,F)/166	Pesticides (608/8081A)	PCBs (8082)	VOC Full list (8260B)	5 Oxygenates (8260B)	Methanol/Ethanol (8015/8260)	Lead Scavengers DCA/EDB (8260B)	Semi VOC Full List (8270C)	CAM 17 Metals (Wet/Total)	Lead (Wet/Total)	Cd, Cr, Pb, Zn, Ni (CAM 5) (Wet/Total)	~~BOD/TSS/TDS~~	~~Ammonia/TKN~~	See attached	Requested TAT: 12hr/24hr/48hr/72hr/1wk	LAB USE ONLY:
testW1	4/30	10:40																															W0404807
2		↓																															
3		↓																															
testA		↓																															
AER-MH																																	
↓																																	

Relinquished by:	Date	Time	Received by:
P. Janicki	4/30	14:41	
Relinquished by:	Date	Time	Received by:
Relinquished by:	Date	Time	Received by Laboratory:
	4/30	11:44	[signature]

Remarks/Condition of Sample: VOAs - slight head retained due to excessive foaming

Bill To:

Excelchem
Environmental Labs

Excelchem Environmental Labs
500 Giuseppe Ct., Suite # 3
Roseville, CA 95678

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Peter Janicki

Company/Address: CIWMB

Fax #:

Project Number/P.O#:

Project Name: YOLO LF

Project Location: Davis, CA

Sampler Signature:

Electronic Data Deliverables Request:
Global I.D.#:
COC #:
Location I.D.#:
Email Address:

ANALYSIS REQUEST

Page ___ of ___

Sample ID	Sampling Date	Sampling Time	Container: VOA	SLEEVE	1L GLASS	PLASTIC	Method Preserved: HCl	HNO3	ICE	NONE	Matrix: WATER	SOIL	AIR	BTEX/TPH as Gasoline (602/8020/8015)	MTBE (8020/8260B)	TPH as Diesel (8015m)	TPH as Oil (8015m)	Total Oil & Grease (SM-18th Ed 5520B,F)/166	Pesticides (608/8081A)	PCBs (8082)	VOC Full list (8260B)	5 Oxygenates (8260B)	Methanol/Ethanol (8015/8260)	Lead Scavengers DCA/EDB (8260B)	Semi VOC Full List (8270C)	CAM 17 Metals	Lead	Cd, Cr, Pb, Zn, Ni (CAM 5)	See attached	Requested TAT: 12hr/24hr/48hr/72hr/1wk	Bin# / Due Date: / LAB USE ONLY:
H3 Pond	4/30	11:20	(10)				(10)																									J404808

Wet
Total

Relinquished by:	Date	Time	Received by:	Remarks/Condition of Sample:
[signature]	4/30	14:41		
Relinquished by:	Date	Time	Received by:	
Relinquished by:	Date	Time	Received by Laboratory:	Bill To:
	4/30	14:41	[signature]	

Date Reported

Laboratory Representative

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

11

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 415.1

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/07/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
TOC	150	1500	15	130

QA/QC %RECOVERY			
	LCS	MS	MSD
TOC	95	97	100

QA/QC Analyzed: 05/07/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 6010B and EPA 7471A (Hg)

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/11,18/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Aluminum	50	1500	50	ND
Barium	20	600	20	190
Beryllium	3.0	4.9	3.0	5.8
Boron	50	18000	50	10000
Calcium	100	98000	100	48000
Chromium	10	360	10	ND
Iron	20	4300	20	250
Magnesium	1000	570000	1000	380000
Manganese	10	430	10	370
Mercury	0.25	0.32	0.25	ND
Molybdenum	10	43	10	ND
Potassium	2000	87000	100	73000
Sodium	4000	2400000	4000	970000
Tin	50	ND	50	ND
Vanadium	20	180	20	ND
Zinc	20	940	20	ND

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in µg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

EXCELCHEM

ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 6010B and EPA 7471A (Hg)

QA/QC %RECOVERY				
	LCS	LCSD	MS	MSD
Aluminum	100	97	102	101
Barium	98	100	101	101
Beryllium	95	93	93	97
Boron	101	101	102	*
Calcium	102	101	*	*
Chromium	98	96	97	97
Iron	102	98	97	100
Magnesium	97	95	*	*
Manganese	99	98	96	100
Molybdenum	95	98	97	98
Potassium	98	98	*	*
Sodium	103	98	*	*
Tin	99	98	93	94
Vanadium	95	98	97	100
Zinc	99	99	94	97

QA/QC Analyzed: 05/11,18/04

QA/QC %RECOVERY		
	LCS	LCSD
Mercury	99	80

QA/QC Analyzed: 05/03/04

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 6020B

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/05/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Antimony	25	ND	2.5	ND
Arsenic	50	ND	5.0	19
Cadmium	25	ND	2.5	ND
Cobalt	25	ND	2.5	4.4
Copper	50	ND	5.0	ND
Lead	50	ND	5.0	ND
Nickel	400	ND	40	70
Selenium	25	ND	2.5	11
Silver	400	ND	40	ND
Thallium	25	ND	2.5	ND

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in µg/L

QA/QC %RECOVERY			
	LCS	MS	MSD
Antimony	97	97	99
Arsenic	84	93	92
Cadmium	97	96	97
Cobalt	95	83	82
Copper	99	66	86
Lead	103	98	100
Nickel	104	78	78
Selenium	81	86	85
Silver	115	93	94
Thallium	98	97	99

QA/QC Analyzed: 05/06/04

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

15

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 365

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/17/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Phosphorus	0.3	6.5	0.03	0.28

QA/QC %RECOVERY		
	LCS	LCSD
Phosphorus	99	96

QA/QC Analyzed: 05/17/04

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2116)

16

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 8260B

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/03/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Dichlorodiflouromethane	5.0	ND	0.5	ND
Chloromethane	5.0	ND	0.5	ND
Vinyl chloride	5.0	ND	0.5	ND
Bromomethane	5.0	ND	0.5	ND
Chloroethane	5.0	ND	0.5	ND
Trichlorofluoromethane	5.0	ND	0.5	ND
Acetone	100	ND	10	ND
1,1-Dichloroethene	5.0	ND	0.5	ND
Iodomethane	5.0	ND	0.5	ND
Methylene chloride	50	ND	5.0	ND
Carbon disulfide	5.0	ND	0.5	ND
trans-1,2-Dichloroethene	5.0	ND	0.5	ND
1,1-Dichloroethane	5.0	ND	0.5	ND
2-Butanone	50	ND	5.0	ND
2,2-Dichloropropane	5.0	ND	0.5	ND
cis-1,2-Dichloroethene	5.0	ND	0.5	ND
Bromochloromethane	5.0	ND	0.5	ND
Chloroform	5.0	ND	0.5	ND
1,1,1-Trichloroethane	5.0	ND	0.5	ND
Carbon tetrachloride	5.0	ND	0.5	ND
1,1-Dichloropropene	5.0	ND	0.5	ND
Benzene	5.0	ND	0.5	ND
1,2-Dichloroethane	5.0	ND	0.5	ND
Trichloroethene	5.0	ND	0.5	ND
1,2-Dichloropropane	5.0	ND	0.5	ND
Dibromomethane	5.0	ND	0.5	ND
Bromodichloromethane	5.0	ND	0.5	ND
cis-1,3-Dichloropropene	5.0	ND	0.5	ND
4-Methyl-2-pentanone	50	370	5.0	ND
Toluene	5.0	5.4	0.5	ND
trans-1,3-Dichloropropene	5.0	ND	0.5	ND
1,1,2-Trichloroethane	5.0	ND	0.5	ND
Tetrachloroethene	5.0	ND	0.5	ND
1,3-Dichloropropane	5.0	ND	0.5	ND
2-Hexanone	50	ND	5.0	ND
Dibromochloromethane	5.0	ND	0.5	ND
1,2-Dibromoethane	5.0	ND	0.5	ND

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY (Certification No. 2119)

1

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 8260B

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/03/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Chlorobenzene	5.0	ND	0.5	ND
1,1,1,2-Tetrachloroethane	5.0	ND	0.5	ND
Ethylbenzene	5.0	ND	0.5	ND
m,p-Xylene	5.0	ND	0.5	ND
o-Xylene	5.0	ND	0.5	ND
Styrene	5.0	ND	0.5	ND
Bromoform	5.0	ND	0.5	ND
Isopropylbenzene	5.0	ND	0.5	ND
Bromobenzene	5.0	ND	0.5	ND
1,1,2,2-Tetrachloroethane	5.0	ND	0.5	ND
1,2,3-Trichloropropane	5.0	ND	0.5	ND
n-Propylbenzene	5.0	ND	0.5	ND
2-Chlorotoluene	5.0	ND	0.5	ND
4-Chlorotoluene	5.0	ND	0.5	ND
1,3,5-Trimethylbenzene	5.0	ND	0.5	ND
tert-Butylbenzene	5.0	ND	0.5	ND
1,2,4-Trimethylbenzene	5.0	ND	0.5	ND
sec-Butylbenzene	5.0	ND	0.5	ND
1,3-Dichlorobenzene	5.0	ND	0.5	ND
4-Isopropyltoluene	5.0	ND	0.5	ND
1,4-Dichlorobenzene	5.0	ND	0.5	ND
1,2-Dichlorobenzene	5.0	ND	0.5	ND
n-Butylbenzene	5.0	ND	0.5	ND
1,2-Dibromo-3-chloropropane	5.0	ND	0.5	ND
1,2,4-Trichlorobenzene	5.0	ND	0.5	ND
Hexachlorobutadiene	5.0	ND	0.5	ND
Naphthalene	5.0	ND	0.5	ND
1,2,3-Trichlorobenzene	5.0	ND	0.5	ND
SURROGATE %RECOVERY				
Dibromofluoromethane	101		102	
Toluene-d8	101		100	
4-Bromofluorobenzene	101		100	

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in ug/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY (Certification No. 2119)

2

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 8260B

QA/QC %RECOVERY		
	LCS	LCSD
1,1-Dichloroethene	103	101
Benzene	95	99
Trichloroethene	94	99
Toluene	92	97
Chlorobenzene	92	98

QA/QC Analyzed: 05/03/04

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 405.1

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/0604

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Biochemical Oxygen Demand	5.0	330	5.0	16

QA/QC %RECOVERY			
	LCS	MS	MSD
Biochemical Oxygen Demand	95	121	111

QA/QC Analyzed: 05/06/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY (Certification No. 2119)

4

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/06/04

Project: Yolo LF
Method: EPA 350.2

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Ammonia	19	420	0.75	11

QA/QC %RECOVERY			
	LCS	MS	MSD
Ammonia	97	91	99

QA/QC Analyzed: 05/06/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY (Certification No. 2119)

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: SM 4500-NH_3B

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/07/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Total Kjeldhal Nitrogen	0.3	600	0.3	25

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 300.0

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 04/30/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Chloride	100	4400	100	1400
Sulfate	40	91	40	72
Nitrate, as Nitrogen	0.11	ND	0.11	ND
Nitrite, as Nitrogen	0.15	ND	0.14	ND

QA/QC %RECOVERY		
	LCS	LCSD
Chloride	111	111
Sulfate	105	105
Nitrate, as Nitrogen	96	97
Nitrite, as Nitrogen	104	101

QA/QC Analyzed: 04/30/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY (Certification No. 2119)

7

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 376.2

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/13/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L*	Results	R/L*	Results
Sulfide	20	ND	2.0	ND

QA/QC %RECOVERY		
	LCS	LCSD
Sulfide	90	84

QA/QC Analyzed: 05/13/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

* Elevated reporting levels are due to sample dilution due to color of sample.

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

8

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: SM 2320B/EPA 310.1

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/04/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Hydroxide (as $CaCO_3$)	400	ND	10	ND
Carbonate (as $CaCO_3$)	400	ND	10	ND
Bicarbonate (as $CaCO_3$)	400	9000	10	1500

QA/QC %RECOVERY		
	LCS	LCSD
Alkalinity, Total	99	95

QA/QC Analyzed: 05/04/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 160.1

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/04/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
TDS	200	12000	10	3800

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812
Project: Yolo LF
Method: EPA 410.4/SM5220D

Date Sampled: 04/30/04
Date Received: 04/30/04
Date Analyzed: 05/11/04

Client Sample I.D.	AER-MH		M3 Pond	
LAB. NO.	W0404807		W0404808	
ANALYTE	R/L	Results	R/L	Results
Chemical Oxygen Demand	50	1200	5.0	140

QA/QC %RECOVERY				
	LCS	LCSD	MS	MSD
Chemical Oxygen Demand	110	90	90	120

QA/QC Analyzed: 05/11/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Water samples reported in mg/L

Laboratory Representative

05/18/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY (Certification No. 2119)

11

Excelchem Environmental Labs

500 Giuseppe Court, Suite 3
Roseville, CA 95678
(916) 773-3664 voice
(916) 773-4784 fax

FAX COVER SHEET

Date: 6/4

To: Peter

Fax Number: 319-7369

From: Laura

Total Pages (including cover sheet): 6

Comments:

Excelchem
Environmental Labs

Excelchem Environmental Labs
500 Giuseppe Ct., Suite # 3
Roseville, CA 95678

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Peter Janicki

Company/Address: CIWMB

Fax #:

Project Number/P.O#: YOLO LF

Project Name: YOLO LF

Project Location: DAVIS, CA

Sampler Signature: CE Summit

Electronic Data Deliverables Request:
Global I.D.#:
COC #:
Location I.D.#:
Email Address:

ANALYSIS REQUEST

Page ___ of ___

Sample ID	Sampling Date	Sampling Time	Container: VOA	SLEEVE	1L GLASS	PLASTIC	SUMMA	Method Preserved: HCl	HNO3	ICE	NONE	Matrix: WATER	SOIL	AIR	BTEX/TPH as Gasoline (602/8020/8015)	MTBE (8020/8260B)	TPH as Diesel (8015m)	TPH as Oil (8015m)	Total Oil & Grease (SM-18th Ed 5520B,F)/166	Pesticides (608/8081A)	PCBs (8082)	VOC Full list (8260B)	5 Oxygenates (8260B)	Methanol/Ethanol (8015/8260)	Lead Scavengers DCA/EDB (8260B)	Semi VOC Full List (8270C)	Wet	Total: CAM 17 Metals	Lead	Cd, Cr, Pb, Zn, Ni (CAM 5)	TO-15	Fixed Gases EPA 15/16	EPA 25C/M00	Requested TAT: 12hr/24hr/48hr/72hr/1wk	Bin#	Due Date: 05/10	LAB USE ONLY:
SF-BLANK	4/30	1006			6044						X			X																	X	X	X	X			A0504003
SF/BF1-1	4/30	1103			5976																															A0504004
SF/BF1-1R	4/30	1109			5192																															A0504005
SF/BF1-2	4/30	1215			5935																															A0504006
SF/BF1-3	4/30	1255			7124																															A0504007
SF/BF2-1	4/30	1348			4431																															A0504008
SF/BF2-2	4/30	1437			1232																															A0504009
SF/BF2-3	4/30	1525			5979																															A0504010
	4/30																																			

Relinquished by:	Date	Time	Received by:
CE Summit	4/30/04	1600	RAMIN YAZDANI
Relinquished by:	Date	Time	Received by:
Ramin Yazdani	5/3/04	10:50	
Relinquished by:	Date	Time	Received by Laboratory:
	5/3/04	10:50	

Remarks/Condition of Sample: 530 529-4256 CE Summit

PLEASE REPORT ppbv, mg/m^3, AND FLUX.

FLUX = $(mg/m^3)(0.0385) = mg/m^2 \cdot min^{-1}$ (OR mg-vs-Hg)

Bill To:

EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812

Project: Yolo LF

Method: EPA TO15

Date Sampled: 04/30/04
Date Received: 05/03/04
Date Analyzed: 05/05/04

Client Sample I.D.	SF-BLANK		SF/BF1-1		SF/BF1-1R		SF/BF1-2		SF/BF1-3	
LAB. NO.	A0504003		A0504004		A0504005		A0504006		A0504007	
ANALYTE	R/L	Results	R/L	Results	R/L	Results	R/L	Results	R/L	Results
Dichlorodifluoromethane	40	ND	40	510	40	510	40	430	40	570
Chloromethane	100	ND	100	200	100	150	100	ND	100	ND
Vinyl chloride	80	ND	80	ND	80	ND	80	ND	80	ND
Bromoethane	50	ND	50	ND	50	ND	50	ND	50	ND
Chloroethane	80	ND	80	ND	80	ND	80	ND	80	ND
Trichlorofluoromethane	40	ND	40	70	40	70	40	50	40	70
1,1-Dichloroethene	50	ND	50	ND	50	ND	50	ND	50	ND
Carbon disulfide	60	ND	60	420	60	420	60	350	60	480
Acetone	840	2200	840	2900	840	4100	840	2000	840	5000
Methylene chloride	600	ND	600	ND	600	ND	600	ND	600	ND
trans-1,2-Dichloroethene	50	ND	50	ND	50	ND	50	ND	50	ND
1,1-Dichloroethene	50	ND	50	ND	50	ND	50	ND	50	ND
Vinyl acetate	560	ND	560	ND	560	ND	560	ND	560	ND
cis-1,2-Dichloroethene	50	ND	50	150	50	170	50	150	50	200
2-Butanone	680	1800	680	ND	680	ND	680	9900	680	1500
2,2-Dichlorophopane	40	ND	40	ND	40	ND	40	ND	40	ND
Chloroform	40	ND	40	ND	40	ND	40	ND	40	ND
1,1,1-trichloroethane	40	ND	40	ND	40	ND	40	ND	40	ND
Carbon Tetrachloride	30	ND	30	ND	30	ND	30	ND	30	ND
Benzene	60	ND	60	ND	60	ND	60	90	60	130
1,2-Dichloroehane	50	ND	50	ND	50	ND	50	ND	50	ND
Trichloroethene	40	ND	40	150	40	150	40	130	40	150
1,2-Dichloropropane	40	ND	40	ND	40	ND	40	ND	40	ND
Dibromomethane	30	ND	30	ND	30	ND	30	ND	30	ND
cis-1,3-Dichloropropene	40	ND	40	ND	40	ND	40	ND	40	ND
4-Methyl-2-pentanone	100	ND	100	ND	100	ND	100	ND	100	490
Toluene	50	50	50	960	50	1000	50	3000	50	390
trans-1,3-Dichloropropene	40	ND	40	ND	40	ND	40	ND	40	ND
1,1,2-Trichloroethane	40	ND	40	ND	40	ND	40	ND	40	ND
Tetrachloroethene	30	ND	30	610	30	610	30	490	30	600
2-Hexanone	480	ND	480	ND	480	ND	480	ND	480	ND
Dibromochloromethane	20	ND	20	ND	20	ND	20	ND	20	ND
1,2-Dibromoethane	30	ND	30	ND	30	ND	30	ND	30	ND
Chlorobenzene	40	ND	40	ND	40	ND	40	ND	40	ND

Laboratory Representative

06/04/04
Date Reported

EXCELCHEM ENVIRONMENTAL LABS IS CERTIFIED BY THE STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES AS A HAZARDOUS WASTE TESTING LABORATORY
(Certification No. 2119)

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812

Project: Yolo LF
Method: TO15

Date Sampled: 04/30/04
Date Received: 05/03/04
Date Analyzed: 05/05/04

Client Sample I.D.	SF-BLANK		SF/BF1-1		SF/BF1-1R		SF/BF1-2		SF/BF1-3	
LAB. NO.	A0504003		A0504004		A0504005		A0504006		A0504007	
ANALYTE	R/L	Results	R/L	Results	R/L	Results	R/L	Results	R/L	Results
Ethylbenzene	50	ND	50	460	50	480	50	1300	50	1600
m,p-Xylene	45	70	45	580	45	600	45	2700	45	4200
o-Xylene	45	ND	45	180	45	210	45	990	45	1300
Styrene	50	ND	50	ND	50	ND	50	120	50	140
Bromoform	20	ND	20	ND	20	ND	20	ND	20	ND
1,1,2,2-Tetrachloroethane	30	ND	30	ND	30	ND	30	ND	30	ND
1,3,5-Trimethylbenzene	40	ND	40	ND	40	ND	40	200	40	240
1,2,4-Trimethylbenzene	40	ND	40	ND	40	ND	40	200	40	350
1,3-Dichlorobenzene	30	ND	30	ND	30	ND	30	ND	30	ND
1,4-Dichlorobenzene	30	30	30	400	30	500	30	490	30	420
1,2-Dichlorobenzene	30	ND	30	ND	30	ND	30	ND	30	ND
1,2,4-Trichlorobenzene	30	ND	30	ND	30	ND	30	ND	30	ND
Hexachlorobutadiene	20	ND	20	ND	20	ND	20	ND	20	ND
SURROGATE %RECOVERY										
Dibromofluoromethane	100		99		100		96		97	
Tuluene-d8	100		102		102		102		101	
4-Bromofluorobenzene	99		98		100		101		99	

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Air samples reported in PPBV

Laboratory Representative

06/04/04
Date Reported

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812

Project: Yolo LF

Method: EPA TO15

Date Sampled: 04/30/04
Date Received: 05/03/04
Date Analyzed: 05/05/04

Client Sample I.D.	SF/BF2-1		SF/BF2-2		SF/BF2-3	
LAB. NO.	A0504008		A0504009		A0504010	
ANALYTE	R/L	Results	R/L	Results	R/L	Results
Dichlorodifluoromethane	40	510	40	430	40	450
Chloromethane	100	ND	100	ND	100	ND
Vinyl chloride	80	ND	80	ND	80	ND
Bromoethane	50	ND	50	ND	50	ND
Chloroethane	80	ND	80	ND	80	ND
Trichlorofluoromethane	40	50	40	50	40	50
1,1-Dichloroethene	50	ND	50	ND	50	ND
Carbon disulfide	60	390	60	320	60	320
Acetone	840	2700	840	1500	840	1300
Methylene chloride	600	ND	600	ND	600	ND
trans-1,2-Dichloroethene	50	ND	50	ND	50	ND
1,1-Dichloroethene	50	ND	50	ND	50	ND
Vinyl acetate	560	ND	560	ND	560	ND
cis-1,2-Dichloroethene	50	150	50	150	50	130
2-Butanone	680	ND	680	ND	680	ND
2,2-Dichlorophopane	40	ND	40	ND	40	ND
Chloroform	40	ND	40	ND	40	ND
1,1,1-trichloroethane	40	ND	40	ND	40	ND
Carbon Tetrachloride	30	ND	30	ND	30	ND
Benzene	60	90	60	60	60	60
1,2-Dichloroehane	50	ND	50	ND	50	ND
Trichloroethene	40	130	40	110	40	110
1,2-Dichloropropane	40	ND	40	ND	40	ND
Dibromomethane	30	ND	30	ND	30	ND
cis-1,3-Dichloropropene	40	ND	40	ND	40	ND
4-Methyl-2-pentanone	100	ND	100	ND	100	ND
Toluene	50	3300	50	2200	50	1900
trans-1,3-Dichloropropene	40	ND	40	ND	40	ND
1,1,2-Trichloroethane	40	ND	40	ND	40	ND
Tetrachloroethene	30	520	30	460	30	450
2-Hexanone	480	ND	480	ND	480	ND
Dibromochloromethane	20	ND	20	ND	20	ND
1,2-Dibromoethane	30	ND	30	ND	30	ND
Chlorobenzene	40	ND	40	ND	40	ND

Laboratory Representative

06/04/04
Date Reported

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EXCELCHEM
ENVIRONMENTAL LABS

500 Giuseppe Court, Suite 3
Roseville, CA 95678
Phone#: (916) 773-3664 Fax#: (916) 773-4784

ANALYSIS REPORT

Attention: Peter Janicki
CIWMB
P.O. Box 4025 / 1001 I Street
Sacramento, CA 95812

Project: Yolo LF

Method: TO15

Date Sampled: 04/30/04
Date Received: 05/03/04
Date Analyzed: 05/05/04

Client Sample I.D.	SF/BF2-1		SF/BF2-2		SF/BF2-3	
LAB. NO.	A0504008		A0504009		A0504010	
ANALYTE	R/L	Results	R/L	Results	R/L	Results
Ethylbenzene	50	1400	50	1200	50	1200
m,p-Xylene	45	3600	45	2800	45	2500
o-Xylene	45	1000	45	1000	45	880
Styrene	50	190	50	120	50	70
Bromoform	20	ND	20	ND	20	ND
1,1,2,2-Tetrachloroethane	30	ND	30	ND	30	ND
1,3,5-Trimethylbenzene	40	200	40	180	40	140
1,2,4-Trimethylbenzene	40	290	40	220	40	160
1,3-Dichlorobenzene	30	ND	30	ND	30	ND
1,4-Dichlorobenzene	30	350	30	330	30	320
1,2-Dichlorobenzene	30	ND	30	ND	30	ND
1,2,4-Trichlorobenzene	30	ND	30	ND	30	ND
Hexachlorobutadiene	20	ND	20	ND	20	ND
SURROGATE %RECOVERY						
Dibromofluoromethane	97		99		99	
Tuluene-d8	102		101		101	
4-Bromofluorobenzene	98		99		99	

QA/QC %RECOVERY		
	LCS	LCSD
1,1-Dichloroethene	97	98
Benzene	95	97
Trichloroethene	96	98
Toluene	95	98
Chlorobenzene	96	101

QA/QC Analyzed: 05/05/04

ND = Not detected. Compound(s) may be present at concentrations below the reporting limit.
R/L = Reporting Limit
Air samples reported in PPBV

Laboratory Representative

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