INTRODUCTION

Site Description

The Cedar Hills Regional Landfill is located near Maple Valley, Washington, 25 miles east of Seattle. The landfill serves as the regional landfill for the disposal of all municipal solid waste (MSW) generated inside King County, except for the cities of Seattle and Milton. King County owns and operates the 940-acre landfill that accepts approximately 3,500 tons per day of MSW. The site has approximately 452 acres of permitted refuse fill area, and a 1,000-foot-wide buffer around the perimeter of the site. Activity is restricted in the buffer areas to preserve native vegetation, including stands of deciduous and conifer trees.

In the early 1960s, waste filling began in an unlined area of the site. In 1985, King County constructed the Central Pit Refuse Area at Cedar Hills. The Central Pit Refuse Area was the first area at Cedar Hills that incorporated a composite-bottom liner with leachate collection. The innovative bottom liner, which incorporated a polyethylene flexible membrane liner, was designed to anticipated Washington State regulations. Although the Central Pit Refuse Area was built well ahead of RCRA Subtitle D implementation, its design complies with the requirements.

King County Solid Waste Division (KCSWD) Operations Section personnel operate and maintain the landfill gas collection system which has approximately 500 gas well and leachate collection system extraction points (Figure 1). Since July 2000, all landfill gas data has been uploaded electronically into a comprehensive database developed by the Operations Section. The gas collection system is now totally active with one central flare station.

In the mid-1980s, vertical gas collection wells were installed in the older, unlined areas of the landfill. More recently, horizontal collectors have been installed in the waste as filling progressed, starting in 1986 in the first lined refuse area. The horizontal collectors consist of thick-walled HDPE pipe embedded in gravel-filled trenches. A HDPE looped header pipe network connects both the horizontal collectors in the newer areas and the vertical wells to a blower/flare station at the north end of the landfill site. To allow measurements of flow, pressure, temperature and gas composition, each wellhead, on both the vertical and horizontal wells, is equipped with a control station.

The header pipe is buried and sloped in a saw-tooth pattern to condensate drains around the perimeter, or shallow-buried over the landfill cover. The header network comprises two complete loops, with main perimeter headers on the east and west sides of the landfill, and an interior header running over the landfill cover. The gas is discharged to a series of enclosed flares at the north end of the landfill. The system collects approximately 9,500 standard cubic feet per minute (scfm) of landfill gas.

King County recently entered into an agreement with Energy Developments, Inc. (EDI), of Houston under which King County will modify the gas collection system to discharge gas to an electric power-generating plant that EDI will build at the Cedar Hills Landfill site. Design of modifications to the existing gas collection system to provide gas to the generating plant is currently under way.

Figure 1. Cedar Hills Regional Landfill Gas Collection System

DESIGN AND CONSTRUCTION

Award Criteria:

- *Discussion of siting, site preparation and design, construction techniques, site soils, hydrology/geology and their suitability for a landfill gas control site.*
- *Discussion of merits of the site preparation and design for environmental protection, demonstrating that it is "state of the art" operation.*
- *Overall planning and end-use planning.*

Design and Construction of the Landfill Gas Control System

Design Principles

Operating the landfill gas control system in a large, wet landfill such as Cedar Hills, and meeting all of the requirements of regulations and permit conditions, demands foolproof design and construction. King County has learned that the following basic principles must govern design efforts:

- Work with the operators
- Design for flexibility
- Design for accessibility (many "cleanouts")
- Design for motion (everything moves in a landfill)
- Design for redundancy

Designers Must Work with the Operators

Operating the Cedar Hills landfill gas collection system is complex. The collection system must be frequently monitored and adjusted to keep the system balanced. The purpose of the gas extraction system is to prevent surface and subsurface landfill gas migration by maintaining a slight vacuum in the landfill gas-producing refuse zone. Controlling the amount of flow and vacuum, and monitoring the landfill gas composition, assure that the amount of landfill gas roughly equals the amount being produced due to anaerobic decomposition. Attempting to remove more gas vapor from the refuse zone than the amount of landfill gas being produced can result in air intrusion. Air intrusion into an anaerobic refuse mound can result in an increase in aerobic activity. Increased aerobic activity results in higher temperatures; worse, still adding oxygen to a methane-rich refuse mound could result in subsurface combustion of the waste. Operations staff carefully monitor each extraction point for methane, oxygen, and carbon dioxide concentrations as well as temperature, vacuum, and gas flow. A significant change in any of these parameters can be used to evaluate if the system needs to be adjusted using the control station valve.

During operations, the collection system must also be maintained to prevent and repair breaks and sags, and to remove condensate and grit. For each expansion or modification of the gas system, it is imperative to consult with the operators during the design to make

certain that the expansion will be consistent with the operators' methods for monitoring and maintaining the system. Consulting with the operators provides *consistency* in effective and safe operations throughout the system, helps identify equipment needs, and ensures comparable results. By working with the operators who have many years of hands-on experience with the existing system, the designers gain valuable, site-specific insights that are critical when incorporating the existing systems into expansions and modifications.

Alternate lifts are used for waste hauling to the working face, pushing down onto the face for one lift and then up onto the next lift, as shown in Figure 2. The horizontal collectors are placed on the intermediate lifts that are not used for waste haul traffic. This not only protects the horizontal collectors from heavy transfer truck and dozer traffic, but minimizes the amount of surface that must receive special treatment, that is, gravel surfacing, in very wet weather to allow truck movement. It is also important to make sure that the lifts are adequately sloped to shed water so that local ponding does not inundate underlying gas collectors.

Design for Flexibility

Special consideration must be made for non-arid landfills since liquids and gases are constantly flowing through the landfill and waste is undergoing continual digestion and motion, phenomena that pose technical challenges to the gas collection designer. A landfill, always settling due to waste decomposition, drags wells, valves, and pipes along with it. Worse, a wet landfill decomposes more quickly than a dry one, rapidly increasing settlement. The conditions of motion and settlement require that the gas collection system be designed to move with the waste as it settles.

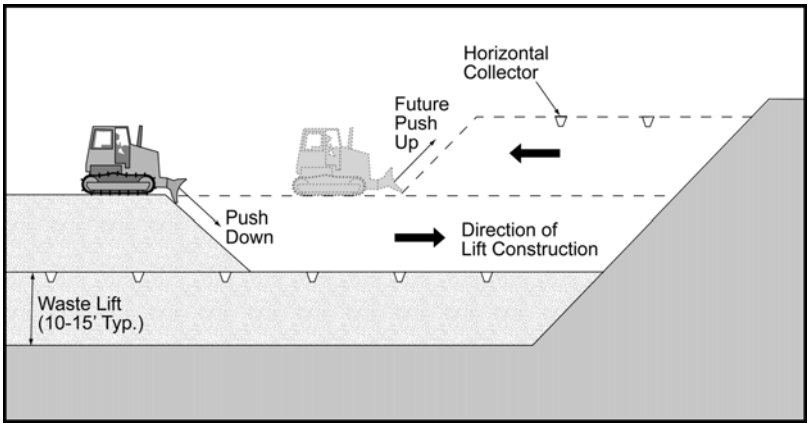


Figure 2. Lift Construction Method To Protect Horizontal Gas Collectors

At Cedar Hills, as much of the system as possible is constructed using polyethylene, typically HDPE for the piping. HDPE is more elastic and stronger than any other readily available pipe material, and in most cases bends without breaking in the landfill environment. The perforated collector piping embedded in the waste, as well as the header piping and condensate drains, are all HDPE.

Design for Motion

To respond to motion, the collection system incorporates flex joints and gas-tight expansion/contraction couplings at as many locations as possible, especially at locations of expected severe settlement. This unique coupling is discussed in the Utilization of Equipment/Systems and Technologies section. For the horizontal collectors, an extension is typically used as the deeper, central portions of the landfill settle more than the edges, pulling the originally straight collectors into a downward bow shape. For this reason, some of the

horizontal collector pipes at Cedar Hills consist of 200-foot lengths of perforated pipe connected by “sleeves” of larger pipe that allow the pipe to expand as the landfill settles (see the section Horizontal Collectors, below). All of the horizontal collector pipes are SDR 11 or thicker wall.

The thicker wall was selected to accommodate as much as practical the unpredictable, localized shearing forces that occur as landfills settle. This principle has allowed most of the original horizontal collectors installed in 1987 to still continue to function today under more than 200 feet of overburden in some cases.

Design for Accessibility

The accessibility principle requires that all pipes, as well as condensate traps, sumps, knockouts and other parts of the system, be accessible. The design also ensures that pipe failure points be quickly identified and accessed for repair. Through “cleanouts” on the line, all header pipes are accessible for camera inspection. Wye fittings, provided in both directions at intervals of not more than 500 feet, can be accessed by surface vaults. Thus, when a pipe fails or becomes blocked, the exact location and nature of the blockage can be determined before digging. To provide more accessibility, condensate drains along the header pipe are designed as annular traps in vaults rather than “U”-type designs. This unique trap design is discussed in more detail in the section Utilization of Equipment/Systems and Technologies.

Design for Redundancy

Another important principle in the design of the site gas control system is that every gas well and collector must have at least two separate pathways from the wellhead to the blower/flare system. This design approach not only allows for alternative routing in case part of the header is obstructed or taken out of service, but the design provides extra capacity for partial blockages. The header system has two primary loops, each with its own header along the east and west site perimeters. These two loops feed the gas to the blower/flare station at the north end of the site; the loops are also connected at the southern end with another interior header creating a double loop system. Headers installed in earlier cell closures remain in service and provide additional redundant loops inside the primary loop system. Each part of the header is sized to carry gas from both directions around the loop, creating excess (at least double) capacity in the system. Shutoff valves are co-located with the “cleanout” header access stations, described earlier, to allow isolation of sections of the main header not exceeding 500 feet.

Horizontal Collectors

The horizontal collectors, installed in all areas of the landfill since 1987, are capable of extracting all gas in these areas and are the sole method of extracting gas. The collectors are spaced at intervals of 200 to 300 feet based on calculations of pressure drop in the landfill and experience with actual vacuum requirements. With few exceptions, all of the horizontal collectors installed since 1987 are still functioning. Some are buried under more than 200 feet of waste. This is due at least in part to their robust design. The horizontal collectors, made from perforated HDPE pipe, SDR 11 or thicker wall (thicker in bottom lifts, up to SDR 7), are bedded in 3-feet-deep gravel trenches. The collectors are constructed from

segmented, 6-inch perforated (or slotted) pipe connected by 8-inch sleeves to allow expansion as the landfill settles (see Figure 3). The layout of the collectors ensures that the collectors can be connected at both ends to the perimeter headers. Data on the effectiveness of the horizontal collectors was presented at SWANA's 19th Annual Landfill Gas Symposium.[1] Finally, the collectors are monitored and controlled at individual monitoring control stations at each end. The collectors extend above grade for easy access, and then direct the gas back below grade to the perimeter header pipe. Figure 4 presents an illustration of the horizontal control station. Control stations are located in groups when possible to assist operations with monitoring.

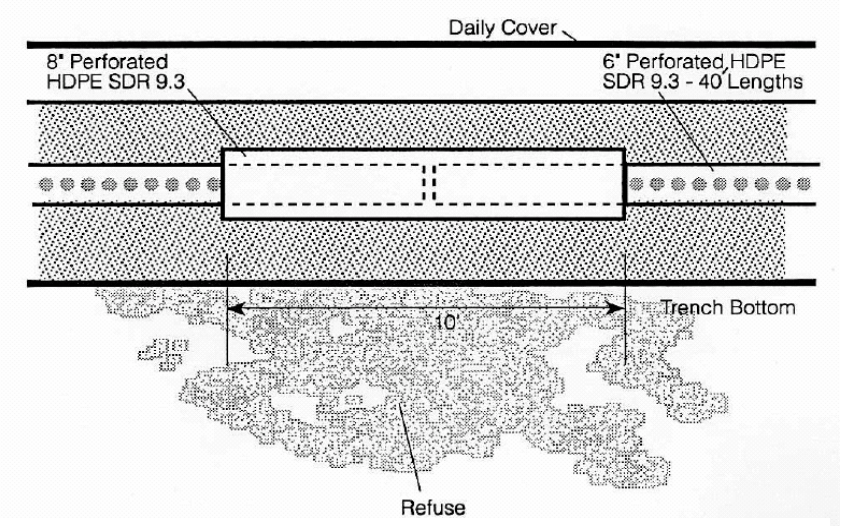


Figure 3. Horizontal Collector Pipe (Perforated Pipe and Sleeve)

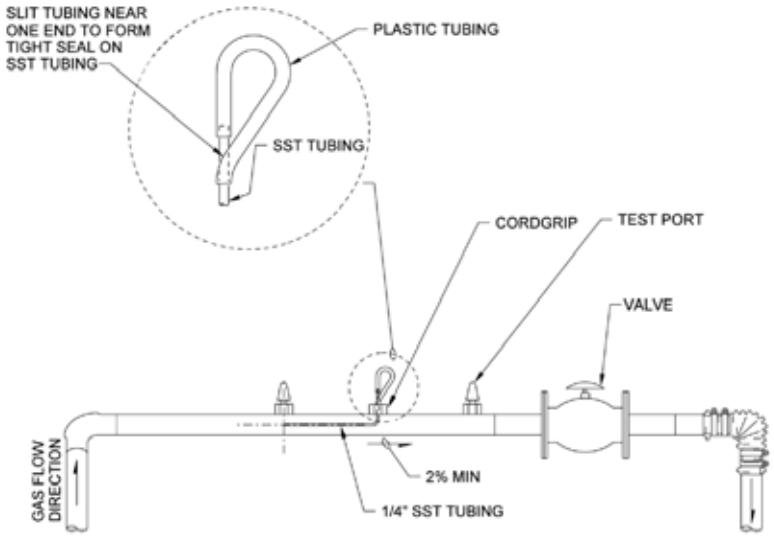


Figure 4. Typical Impact Port Monitoring Station

[1] Voelker, Dean and Thomas Kraemer, "Landfill Gas Collection System Design and Operation in a Wet Landfill." SWANA, 19th Annual Landfill Gas Symposium. 2004.

King County has found that simple velocity pressure tubes installed in straight runs of pipe at the wellheads provide good, consistent monitoring data on flow rates that are adequate for system adjustments. When combined with a static pressure measurement port in the pipe adjacent to the impact tube, the velocity pressure can be subtracted from total pressure to estimate the gas flow rate, similar to a pitot tube. This arrangement is simple, easily constructed and repaired and, most important, provides consistent data.

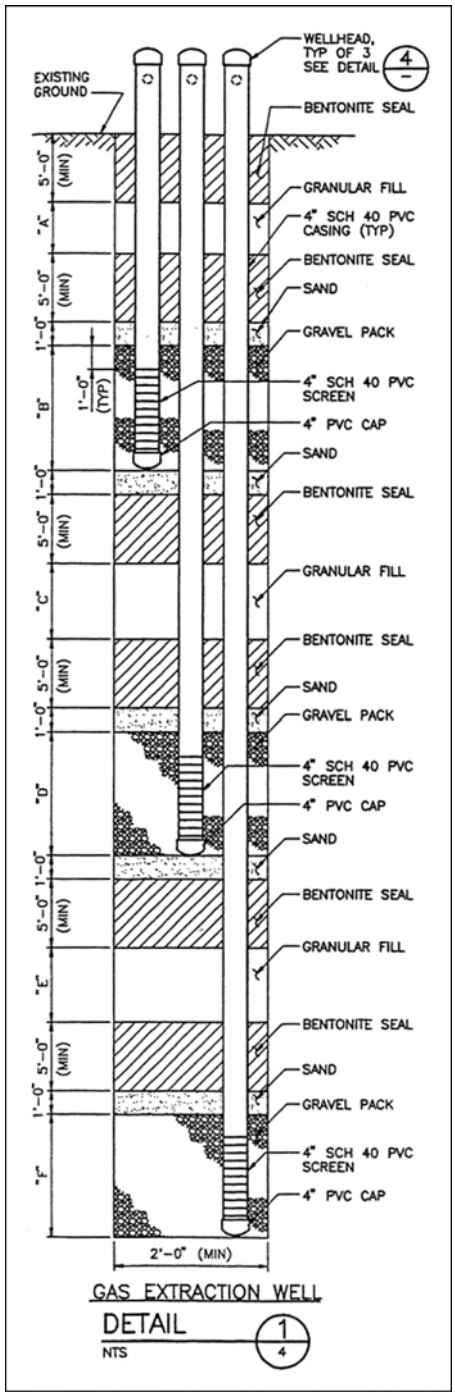


Figure 5. Typical Vertical Gas Extraction Well

Interior Gas Wells

Interior gas wells have been installed in the older parts of the landfill. These wells are booted through the final cover, which incorporates a geomembrane in all parts of the landfill. Figure 5 shows a typical vertical gas extraction well.

Dual Extraction/Leachate Pumping Wells

Dual function wells increase the effectiveness of gas removal since the gas well does not flood with leachate. Each application can be effective for a different reason: the South West Main Hill wells removed perched leachate, SE Pit wells dewatered saturated refuse; and the East Main Hill wells pump condensate. By installing the gas and leachate completion pipes in the same well connected by drain rock, water blockage of the gas well completion is prevented regardless of the source of the liquid. In a non-arid landfill, liquid from stormwater, leachate, and/or condensate could block a vertical gas well unless that liquid can be pumped out in a continuous fashion.

Since 2002, King County has changed the design from the originally installed wells. The County prefers rod-driven pneumatic pumps in lieu of the original AutoPumps that injected compressed air into the leachate completion. Stainless steel completions have been replaced with PVC or HDPE. The screens are still stainless steel and match the original design.

Figure 6 shows a cross-section of the dual leachate/gas extraction wells. The dual leachate gas wells are described in more detail in a paper by Udaloy et al.[2]

[2] Udaloy, Anne G., John D. Komorita and Peter J. Rowland, Retrofitting a Combined Leachate and Landfill Gas Collection System in Solid Waste.

Perimeter Wells

Perimeter gas extraction wells have been installed around an older area of the landfill where a lining system was not constructed and the waste is in contact with permeable strata. These wells are functional and currently in use. Figure 7 shows the locations of the perimeter wells as well as all vertical wells. The perimeter gas migration control wells are shown in the figure as LFG EXTRACTION WELL IN SOIL and are numbered as: E-29A, 29B, 29C, 29D, 58, 59, 60, 61, 62, 63, 64, 65, and B-4.

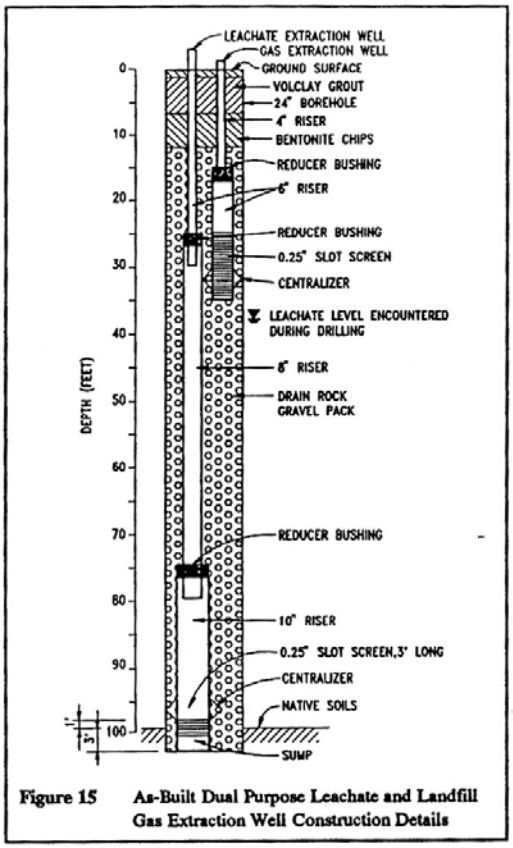


Figure 6. Cross-Section of Dual Leachate/ Gas Extraction Well

Blower/Flare System

The blower/flare station is comprised of five identical, 75-horsepower centrifugal blowers in parallel. The blowers discharge to five identical, enclosed, 40-feet-tall flares with piping and control systems designed to allow any combination of blowers to discharge to any combination of flares. Each flare and blower is designed to handle 3,000 scfm of gas, providing 50% redundancy in the blower/flare system. The vacuum capacity of the blowers at full flow also provides a 50% safety factor above what is needed to overcome the cumulative pressure drops through the gas collection system and in the waste, making certain that the system prevents positive pressures from occurring in the landfill. All points in the piping and in the condensate drains and knockouts are accessible through blind flanges on cleanout wyes. Cyclonic knockouts designed to remove all free water are located in front of the blowers (see Figure 8). The cyclonic knockouts are effective at removing fog, mist, and particles down to 3 to 5 microns.

Figure 9 presents an aerial view of the blower/flare system at Cedar Hills. (The air photo was taken before the fifth flare was added in 1999.)

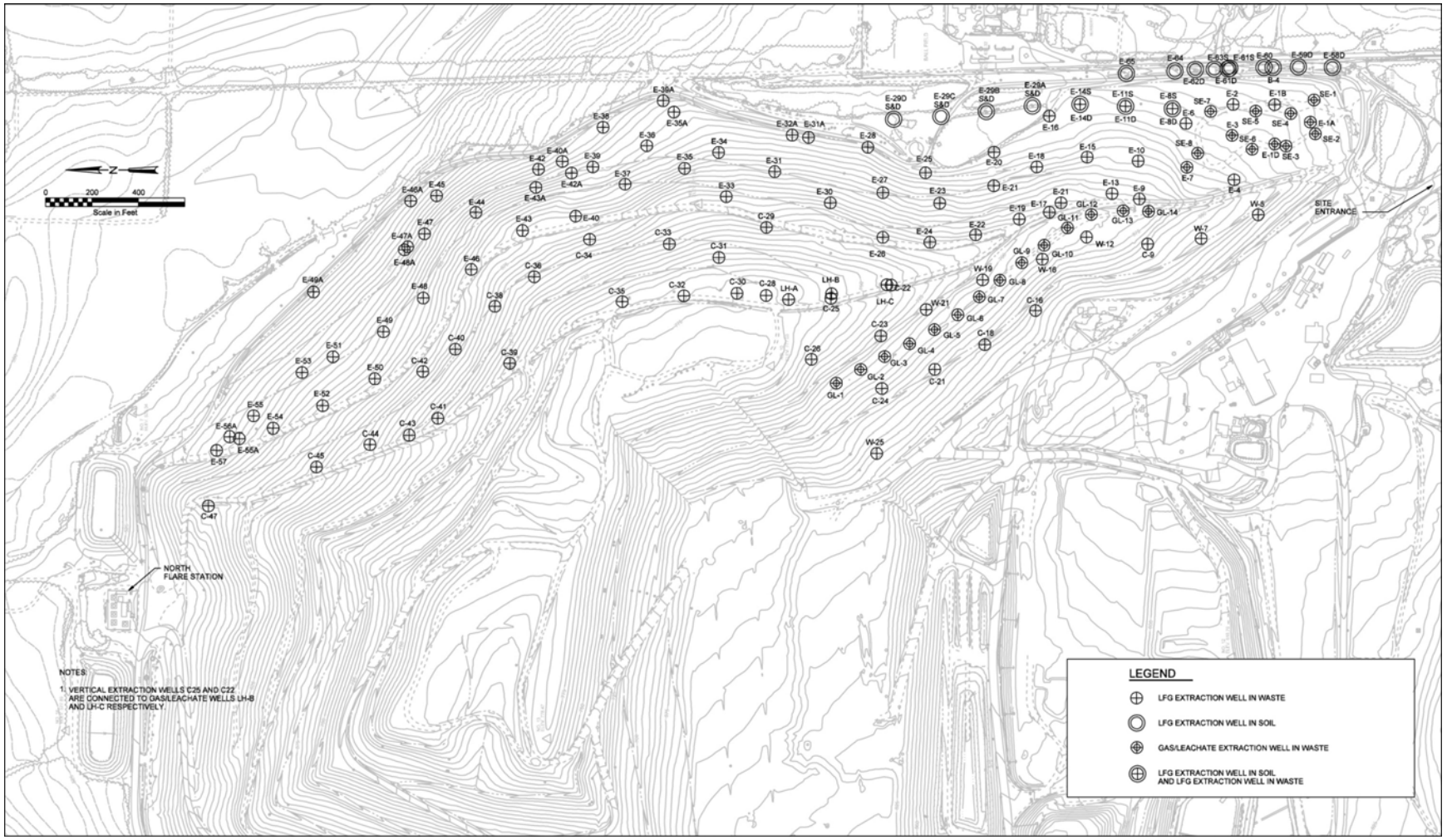


Figure 7. Locations of Landfill Gas Extraction Wells at Cedar Hills Regional Landfill

Figure 8. Cyclonic Knockouts at the North Flare Station

Figure 9. Blower/Flare System at Cedar Hills Regional Landfill

ENVIRONMENTAL CONTROLS

Award Criteria:

- *Discussion of groundwater, landfill gas and leachate monitoring; collection and treatment methods employed; quantities produced/collected; materials used for environmental protection (liners, filter layers, etc.). Photographs/ schematics included as necessary.*
- *Overall impact of the program on human health, environmental quality and resource conservation.*
- *Compatibility with the environment.*

Perimeter Monitoring

Perimeter monitoring probes are arrayed around the landfill site. Many of the probes are multiple-depth probes with three completions in the more permeable formations surrounding the landfill. The probes are monitored monthly, exceeding the required quarterly monitoring frequency under RCRA Subtitle D.

Surface Monitoring

King County conducts surface monitoring in accordance with New Source Performance Standards (NSPS) requirements, and tracks the locations of the surface monitoring probe using a differential Global Positioning System (GPS). Through a campaign of aggressive inspections of the final cover, King County has been able to locate and repair all leaks. For example, during September 2004, a location was located and remedied. KCSWD performs all surface monitoring and has never had a violation; all exceedances have been remedied as required in Subpart WWW.Last NSPS Surface Monitoring.

Condensate Management

In a wet landfill, at least as much design work in the gas collection system must go into removing water as in conveying the gas itself. All pipes must be sloped toward condensate drains. Our criteria are that all pipe on waste (that is, subject to settlement) should be sloped at least 2.5%; and that all pipes outside of waste (for example, the perimeter headers) must be sloped at least 1%. Condensate is either drained directly, through gas-tight traps, or pumped to the leachate collection system. There is no maximum-length criterion for the distance between condensate drains; in fact, King County strives to minimize the number of drain points (low points) by maximizing the length of pipe slopes. Site geometry constrains the length of pipe slopes that meet the above-minimum slope criterion.

In a wet landfill, there will be excessive “free water” entrained in the gas stream as droplets of various sizes, in addition to water vapor that condenses out as the gas cools in the header pipes. The free water must be removed before the gas stream enters the blowers, or it will damage the blowers. The size of the droplets and corresponding total mass flow of water that

can be entrained depend on the gas velocity in the header pipe. At a *large*, wet landfill like Cedar Hills, which produces 9,500 scfm of gas, the typical simple knockout pot installed by rule of thumb in a typical gas collection system is not adequate. The original system knockouts experienced bypass problems, including both water and particulate matter from the landfill that clogged the flare burner heads. These problems were solved with the installation of fiberglass cyclonic water knockouts.

Odor Monitoring

King County has adopted a regular odor monitoring program around the perimeter of the landfill. The program is the "Nasal Ranger" program developed by St. Croix Sensory, Inc., Lake Elmo, Minnesota. King County operations personnel have been trained and certified in these odor monitoring techniques and document results as required. A copy of the Nasal Ranger certification for King County is included in the Supplemental Materials section.

REGULATORY COMPLIANCE

Award Criteria:

- *The system's role in local community's integrated solid waste management system.*
- *Details showing that the site is in environmental compliance (facilities that are not in compliance may be disqualified).*
- *Have they submitted any awards letters or facility inspection data?*

Role of Landfill in Community's Integrated Solid Waste Management Systems

The King County Solid Waste Division is responsible for regional solid waste planning for the unincorporated areas of King County and 37 of 39 County cities (less Seattle and Milton). As such, the KCSWD is responsible for the State-mandated Comprehensive Solid Waste Management Plan that is updated every 5 years, or more often as necessary. In this function, the KCSWD leads the region in developing/revising the plan through stakeholder involvement in plan development and review.

King County/KCSWD own and operate the Cedar Hills Regional Landfill, and own and operate 8 solid waste transfer stations. Nearly 1 million tons of MSW received from throughout the region are processed through the transfer stations and disposed of at the Cedar Hills Regional Landfill.

Brief Description of Applicable Regulations

King County is subject to and in compliance with the following regulations that apply to the Cedar Hills Regional Landfill:

- Federal Regulations: 40CFR Parts 258, 60, 61 and 62, subpart WWW and landfill MACT.
- State Regulations: WA Admin Code Part 351, which incorporates the requirements of 40CFR Part 258.
- Local/Regional: Puget Sound Clean Air Agency Rules I, II and III.
- Permits: The Cedar Hills Regional Landfill operates under a permit issued by the Seattle/King County Health District (SKCHD). In Washington, "jurisdictional health departments" issue and enforce solid waste facility permits in accordance with the state solid waste regulations noted above. SKCHD is such a health district. The facility's solid waste permit requires submittal of design plans and supporting engineering calculations for each expansion of the landfill within the site. The SKCHD typically requests design review by specialists in the Washington Department of Ecology (Ecology). Ecology conducts strict reviews, sometimes employing third-party engineering consultants, and has praised King County for the excellence of its landfill designs.

The Cedar Hills Regional Landfill also operates under permits issued by the Puget Sound Clean Air Agency (PSCAA) that incorporate requirements of the federal air emission and gas control requirements referenced above, as well as additional requirements. These permits include permits to construct each cell of the landfill and a Title V permit for the overall site.

Both SKCHD and PSCAA carry out regular and surprise inspections. No notices of violation have been received within the past 5 years.

A letter of recognition from the Washington State Department of Ecology can be found in the Supplemental Materials section for KCWSD and its consultants' efforts in the planning, permitting, design, and construction of the Cedar Hills Regional Landfill Area 5 cell.

NSPS – Surface Monitoring

King County's pro-active landfill cover inspection and maintenance program and its gas system have prevented any exceedances of the 500 ppm methane standard for surface monitoring in more than 2 years.

Perimeter Monitoring

Monitoring of perimeter gas migration probes occurs monthly.

PSCAA and Title V Compliance

No notices of violation have been received in more than 5 years.

Flare Testing Program

King County conducts emission tests for criteria pollutants as well as regulated volatile organic compounds (VOCs) in accordance with permit requirements issued by PSCAA. Tests are conducted bi-annually. Samples, taken at the top of the enclosed flare stacks, are analyzed by a certified laboratory. No permit exceedances have occurred.

Continuous temperature monitoring using electronic dataloggers is performed at all flares. No under-temperature conditions have occurred over the past 5 years, except during unexpected shutdowns. An emergency generator capable of powering the blower/flare station is kept at the site. During unexpected shutdowns, operations staff are alerted; they have been able to restart within one hour of shutdown using either line power or the emergency generator.

Maximum Achievable Control Technology (MACT) Compliance (Startup, Shutdown, Upset Monitoring Program)

King County has prepared a startup, shutdown, and upset condition plan as required under the landfill MACT provisions, and the plan has been implemented. The required reports are provided to PSCAA.

PLANNING, OPERATIONS AND FINANCIAL MANAGEMENT

Award Criteria:

- *Description of operation and program used to meet design and operational objectives.*
- *Estimated operating budget/year.*
- *Does the facility have room to expand and create new programs for future?*
- *Employee health and safety training, waste screening programs, etc.*

Safety

King County maintains a safe workplace for its employees. The Landfill Operations Manual details safety programs for all aspects of operation. Regular safety training is provided for all 113 KCSWD Operations staff, and safety meetings are held monthly. All staff is trained. The staff includes 41 landfill gas operations staff (disposal, gas, and water control); 62 shop/maintenance staff; and nine support staff, including one manager. The staff completes as few as 1 safety and health program element up to 17 elements (Table 1 lists the program elements). Training is administered annually, biannually, and every three years, depending upon the federal, state, or King County requirement. Training time for the program elements ranges from one-half hour up to eight hours depending upon technical complexity. KCSWD Safety Office in-house trainers and supervisors provide the training; in some cases, contract trainers or contract vendors provide the training. KCSWD also provides personal protective equipment training in hard hat; safety glasses, goggles and safety shield; safety shoes and boots; rain gear; safety vest; puncture-resistant leather, rubber, electrician, and non-latex surgical gloves; steel inserts for boots; and respirator.

Table 1
Safety and Health Program Elements

Alcohol Drug Testing Overview/CDL (KC Policy PER-15-2-(AEP)
Alternate Fuel Safety (KC Policy (G) FES 12-11 & FES 12-3 (AEP)
Asbestos Awareness (WAC 296-62-07721 (1) (2); WAC 296-65-003, 010, 012, 030)
Bloodborne Pathogens (WAC 296-62-08001)
Confined Space Permit Entry (WAC 296-62-145), 29CFR
Confined Space Awareness (WAC 296-62-145), 29CFR
Crane/hoist/lifts (WAC 296-24-23529-1, WAC 296-155-525)
Defensive Driving (KC Policy FES-12-1-2)
Electrical Safety
Fall Hazards (WAC 296-155-24507,24501,48060, 245-C1)
Fire Extinguisher Use(WAC 296-24-59213)
First Aid Training/CPR (WAC 296-24-060 & 296-155-120)

Table 1 (continued)
Safety and Health Program Elements

Flagging (WAC 296-155-305, WRD 84-8, ANSI D6-1-1988, WSCOT-M24-01HT)
Forklift (WAC 296-61-0780, WAC 296-56-6077, WRD78-25A, OSHA 1910-178)
Fuel Handling/Storage (NFPA 30-1969, 58-1969, WAC 296-24-475)
Compressed Gas Safety
Hazard Communication/MSDS (WAC 296-62-05409, 05249C) 29CFR 1910.1200
Handtool Safety
Hazardous Waste Awareness RCRA (RCRA Subtitle D 40 CFR 258.20a3)
Hearing Conservation Program (WAC 296-62-09015)
Heavy Equipment Safety
Hot Work--Welding, Cutting, Brazing
Lock-out/Tag-out (wac 296-24-110, 119, 975) (29CFR 1910.147)
Motor Vehicle Air Conditioner Service (40 cfr 82.34A Subpart B; 40 CFR 82, Subpart B, Appendix A)
Personal Protective Equipment (29CFR 1910.13)
Power Tool Safety
Refrigerant Extraction (RCW 70.94.970)
Renton Aquifer [Required for all employees who work at the Renton Transfer Station]
Respiratory Protection Program (WAC 296-62-071) (Voluntary Program)
Rim Wheel Servicing (WAC 296-24-217)
Stormwater Pollution Prevention (NPDES)
Supervisor Safety Awareness Training
Trenching, Excavation and Shoring (WAC 296-155-650)

Forward Planning of System Expansions

Expansions of the gas collection system are designed as each new cell of the landfill is designed. Before the first waste is put in place in a new cell area, the gas collection system design for that area has been completed; and the perimeter header pipes have been extended around the new area and equipped with monitoring ports and stubouts for attaching the horizontal collectors to be constructed in that area. All materials needed for construction of the first lift of horizontal collectors have been ordered and placed in protected areas ready for the operation crews to begin construction as the first lift is completed.

Operating Philosophy

Operations Are Focused on Goals

King County has established strict, specific goals that must be met by the gas control system at the Cedar Hills Regional Landfill. All operational procedures are developed with these goals in mind. All operations personnel are familiar with these goals and how their specific jobs affect achievement of the goals. The goals are:

1. Zero gas migration beyond the boundary of the landfill.
2. Zero odors detectable at the landfill boundary.
3. Meet the surface emission, system vacuum, and oxygen concentration requirements of NSPS,
4. Maintain methane concentrations in the entire system at 50% or greater in order to provide quality landfill gas recovery (LFG) fuel to a new landfill gas-to-energy (LFGTE) plant.

Note that all of these goals must be met all of the time. There is little margin for error. Therefore, King County establishes operational targets for day-to-day operation that are more ambitious than the overall system goals. These operational targets establish a margin for operating error. For example, the operators strive to maintain the methane concentration in the system of at least 50% by volume, while meeting all other goals. Note also that meeting all of the above goals requires a careful balance between over- and under-extraction of gas in all areas of the landfill.

The sensitivity of the system and its speed of response to changes determine the frequency of monitoring.

Anticipate Problems – Identify the Fixes Ahead of Time and Take Preventive Actions

All of us in the field of landfill gas management are familiar with Murphy's law: what can go wrong will go wrong. Therefore, it pays to anticipate what types of problems may occur and have the materials and methods ready to fix them. Better yet: *Fix things before they break*. This is the philosophy of preventive maintenance. King County operations has found that it pays to spend about two-thirds of its efforts on preventive maintenance, and about one-third on monitoring and adjusting the system. Some specific examples of preventive maintenance include:

- Replacing flex-hoses on wellheads before they fail. It costs less in the long run to replace these couplings on a regular basis than to continually deal with the disruptions that occur if they are allowed to fail.
- Install expansion/contraction couplings where settlement can occur, and inspect all piping subject to settlement to make corrections before a pipe break or blockage occurs.
- Inspect cover membrane integrity before doing NSPS surface monitoring. Experience has shown that the most likely places for leaks to occur are at seams, slope discontinuities, connections, and penetrations. These areas are inspected for shifting surface soils, and in some cases surface soils are removed to inspect the membrane. The King County

operations program has minimized exceedances of the surface emission standards and the onerous requirements for responding to exceedances.

Operational Targets

Based on the overall gas collection system goals, specific operational targets are established with associated monitoring parameters and methods for adjustments to keep the parameters within the targets. Operational targets for the Cedar Hills gas control system are:

- Methane: 50% or better at flare
- O_2: Less than 1%
- Pressure: negative at all wells that have O_2 less than 5%
- Flow: Established individually for each well, based on history
- Temperature: Established for each well, but not to exceed 131 degrees F, unless established higher temperature.

Monitoring Frequency and Parameters

The approximately 500 wellheads in the Cedar Hills gas collection system are monitored twice per month for the following:

- Methane
- Carbon dioxide
- Temperature
- Pressure
- Flow rate

Monitoring Methods

One of the key principles of monitoring operations at the Cedar Hills landfill is *consistency* in method and results. Once an operational target for a given wellhead or sub-header has been set in terms of flow rate, pressure, and other parameters, the use of a given monitoring method becomes more important to achieve consistent data than having absolute accuracy. It is the *change* in operational data in subsequent monitoring that reveals trends, not accuracy of the numerical results. While reasonable accuracy is desirable, consistency is more important. To that end, great attention is given to having all field readings taken exactly the same way, preferably by the same operators using the same instruments. Note that this method applies to field readings taken for operational purposes, not to the compliance data taken at the flare system or the surface monitoring, which must be as accurate as possible and for which more elaborate instruments are used.

King County has found that simple velocity pressure tubes installed in straight runs of pipe at the wellheads provide good, consistent monitoring data on flow rates that are adequate for system adjustments, as described earlier in the section Design and Construction. King County uses the Landtec GEM series equipment to take the differential and absolute pressure readings as well the other parameters in the gas system.

Work Process and Preventive Maintenance Program

Routine maintenance to equipment, systems and facilities are conducted using manufacturers' suggested maintenance practices, best maintenance practice, and preventative maintenance practices developed by KCSWD.

All preventative maintenance requirements are loaded into the maintenance planning and scheduling software system CCG Faster. CCG Faster automatically creates a work order for each item of preventative maintenance, which is scheduled and assigned by the Shop Scheduling and Planning Unit. CCG Faster tracks all aspects of the maintenance, including technician, hours on task, parts, and so on. This information is rolled into CCG Faster's equipment database. This database is available to planners, schedulers, supervisors, and managers for oversight and review. The CCG Faster system is used to roll up labor and expense requirements for all work at the management level for resource planning and to review trends in efficiency. The system also issues reminders for needed work based on past patterns and inputs by operators or management.

Continuous Improvement Policy – Lessons Learned Database

KCSWD has a policy of continuous improvement in all aspects of landfill operations, especially safety. Weekly meetings are held with all operations supervisors to review lessons learned, as well as monthly meetings with division managers, senior engineering staff, and operations staff.

Operating Budget

The annual operating budget of the Cedar Hills Regional Landfill is $85 million.

UTILIZATION OF EQUIPMENT/SYSTEMS AND TECHNOLOGIES

Award Criteria:

- *Types of landfill gas equipment being utilized. Detail efficiency and effectiveness of equipment.*
- *Demonstrate the routine maintenance and employee training on equipment.*

System Accessible at all Points

All header pipes are accessible for camera inspection through "cleanouts" on the line. Wye fittings, accessed from surface vaults, are provided in both directions at intervals of not more than 500 feet. Thus, when a pipe fails or becomes blocked, the exact location and nature of the blockage can be determined before digging.

Condensate drain traps are notorious failure points for landfill gas collection systems. Accessing all parts of a condensate drain and/or trap is important to allow removal of blockages, such as grit accumulations, without removing or destroying the trap in the process. At Cedar Hills, an annular trap design is used in which the water elevation between an inner pipe and outer pipe or vault creates the vacuum trap. This design is inherently more accessible than a "U-tube" trap. Design review makes certain that every segment of pipe in the trap assembly can be accessed. Figure 10 shows a typical drain trap installation designed for maximum accessibility.

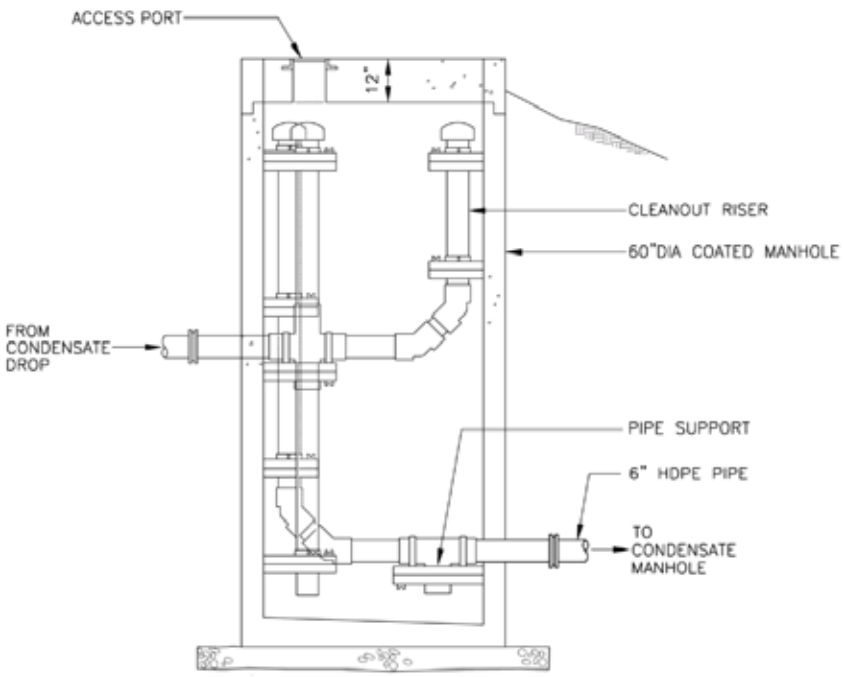


Figure 10. Typical Drain Trap Installation

The design for accessibility principle applies to all other parts of the system, allowing preventive inspections and, if necessary, repairs to be made quickly to minimize system downtime. Valve vaults, wellhead vaults, and all parts of blower/flare system expansion and modification designs undergo review for accessibility, as well as the usual constructibility review.

Inventing New Equipment for Gas System when Needed

For lateral piping connecting wellheads on the landfill cover slopes to the perimeter headers, contractions are expected as the slopes settle down. Contractions have resulted in numerous failures at this and other landfills. Figure 11 shows a typical buckling failure of a buried lateral at its entrance into a valve vault. This figure is a good illustration of what the force of landfill settlement can do. In this situation, accordion joints will not provide enough expansion; and loops are not practical because the shallow-buried pipe must carry condensate. The solution, invented by King County operations staff, is a vacuum-tight, in-line expansion/contraction joint that allows the smaller pipe (upstream) to move back and forth through a pressure gasket set in a flange on the end of the larger pipe. Figure 12 shows a typical installation of this special joint.

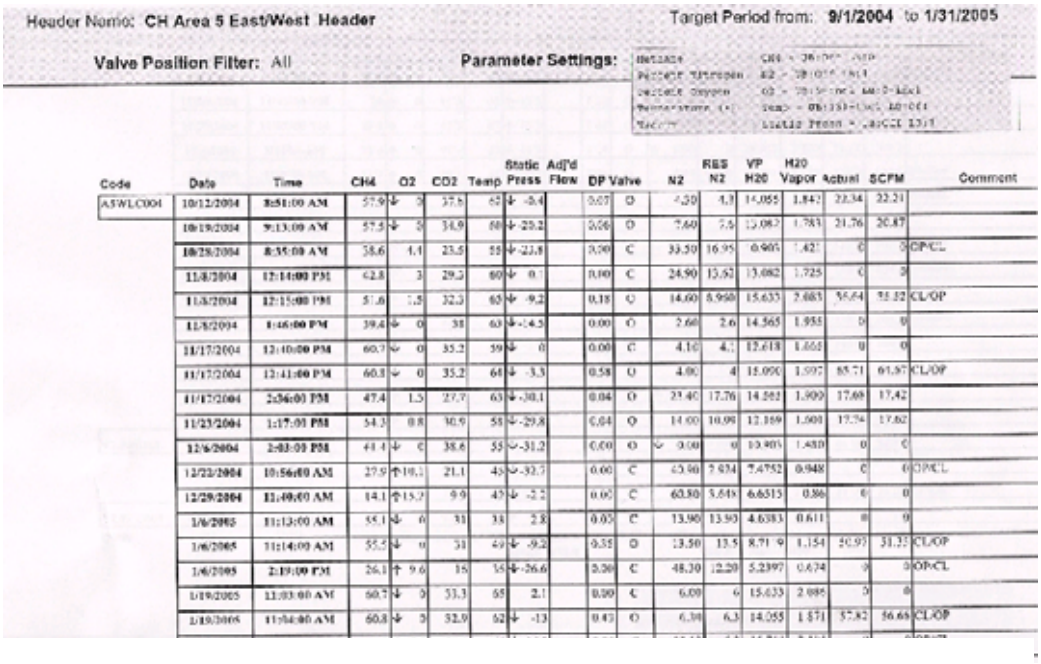
Figure 11. LFG Pipe Buckling Failure

Figure 12. Expansion/Contraction Coupler

Using the Monitoring Data to Make System Adjustments

King County has developed a structured database specifically designed to allow extraction of results to guide gas collection system adjustments. Data on the monitoring parameters mentioned above, as well as time, valve positions, and barometric pressures at the start and end of the monitoring rounds are entered into the database from the GEM's internal data storage. Paper records are also kept for redundancy. The technician's name is also entered, and the same group of wells is permanently assigned to each technician to promote consistency. A typical data report on the recent history of readings at a well is shown in Figure 13.

On the next monitoring round, a database report is generated that shows "exceptions" in the previous monitoring round data. Exceptions are defined as either data outside of operational targets or significant changes from previous data that indicate that adjustments should be made. King County designed this report to not only provide indications of where adjustments should be made, but *to provide the technician with the required information (and only the required information) to make the right adjustments on the spot.* For example, in the exceptions report generated for a technician, any well showing a significant change in methane over time will show the flow rates and methane concentrations for the previous four months' monitoring, as well as the valve positions. This will allow the technician to make a quick assessment of the effect of moving the valve a certain amount as soon as the current day's readings are taken.



Header Name: CH Area 5 East/West Header Target Period from: 9/1/2004 to 1/31/2005

Valve Position Filter: All Parameter Settings:

Code	Date	Time	CH4	O2	CO2	Temp	Static Press	Adj'd Flow	DP	Valve	N2	RES N2	VP H20	H20 Vapor	Actual	SCFM	Comment
ASWLC004	10/12/2004	8:51:00 AM	57.9	3	37.6	65	-8.4		0.07	O	4.50	4.3	14.055	1.842	22.34	22.21	
	10/19/2004	9:13:00 AM	57.5	3	34.9	60	-29.2		0.06	O	7.60	7.5	13.082	1.783	21.76	20.87	
	10/25/2004	8:55:00 AM	58.6	4.1	23.5	55	-23.8		0.00	C	33.50	16.95	0.905	1.421	0	0	OP/CL
	11/8/2004	12:14:00 PM	62.8	3	29.3	60	0		0.00	C	24.90	15.62	13.082	1.725	0	0	
	11/8/2004	12:15:00 PM	57.6	1.5	32.3	65	-9.2		0.18	O	14.60	8.960	15.635	2.085	56.64	55.52	CL/OP
	11/8/2004	1:46:00 PM	39.6	0	38	60	+14.5		0.00	O	2.60	2.6	14.565	1.955	0	0	
	11/17/2004	12:40:00 PM	60.7	0	35.2	59	0		0.00	C	4.10	4.1	12.618	1.668	0	0	
	11/17/2004	12:41:00 PM	60.8	0	35.2	61	-3.3		0.58	O	4.00	4	15.090	1.997	85.71	81.87	CL/OP
	11/17/2004	2:36:00 PM	47.4	1.5	27.7	63	-30.1		0.04	O	23.40	17.76	14.565	1.909	17.69	17.42	
	11/23/2004	1:17:00 PM	54.3	0.8	30.9	55	-29.8		0.04	O	14.00	10.99	12.169	1.600	13.74	13.62	
	12/6/2004	2:03:00 PM	41.4	0	38.6	55	-31.2		0.00	O	0.00	0	13.905	1.850	0	0	
	12/22/2004	10:56:00 AM	27.9	18.1	21.1	45	-32.7		0.00	C	43.90	7.934	5.4752	0.948	0	0	OP/CL
	12/29/2004	11:40:00 AM	14.1	15.2	9.9	47	-2.2		0.02	C	60.80	5.648	6.6515	0.86	0	0	
	1/6/2005	11:13:00 AM	55.1	0	33	38	2.8		0.02	C	13.90	13.90	4.6383	0.611	0	0	
	1/6/2005	11:14:00 AM	55.5	0	33	49	-9.2		0.35	O	13.50	13.5	8.71	1.154	50.97	31.33	CL/OP
	1/6/2005	2:19:00 PM	26.1	9.6	15	55	-26.6		0.00	C	48.30	12.20	5.2397	0.674	0	0	OP/CL
	1/19/2005	11:03:00 AM	60.7	0	33.3	65	2.1		0.00	C	6.00	6	15.633	2.085	0	0	
	1/19/2005	11:04:00 AM	60.8	0	32.9	62	-13		0.43	O	6.30	6.3	14.055	1.871	57.82	56.68	CL/OP

Figure 13. Typical Well Report Showing Trends for Field Technicians

Troubleshooting

King County's gas collection system database also provides instant warning flags for any parameters exceeding their operational targets, although operators are trained to spot these and take immediate corrective action as soon as they are detected. Examples include completely shutting down a well if the temperature exceeds its target range, while the CO_2/CH_4 ratio exceeds 1.2, or throttling by at least half if O_2 exceeds 2%.

If flow rates suddenly decrease at the flare station, then a header pipe blockage, either by condensate or pipe failure, is likely the cause. Similarly, if O_2 spikes at the flare station, a pipe break is suspected. The location, in either case, is determined by a combination of gas monitoring along the header pipe, which is equipped with ports for this purpose, and physical inspection using a pipe camera system. Two recording pipeline inspection camera systems are kept at the landfill. Trained LFG system operators use the cameras. The gas ports are tested successively, moving upstream from the flare station, until the failure is localized in a 500-foot section of header pipe (the ports are installed at 500-foot intervals). The ports are co-located with "cleanout" ports that can be used to access the pipe as well as with isolation valves. When the affected section of pipe has been located, it is isolated using the shutoff valves, and the gas is routed around it. (Recall that the entire system is a series of redundant loops allowing gas at any point to be re-routed.) A pipe camera with the ability to signal its location is then inserted into the affected pipe section to inspect and locate the exact location of the problem. This method allows the operators to dig only once to fix the problem. Reliable, explosion- and water-proof downhole cameras with push rods that can access and illuminate pipes as small as 2 inches diameter and as large as 24 inches for up to 500 feet are now available from several manufacturers. Different cameras may have to be used for different size ranges of pipes to illuminate the entire pipe wall from the center of the pipe. King County has recently purchased two camera sets for 2- to 4-inch and 6- to 24-inch pipes, respectively. Prior to this, King County relied on an outside pipe inspection service.

Landfill Gas-to-Energy Project

A landfill gas-to-energy project (LFGTE) is currently under development at the site. King County's Solid Waste Division initiated the process by issuing a Request for Proposals in 2001. King County has signed an agreement with Energy Developments, Inc., of Houston, Texas, to construct and operate a gas-turbine generator plant at the site. The LFGTE project will be one of the largest in the country, converting nearly 10,000 cubic feet per minute of landfill gas to more than 20 MW of electric power.

PUBLIC ACCEPTANCE, APPEARANCE, AND AESTHETICS

Award Criteria:

- *Overall appearance of site; is the facility kept neat and clean and overall appearance.*
- *Demonstrate the community education and customer service.*
- *Discuss the landscaping and onsite facilities.*

Appearance and Aesthetics

The Cedar Hills is isolated, and because the general public is not granted access, nor is the landfill visible to the public from roadways or residences, KCSWD has not invested a great deal in appearance or aesthetics. Nonetheless, the landfill is kept as neat and clean as possible. We routinely (weekly or more often, if required) sweep and wash our paved surfaces. Litter control is a daily effort, and we maintain a nearly litter-free landfill at all times. Tracking of contaminants from the landfill is strictly controlled, largely through the use of our undercarriage truck wash system. Vehicles exiting the working face must drive through the truck wash before proceeding onto public roadways. In conjunction with King County Parks Division, we have flower planters and hanging baskets in the Administration area of the landfill.

Zero Odor, Zero Complaint Goal

40-foot-high gas flares with buffer zone trees in background

King County maintains a zero odor, zero complaint goal. KCSWD maintains a hotline staffed 24 hours a day to provide immediate response to any problem that might be reported by site neighbors. All neighbors within 3.2 miles of the landfill have been made aware of a formal complaint response plan created by King County. The response tool is discussed at each Community Relations Council (CRC) meeting. The plan commits the County to respond rapidly with specific actions and time frames. The title page of the current plan and a complaint form used to document any complaints from neighbors are included in the Supplemental Materials section. KCSWD had 15 odor complaints about the Cedar Hills Landfill in 2004, and one complaint so far in 2005 (as of March 30).

Nasal Ranger Program and Certification

The odor monitoring program described above provides verifiable, quantitative odor measurements around the landfill perimeter.

The 450-acre landfill receives few odor complaints, even though it is located adjacent to a small compost plant that receives numerous complaints.

Regular Meetings with Neighborhood Groups

KCSWD management meets three times per year with neighborhood groups from the surrounding rural residential areas. Landfill development plans are reviewed and citizens' concerns are addressed at these meetings. A sample of a neighborhood group meeting announcement can be found in the Supplemental Materials section.

Tours on Demand

KCSWD managers and supervisors conduct frequent tours for visiting engineering professors, managers from other cities and counties and foreign countries, and King County residents and science classes. Tours are also provided for the public.

INNOVATION AND CREATIVITY

Award Criteria:

- *Innovative or unique aspects of the facility.*
- *What makes this facility different from the rest?*

Horizontal Collector Design

Horizontal collectors designed by local consulting firm CH2M HILL were first installed in the landfill in 1987. The Cedar Hills Regional Landfill was one of the first landfills to install horizontal gas collectors, and the first to use the robust design currently in use—thick-walled HDPE pipe. In 1987, only a few landfills had experimented with horizontal gas collectors, and many of those experienced difficulties. However, the robust design adopted at the Cedar Hills landfill has allowed the great majority of the collectors installed in that first year to continue operating, even though today they are buried under more than 200 feet of waste.

Velocity Tubes for Flow Monitoring

Landfill Operations Supervisor Dean Voelker developed a tube that is uniquely suited not only to the conditions inside the pipe; the simple and inexpensive design has allowed the Operation Section to implement a retrofitting program for the more than 500 control stations. This innovation has saved King County time and money and enhanced the accuracy of the gas flow data.

Gas-Tight Expansion/Contraction Couplings

Also described previously is the gas-tight expansion/contraction coupling used to prevent pipe failure in areas of severe settlement. King County operations staff invented this fitting which is under patent protection (patent pending).

NSPS Surface Monitoring Vehicle

In 2002, the KCSWD received a John Deere 2x6 "Gator." KCSWD retrofitted the Gator with a Foxboro TVA 1000 Gas Analyzer and placed a sampling probe behind the front tire six inches off the ground connected to the TVA 1000 via a stainless steel tube. Our air regulator, PSCAA, approved the Gator's use for quarterly NSPS monitoring. As a result, KCSWD significantly reduced the risk of injury to our landfill gas technicians, who used to walk the 33-mile serpentine survey route.

SCADA System

The County and ECS Engineering, Inc., have developed a SCADA system that monitors Cedar Hills and all other transfer stations and closed landfills with leachate and landfill gas installations. The pumps, blowers, and monitoring sensors in the landfill gas control system are monitored by a SCADA system that transmits data to the site office through a fiber optic, eternet radio, cellular modem, and lease line modem network installed around the County. This network is accessible throughout KCSWD’s local area network (LAN) system from any

remote desktop regardless of physical location. Figure 14 presents two sample SCADA system data screens.

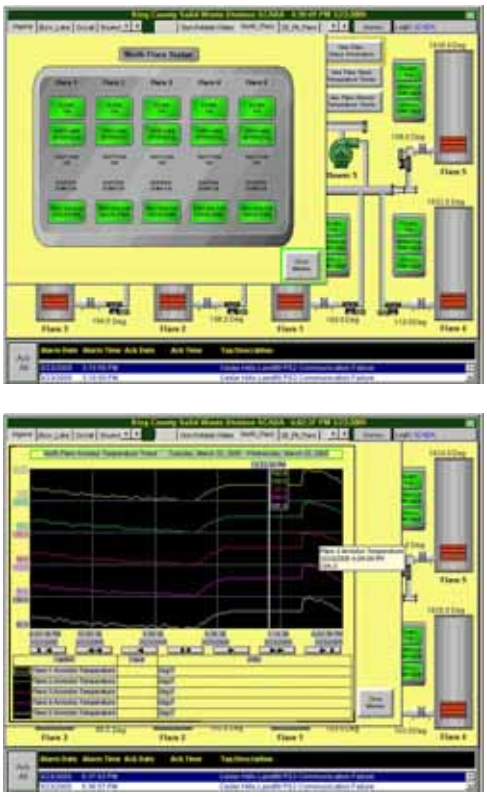


Figure 14. Sample SCADA System Data Screens – Flare Status (top), Flame Arrestor Temperature Trends (bottom)

Condensate Cyclonic Knockouts

In 1992, the wet conditions in the landfill and the very long and large-diameter (up to 24 inches) header pipes in the system caused large amounts of water droplets, as well as grit, to be carried through the original knockouts to the blowers and flares. In 1996, CH2M HILL designed the cyclonic knockouts currently in place to prevent water droplets from passing into the blowers at the maximum flow rates experienced in the landfill, plus designed in a 50% safety factor on flow. The cyclonic knockouts have prevented the water problems previously experienced at the blowers. Figure 15 shows the cyclonic knockouts at the North Flare station.

Removable Burner Heads in Flares

Prior to installation of the cyclonic knockouts, King County experienced frequent problems with grit bypassing the blowers and clogging the burner heads in the enclosed flares. Typically, burner heads are welded in place because the temperature changes on the burner heads are not conducive to bolted connections. However, King County's operations staff devised a removable burner head that uses specialty lock washers to absorb heat expansion and contraction while maintaining the burner heads in place and tight-fitting.

Figure 15. Cyclonic Knockouts at the North Flare Station

Supplemental Materials

IRG 10.5

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

Northwest Regional Office, 3190 - 160th Ave S.E. • Bellevue, Washington 98008-5452 • (425) 649-7000

October 22, 1999

RECEIVED
OCT 26 1999
SOLID WASTE DIVISION

Mr. Rodney Hansen
King County Department of Natural Resources
Solid Waste Division
400 Yesler Way Room 600
Seattle, WA 98104-2637

Mr. Larry Kirchner
Seattle-King Co. Department of Public Health
Wells Fargo Center
999 3rd Avenue, Suite 700
Seattle, WA 98104-4099

Gentlemen:

Construction of the new North cell in Area 5 of the Cedar Hills landfill is complete and complies with all relevant plans and specifications. This new cell meets or exceeds the public health and environmental protection requirements of Chapter 173-351 WAC. To construct a landfill cell in compliance with the demanding standards of modern environmental regulatory requirements is a significant accomplishment. Now that the new cell is ready to receive waste it is appropriate to acknowledge the outstanding efforts of both your agencies to keep this project on time and under budget.

You have reason to be proud of all the staff and contracted professionals involved in this enterprise. Several individuals deserve specific mention.

- Mike Reimbold, Jim Walker, and Elaine Springier of CH2M Hill should be acknowledged for their excellent design and construction support.
- The on-site engineer, Mike Spillane of Herrera Environmental Consultants, deserves complement for his construction management and quality assurance.
- This project required extraordinary permitting and regulatory oversight. Dave Hickok of Seattle King County Department of Public Health did an outstanding job coordinating this effort.

- Finally, the overall project management effort of Victor Okereke of King County Solid Waste was exemplary. His drive to hold all of the project contractors accountable to exacting regulatory and engineering standards is noteworthy. His dedication to these standards while meeting the strict time and budgetary requirements of this project is meritorious.

Again, our complements to you and your staffs for jobs well done.

Sincerely,

George Sidles
Regional Supervisor
Solid Waste and Financial Assistance Program

GS/jk/dm

cc: Cullen Stephenson, Ecology, HQ
File

NOTICE OF MEETING TIME

CEDAR HILLS CITIZEN REVIEW COMMITTEE PUBLIC MEETING

The next Citizen Review Committee Meeting

will be held

Wednesday, February 16, 2005

at

7:00 pm to 8:30 pm

Issaquah School District Bus Barn
805 Second Avenue SE, Issaquah
(across the street from Issaquah High School)

For more information regarding this notice, please contact:

Annette Mentzer
King County Solid Waste Division
(206) 296-0465 or
annette.mentzer@metrokc.gov

DEPARTMENT OF NATURAL RESOURCES
KING COUNTY SOLID WASTE DIVISION

CEDAR HILLS REGIONAL LANDFILL ODOR, FUGITIVE DUST OR NUISANCE COMPLAINT RESPONSE PLAN

PREPARED BY:

ENGINEERING SERVICES SECTION

JANUARY 12, 2000

VOO/2000/COMPLAINT RESPONSE PLAN

KING COUNTY SOLID WASTE DIVISION
COMPLAINT COMMENT FORM

Complaint handled by: First Name: _____ Last Name: _____
Date: _____ Time rec'd: _____

Type of Comment: Internal (employee): ☐ External (public): ☐
Written: ☐ Verbal: ☐
(check all that apply) Odor report line: ☐ CCF: ☐
Telephone call: ☐ Agency (PSCAA) ☐

Complainant Info:

First Name: _____ Last Name: _____
Address: _____
City _____ Zip Code: _____
Home phone: _____ Work phone: _____

Comment: _____

Did complainant decline an informational bulletin? (Y/N) :_____
If no, Date informational bulletin was sent: (MM/DD/YY):_____

Complaint Investigation

Investigated by:
First Name: _____ Last Name: _____

Date Investigation Started: _____ Date Investigation Ended: _____
Time Investigation Started: _____ Time Investigation Ended: _____

Results and Data: _____

Investigator:_____Date_____Time:_____
(signature)
Action Taken:_____
Action Completed:_____Date:_____Time:_____
(signature)
Supervisor:_____Date:_____Time:_____
(signature)
[Note to Supervisor: Please confirm that all Date and Time field have been completed to facilitate permit compliance review.]

"ODOR SCHOOL"®

NASAL RANGER®

JOHN B. BELL

Investigator

Odorous Emissions Evaluation Field Certification
Referencing Ambient Odors

04 September 2002
King County Solid Waste
Cedar Hills Landfill

ASTM Odor Intensity Referencing Scale, ASTM E544-99
Standard Practice for Referencing Suprathreshold Odor Intensity

International Association on Water Pollution Research & Control
Standard Characterization of Ambient Odors

St. Croix Sensory, Inc. Lake Elmo, MN, U.S.A.
www.fivesenses.com