# STEAM INJECTION LANDFILL BIOREACTORS A PILOT STUDY

By

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**STI Engineering**

# Biography

- Developed PPT For American Market – Over 1 Million Feet
- Worked On Nuclear PP., MX Missile, Many Dams, Dozens Of Landfills
- PPT Instructor At 4 Universities
- Worked In Solid Waste Industry For 30 Years
- Hold Several Patents
- Author Of Several Papers And A Book
- Member & Presenter At SWANA

# BIOREACTOR LANDFILLS
# vs.
# DRY TOMB LANDFILLS

- Enhances biodegradation of organic waste
- Increases LFG production for waste-to-energy & Alternative Fuels
- Enhances settlement
- Recovers airspace
- Reduces organic related impacts while landfill is still in operation

# STEAM INJECTION

- The intent is to increase the humidity of the landfill not to saturate the refuse
- More uniform distribution
- Only 1/1600th of the water required
- Enhanced settlement, water is not compressible
- Low temperature steam will biodegrade organics

# STEAM vs. LIQUID

- Steam warms refuse
- Steam moves in all directions
- Steam will not flood collectors
- Better moist. distribution
- Will not plug bottom drains
- Steam will not displace void spaces, more settle.
- Steam migration can be monitored easier, by temp.

- Liquid cools refuse
- Moves down & laterally under a head pressure
- Liquid could flood collect.
- Poor moist. distribution
- Could plug bottom drains
- Liquid will fill void spaces, inhibits settlement
- Liquid migration is difficult to monitor
- Liquid cannot

# AIRSPACE RECOVERY
vs.
# LANDFILL EXPANSION

- Steam Injection could recover 30 to 50% more air space
- Should Steam Injection be used first, before applying for landfill expansion?
- The sooner the Steam Injection is applied the more airspace recovered
- Steam costs a fraction of a bottom liner

# Technology Application

- **Established Technology Being Used In A New Application: Piezo- Penetrometer Test (PPT)**
  - Geotechnical Applications for Over 30 Years
  - ASTM Procedures
  - CPT Used for Soil Behavior Type, Density, Strength
  - Piezo-Penetrometer Cone Used for Water Table Depth, Excess Pore Pressure in Clays

# Technology Application

- **Established Technology Being Used In Landfills:**
  - Data on Foundation Conditions, Sand Layers
  - Information on “Relative Refuse Density”
  - Rapid Data on Liquid Zones: Both Horizontal and Vertical
  - Rapid Data on LFG Pressure Zones: Both Horizontal and Vertical
  - Data on Extent of Vacuum from Existing LFG Extraction Systems: Both Horizontal and Vertical

# Technology Application

- **Established Technology Being Used In Landfills:**
  - Directly Useful in Design/Modification of LFG and Liquid Extraction Systems
  - Selective Well Location and Screening Based on Field Data
  - Determine Best Locations For Steam Injection
  - Push-in Wells, Perimeter Probes and Steam Injectors are Fast and Economical

# Description

- CPT and PPT Used to Characterize Subsurface Conditions


# Description

- CPT Indicates Material Strength/ Density and Behavior Type: Cover Layers vs MSW
- PPT Indicates Liquid, Vacuum and/or LFG Pressure

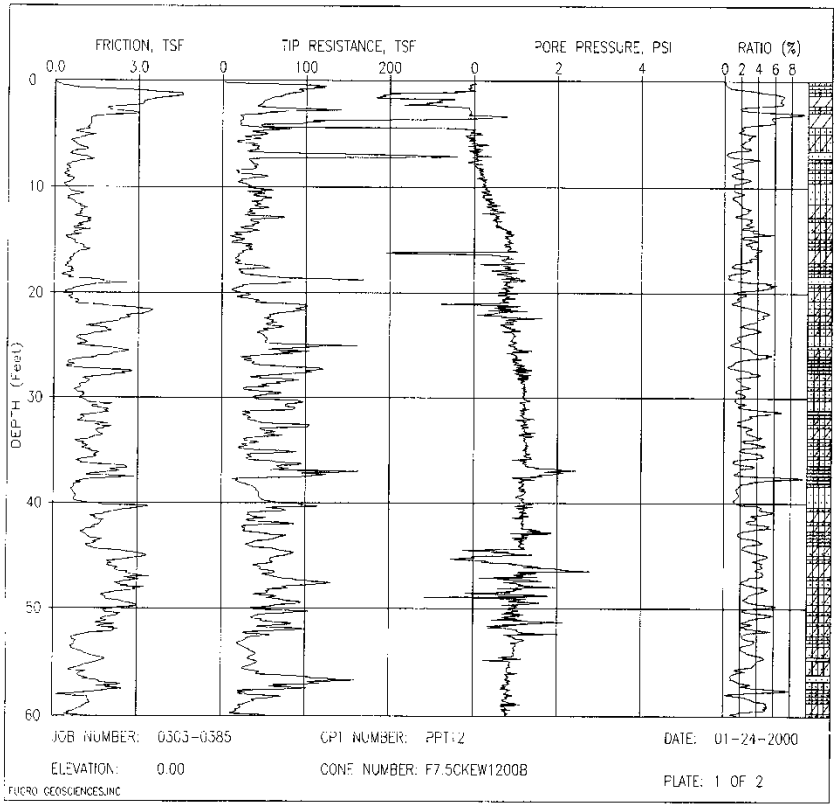
- Field Review of Data to Select Push-in Gas Well Locations and Screen Intervals

# Interpretation of PPT Logs

- Identify Dense/Daily Cover Layers
- Distinguish Liquid and Gas Pressures
- Identify Zones of Vacuum
- Evaluate Zones of Low Density MSW
- Determine The Density Of Bottom Native Soils In Unlined Landfills

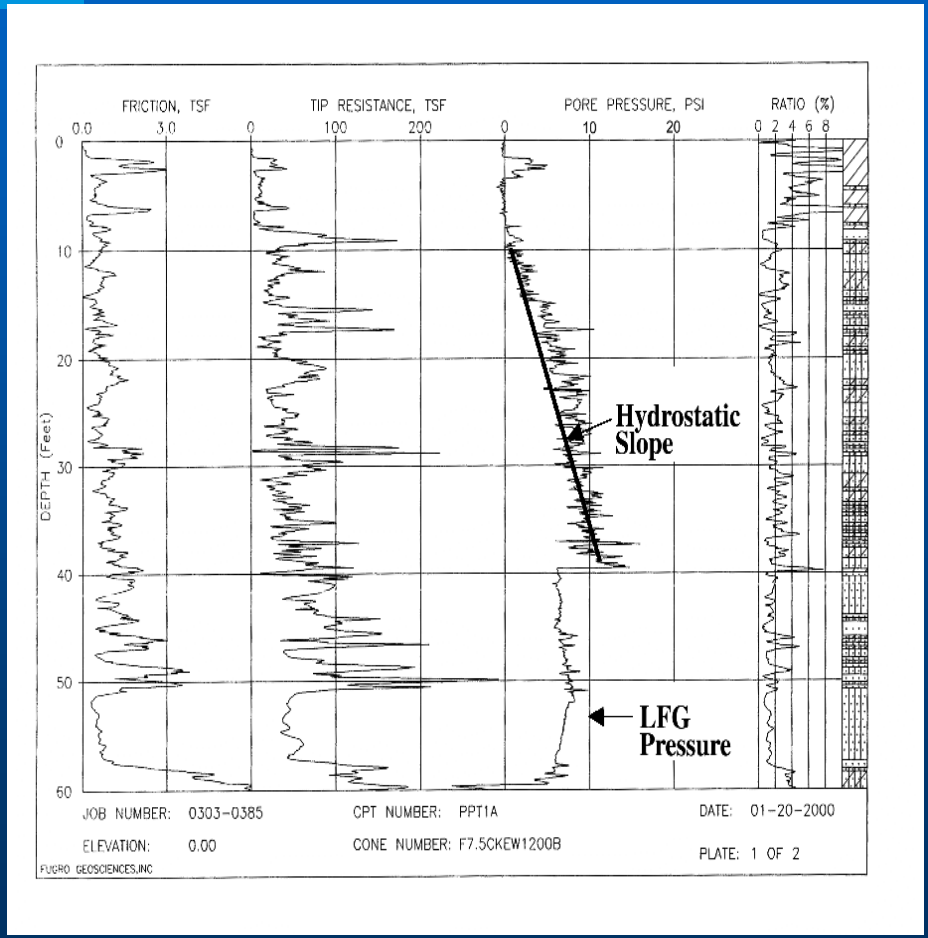
# TYPICAL PPT LOG

- Column 1-Depth, ft.
- Column 2-Friction, tsf
- Column 3-Tip Resist., tsf
- Column 4-Pore Pres., psi
- Column 5-Friction Ratio %
- Column 6-Lithology



# HYDROSTATIC PRESSURE SLOPE

- PPT Indicates Hydrostatic Liquid Pressure
- Interim Cover Layer at 40-ft Depth Causing Perched Water
- LFG Pressure Indicated Below Water Column

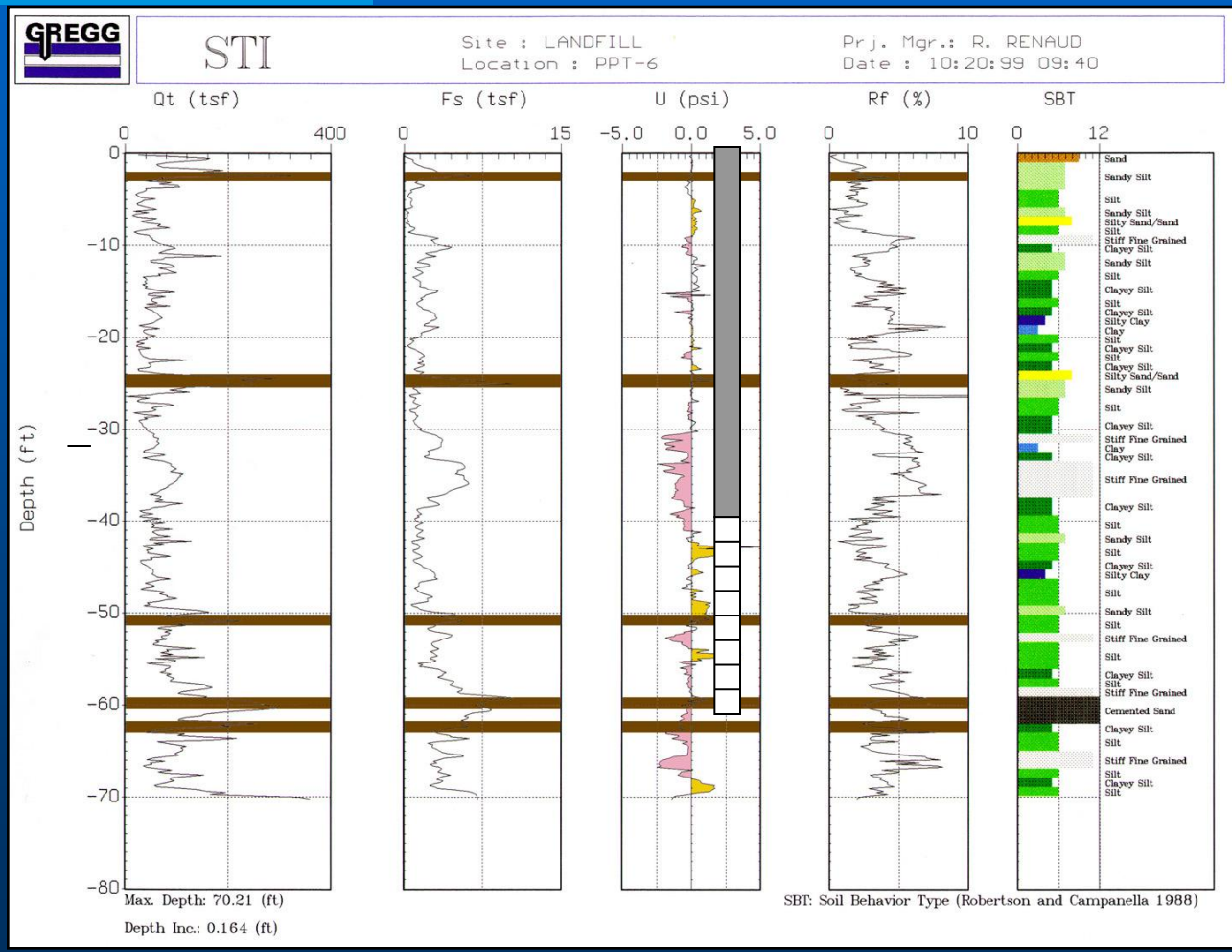


# Internal Conduits

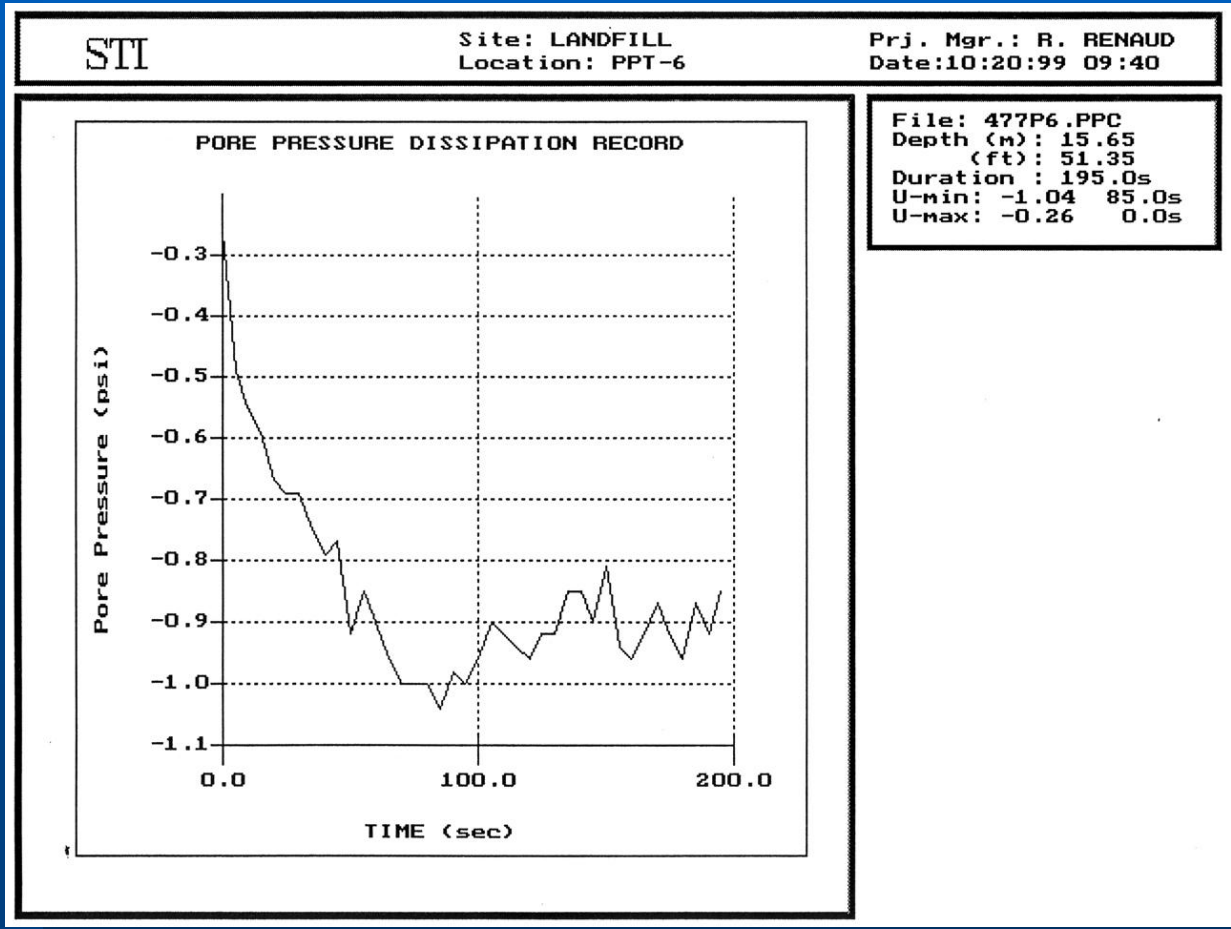
¾” PVC Slotted Pipe

Slots Connect Gas Layers to Vacuum Layers

The Hole Above the PVC Pipe is Grouted Up

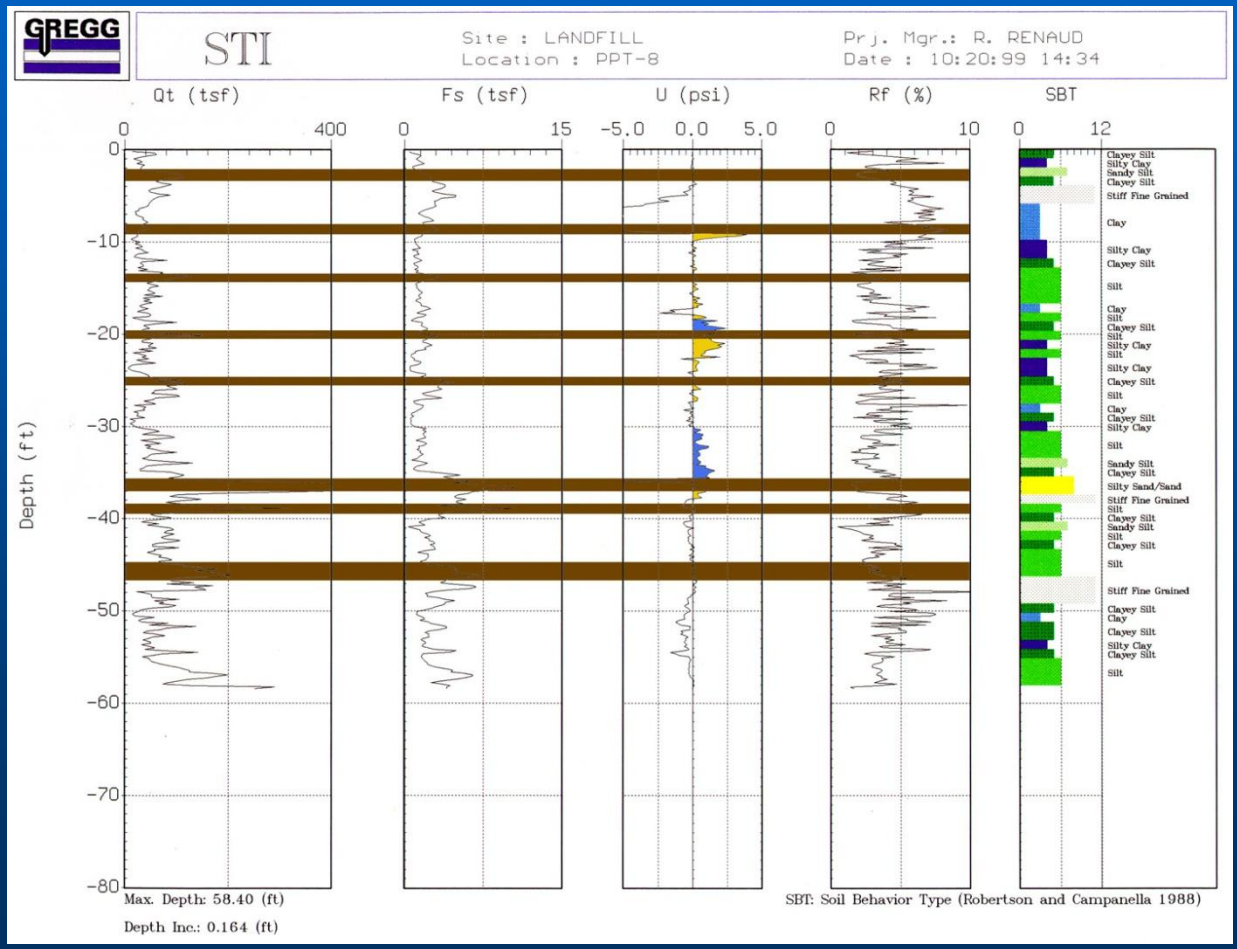


# Stabilization of Vacuum



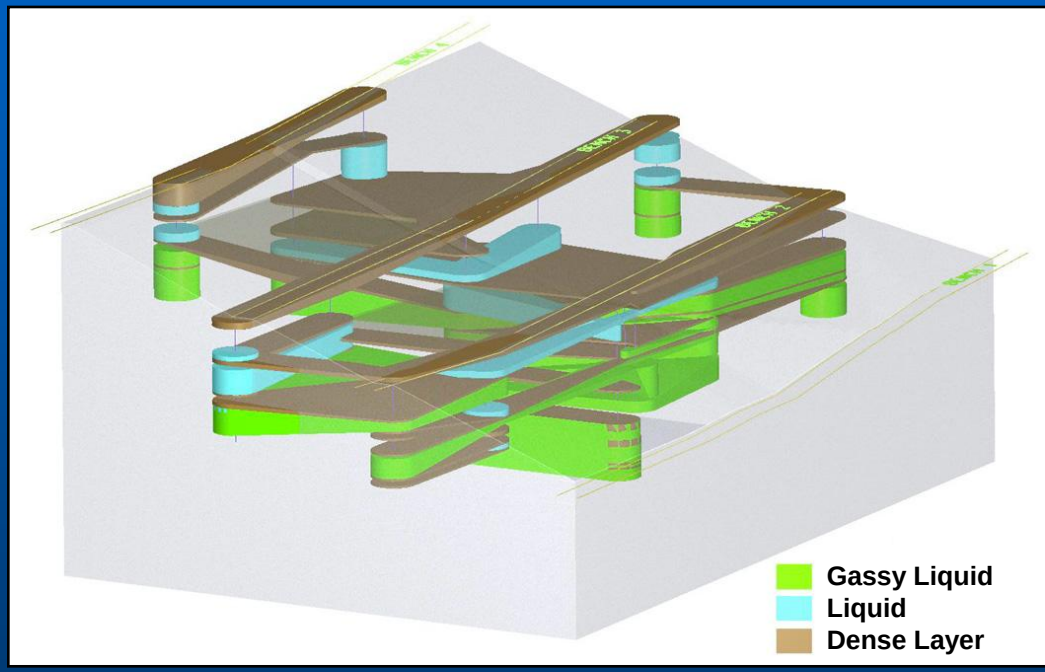
# Identifying Liquid Layers

- Fewer Daily Cover Layers Minimizes Liquid Layers



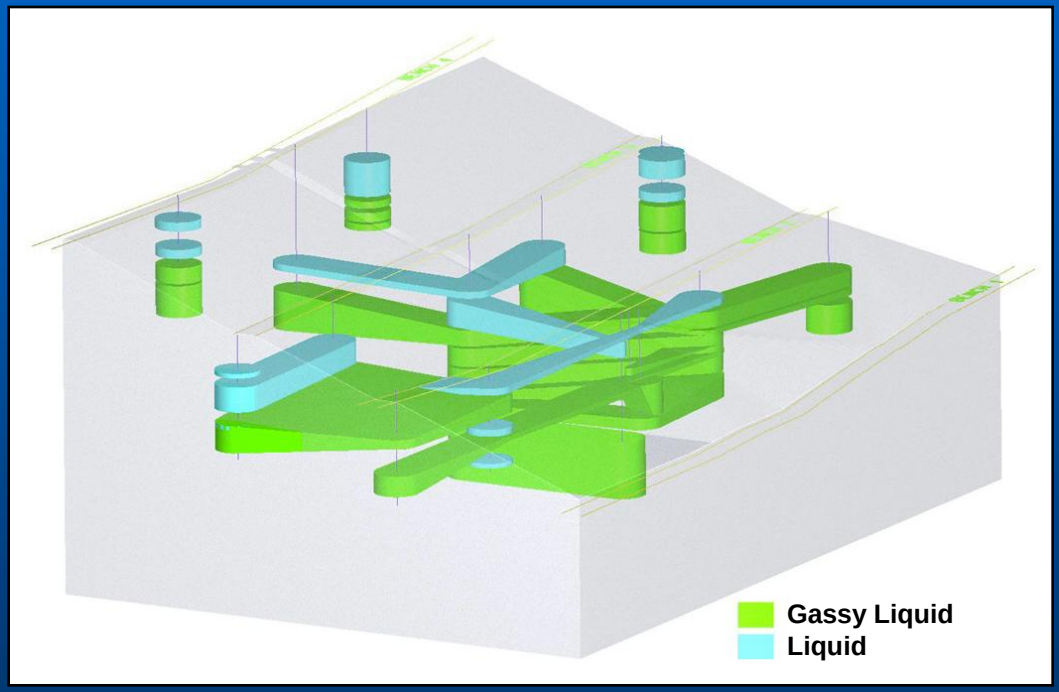
# Building 3-D Profiles in Stages

- Liquids Trapped on Dense Layers
- Gassy Liquids Generally Trapped Between Dense Layers
- Continuity Between Liquid Layers Encountered Below Bench Roads

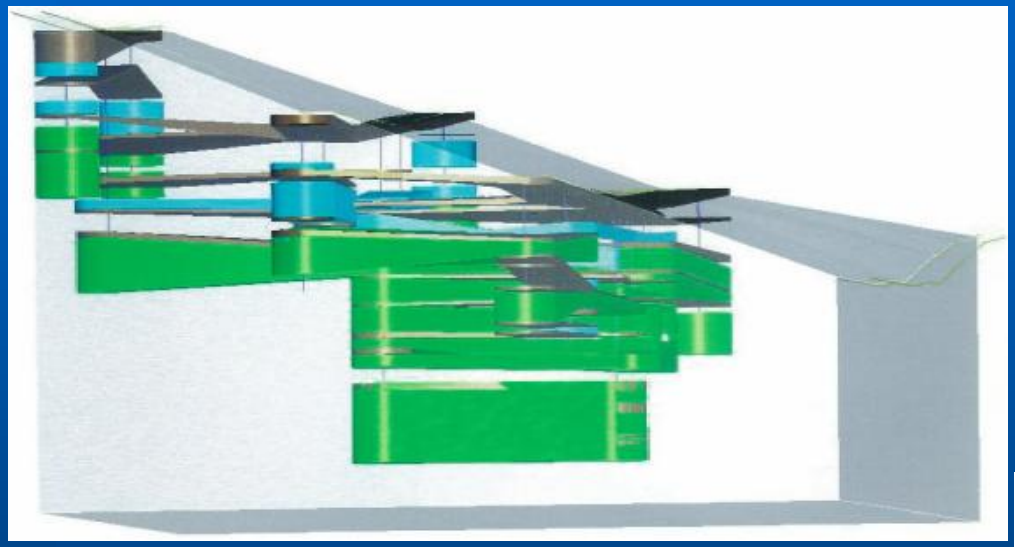


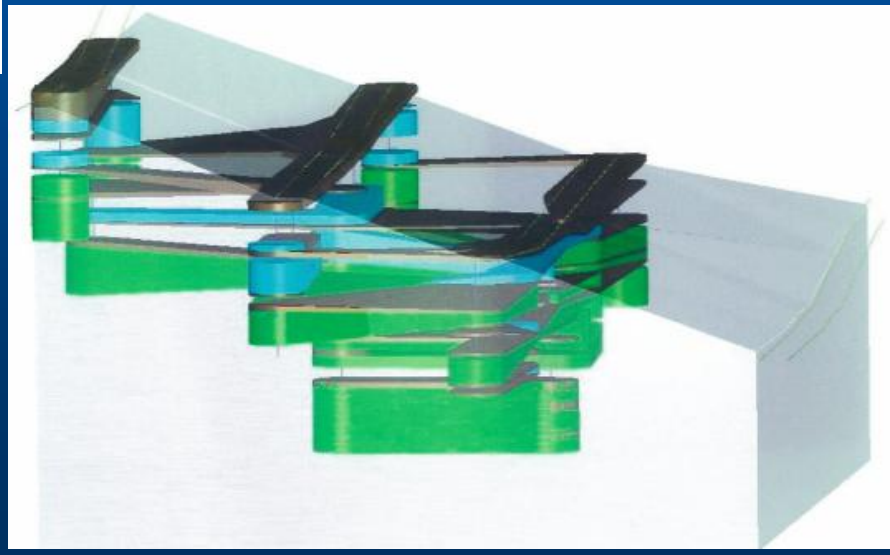
# 3-D Profile Enhances Understanding of Conditions

- Continuity of Liquid or Gassy Liquid Between and Along Bench Roads
- Liquids Above Gassy Liquids Indicates Water Intrusion

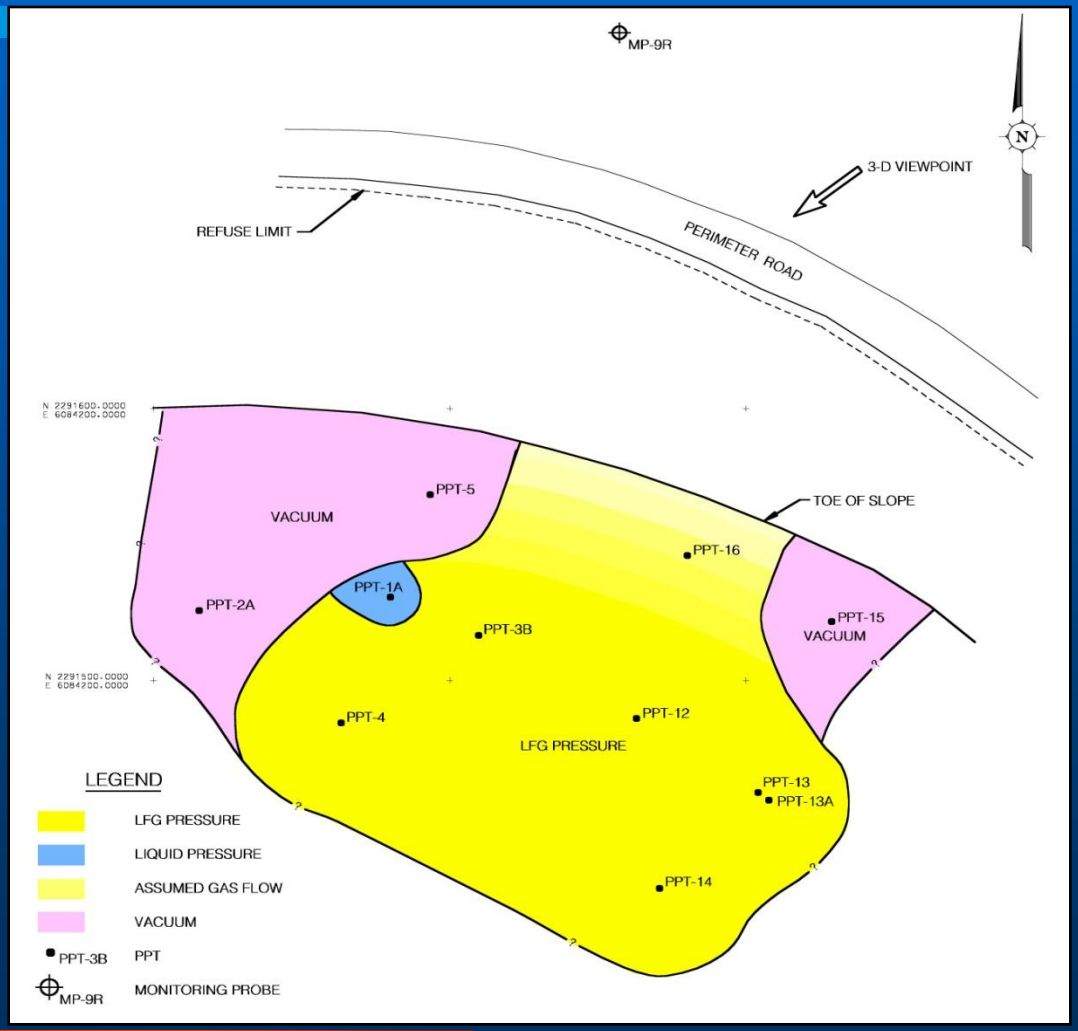


# 3-D Profiles Side View

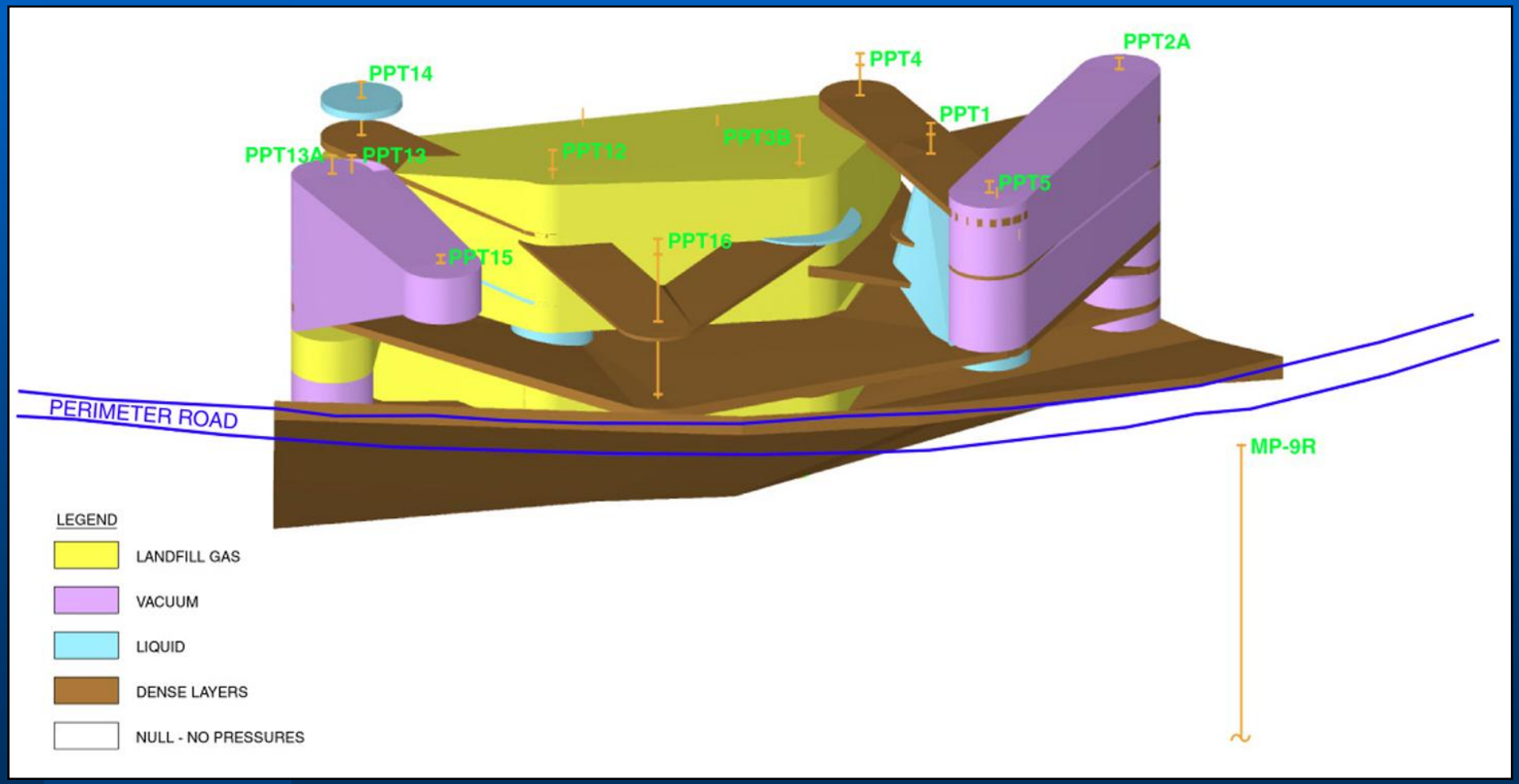




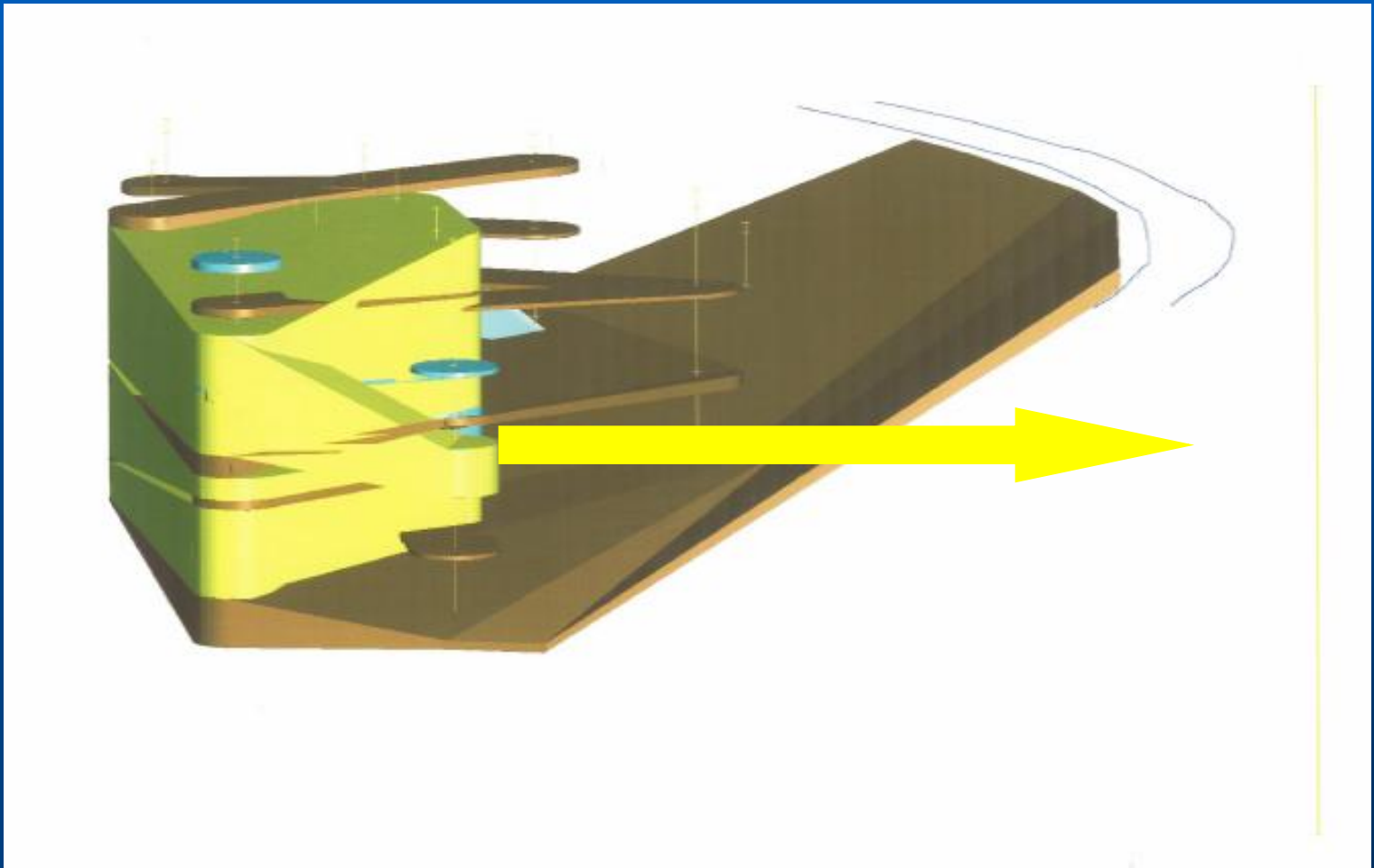
# Landfill PPT Profiling Plan View



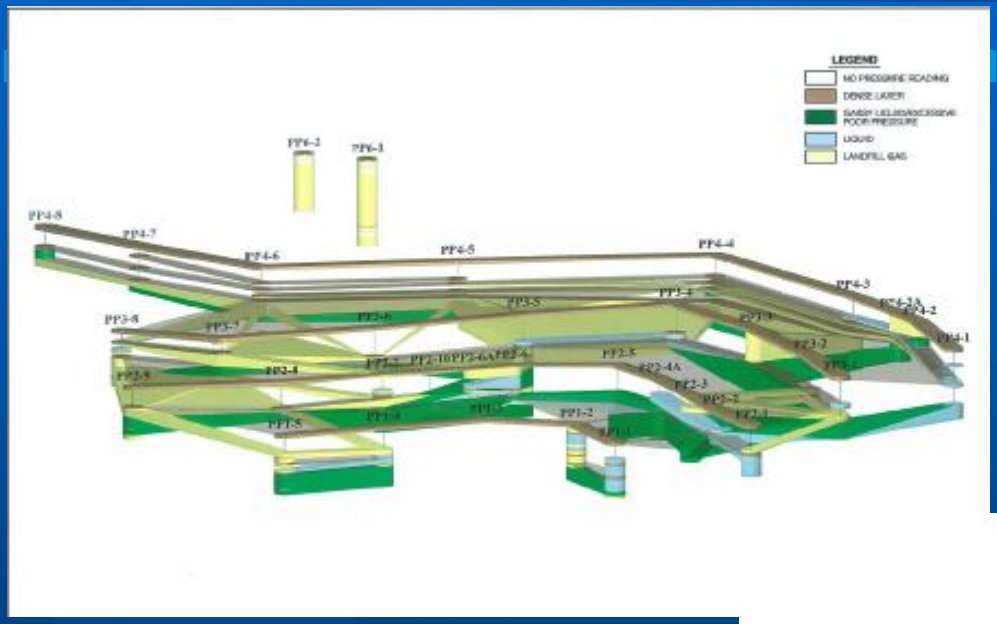
# Landfill PPT Profiling
# 3-D Profile



# Landfill PPT Profiling
## Side View

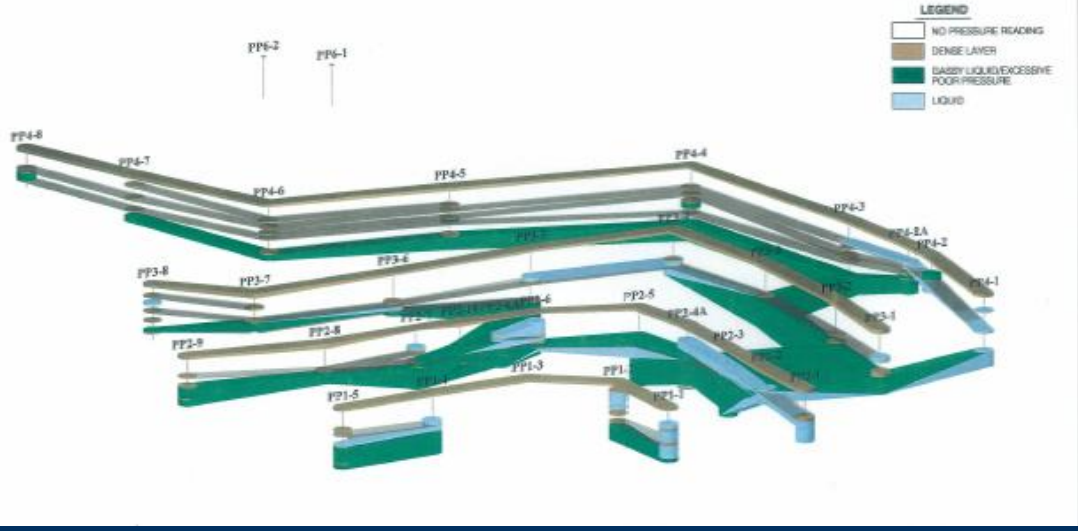


# 3-D Profiling With Colors On & Off

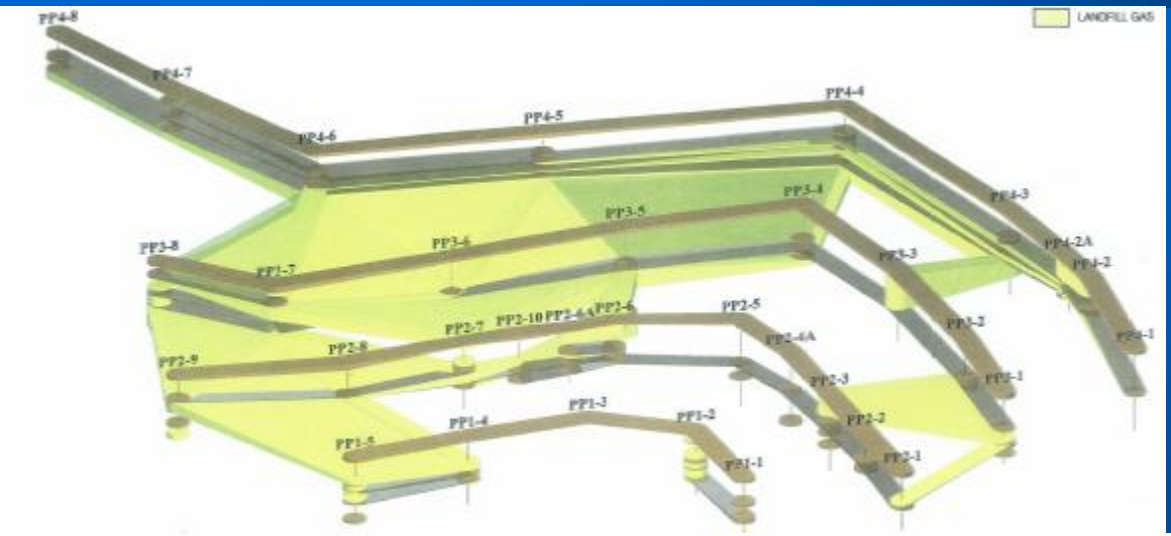



**All Colors On**

**Gas Off**

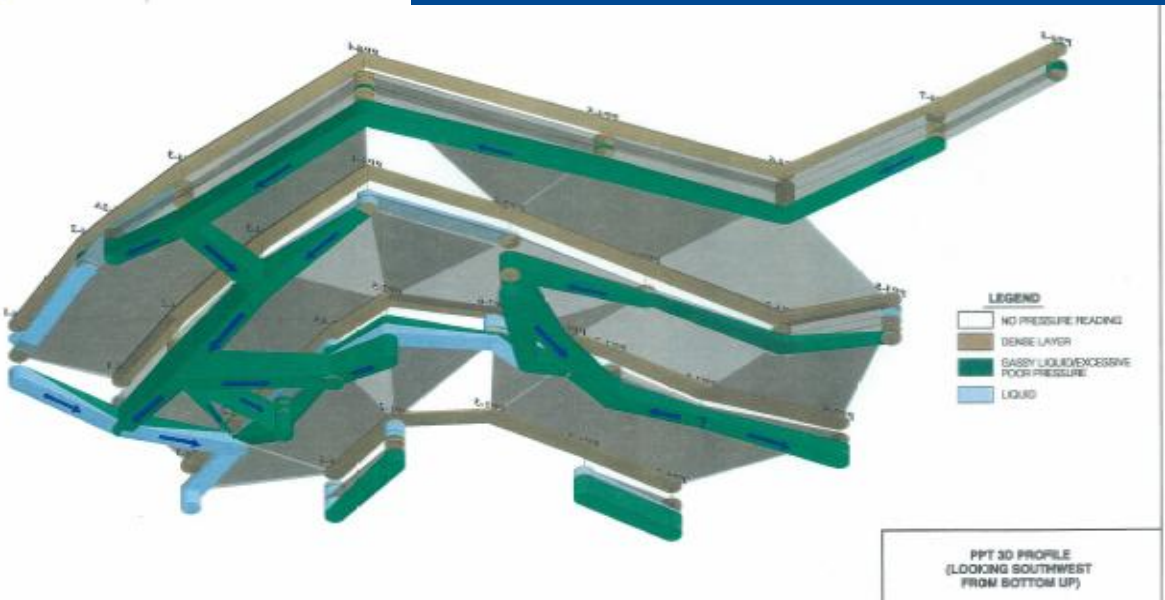


# 3-D Profiling




Gas Only

Water Gradient



# Steam Injection Bioreactors
# Miramar Landfill Pilot Study

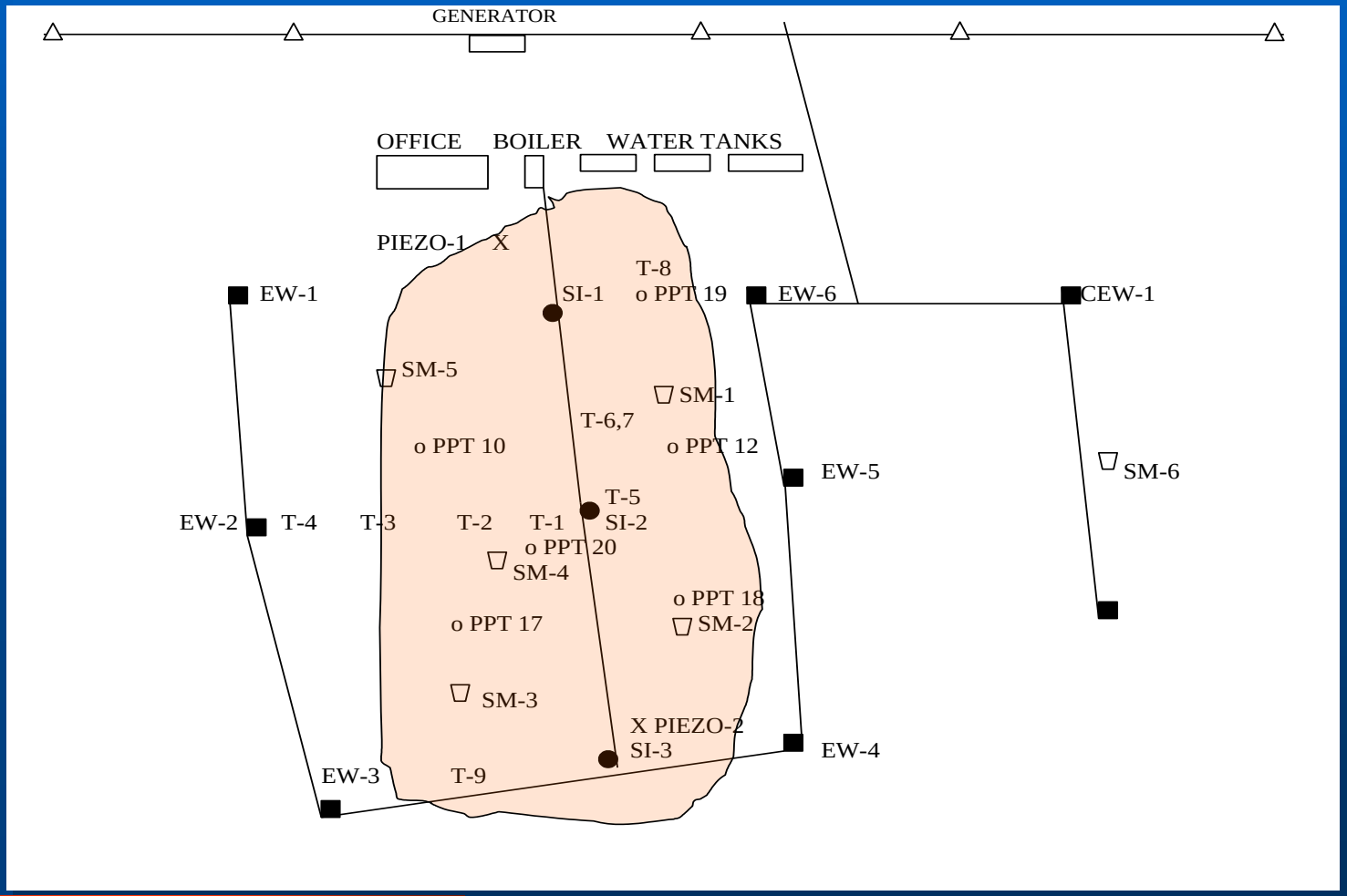
# Miramar Landfill Pilot Study

## 2005 & 2006

## Layout

- **4 Acres Were Profiled With The PPT**
- **1 Acre Was Chosen For The Study**
- **PPT Rig Installed**
  - 8 Collectors
  - 3 Injectors
  - 9 Thermocouples
  - 2 Static Piezometers
- **Collectors Were Connected To Existing Vacuum System**
- **6 Settlement Monuments Were Installed**

# Site Layout Map



# LFG Collector System

# Steam Injector

# Push-In Collectors & Injectors

- Wells and Injectors Are Pushed In, Not Drilled
- Following PPT The Hole Is Expanded To 3” Dia.
- 2” Dia. Black Steel Pipe
- Oilfield Mill Slots
- 10 Times The Open Space Than Drilled Holes
- No Cuttings Disposal
- 1/3 The Cost Of Drilled In Collectors
- Can Be Cleared With Steam

# Four GPM Boiler

# Steam Injection

# Steam Injection Pipeline

# Landfill Settlement

# Miramar Landfill Pilot Study Objectives

- Determine If The Steam Migration Can Be Controlled By The LFG Collectors
- Determine If The Steam Can Heat Up & Moisten The Waste
- Determine If The Steam Increases Quality & Quantity Of Methane Gas
- Determine If Steam Injection Can Recover Airspace
- Determine If Leachate and Condensate Can Be Used In The Steam Process

# Miramar Landfill Pilot Study
# All Objectives Were Achieved

- By Increasing The Vacuum At The Collectors Steam Migration Was Indicated By The Thermocouples
- Thermocouples Indicated Increased Waste Temperature And Moisture
- Methane Started At 54% Increased To 66%
- Test Cell Settled 26 Inches Near Injector # 2, In 7 Months
- Leachate and Condensate Was Used In The Steam Process

# Natural - Gas Generation Potential

- 208’ x 208’ x 50’ = 2,163,200 x .50 = 1,081,600 / 42.9 Cu. Ft./Ton Density = 25,212 Organic Tons
- 25,212 Or. Tons x 12,000 = 302,545,455 Cu. Ft. LFG
- 50% Methane & 50% CO2 = 151,272,728 Each
- 50 scfm Per Acre x 1440 Min.= 72,000 Cu. Ft. / 12,000 = 6 Organic Tons Converted / Acre / Day

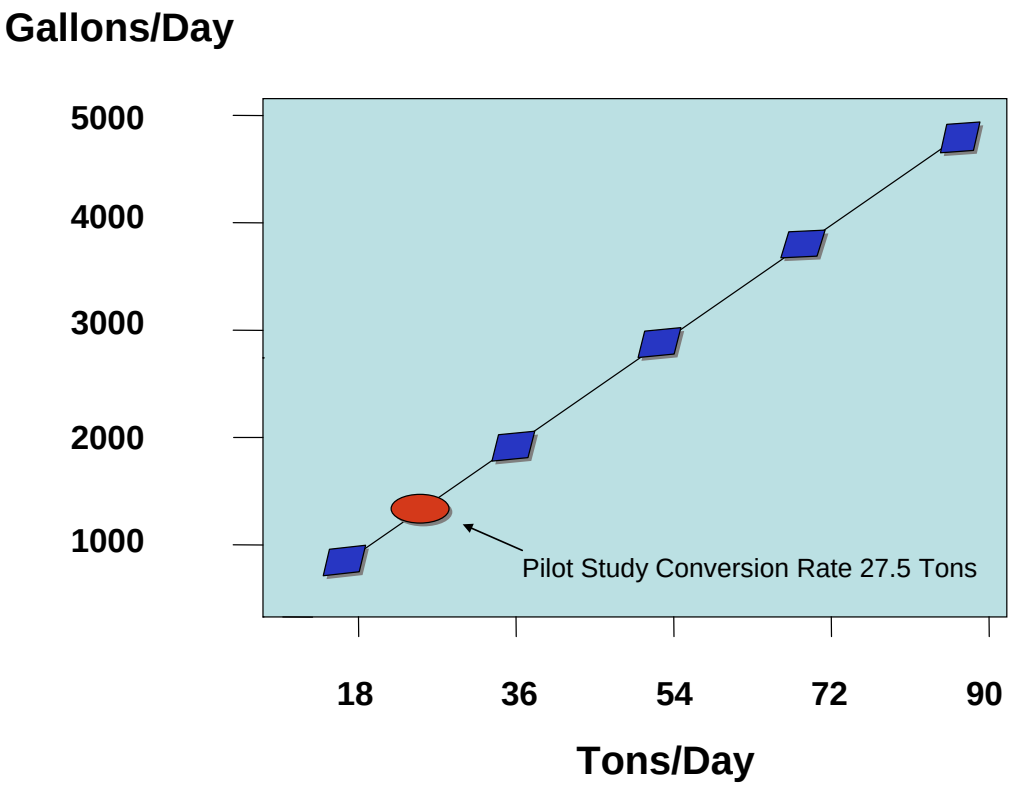
- 25,212 / 6 Tons/Day = 4,202 / 365 = <u>11.5 Years</u>

# Study Gas Production

- 1,500 Gallons/Steam Per Day
- Average 229 scfm Of LFG
- 229 x 1440 Minutes = 329,760 Cu. Ft. / Day
- 329,760 / 12,000 = 27.5 Organic Tons Converted/Day
- 25,212 / 27.5 = 917 / 365 = 2.5 Years

- If 5,000 Gallons/Steam Per Day
- 5,000 / 7.5 x1,600 = 1,066,666 Cu.Ft. Steam
- 1:1 Conversion Ratio = 1,066,666 Cu.Ft. LFG
- 1,066,666 / 12,000 = 89 Organic Tons Converted/Day
- 25,212 / 89 = 283 / 365 = 9 Months

# Conversion Rate



# No County Funding

| BUDGET SUMMARY: | | |
|---|---|---|
| Total Estimated Cost | | $0.00 |
| | | |
| Funding | | |
| Budgeted | $ | |
| New Funding | $ | |
| Savings | $ | |
| Other | $ | |
| Total Funding Available | $ | |
| Change To Net County Cost | | $0.00 |

# Financial Benefits To County

- Supplying all electricity for the operation of the Waste Water Treatment plant. Current annual electricity usage value is approximately $250,000.
- Maintenance of landfill gas collection system and landfill cover. Current annual gas collection and cover maintenance cost is approximately $5,000.
- A 10% royalty on the sale of gas to an electricity utility (PG&E, SMUD or other). Utilizing existing gas production levels to produce 2 Megawatts of power would result in an annual royalty of approximately $122,000 (based on a purchase price of $0.10/kw/hr). If steam injection produces higher levels of gas that is also converted to electricity, higher royalties would be realized.

# Other Potential Revenues

- There are potentially additional sources of revenue. Exhaust gas carbon dioxide could be converted to dry ice and marketed.
- The steam injection technology could be applied to incoming municipal solid waste, should the landfill be reopened.
- Carbon credits from the conversion of landfill gas to electricity could be marketed. Should any of these or additional revenue sources be realized, the County would receive a 10% royalty.

# Action To Be Taken Following Board Approval

- Following Board approval, and upon approval by County Counsel and Risk Management, the Director of Environmental Management Department, or her designee, will execute the subject contract and will proceed with obtaining, installing and operating the system.

- The contract will include onsite electricity usage and revenue sharing agreements.

# QUESTIONS?

- **Answer All Questions If Time Allows Today And/Or**
- **Contact:**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