# FINAL REPORT
## July 1,1995 through March 31,1997

# WASTE TIRE
# MARKET DEVELOPMENT PROJECT
## Contract Number TR-94-1033-57

**Prepared for:**

**California Integrated Waste Management Board**
**Local Government Innovations Program**

**Prepared by:**

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# 1. EXECUTIVE SUMMARY

Due to limited markets for the use of waste tires, it is estimated that thirty percent of the used and waste tires in California are disposed of in landfills, stored in stockpiles, or illegally dumped. This disposal of tires represent a loss of a useful resource, a loss of landfill capacity, and a loss of revenue for disposal and processing costs. Therefore, development of new tire markets are needed to reduce the waste of this useful resource.

Waste management practices at Yolo County Central Landfill (YCCL) currently consist of waste tire collection in the landfill's recycling area, followed by periodic removal by licensed waste tire collection contractors. The collection fee charged by the waste tire collection contractor offsets the contractor's cost to collect, process, and dispose of the unmarketable portion of the waste tires. Waste tires are currently not landfilled at YCCL. This practice of waste tire collection and disposal at the YCCL is the result of a poor market for shredded tire use in landfill operations, such as using waste tires to collect landfill gas. The objective of this project is to promote a potential market for waste tires in the landfill industry, in particular, the use of shredded tires as a component in landfill gas collection systems. Results from this project provides data documenting that shredded waste tires perform as well or better than gravel as a gas collection media at a lower cost.

Objectives of this project are as follows:

- Investigate and document the performance of shredded waste tire components in vertical well landfill gas collection systems.
- Investigate and document the performance of shredded waste tire components in horizontal blanket landfill gas collection systems.
- Demonstrate the constructability of two landfill gas collection systems utilizing shredded waste tire components.
- Disseminate information and create new markets for shredded waste tires.

This project was conducted in conjunction with research investigating "enhanced" landfilling techniques to maximize methane production through accelerated waste decomposition. The methane enhancement project entailed the construction and instrumentation of two demonstration test cells. Instrumentation of each cell includes measurement of waste temperature, moisture, pressure, and volumetric gas flow. One test cells serves as a control while the other, enhanced cell, incorporates liquid addition and leachate recirculation.

Each test cell has one experimental vertical shredded tire gas well, and one standard vertical gravel gas well. A horizontal gas collection system that consists of a 'blanket' of shredded tires was also constructed over the surface of each test cell. The design and construction of each gas collection system was documented and compared to determine the constructability of the shredded tire gas collection systems. A comprehensive monitoring plan was then implemented to investigate the performance of each gas collection system. The monitoring plan includes gas composition measurements and gas collection tests performed on each well configuration. Results of the monitoring phase were compared between each well type to determine the relative performance of shredded tire as a gas collection media.

In conclusion, this report will discuss the design and construction process, project results, and provide recommendations for the potential application of shredded tires in landfill operations. The purpose of this project is to demonstrate the constructability and performance of shredded waste tires as a gas collection media. Major benefits of this applications is the creation of a new market for shredded waste tires in landfill gas extraction systems and leachate recirculation projects by providing necessary results to demonstrate shredded waste tire preform comparable or better than gravel as a gas collection media.

The constructability of both the vertical and horizontal shredded tire gas collection systems were proven by this project. Results from the monitoring and performance tests indicate shredded waste tires are comparable to gravel as a gas collection media. In the enhanced cell the horizontal shredded tire layer also served as a media to distribute liquid into the waste. Additional benefits of such a dual system using shredded tires could improve the economics of gas to energy projects, extend landfill life and potentially reduce closure costs. However, optimal design and application of such a system still needs to be determined.

It is hoped that results from this demonstration project will lead to the use of shredded waste tires as components of landfill gas collection systems. It is strongly recommended that a full scale demonstration project be constructed to critically assess the optimum design of a horizontal gas collection system using shredded waste tires. Excavation and testing of shredded tires used in both the control and enhanced cell would also provide information on the long term effects of the corrosive landfill environment on shredded waste tires.

# 2. WORK STATUS

The status of the project tasks is described below. All of the tasks are being carried out in conjunction with the ongoing research project entitled 'Methane Enhancement by Accelerated Anaerobic Composting at the Yolo County Central Landfill'. In addition to the funding provided by the California Integrated Waste Management Board, financial assistance has also been received from the California Energy Commission, Urban Consortium Energy Task Force, Western Regional Biomass Energy Program, and Sacramento County. The engineering drawings of the features constructed for the California Integrated Waste Management Board grant project carry the "CEC Project" title, reflecting the early funding from the California Energy Commission.

**Task 1 Design and Construct a Vertical Landfill Gas Collection System**

| | |
|---|---|
| Scheduled Completion Date: | December 1995 |
| Actual Completion Date: | September 1995 |
| Percent complete: | 100% |

Four vertical gas collection wells were designed and constructed at the Yolo County Central Landfill demonstration project. Two experimental landfill gas collection wells using 'one-pass' 12 inch shredded waste tires as fill material were constructed, while two control or 'conventional' wells using gravel were also constructed. The enhanced and control cell each had one vertical tire well and one gravel well. Each well consists of a circular wire mesh cylinder filled with either shredded waste tires or gravel. Gas is collected through a 4 inch slotted PVC pipe placed in the center of each well. A cut-off collar consisting of compacted clay and geomembrane was constructed near the top and bottom of each well to isolate each well from the leachate collection system and horizontal tire layers, thereby eliminating any direct hydraulic connections between the wells. The vertical well assemblies were raised after each 5 foot lift of waste was placed, for a total depth of approximately 45 feet of solid waste in each cell. For an overview of the vertical tire and gravel wells in both cells after the first lift of waste was placed, see Photo 1, Appendix C. The enhanced cell is on the left side of the photo and the control cell is on the right side. The tire wells are located on the far left (enhanced cell) and right (control cell) while the gravel wells are the two wells located in the center.

***Design and construction considerations:***

1. The same construction procedure was used for the gravel and shredded tire wells.

2. Both wells were filled by shoveling the gravel or shredded tires from a back hoe into a confining wire cage that contained the gravel or shredded tires while waste was placed around the wells. (see Photo 3, Appendix C).

3. Because the slotted gas collection pipe was set in the center of the well, it would have been difficult to fill a 2 foot diameter well with the large sized tire chips. Therefore, for ease of

construction, the shredded tire well diameter was increased to 4 feet. However, based on project results, shredded tires can conduct landfill gas to a collection point without a slotted gas collection pipe in the well, allowing the smaller diameter to be used.

4. The larger diameter wire cage used to contain the shredded tires while waste was being placed tended to bend and deform while extending the well vertically. The smaller wire cage used in the gravel wells was more sturdy which made the well construction easier. If the tire particle size was reduced or the slotted pipe was not used, the well size could be reduced thereby easing the tire well constructability.

5. The method of constructing the two gas wells is not standard practice in the industry (see Photo 4, Appendix C). Typically, a 2 foot diameter gas well is drilled and installed into the refuse after completion of waste placement rather than constructed during waste filling. There are different types drill equipment capable of drilling boreholes up to 4 feet in diameter.

6. The premise that shredded tires can perform as well or better than gravel as a gas collection media was based on laboratory permeability tests performed on 3 inch minus shredded tires. However, 3 inch minus shredded tires were not available at the time of construction so 'one-pass' 12 inch shredded tires were used in the project. Based on field observations during construction (see Photo 5, Appendix C), the larger tire chips created sufficient void spaces for gas flow with minimal friction losses.

***Cost comparison:***

1. Shredded tires are typically landfilled due to the poor market for tire recycling. Currently, Yolo County does not landfill shredded tires, because the tipping fee at Yolo County Central Landfill (YCCL) is higher than at other waste disposal facilities located closer to waste tire processors. However, Yolo County could attract shredded tires to YCCL by lowering the tipping fee for tire disposal. The revenue derived from the tipping fee would easily cover costs of shredded tire placement for gas collection.

2. The County's cost for gravel is about $20.00 per cubic yard but is dependent on availability, quantity, and transportation.

3. Well construction time were about the same for the gravel and shredded tire wells. If the wells were drilled, equipment costs and time would not vary between the gravel and the tire wells, assuming equal well diameters.

4. The cost of landfill gas collection system construction is less when using shredded tires because of the expense of purchasing gravel. Shredded tires actually provides revenue for a disposal facility, and, at worst, can be acquired at no cost.

5. The cost saving associated with using shredded tires as a substitute for gravel is dependent on

local availability of tires, processing costs, transportation costs and net landfill space acquired from diverted tires. Landfill space is also lost by the larger tire well size and should be included an additional cost. However, this may be neglected if the size of the tire chips were reduced so that the tire well is the same size as the gravel well. Another alternative would be to install a 2 foot diameter shredded tire well with the same shredded tire size used in this project, 'one-pass' 12 inch minus pieces, but without the slotted gas collection pipe. Based on gas flow rates and uniform pressure measurements within the horizontal shredded tire layer, a shredded tire well can collect and transfer the gas without the aid of the slotted gas collection pipe.

**Task 2 Design and Construct a Horizontal Landfill Gas Collection System**

Scheduled Completion Date: December 1995
Actual Completion Date: December 1995
Percent complete: 100%

Two horizontal gas collection systems were constructed that consists of a 'blanket' of shredded tires over the entire surface of each demonstration cell. The system profile above the waste includes (from the bottom up) a 2 foot layer (compacted thickness) of 'one-pass' shredded tires, a non-woven geotextile layer, a 1.5 foot protective layer of soil, and a 40-mil linear low density polyethylene (LLDPE) geomembrane surface cover (see Photo 2, Appendix C).

***Design and construction considerations:***

1. A front-end loader with a large bucket, rather than a small bucket was the preferred equipment for the placement of shredded tire because of the larger particle size of the tires.

2. The shredded tire layer was placed and graded using a Caterpillar D6 dozer and a backhoe (see Photo 6 and 7, Appendix C). Accurately reaching final grade was difficult due to the compressibility of the tire layer under the weight of the equipment. Average uncompacted density of the shredded tires is approximately 17 pounds per cubic feet, compacted density is about 25 pounds per cubic feet. This was calculated based on the tonnage of shredded tires used in the horizontal layers, the surface area covered, and the observed thickness of the shredded tire layers.

3. To protect the surface liner from punctures caused by metal protrusions from the shredded radial tires, a 1.5 foot layer of soil was placed above the shredded tire layer. A geotextile layer was placed between the shredded tire layer and the soil to prevent soil intrusion into the tire layer.

4. During soil placement, the weight of the soil layer caused differential settlement in the shredded tire layer, resulting in the placement of an uneven thickness of soil to obtain a final smooth grade.

5. The surface liner must be adequately weighted after final placement to eliminate damage that may occur by wind uplift.

6. The project's horizontal shredded tire gas collection system covers the full surface area of each demonstration cell and was part of the cover system. Typical horizontal gas collection systems consist of trenches similar to vertical gas wells in that they are placed in the waste with a set spacing. The constructability of a horizontal tire layer was proven by this project but the optimal design and application for this type of collection system still needs to be determined.

***Cost comparisons:***

1. The 2 foot horizontal tire layer in the control cell used roughly 200 tons of shredded tires and 295 tons in the enhanced cell. The enhanced cell used more shredded tires to fill the 14 leachate infiltration pits used for liquid addition and leachate recirculation. About 50,000 tires were used to construct the two horizontal layers. As previously discussed, processing costs for full scale projects using large quantities of shredded tire could be covered by the shredded tire disposal fees.

2. The horizontal system used in this project is an innovative design that was implemented for the first time in this project. Costs for a full scale applications are difficult to ascertain without going through a design process to determine optimal design parameters and associated costs.

3. There is a cost associated with the loss of landfill volume that would be occupied by the shredded tire horizontal collection system. However, this loss of landfill volume could be mitigated by modifying the design cover system to use the shredded tire layer as a substitute for another component such as the foundation layer or using shredded tires as an intermediate cover within the waste fill.

**Task 3 Design and Construct a Gas Recovery System**

| | |
|---|---|
| Scheduled Completion Date: | August 1996 |
| Actual Completion Date: | August 1996 |
| Percent complete: | 100% |

The gas recovery system includes the gas condensate removal system, gas recovery pipeline, monitoring ports, and flow meters (see Photo 8 and 9, Appendix C). Attached in Appendix B is a set of final as-built drawings for the gas recovery system.

***Design and construction considerations:***

1. Gas recovery pipeline supports were constructed to elevate and level the gas recovery pipeline above the surface liner. These supports were fabricated by embedding metal fence posts in concrete filled tires. A geotextile mat was also placed underneath each tire to protect the surface liner from puncture (see Photo 9, Appendix C).

2. Sealing air leaks in the gas recovery pipeline was problematic due to acidic condensate. After several sealants were tried, a corrosion resistant gasket compound was found to provide a leak proof seal.

**Task 4 Operation and Data Analysis**

| | |
|---|---|
| Scheduled Completion Date: | March 1997 |
| Actual Completion Date: | March 1997 |
| Percent complete: | 100% |

Daily operation of the demonstration project includes monitoring of the gas and leachate composition, recording field measurements, and compiling acquired data (moisture, temperature, landfill gas volumes, and liquid measurements). Based on the interpretation of the data, adjustments to the liquid or gas management are determined. During the grant period performance tests that measured gas flow rates were conducted to determine the performance of the shredded tires as a gas collection media. Gas composition from each component of the gas collection system (vertical wells and horizontal layers) was also monitored throughout this phase of the project. Results of this phase of the project are discussed in the Project results section of this report.

**Task 5 Data Analysis and Education**

| | |
|---|---|
| Scheduled Completion Date: | April 1997 |
| Actual Completion Date: | April 1997 |
| Percent complete: | 100% |

Although Task 5, Data Analysis and Education, was not included in the scope of work for the grant contract, Yolo County Public Works would like to take advantage of this opportunity to present the results of this demonstration project to the California Integrated Waste Management Board. The workshop would discuss the following topics: the design and construction process, results of performance monitoring and implications to landfill management. A goal of this workshop is to disseminate information of shredded tires in landfill applications and to continue the partnerships for full scale demonstration project. Further education of this technology will be disseminated through future publications and presentations, such as the Solid Waste Association of North America (SWANA) conference in Sacramento, California, August 4-6, 1997, which features a technical tour of this project.

## PROJECT RESULTS

The objective of this project is to demonstrate that shredded waste tires will perform as well as gravel material in landfill gas collection systems. This was achieved by monitoring and comparing the gas composition and flow rates of the two types of shredded tire gas collection systems to conventional gravel wells. During the monitoring phase, nine gas collection performance tests were conducted on the horizontal shredded tire layer, the vertical tire well and the vertical gravel well. Gas composition from each well configuration was monitored throughout this phase of the project. Project results related to the performance of the shredded tire gas collection systems are discussed below.

***Gas composition comparison:***

To determine the effect of shredded waste tires on gas composition, the methane percentage from each well was measured weekly starting in November 1996. The methane percentage from the horizontal tire layer, vertical tire well and vertical gravel well for the enhanced and control cell are plotted versus time in Figures 1 and 2. Throughout the gas composition monitoring, the percent methane did not vary significantly between the different well types. The methane percentage in the vertical tire well averaged 2% higher than the gravel well in the enhanced cell and was 4% higher in the control cell. The methane percent from the horizontal layers are consistent with the vertical wells. Based on these measurements, gas composition in this project is independent of the type of collection media. The methane percentages for both the enhanced and control cell on May 2, 1997 are listed in Table 1. These measurements were corrected for air infiltration.

**Table 1. Enhanced and Control Cell Methane Percentages, May 2, 1997.**

| Location | Enhanced Cell Methane Percent (%) | Control Cell Methane Percent (%) |
|---|---|---|
| **Horizontal Layer** | 55 | 53 |
| **Vertical Tire Well** | 55 | 53 |
| **Vertical Gravel Well** | 52 | 52 |

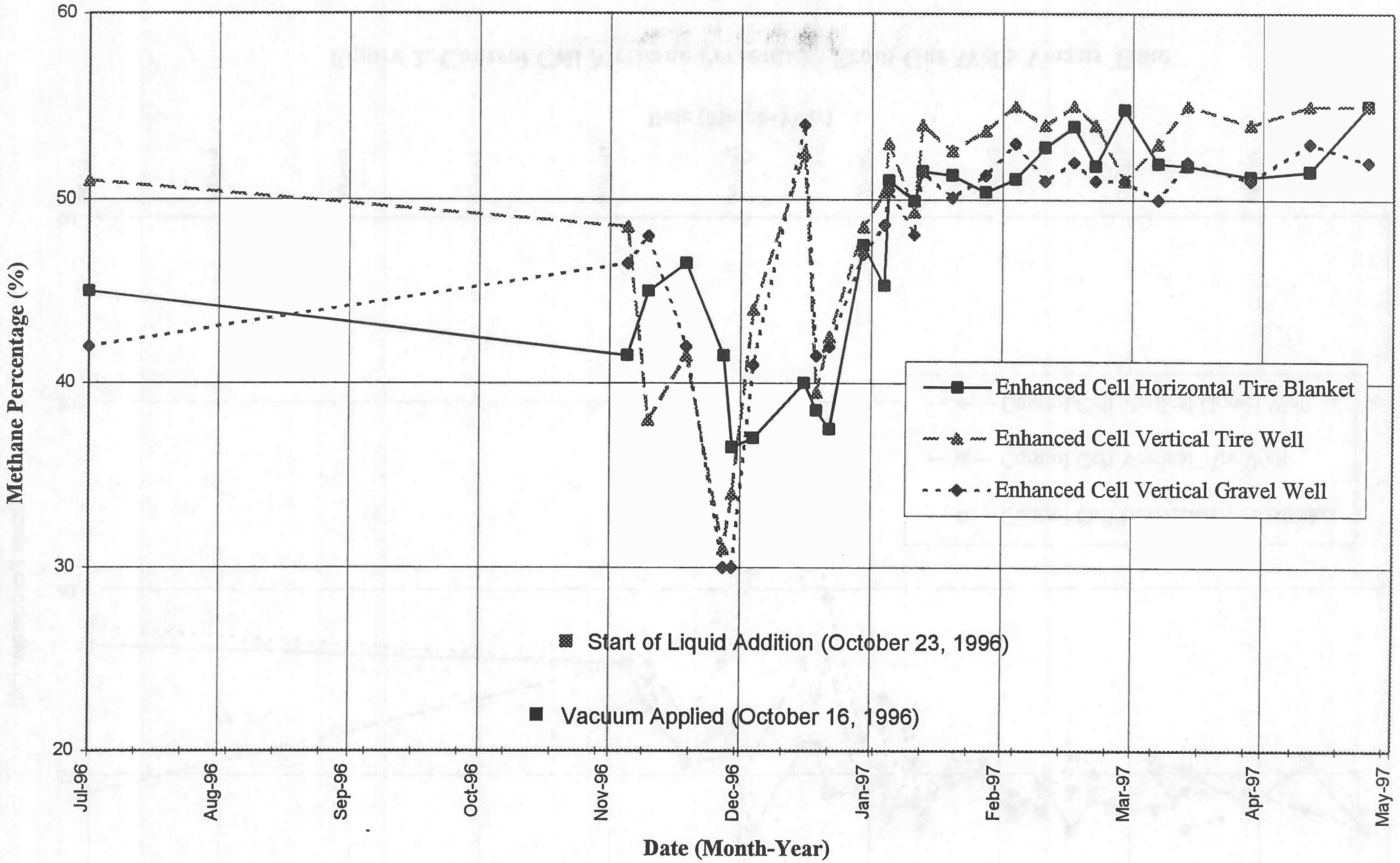



**Figure 1. Enhanced Cell Methane Percentage From Gas Wells Versus Time**

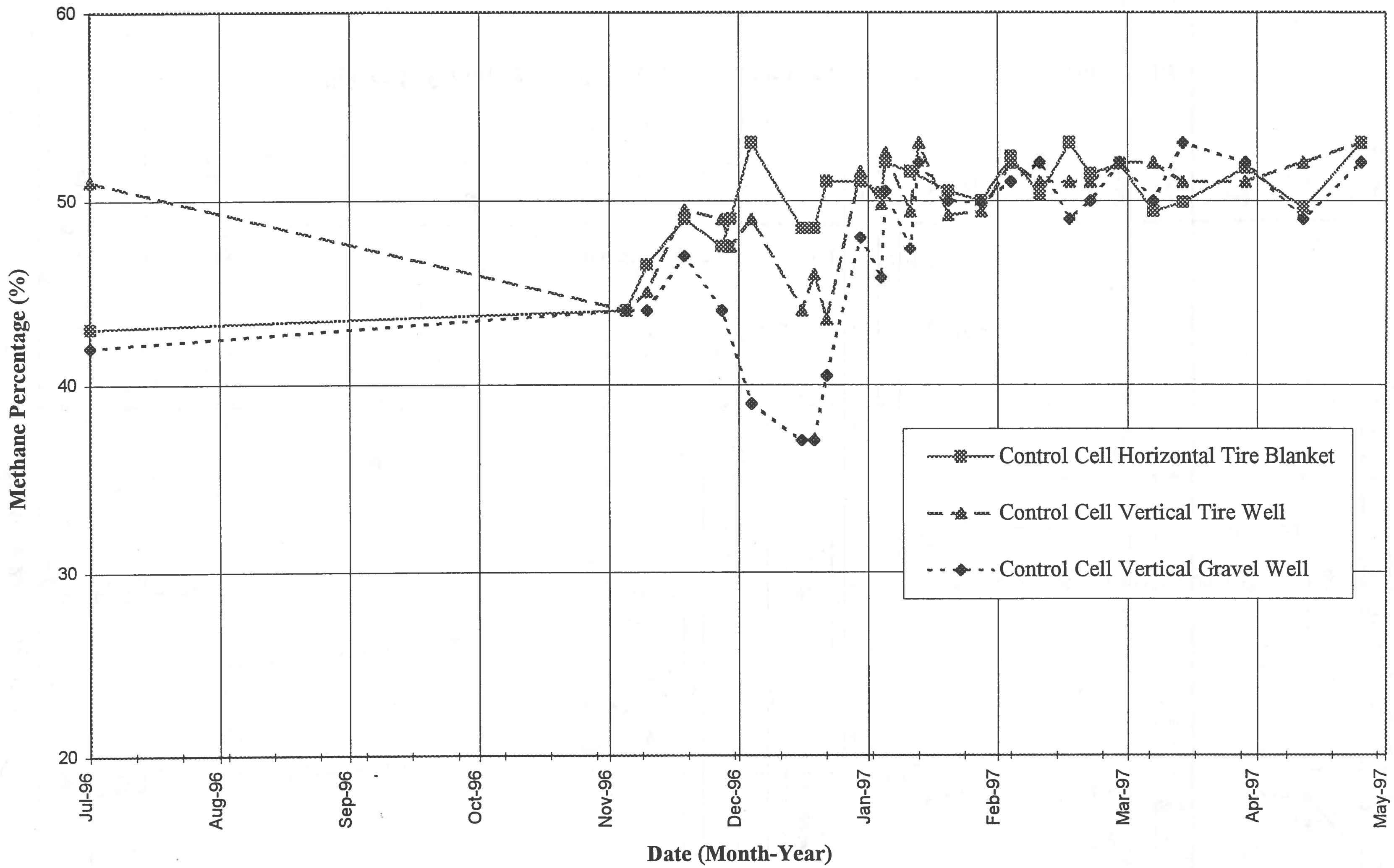



**Figure 2. Control Cell Methane Percentage From Gas Wells Versus Time**

***Gas flow rate comparisons***

To determine if the permeability of compacted shredded tires is comparable to gravel as a gas collection media, nine gas collection tests were performed. During each test, a vacuum was applied to only one gas well and the volumetric flow was measured. Gas flow rates were then calculated and compared between each well type. Pressure measurements were also taken within the waste mass to determine if any correlations can be made with well type. For a complete discussion of the gas collection test procedures refer to the July to September 1996 quarterly report.

***Horizontal gas collection tests***

During the horizontal gas collection tests a vacuum was applied only to the horizontal layer while both vertical gas wells were closed. Table 2 lists the gas flow rates for the horizontal gas collection tests. Two gas collection tests were performed in October 1996 and one in February 1997. Gas flow rates from the October 1996 tests were about 55 scfm and at least five times larger than the average flow for the month. These elevated flow rates were attributed to air leaks in the gas recovery pipeline and do not represent actual gas generation. The air leaks in the gas recovery pipeline were sealed in November 1996. For a listing of October 1996 data refer to the July to September 1996 quarterly report. Flow rates in the February 1997 test were within 6 scfm of the average flow rate of the month. The enhanced cell flow rate was 40 scfm and 20 scfm in the control cell.

Pressure sensors are located throughout the horizontal tire layer and were measured during the gas collection tests. Pressure within horizontal layer stabilized within ten minutes to an equalized pressure gradient. This quick stabilization of pressure indicates there are low friction losses within the shredded tires.

Based on the flow rates and pressure measurements, the horizontal tire layer was able to transfer all of the gas generated without extraction from the vertical wells. Placement of a horizontal shredded tire gas collection system in a landfill would be able to capture the gas while eliminate the need for vertical gas wells. Significate cost savings could then be realized while developing a new market for shredded waste tires.

**Table 2. Enhanced and Control Cell Horizontal Tire Layer Gas Collection Test Results.**

| Date and Duration of Test (minutes) | Applied Vacuum (inches of water) *(Applied Vacuum During Normal Operation)* | Control Cell Flow Rate (scfm) *(Average Monthly Flow Rate)* | Enhanced Cell Flow Rate (scfm) *(Average Monthly Flow Rate)* |
|---|---|---|---|
| 2/27/97 120minutes | -1.00 *(-0.7 to -1.2)* | 20.3 *(25.8)* | 40.4 *(38.7)* |

*Vertical gas collection tests*

A vertical gas collection test was performed on both the vertical tire and gravel wells. In each test the vacuum was applied to only one vertical well while the other vertical well and horizontal tire layer were closed. Gas volumes and pressure within the waste mass were measured during each test. Gas collection tests were performed in October 1996, February 1997, and May 1997. Results of the vertical tire and gravel well tests for the enhanced and control cell are listed in Table 3 and 4. As previously discussed, results from the October 1996 test are not reflective of system performance due to air leaks in the gas recovery pipeline. For a list of October 1996 results refer to the July to September 1996 quarterly report. Flow rates measured during the February and March 1997 tests are not directly comparably between the tire and gravel wells due to the applied vacuum differences. However, results from the May 1997 test show the gas flow rates were the same between the tire and gravel well in the enhanced cell and differed by only 2 scfm in the control cell. Pressure readings measured within the waste during each test varied significantly and had no correlation with well type. Based on the flow rate comparisons, the tire wells performed comparably to the conventional gravel wells.

**Table 3 . Enhanced Cell Vertical Tire and Gravel Well Gas Collection Test Results.**

| Date and Duration of Test (minutes) | Applied Vacuum (inches of water) *(Applied Vacuum During Normal Operation)* | Tire Well Gas Flow Rate (scfm) *(Average Monthly Flow Rate)* | Gravel Well Gas Flow Rate (scfm) *(Average Monthly Flow Rate)* |
|---|---|---|---|
| 2/28/97<br>156 minutes | -2.12<br>*(-0.0 to -0.1)* | 45.9<br>*(38.7)* | ______ |
| 3/6/97<br>294 minutes | -.81<br>*(-0.7 to -1.2)* | ______ | 33.2<br>*(38.7)* |
| 5/6/97<br>28 minutes | -1.25<br>*(-1.25)* | 37<br>*(40)* | 37<br>*(40)* |

**Table 4. Control Cell Vertical Tire and Gravel Well Gas Collection Test Results.**

| Date and Duration of Test (minutes) | Applied Vacuum (inches of water) (*Applied Vacuum During Normal Operation*) | Tire Well Gas Flow Rate (scfm) (*Average Monthly Flow Rate*) | Gravel Well Gas Flow Rate (scfm) (*Average Monthly Flow Rate*) |
|---|---|---|---|
| 2/28/97<br>156 minutes | -2.12<br>(*-0.0 to -0.1*) | 39.0<br>(*25.8*) | ——— |
| 3/6/97<br>294 minutes | -0.81<br>(*-0.7 to -1.2*) | ——— | 13.1<br>(*25.8*) |
| 5/6/97<br>28 minutes | -1.25<br>(*-1.25*) | 29<br>(*26*) | 31<br>(*26*) |

***Fire hazard potential***

One of the greatest concerns in using shredded waste tires is the potential for them to catch on fire. The fire hazard of tires is increased when there are elevated temperatures and a supply of fuel and oxygen. To assess the fire potential of the shredded tires placed in the wells, temperature in the shredded tire and oxygen content of gas were investigated.

To determine if any elevated temperatures are occurring within the shredded tires, temperatures inside each vertical well were measured and compared. Temperature within each well and the surrounding waste temperature is plotted versus depth in Figures 3, 4, and 5. The surrounding waste temperatures were measured by thermistors placed in the refuse while filling. The temperature in the wells were measured using a K-type thermocouple that was lowered into the well casing from the top of well. Due to difficulties in lowering the thermocouple into the enhanced cell gravel well, temperature measurements are limited to 25 feet below the top of the well on February 6 and March 4, 1997. A depth of 20 feet from the top of the well corresponds to Level 3 in the waste mass and a depth of 40 feet corresponds to Level 2 as depicted on Sheet 3, Appendix B. In all figures the temperature in the tire wells followed the same general trend as the gravel wells. Temperatures increased slightly until reaching a steady state condition at a depth of about 20 feet (Level 3). The initial temperature increase is associated with moving the thermocouple past the section of the well located above the surface liner to the well section embedded in the waste. In all figures the majority of the tire well temperatures were slightly lower than or equal to the gravel well temperatures. The lower temperature in the tire wells is attributed to heat losses while passing through the larger well diameter in the tire wells.

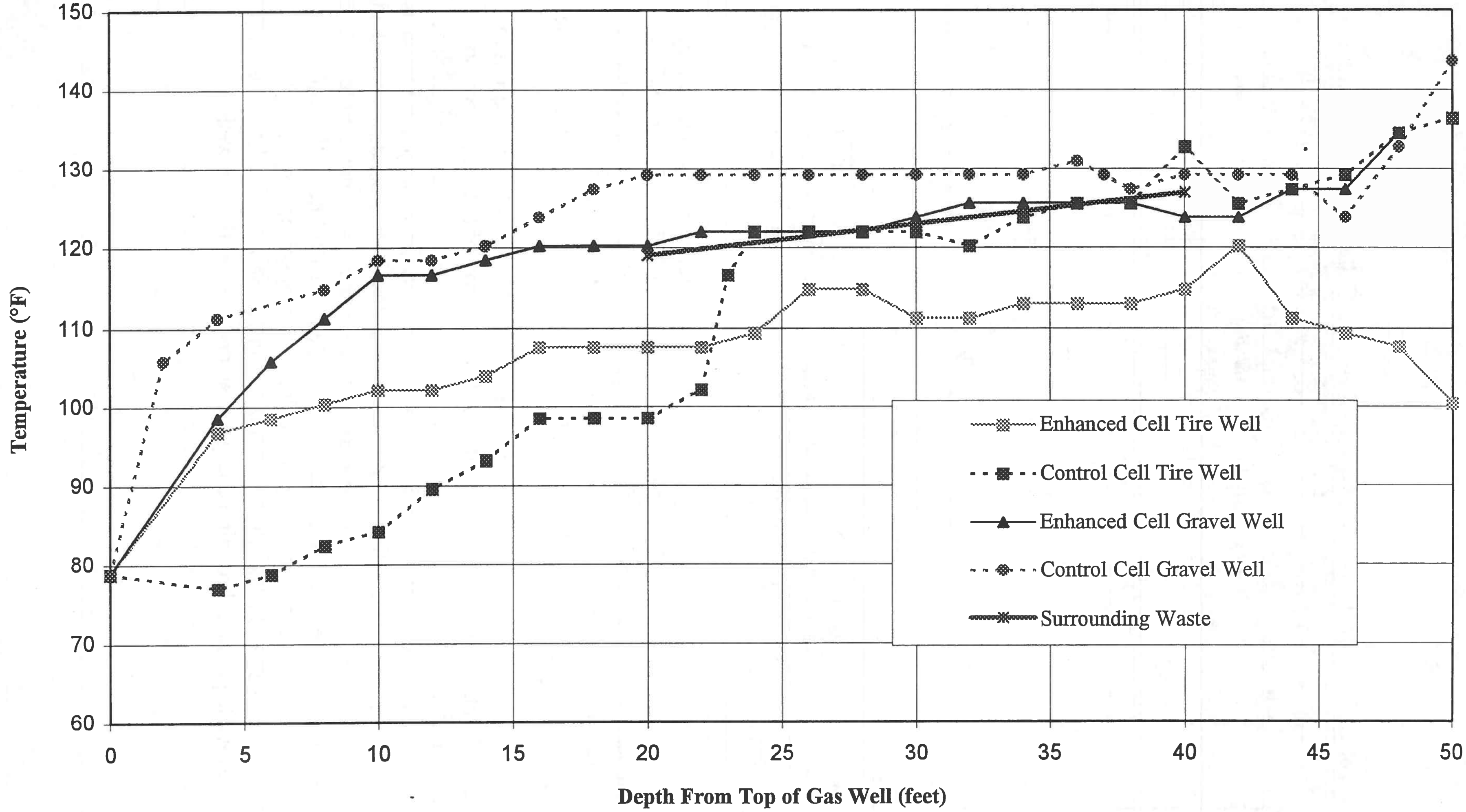



**Figure 3. Enhanced and Control Cell Vertical Gas Well Temperature Versus Depth, November 5, 1995**

Measurements Taken Immediately After Completion of Waste Filling

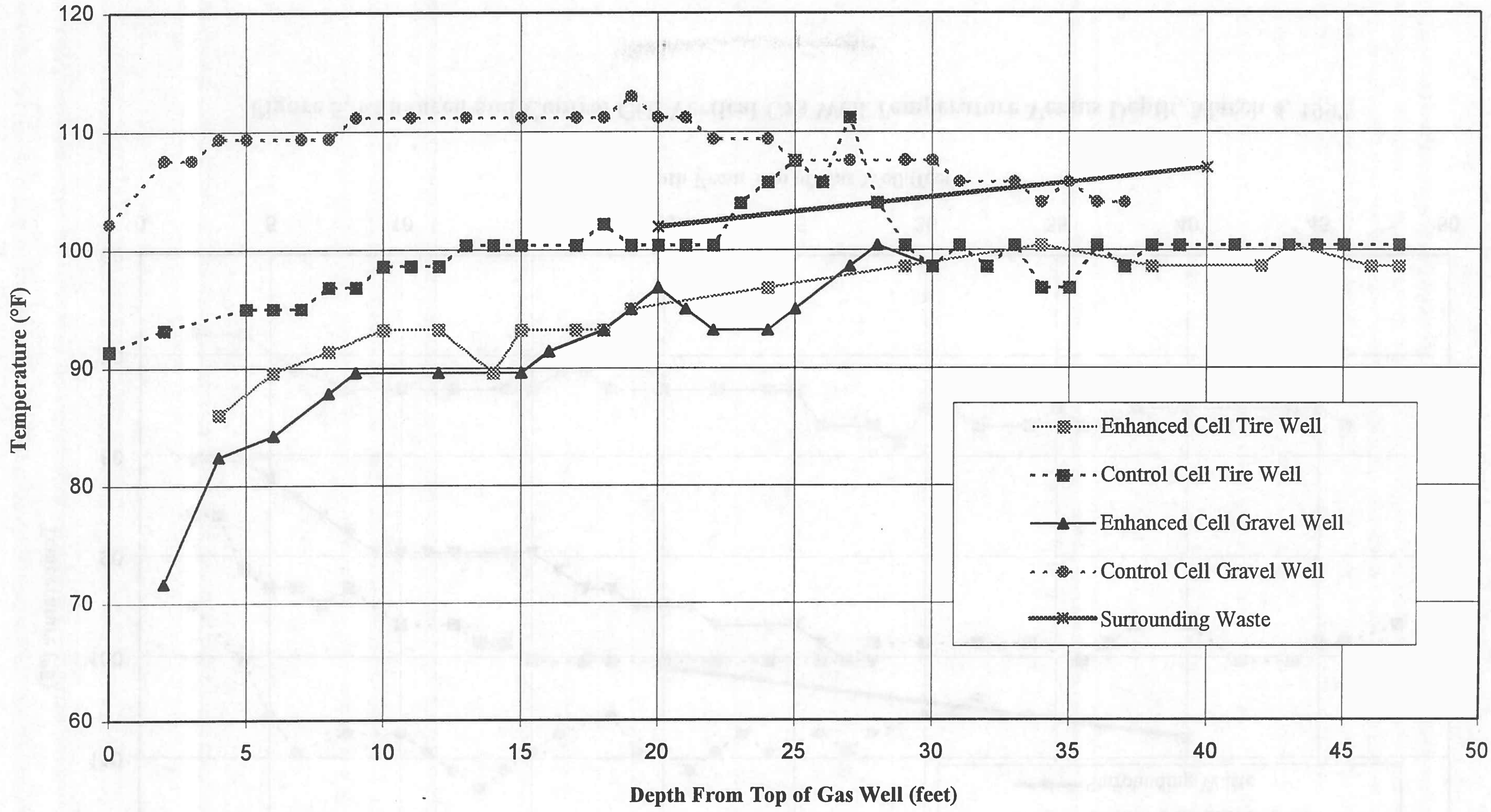



**Figure 4. Enhanced and Control Cell Vertical Gas Well Temperature Versus Depth, February 6 & 7, 1997**

The Consistently Lower Temperatures In The Enhanced Cell Wells Are Believed To Be Due To Liquid Addition That Began On October 23, 1996.

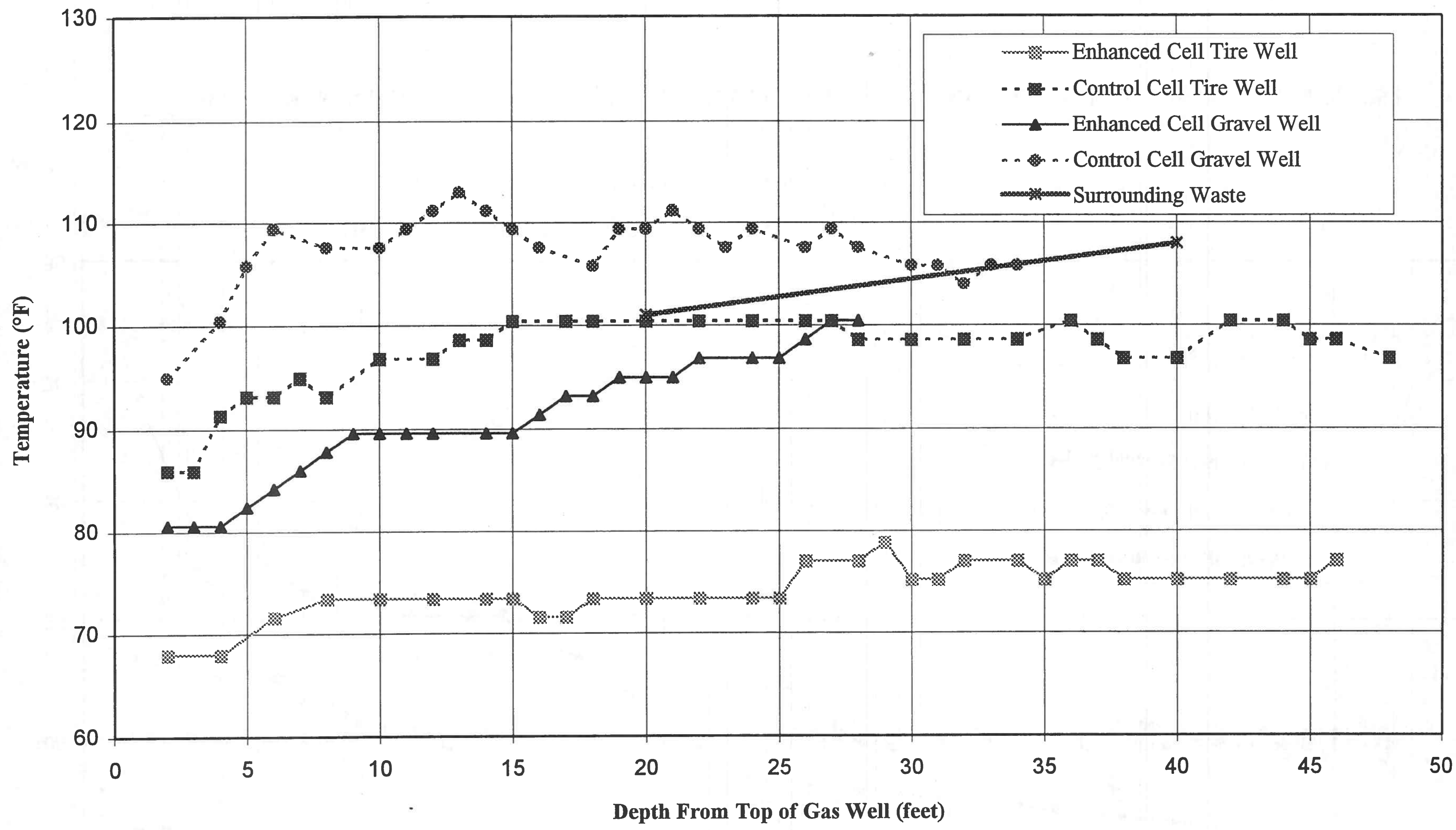



**Figure 5. Enhanced and Control Cell Vertical Gas Well Temperature Versus Depth, March 4, 1997**

The Consistently Lower Temperatures In The Enhanced Cell Wells Are Believed To Be Due To Liquid Addition That Began On October 23, 1996.

Both the tire and gravel well temperatures were representative of the surrounding waste temperature. The tire wells averaged 5 degrees lower than the surrounding waste temperature while the gravel well averaged 1 degree lower. The lower temperatures in the enhanced cell are due to the addition of cool liquid into the cell which cooled the waste.

The gas composition for each cell has been monitored since July 1996. The gas analyses were performed using a thermal conductivity detector gas chromatograph. The landfill gas was analyzed for methane, carbon dioxide, nitrogen and oxygen. The percent oxygen measured in the gas samples collected from the vertical wells and horizontal layer have averaged 0.4%. This is below background levels of 0.7% oxygen associated with sample collection methodologies. None of the data gathered in this project supports the notion that shredded tires in the landfill are a fire hazard.

***Shredded tires as insulators***

Waste decomposition and gas production are strongly correlated to waste temperatures. By maintaining the temperature within the waste these parameters can be maximized. To determine the insulating effect of the shredded tires, temperatures above and below the layer have been measured. These measurements for both the enhanced and control cell are listed in Table 5. For the enhanced and control cells an average temperature drop of 16°F has been measured across the shredded tire layer. The temperature gradient across the shredded tire layer averaged 6°F per foot.

**Table 5. Temperature Measurements Above and Below the Horizontal Shredded Waste Tire Gas Collection System.**

| Date | Ambient Air Temperature (°F) | Enhanced Cell | | | Control Cell | | |
|---|---|---|---|---|---|---|---|
| | | Temperature Above Tires (°F) | Temperature Below Tires (°F) | Temperature Difference (°F) | Temperature Above Tires (°F) | Temperature Below Tires (°F) | Temperature Difference (°F) |
| 12/12/95 | 57 | 88 | 111 | 23 | 104 | 120 | 16 |
| 2/2/96 | 57 | 70 | 81 | 11 | 68 | 82 | 14 |
| 7/5/96 | 88 | 104 | 115 | 11 | 104 | 117 | 13 |
| 10/25/96 | 59 | 82 | 90 | 8 | 81 | 91 | 10 |
| 2/27/97 | 64 | 66 | 61 | 5 | 63 | 73 | 10 |

## 3. WORK PLANS

This section discusses the potential for commercial implementation of this technology and the implications for solid waste management. Recommendations to further this technology by building on the work that has already been done are also made. The schedule work performed and completed during the grant period is also presented.

***Potential for Technology Application***

Shredded tires were used in the demonstration cells for two different applications. First, shredded tires were used as a landfill gas collection media as a substitute for gravel, which is the typical media used. The results of this demonstration project show that shredded tires function as well or better than gravel as a landfill gas collection media. Shredded tires were used in both conventional vertical recovery wells as well as a horizontal "blanket" layer over the surface of the waste fill. The horizontal blanket of shredded tires is not a typical method for the recovery of landfill gas, although it proved to work well in this application. The demonstration project also involved the addition of liquid to the landfill and the recirculation of leachate to accelerate landfill decomposition. Infiltration chambers were constructed in the surface of the waste and filled with shredded tires to function as a distribution media for supplemental liquid/recycled leachate. The shredded tires performed well in both applications. Based on these results, a dual system that uses the same shredded tire layer for both landfill gas collection and liquid addition/leachate recirculation appears to be a viable system.

***Implications for Landfill Management***

The success of shredded tires as a landfill gas recovery media has generated a number of ideas regarding their use in landfills with significant implications for solid waste management. In particular, the combination of early landfill gas recovery with accelerated landfill decomposition could greatly improve the economics for landfill gas energy projects. Even more significant is the potential for closure cost savings. Using horizontal shredded tire layers to collect landfill gas early in the decomposition process combined with accelerated landfill decomposition through liquid addition and leachate recirculation, the need for long-term waste containment with low permeability layers (geosynthetics or low permeability clay) could be precluded. If the landfill could be managed to rapidly decompose, thereby achieving total landfill gas yield within a relatively short time period while controlling emissions, it might be possible to close the landfill with a soil layer for vegetative growth without the cost of a composite liner system (geosynthetics and soil) as current regulations require. Such an approach would result in a significant cost savings.

In addition to the implications cited in the above paragraph, an additional benefit of landfill life extension could also be realized. The rapid decomposition of the landfilled waste would also translate into relatively rapid settlement of the landfill. Settlement that occurs early in the landfill's life, prior to final closure, creates landfill space that can be used for additional waste placement, rather than representing an on-going post-closure maintenance problem as is currently the case. Some conceptual approaches to this technology are described below.

### *Conceptual Approaches to Shredded Tire Use in Landfills*

The conceptual plan is to install trenches or "blanket" layers of shredded tires during filling of the landfill. Developing a design for such a concept was not included in the scope of work for this project, however, definition sketches are shown in Figures 6 and 7 that defines the major variables to be quantified during a design process. Design issues to investigate include the following:

1. Should shredded tire filled trenches be used as shown in Section A-A, No. 1, Figure 7, rather than a "blanket" of shredded tires as shown in Section A-A, No. 2?

2. What is the optimal areal extent of the shredded tire layer(s)? The response to this question would quantify variables "w" and "l" in Figures 7.

3. At what landfill depth should multiple layers of shredded tire collection media be used rather than a single layer?

4. At what distance from the surface of the landfill should the shredded tire gas collection layer be placed to both control emissions and limit atmospheric air intrusion through the surface (variable 'a' in Figures 6 and 7)?

5. What is the optimal distance of separation between layers and from the landfill base (variables 'b' and 'c' in Figures 6 and 7?

6. What is the minimum thickness of shredded tires that would be effective (variable 't' in Figures 6 and 7)?

7. What is the optimal vacuum to apply to the system?

8. What is the optimal method for using the shredded tire layers to both collect landfill gas and add supplemental liquid and leachate to the waste to accelerate decomposition?

### *Qualitative Economics*

An overview of the benefits and costs for utilization of horizontal landfill gas collection trenches or blankets while the landfill is being filled is provided in this section.

### *Benefits*

1. This end use for used tires would create a market for this waste stream.

2. The cost for installation of vertical wells is eliminated. This cost savings amounts to $3,000 to $6,000 per acre.

FIGURE 6. Definition Sketch: Conceptual Design of a Shredded Tire Landfill Gas Recovery System – Profile View

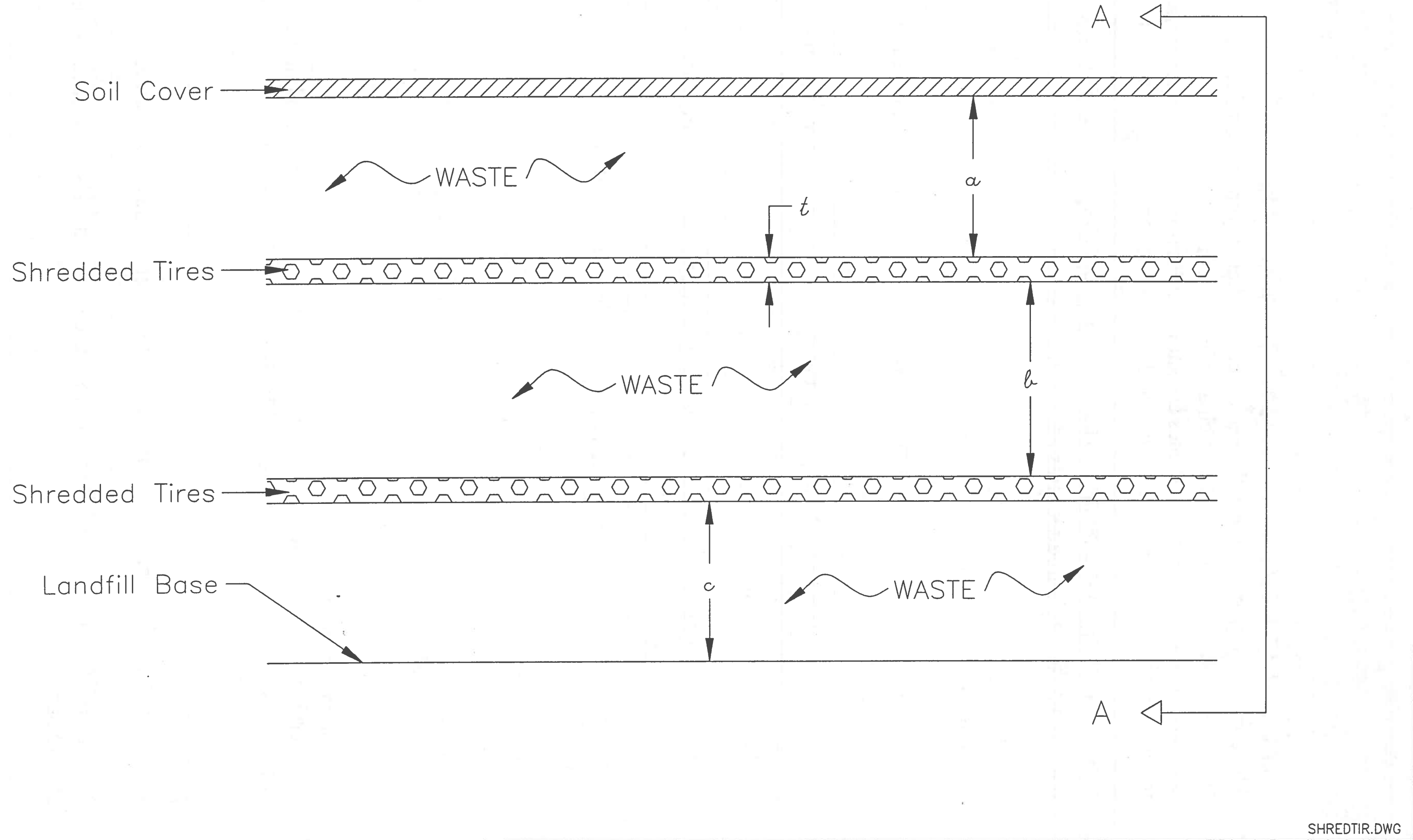
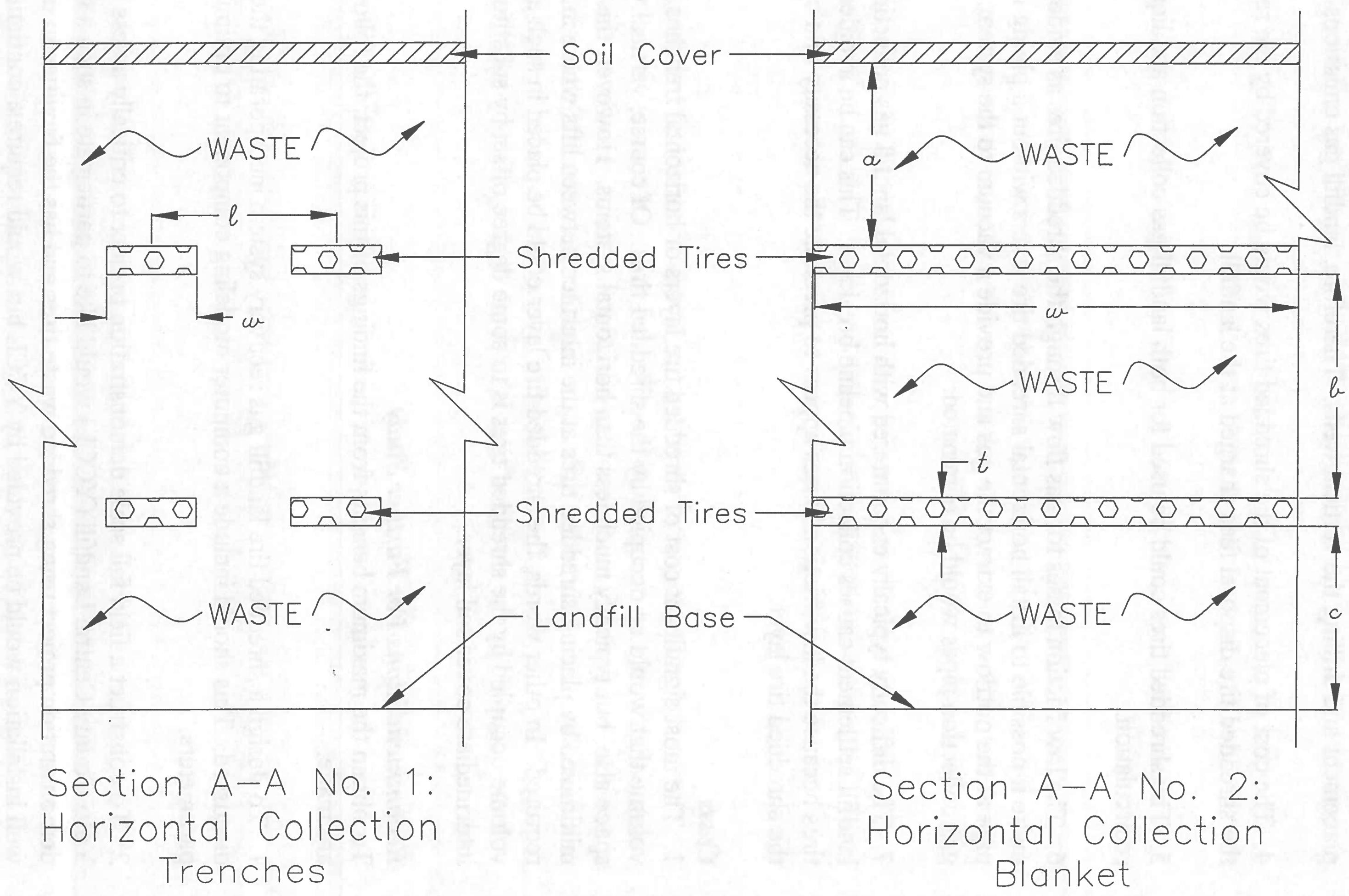


FIGURE 7. Definition Sketch: Potential Horizontal Landfill Gas Collection Layers – Section Views



3. An environmental benefit is derived from the fact that landfill gas collection could begin sooner with a horizontal collection system because of the lag time between the completion of waste placement and drilling the vertical wells. Therefore, landfill gas emissions would be reduced.

4. The cost of placement of the shredded tires would be covered by the revenue resulting from the shredded tire disposal fees charged at the landfill.

5. The shredded tires could be used for both landfill gas collection and liquid addition/leachate recirculation.

6. The low friction losses for gas flow through the shredded tires as evidenced in this study may make it possible to install horizontal shredded tire layers without a piping network, simply using a pipe at the outflow to extract the gas and provide a vacuum to the system. Therefore, the cost of gas collection pipes would be eliminated.

7. The difficulty typically encountered with horizontal landfill gas collection systems is that landfill settlement causes collection pipeline breakage. This can be avoided by using shredded tires because the low friction losses appear to preclude the necessity of a collection pipe within the shredded tire layer.

***Costs***

1. The most significant cost of shredded tire layers or horizontal trenches is the loss of landfill volume that would be occupied by the shredded tires. Of course, vertical wells occupy landfill space also, but typically much less than horizontal systems. However, this cost could be minimized by placing shredded tires at the interface between lifts where intermediate cover is required. In other words, the shredded tire layer could be placed in such a way that the landfill volume occupied by the shredded tires is to some degree offset by substituting for the required intermediate cover soil layer.

***Recommendations For Further Study***

To obtain the maximum benefits from the findings of this project, the following recommendations are made.

1. To design a shredded tire landfill gas recovery system incorporating the concepts previously discussed. This should include a computer modeling component to optimize the relevant design parameters.

2. To construct a field full scale demonstration project to critically assess the selected design. Yolo County Central Landfill (YCCL) would like to participate in such a field full scale demonstration project using shredded waste tires and has the facilities to do so. Funding for the well installation would be provided by YCCL but would require a continued partnership with the California Integrated Waste Management Board to fund monitoring costs and documentation of well installation.

3. To conduct an economic analysis of the application of this technology, including the potential for used tire market development.

4. To excavate a portion of the shredded tires from the horizontal gas collection layer in both the enhanced and control cell at a future date. Samples would then be analyzed to determine the effects of a corrosive landfill environment has on shredded tires over time. This would also determine the effects of leachate recirculation on shredded tires by comparing samples collected from the enhanced cell to the control cell.

***Work schedule for the grant period***

**Work Schedule: through May 1996**

| TASK NO. | JUN 1995 | JUL 1995 | AUG 1995 | SEP 1995 | OCT 1995 | NOV 1995 | DEC 1995 | JAN 1996 | FEB 1996 | MAR 1996 | APR 1996 | MAY 1996 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | •> | | | | | | | | | | | |
| 1B | • | — | — | — | — | — | > | | | | | |
| 2A | • | > | | | | | | | | | | |
| 2B | | | | | • | — | > | | | | | |
| 3A | | • | — | — | — | — | > | | | | | |
| 3B | | | | | | | | • | — | — | — | — |
| 4 | | | | | | | | | | | • | — |

**Work Schedule: through May 1997**

| TASK NO. | JUN 1996 | JUL 1996 | AUG 1996 | SEP 1996 | OCT 1996 | NOV 1996 | DEC 1996 | JAN 1997 | FEB 1997 | MAR 1997 | APR 1997 | MAY 1997 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3B | — | — | > | | | | | | | | | |
| 4 | — | — | — | • | — | — | — | — | — | > | | |

## 4. FINANCIAL STATUS

**Task 1 Design and Construct a Vertical Landfill Gas Collection System**

| | |
|---|---|
| Original Task Budget, CIWMB Funds: | $1000.00 |
| Amount Invoiced to CIWMB this Quarter: | $ 0 |
| Amount Invoiced to CIWMB previous Quarters: | $1,000.00 |
| Task Budget Balance, CIWMB Funds: | $ 0 |

Task 1 was completed within the CIWMB grant budget.

**Task 2 Design and Construct a Horizontal Landfill, Gas Collection System**

| | |
|---|---|
| Original Task Budget, CIWMB Funds: | $27,000.00 |
| Amount Invoiced to CIWMB this Quarter: | $ 0 |
| Amount Invoiced to CIWMB previous Quarters: | $27,003.00 |
| Task Budget Balance, CIWMB Funds: | $<$3.00> |

The horizontal gas collection system design and construction were completed within the CIWMB budget.

**Task 3 Design and Construct a Gas Recovery System**

| | |
|---|---|
| Original Task Budget, CIWMB Funds: | $34,000.00 |
| Amount Invoiced to CIWMB this Quarter: | $ 5,300.00 |
| Amount Invoiced to CIWMB previous Quarters: | $28,697.00 |
| Task Budget Balance, CIWMB Funds: | $ 3.00 |

Task 3 was completed within the CIWMB grant budget.

**Task 4 Operation and Data Analysis**

| | |
|---|---|
| Original Task Budget, CIWMB Funds: | $1,000.00 |
| Amount Invoiced to CIWMB this Quarter: | $1,000.00 |
| Task Budget Balance, CIWMB Funds: | $ 0 |

Task 4 was completed within the CIWMB grant budget.

This Waste Tire Market Development grant, TR-94-1033-57, was awarded a total of $63,000.00.

## 5. CONCLUSIONS

Shredded tires as a landfill gas collection media shows great potential based on the results of this project. The low cost of shredded tires removes economic constraints and creates opportunities for innovative designs using shredded tires for gas collection. The use of shredded tires for intermediate cover or as a component of final cover system could provide early and effective landfill gas collection at a low cost.

During the grant period the constructablility of vertical gas collection wells using shredded waste tires was successfully demonstrated. The same equipment and methodology was used to construct both the vertical tire well and the conventional vertical gravel well. However, due to the well configuration (i.e. placement of the gas collection pipe and size of tire chips), it was necessary to construct the shredded tire wells with a diameter of 4 feet as opposed to a 2 foot diameter for gravel wells. If the size of shredded tires were reduced, then the well size could also be reduced. Another alternative would be to use the 'one-pass' 12 inch minus shredded tires in a 2 foot diameter well without the installation of a slotted gas collection pipe. Based on project results, the shredded tires would be able to capture the gas without the aid of this slotted gas collection pipe.

Based on gas flow rates measured from the vertical shredded tire well and the conventional gravel wells, the shredded tires performed comparably to gravel as a media to collect landfill gas from solid waste landfills. The horizontal tire layer was able to transfer all of the gas generated in the each cell without extraction from the vertical wells. Pressure within the tire layer indicates that friction losses are low within shredded tires at the velocities associated with landfill gas collection. Low friction losses within the shredded tires indicate a gas collection pipe is not necessary for gas capture. Full scale horizontal shredded tire gas collection system in a landfill would then be able to capture the gas while eliminating the need for vertical gas wells. Significate cost savings could then be realized while developing a new market for shredded waste tires.

The constructability of a horizontal gas collection system that consists of a 'blanket' layer of shredded tires has also been successfully demonstrated in this project. Roughly 500 tons of shredded waste tires were used to construct two horizontal systems. The contractor was able to use standard construction equipment to place and grade the shredded tires. The tendency of the shredded tire layer to compress caused only minor difficulties in accurately reaching final grade.

The insulating properties of shredded tires were measured in this project. With an average temperature drop of 16°F measured across the shredded tire layer in both the enhanced and control cells, the temperature gradient across the shredded tire layer averaged 6°F per foot. Since waste decomposition and gas production are strongly correlated to waste temperatures, the layer of shredded tires provides additional insulation to maintain the waste temperature for maximum benefit.

Gas analyses performed on each gas collection system indicates that the gas composition is independent of the type of collection media. Well temperatures in the vertical gravel and shredded tire wells did not vary significantly and were representative of the surrounding waste temperature. The temperature measurements within the wells and oxygen concentration in the landfill gas do not support the notion that shredded tires in the landfill are a fire hazard.

The shredded tires in the enhanced cell's horizontal layer were also used to distribute liquid and recirculate leachate. Based on the project results, a dual system that uses a shredded tire layer for both landfill gas collection and liquid addition and leachate recirculation appears to be a viable system. This combination of landfill gas recovery with accelerated landfill decomposition could greatly improve the economics for landfill gas to energy projects. By managing the landfill to rapidly decompose, the total landfill gas yield can be collected within a short time rather than over an extended period.

Landfill management using rapid decomposition could also provide a significant closure cost savings. Since complete decomposition and landfill gas yield is attained in a shorter time, long term risk to the environment may be reduced. This may make it possible to close the landfill with a final cover that would not include a costly composite liner system as is currently required.

An additional benefit of accelerated decomposition is landfill life extension. Decomposition of waste would translate into rapid settlement of the landfill. Settlement that occurs prior to final closure creates landfill space that can be used for additional waste placement.

The horizontal shredded tire layer in this project is an innovative design. It served not only to collect landfill gas but also in liquid addition and leachate recirculation. Positive results from this project show promise that this design is feasible for full scale operation. However, since this is an innovative design, the optimal design still needs to be determined and should be investigated. By constructing and monitoring a field full scale demonstration project, critical design issues can be assessed and further performance data can be collected. This would facilitate the promotion of a new market for shredded waste tires in landfill operations.

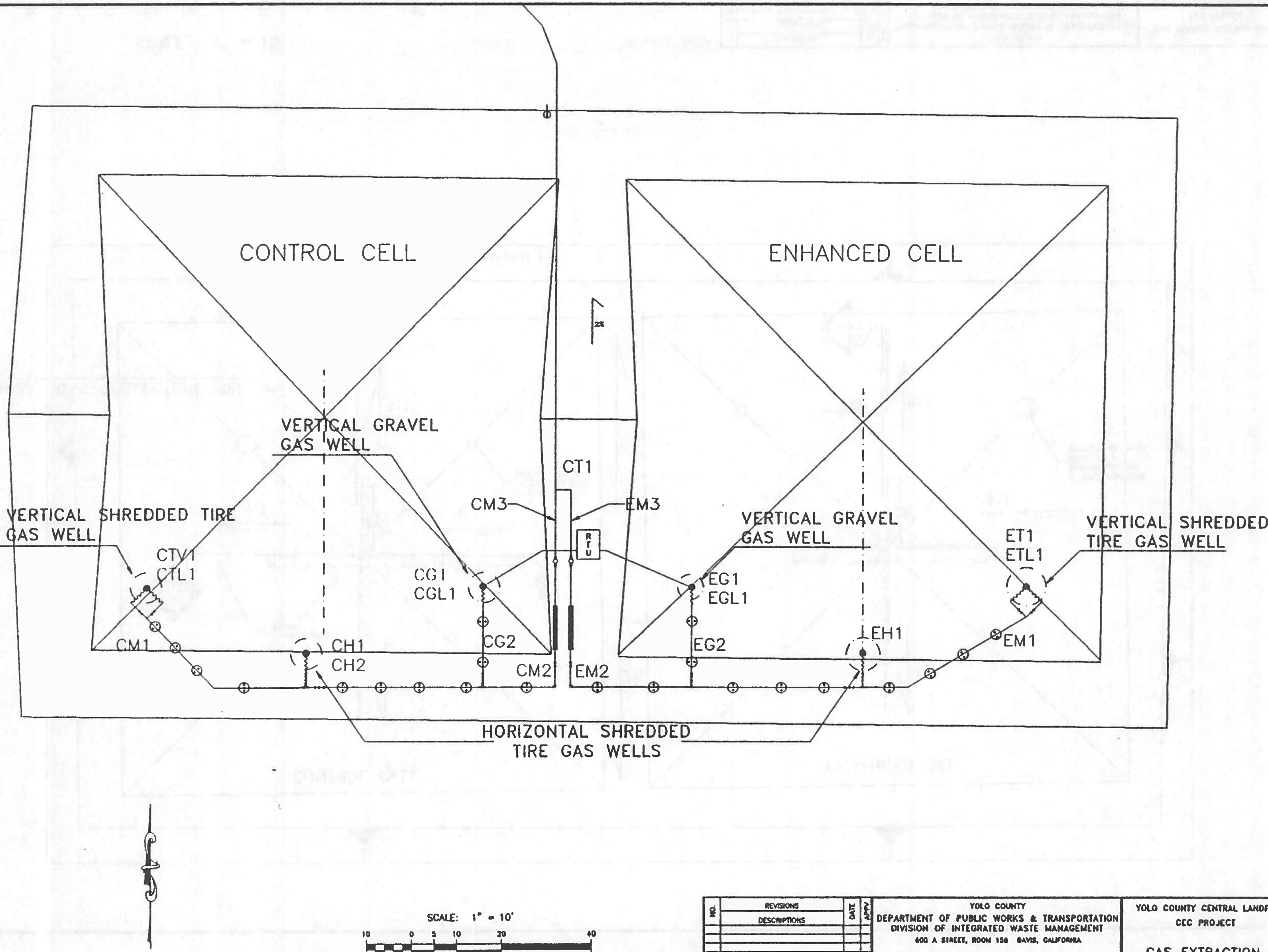
# APPENDIX A

## TASK SUMMARY

| TASKS | DESCRIPTIVE SUMMARY | TIME (Months Duration) |
|---|---|---|
| **Task 1** | **Design and Construct a Vertical Landfill Gas Collection System** | |
| 1A | Engineering Design of Vertical Gas Collection System | 1 |
| 1B | Construct Vertical Gas Collection System during Waste Placement Phase of Project | 4 |
| **Task 2** | **Design and Construct a Horizontal Landfill Gas Collection System** | |
| 2A | Engineering Design of Horizontal Gas Collection System | 2 |
| 2B | Construct Horizontal Gas Collection System following Waste Placement Phase of Project | 6 |
| **Task 3** | **Design and Construct a Gas Recovery System** | |
| 3A | Engineering Design of Gas Recovery System to include gas condensate removal, gas composition monitoring, and gas metering | 3 |
| 3B | Construction of Gas Recovery System | 8 |
| **Task 4** | **Operation and Data Analysis** | |
| A | Final Report Presented to Integrated Waste Management Board, Contract Workshop | 7 |

# APPENDIX B

## FINAL AS-BUILT DRAWINGS

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DIRECTOR OF PUBLIC WORKS

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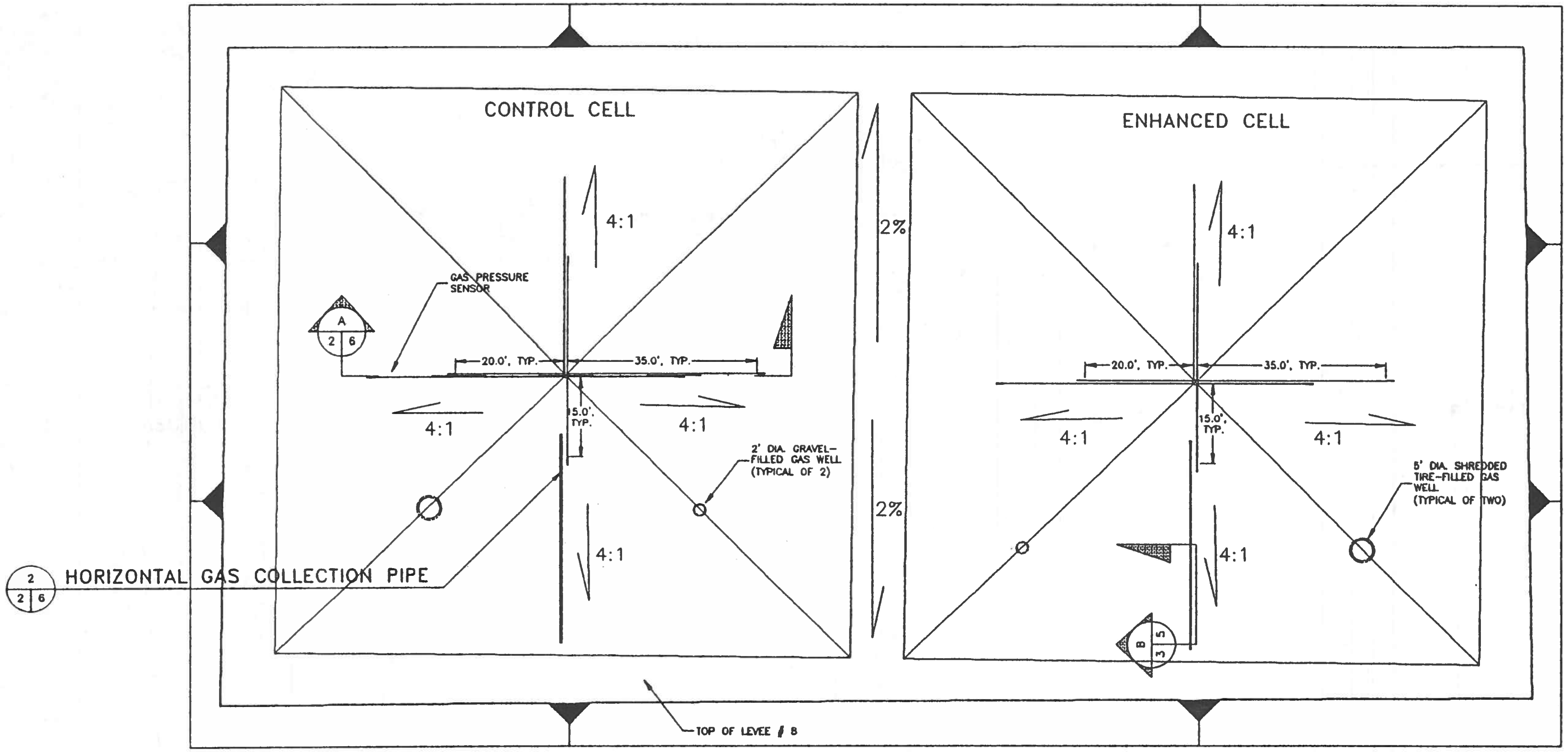
YOLO COUNTY CENTRAL LANDFILL
CEC PROJECT

# GAS EXTRACTION SYSTEM (AS BUILT)

DRAWING NO. YCCL-1993-07

W.O. NO. [illegible]
DATE 11/15/94
SHEET 1 OF 7

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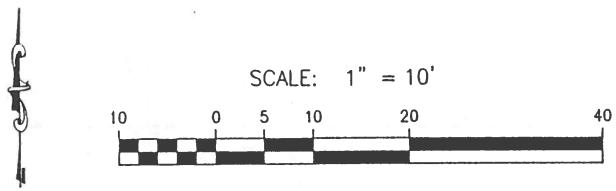


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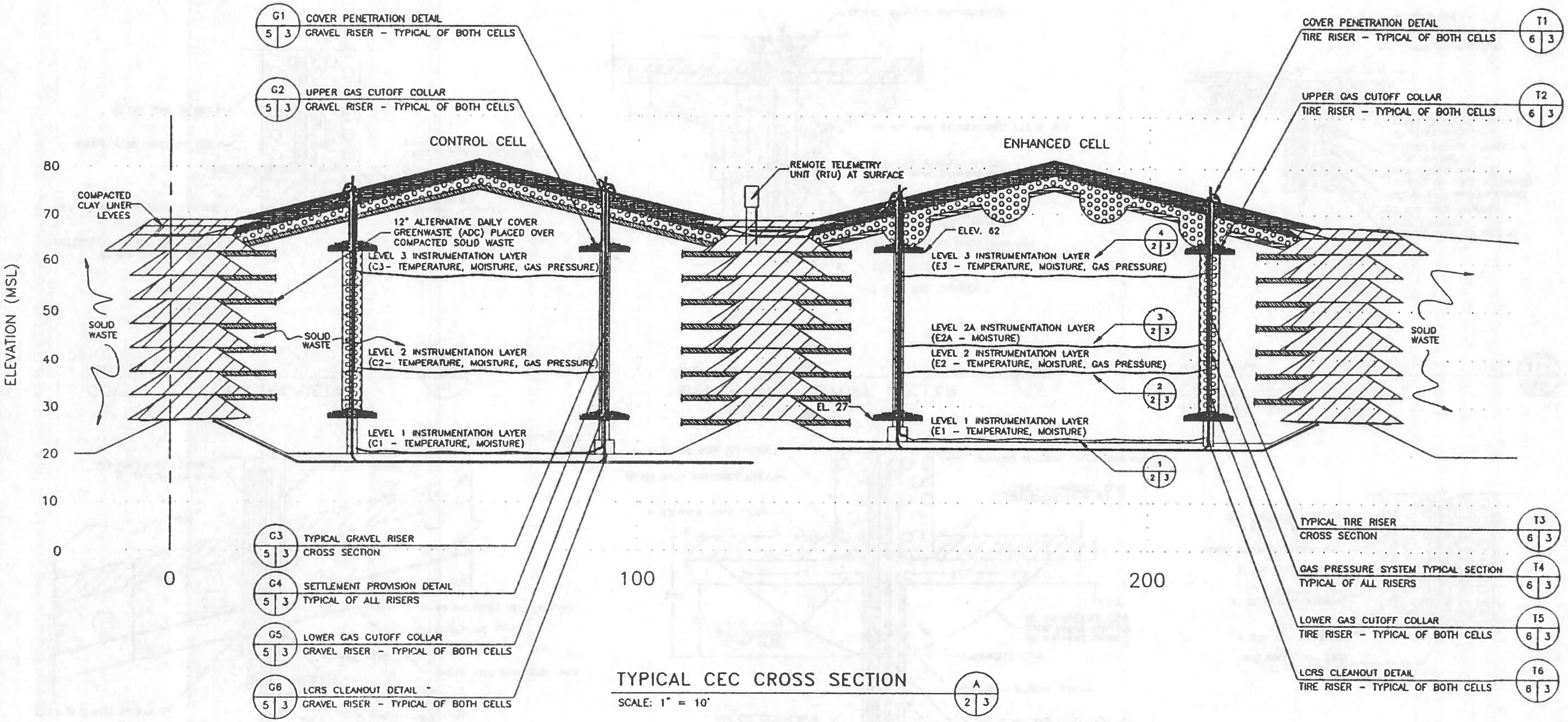
CEC PROJECT

**CEC HORIZONTAL GAS COLLECTION AND PRESSURE MEASUREMENT LAYOUT**

DRAWING NO. YOCL-1993-07

SHEET 2 OF 7




## TYPICAL CEC CROSS SECTION

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A 2|3

REDUCED COPY

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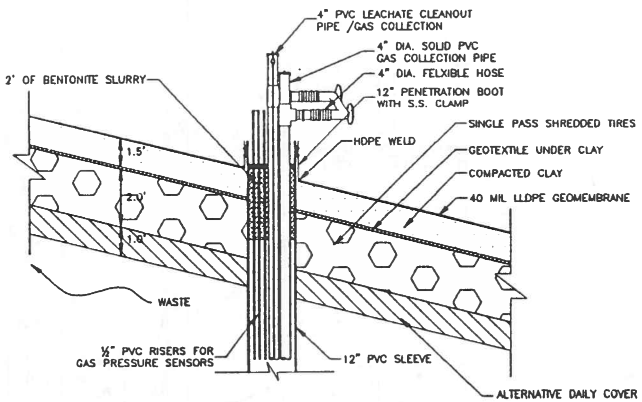
YOLO COUNTY CENTRAL LANDFILL
CEC CELLS

MONITORING SYSTEM FOR WASTE MASS

CROSS SECTION

DRAWING NO. YCCL-1995-08

SHEET 3 OF 7




COVER PENETRATION DETAIL
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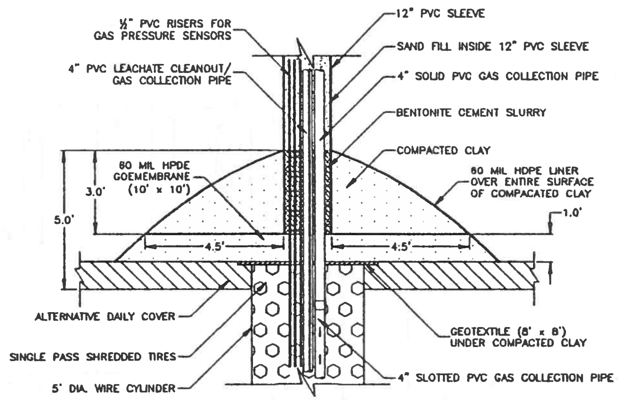


UPPER GAS CUTOFF COLLAR
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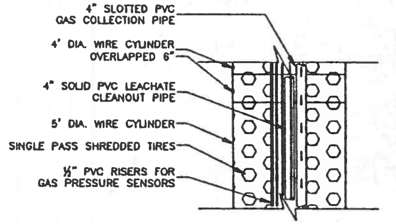
T2 3 | 4




TYPICAL TIRE RISER
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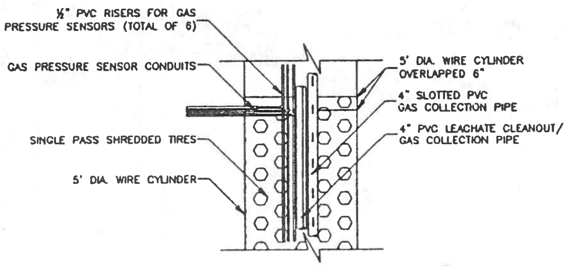


GAS PRESSURE SYSTEM
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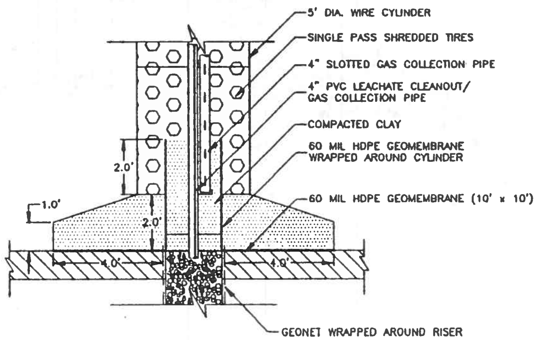


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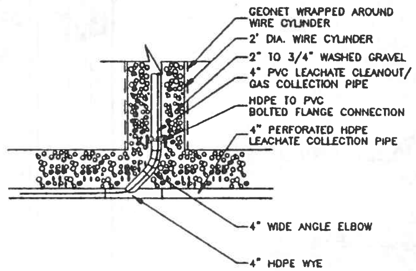


LCRS CLEANOUT DETAIL
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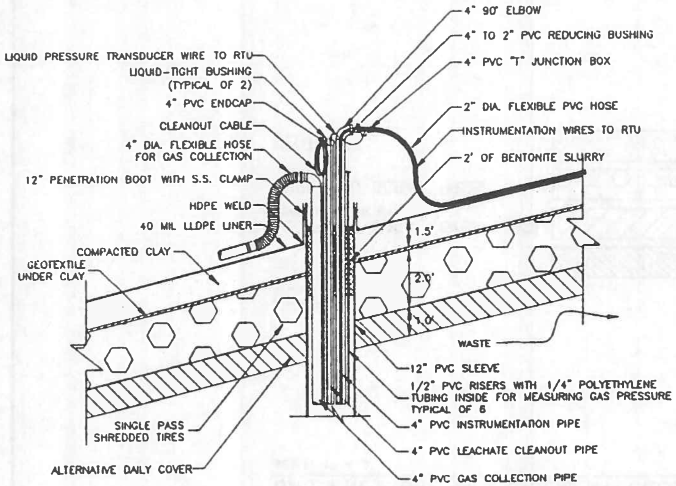
MONITORING SYSTEM
FOR WASTE MASS

TIRE RISER DETAILS

DRAWING NO. YOCL-1999-08

SHEET 4
OF 7

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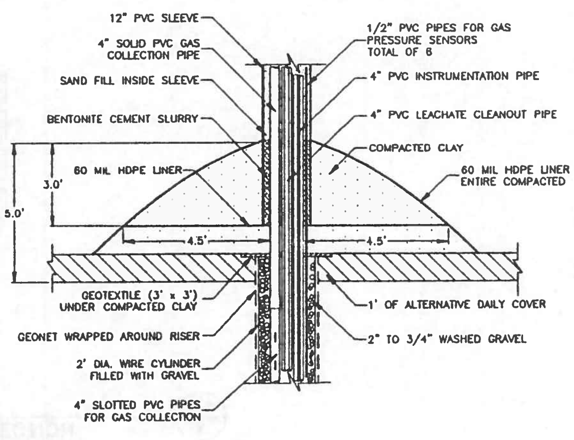


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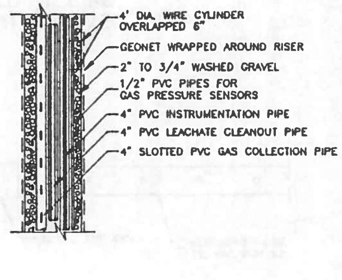


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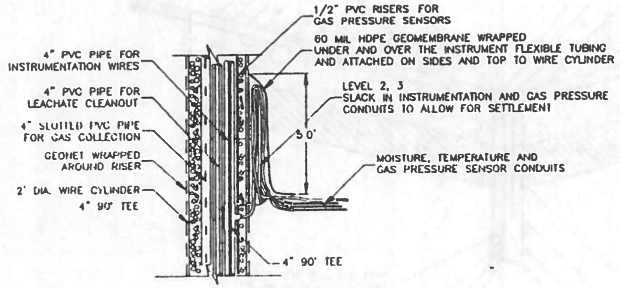


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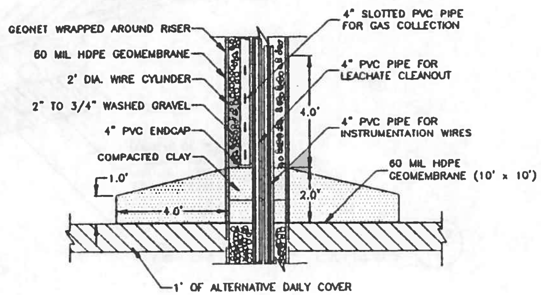


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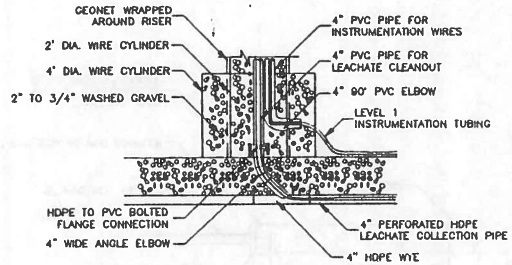


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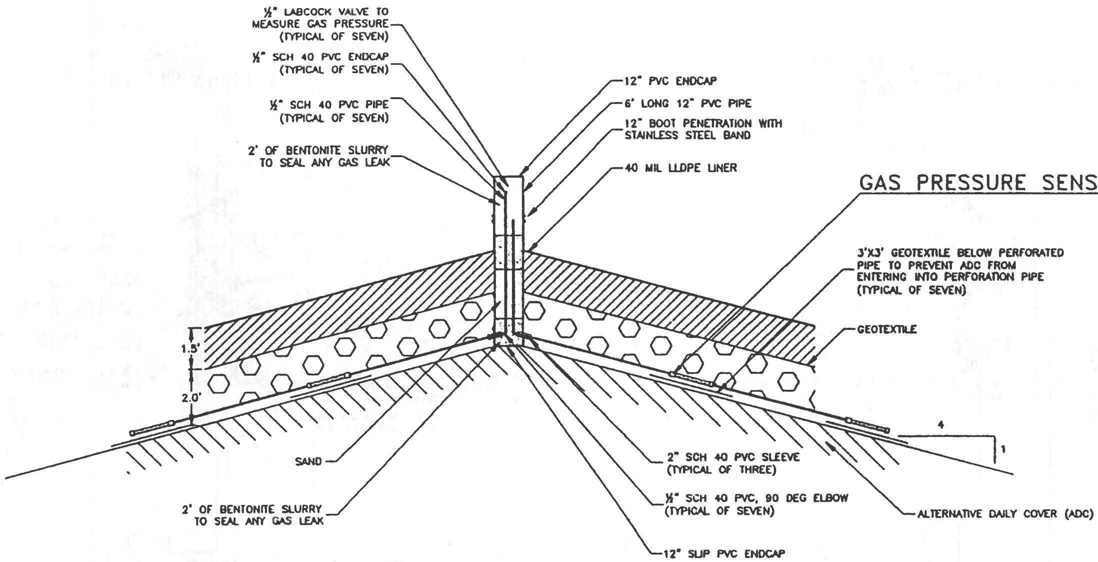
CEC CELLS

MONITORING SYSTEM FOR WASTE MASS

GRAVEL RISER DETAILS

DRAWING NO. YOCL-1035-88

SHEET 5 OF 7




CEC CONTROL AND ENHANCED CELL HORIZONTAL GAS PRESSURE MEASUREMENT CROSS SECTION (A, 3|5)

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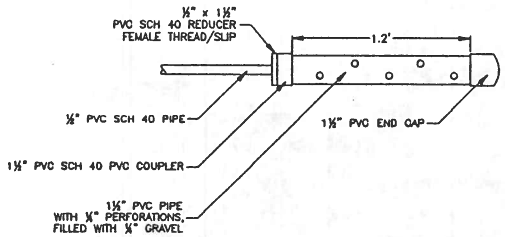


GAS PRESSURE SENSOR (1, 3|5)

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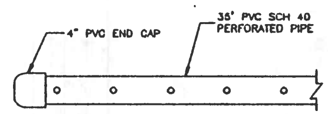


HORIZONTAL GAS COLLECTION PIPE (2, 3|5)

NOT TO SCALE

LEGEND

SOIL COVER

ALTERNATE DAILY COVER (ADC)
CHIPPED GREEN WASTE

SHREDDED SCRAP TIRES

BENTONITE

WARNING: THE ORIGINAL DOCUMENTS CONTAIN A RED COLORED PROFESSIONAL SEAL AND BLACK SIGNATURE.

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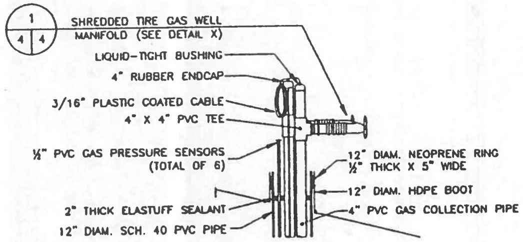
YOLO COUNTY CENTRAL LANDFILL
BASE MAP

GAS SYSTEM DETAILS

DRAWING NO. YOCL-1993-07

SHEET 6 OF 7

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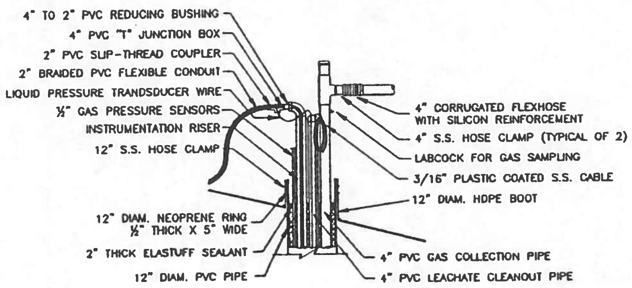


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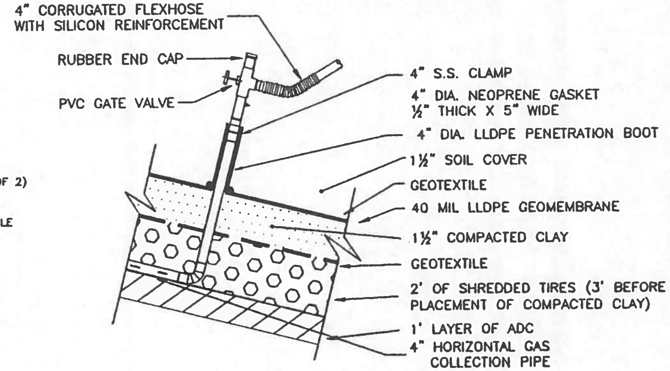


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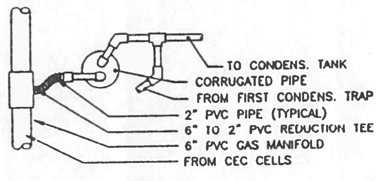


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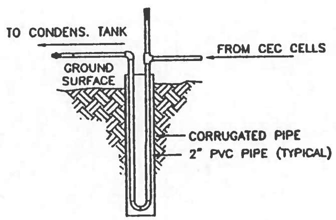


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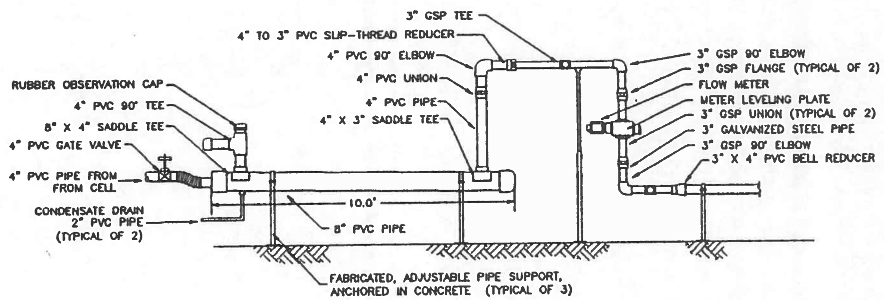


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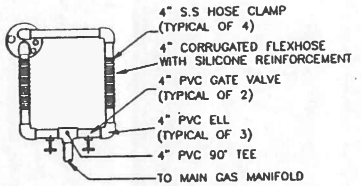


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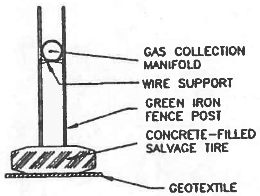


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YOLO COUNTY CENTRAL LANDFILL
CEC PROJECT

GAS SYSTEM DETAILS

DRAWING NO. YOCL-1895-87

SHEET 7 OF 7