WASTE TECH

LANDFILL TECHNOLOGY CONFERENCE

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LANDFILL TECHNOLOGY CONFERENCE

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8:00 A.M. - 9:30 A.M. LANDFILL CASE STUDIES

Moderator: Robert Gardner, SCS Engineers

Hillsborough County, Florida's Southeast County Landfill: An Integrated System Approach
Megan Miller and Patricia Berry, Hillsborough County Solid Waste Management Department

Permitting and Use of Construction/Demolition Waste Derived Alternative Intermediate Cover at Chester County Solid Waste Authority's Lanchester Landfill
George Barstar, Shaw Environmental & Infrastructure, Inc., and Robert Watts, Chester County Solid Waste Authority

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Moderator: Craig Johanesen, Craig Environmental, LLC

Identifying and Resolving PCB Issues in Landfill Gas Condensate – A Case Study
Adam Larky and John Davis, Cornerstone Environmental Group, LLC, and Robert Bobeck, City of Riverview, Michigan

Current Design Approaches for Landfill Leachate Removal Systems
John Banks, SCS Engineers

A Case Study of the Causes of Apparent Versus Actual Leachate Head on Liner Conditions at a Modern Landfill
Terry Johnson, Waste Management, Inc.

11:30 A.M. - 1:00 P.M. LUNCH WITH SPONSORS

CURRENT DESIGN APPROACHES FOR LANDFILL LEACHATE REMOVAL SYSTEMS

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CURRENT DESIGN APPROACHES FOR LANDFILL LEACHATE REMOVAL SYSTEMS

INTRODUCTION

The purpose of this paper is to present the current design approaches available for removing leachate from landfills. All lined landfills must have a method to remove leachate from within the lined cell. The design of the leachate removal system must address a number of variables in order to achieve the desired performance and reliability required.

The design of an effective leachate removal system must, at minimum, address the following design considerations:

- General site layout and pumping requirements
- Sump and pumping arrangement
- Pump sizing criteria
- Hydraulic analysis and pump selection
- Sump sizing
- Controls and power supply

GENERAL SITE LAYOUT CONSIDERATIONS

Several aspects of the overall site layout need to be considered in the initial planning for the leachate removal system (LRS). In almost all cases the LRS will require pumping of the leachate at some point. The design of the landfill cell may dictate the location of the sump and pump station. Ideally the design of the LRS is considered while the cell is being designed so that an optimum location can be selected, assuming no other constraints are present. If existing landfill cells and associated LRS components are present, the new system should be designed to make optimum use of the existing infrastructure. The elevation of the proposed sump water levels and pumping equipment should also be determined for future hydraulic analysis.

The ultimate destination of the leachate delivered by the LRS must be determined. If this location is a storage tank, the distance to the tank along the pipeline route must be determined as well as the worse case elevation condition. Discharge to a storage tank should be achieved through an inlet that is elevated above the high water level in the tank so that the pumping rate is not affected by the water level in the tank. The LRS discharge may include connection to an existing pipeline which is used by other pumping systems. In this case a transient analysis must be conducted to identify the effect the new system will impose on the existing systems under various scenarios. The new LRS discharge may also be directed to another pump station wet well where the leachate will be re-pumped to another location. The existing pump station must be evaluated for its ability to hand the additional flow presented by the new system.

Another general site consideration is future landfill expansion. Ideally there would be an overall site master plan that identifies the future landfill cell construction phases and associated LRS locations. With this information, the new LRS can be designed to work in concert with future systems, just as they must work with the existing systems as described above.

Availability of power supply should not be overlooked when considering the pump station location and type of pumping equipment. Electric power service can be provided in almost all cases; however, the cost of this item can be considerable and alternative locations for pumping equipment may need to be considered.

SUMP AND PUMPING ARRANGEMENT

All pumping systems require a sump from which the pump will draw water (leachate). The type of sump/pump arrangement falls into one of two basic types; external systems and internal systems.

External Pumping Systems

An external pumping system includes a wet well (sump) and pumping equipment that is located outside of the lined landfill cell. The advantage of this system is accessibility to the pumping equipment. The external system can be designed similar to a traditional wastewater lift station. Municipal operations and maintenance personnel are familiar with these systems based on experience with the similar wastewater pump stations. In many cases, a site will include internal pump stations that discharge to an external "master" pump station that conveys leachate to a more distant discharge point. This arrangement avoids liner penetrations while locating larger pumps in a more accessible location.

The primary disadvantage of this system is that it requires a penetration in the landfill liner system for leachate to flow by gravity from the cell to the wet well. For this reason, and the availability of pumps specifically made for use in internal systems, use of external pump systems have decreased in the past 10 to 15 years.

Internal Pumping Systems

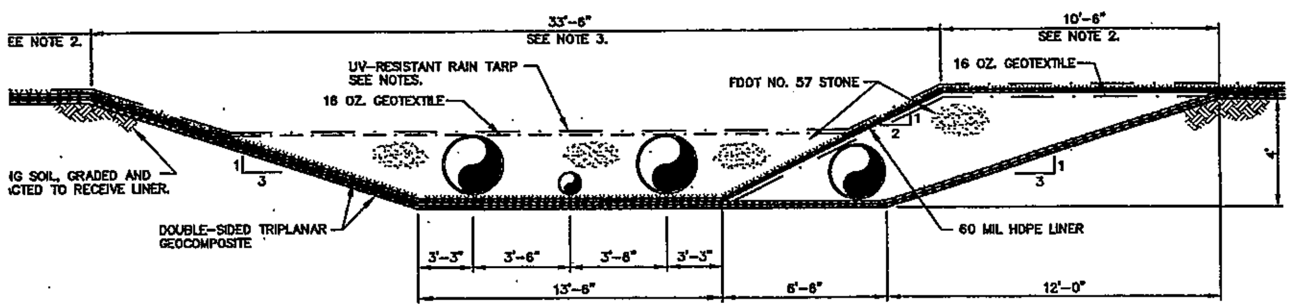
An internal pumping system includes a vertical or sloped wet well pipe or pipes, into which pumps are placed. Because these wet well pipes must be accessible at the final build out elevation of the landfill, or at the edge of the cell in the case of the sloped pipes, these pipe are typically referred to as riser pipes. The major advantage of this system is the avoidance of penetrations in the liner system. A disadvantage is accessibility to the pumping equipment.

The accessibility issue becomes a greater concern as the depth of the riser pipes increases. The pumps, power and control cables, and discharge piping must all be removed from the riser pipe to service or replace a pump. There must be room and/or methods available to pull the pump and associated pipes and cables to the surface. Methods for draining water from the discharge piping should be considered for deeper installations due to the weight of the water in the pipe.

Most internal designs over 20-years old involved the use of vertical risers. Since the introduction of pumps specifically designed for slope riser applications, most systems have been designed using side slope risers. Side slope risers improve the access to the pumping equipment by placing the access point at the perimeter of the cell.

There are some design issues to be addressed that are specific to side slope riser designs. Most mission critical industrial pump stations include two pumps so there is always a backup pump in the event of a pump failure. These "duplex" systems usually operate in a lead-lag mode that allows a second pump to engage if the first pump fails to draw down the water level. Typically the pumps alternate between the lead and lag pump role between cycles. Slope riser pump stations can be designed as duplex stations by simply installing dual slope riser pipes and pumps. The pump station is operated from a single control panel designed for duplex pump station operation.

The riser pipes are typically constructed of HDPE and are subject to thermal expansion and contraction. Cyclic expansion and contraction of pipes of more than a few dozen feet in length will cause them to become displaced along the horizontal axis of the pipe. This effect is more pronounced when the pipe is located on a sloped surface and on a low friction material such as a geomembrane. Even texture geomembrane is a relatively low friction surface compared to soil. One design approach to address this issue is to encase the riser pipes within a soil or gravel blanket. Other approaches include anchoring the pipe at the top of the slope in a cast-in-place concrete wall or providing a concrete "dead man" with a tie-down for the end of the pipe. A design detail for encasing the side slope risers is presented below. Note that this detail is for a double liner system and the leak detection pump slope riser is shown on the right of the figure and is encased below the primary liner.



A number of materials are used for the discharge piping for slope riser systems. A PVC flexible tubing is the most common application. The advantage of the tubing is that it can be coiled up while extracting the pump. Thin wall HDPE pipe can also be used and is desirable for deeper installations. While this material cannot be coiled, it can bend in a relatively tight radius, allowing the extraction process provided there is ample clear space in at least one direction no more than 90 degrees from the alignment of the riser pipe. An advantage of the solid wall HDPE discharge pipe is that the pipe can be used to assist in pushing the pump into the sump. This becomes important in deeper installations as the drag from the flexible tubing and cables overcomes the gravitational force of the pump as it is lowered down the riser pipe. Another advantage of the solid wall pipe is that a bleed down orifice can be installed in the discharge pipe a short distance above the pump. The orifice will pass a relatively small amount of low when the pump is running but will allow the pipe to drain once vacuum at the high end of the discharge pipe is broken. This occurs when the discharge line is disconnected in preparation for removing the pump for service. Draining of the discharge line inside the riser pipe greatly improves the extraction process by reducing the weight of the materials to be removed.

Other design features to include are air release valves at high points along the discharge piping, provision for metering leachate flow from each pump, and provision for by-pass discharge of stormwater. When the cell is initially constructed and before any waste is placed in the cell, clean stormwater will find its way into the leachate collection system. In order to avoid pumping this water to the leachate management system, a by-pass valve should be included in the discharge piping. The valve should direct water to piping which leads to the stormwater management system for the site. Once waste is places in the cell, the valve shall be permanently closed or removed to avoid any possibility that leachate could be accidentally discharged to the stormwater system.

PUMP SIZING CRITERIA

A fundamental question that should be resolved early in the design of a LRS is the maximum rate of leachate removal that will be required. This question is related to several factors including the size of the lined cell serviced by the LRS, the projected leachate generation rate under various operating conditions and assumptions, and the allowable amount of "storage" available within the lined cell.

Typically the HELP model is used to make estimates of leachate generation. This modeling effort should be performed in conjunction with the design of the cell. The allowable head on the liner is a key criterion for the modeling effort. The maximum head on the liner is one foot under normal operating conditions. It is usually assumed that temporary deviations above one foot must be restored within 72 hours. This flexibility allows for some storage capacity for extreme events.

The assumptions used in the HELP model can greatly affect the results. Cover soil parameters, runoff coefficients, percent of allowable runoff, waste thickness and waste parameters, and inclusion of short-term storm vents are variables available to the modeler. The HELP model can be set up to estimate leachate generation on a per acre basis or based on the actual size of the cell. One approach to estimating projected leachate generation rates for pump sizing purposes is to initially use the most conservative assumptions and determine if there is a need to take a more aggressive approach.

Recommendations for determination of the peak required pumping rate include modeling the cell with 10 feet of waste and running a simulation for two years with above average second year rainfall data. An overall factor of safety of 2 should be applied to the results. Convert the peak day discharge from the lateral drainage layer to arrive at a peak flow in terms of gallons per minute for the pumping equipment.

A check of this pumping rate can be accomplished by multiplying the pumping rate by 72 hours and converting this result to inches of rainfall over the open cell area. This result should be compared to a typical design storm event for the geographic location of the landfill. If the pumping rate is less than the design storm event, the open cell area can be reduced through the use of a new cell cover. A new cell cover is an expendable, thin (10 mil) membrane that is placed over the liner system to shed rainfall from entering the leachate collection system. Use of a new cell cover effectively reduces the area exposed to rainfall, thus reducing the ultimate pumping capacity requirement and reducing the amount of leachate generated in early cell operations.

HYDRAULIC CALCULATIONS AND PUMP SELECTION

In order to analyze the system hydraulics the following information must be known:

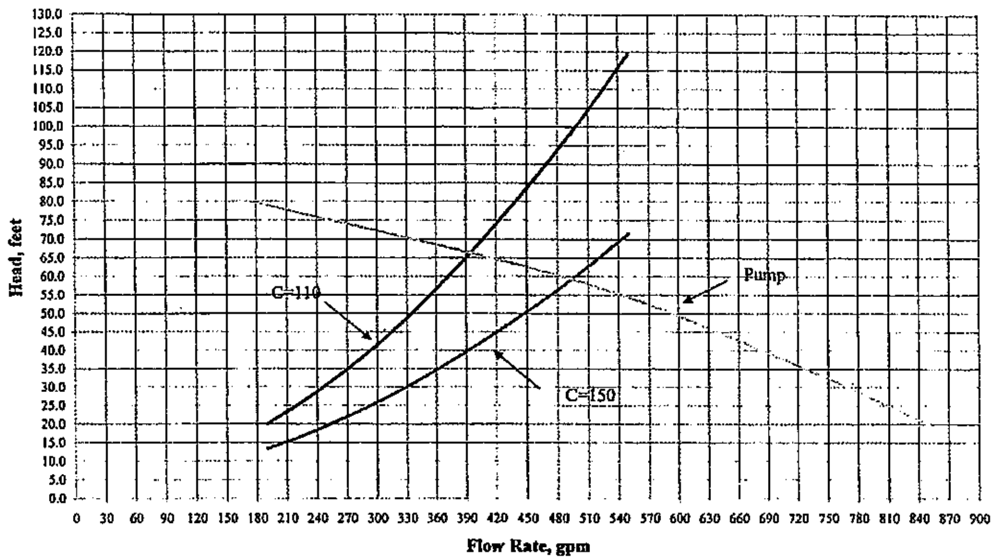
- Pump elevation
- Maximum and minimum sump water elevations
- Discharge elevation or maximum pressure
- Maximum elevation along force main route
- Length of force main
- Force main material

The size of the force main should be determined based on velocity using $A = Q/V$ where Q is the design pumping rate and V is the design maximum velocity. A velocity above 6 feet per second (fps) begins to generate relatively high frictional head loss. This is not critical for short force mains; however, higher velocities could also create unwanted scour at the discharge point. Thus a maximum velocity of 7-8 fps is generally employed with a maximum of 6 fps for longer force mains.

The total dynamic head (TDH) of a system is the sum of the frictional losses and the static head. The TDH of a system should be calculated for various flow rates. A spread sheet can be developed to tabularize the results and plot TDH as a function of flow rate. This plot is referred to as a system head curve. The system head curve is then compared to pump curves to identify a pump that will operate at the desired flow rate.

The system curves can be developed for new piping and piping with a degraded interior surface due to scum build-up to simulate the piping network after years of service. The degraded pipe has a higher friction factor and greater resistance to fluid flow. The resulting system curves are plotted along with an example pump curve below.

System Curve, Leachate Flow
Citrus County Landfill
Current Conditions



02199001.07\Copy of PumpSystemCurrent

As can be seen from this example, fouling of the pipe can result is significant reductions in flow capacity. Fortunately, the greatest flow capacity is required when systems are new. For a new design the flow capacity requirement in the early operational stages could be met by the "clean" pipe. It is important to note that if the new system is to be tied in to an older piping network, the older pipe should be modeled in the degraded condition.

SUMP SIZING CRITERIA

A very important aspect of the LRS design is sizing the sump. The sump must be of adequate size to provide enough water to the pump so that the pump does not cycle excessively. A pump cycles each time the water level in the sump reaches the preset level whereby the level detector activates the pump and the pump removes the water from the sump to the preset level which deactivates the pump. Pumps typically should not have more than 100 cycles per day. Excessive cycles will result in shorter pump life or overheating of the motor and complete failure of the system. An excessively large sump creates additional risk of leakage through the liner as this area has, due to its function, greater head conditions than the typical cell floor.

The sump volume can be calculated based on the pumping capacity using the following formula:

Minimum Sump Volume= (15 min x 0.5 pump rate)/2

The minimum cycle time is 15 minutes based on 100 cycles per day. The cycle time includes the time required to pump down the sump and the time required for the sump to refill. The time required to pump the sump down is proportional to the pumping rate minus the flow of leachate coming in to the cell. The time to refill the cell is proportional to the leachate flow rate entering the sump. Thus the cycle time can be expressed as follows:

$$\text{Cycle Time} = (SV/(\text{pump rate} - \text{leachate flow}) + (SV/\text{leachate flow})$$

From this equation it can be seen that the minimum cycle time occurs when the leachate flow rate is exactly one half of the pumping rate. Thus the equation for the minimum cycle time can be expressed as follows:

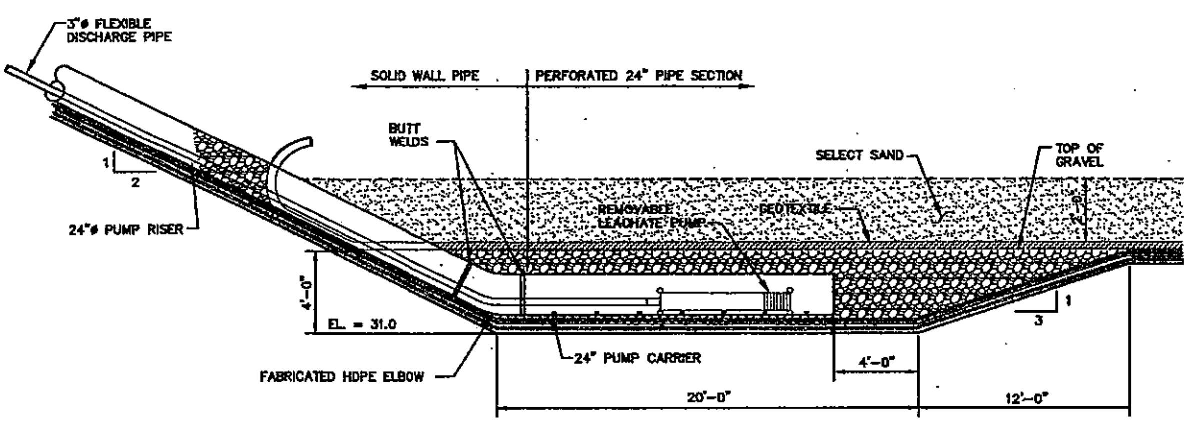
$$\text{Cycle Time} = (SV/0.5\ \text{pump rate}) + (SV/0.5\ \text{pump rate})$$

or

$$\text{Cycle Time} = 2 \times (SV/0.5\ \text{pump rate})$$

Thus, substituting 15 minutes for the minimum cycle time and rearranging the equation we obtain the above simplified equation for the minimum sump volume.

There are several additional considerations that must be reviewed when developing the physical dimensions for the sump. For an internal LRS the sump is typically filled with gravel, thus the effective volume of the sump is the void volume within the gravel. The required minimum sump volume must be divided by the porosity of the gravel to obtain the physical volume of the sump. The riser pipe dose not contain gavel, thus its entire volume may be used in the sump volume or this extra volume can be used as a safety factor. The effective sump volume does not include the volume below the shutoff level of the sump. This "dead" volume must be provided in accordance with the pump manufacturer's requirements and included in the overall sump volume. A typical sump arrangement for a slope riser system is shown below.



DESIGN EXAMPLE

A simplified design example using a 6 acre cell follows to illustrate the concepts presented above. The HELP model is used to predict leachate generation for the example site using the recommended guidelines. This results in a peak daily leachate generation rate of 15,000 gallons per day (gpd). For the 6 acre cell this equates to 90,000 gpd or 62.5 gallons per minute (gpm). Applying a factor of safety of two, the design pumping rate is 125 gpm.

The extreme event is checked by multiplying the design pumping rate by 72 hours to obtain 540,000 gallons. This is equal to 72,200 cubic feet of pumping capacity over 72 hours. To relate this to a rainfall event, this capacity is divided by the area of the cell to obtain the depth over the cell. For the example, 72,200 cubic feet divided by 6 acres results in 0.28 feet or 3.3 inches of depth. For the example site, a 25-year storm event would be 6 inches, therefore a new cell cover is proposed for half the cell. Thus in 3 acres the 72 hour pumping capacity is equal to a 6.6 inch storm event. This is a conservative approach as no losses are taken for evaporation.

The minimum sump size is calculated as follows:

Minimum Sump Volume= (15 min x 0.5 x 125 gpm)/2
= 496 gallons
= 63 cubic feet

Using 30 percent for the porosity of the gravel the physical sump volume is 209 cubic feet. Assuming the vertical dimension within the effective sump volume is 1 foot, the area must be 209 square feet or greater. Thus the sump dimension could be 12 feet by 18 feet. The total depth would be 1 foot plus the dead volume based on the type of pump selected, usually 10 to 12 inches, or a total depth of 2 feet.

CONTROLS AND POWER SUPPLY

The pumps are typically controlled by devises that detect the water level in the sump. These can be float balls with internal switches, transducers, or bubbler systems. A number of suppliers for slope riser systems incorporate a transducer mounted on the pump. The transducer or bubbler systems can provide a digital display of the water level above the transducer. This display is typically provided at the control panel and is also used to set the various control levels for pump operations. It is important to note that the control settings are relative to the location of the transducer location. If it is important to know the control levels in terms of elevation per a site datum, the elevation of the installed transducer/pump must be establish during the construction of the sump.

The control panels for the pumping station should be provided by the pump supplier. A single vendor is thus responsible for the function of the pumping system as a total package. This provides continuity of responsibility and a single source for service issues. The type of enclosure for the control panel and other preferences for electrical components can be accommodated by most vendors. Most pump control systems can be adapted to telemetry systems.

Provision for power supply should not be overlooked. If a service drop is required, an analysis of the power transmission extension should be performed by an electrical engineer. Low voltage and/or voltage fluctuations will lead to reliability problems with the system.

The power supply leads to the control panel should include a shutoff breaker and conduit seals before entering the panel. A provision for emergency power supply should also be provided. This may include an external power supply receptacle mounted on the panel. The type of receptacle must be matched to the portable generator to be used for emergency power. The power and control wires from the panel to the pumps should also be equipped with conduit seals and breakout or junction boxes. Conduit seals are important in keeping potentially explosive gasses associated with landfill from entering the panel. These gasses will also damage the electrical components inside the panel if allowed to enter. The breakout boxes should be located on the pump side of the conduit seals. They provide a location to disconnect a pump from the panel without the need to enter the panel or replace the conduit seals.

CONCLUSION

There are many issues to consider when designing a leachate removal system for a landfill cell. Careful consideration of all design conditions is needed to fully analyze the requirements for any given situation. A well designed system should provide years of reliable function and should not be overly burdensome to maintain. That being said, no system will function indefinitely without routine preventative maintenance. A good design, coupled with a good maintenance program is essential to reliable performance and avoidance of crisis situations.