

**Performance Based Decision System for Determining Post Closure Care  
(PCC) Period in Florida Landfills**

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**PROJECT TITLE:** Performance Based Decision System for Determining Post Closure Care (PCC) Period in Florida Landfills.

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**ABSTRACT:**

The 30-year funding period for post closure monitoring and maintenance for non hazardous landfills is required by Subtitle D of the Resource Conservation and Recovery Act (RCRA). According to solid waste facility regulations codified in 40 CFR §258.61(b), the 30-year PCC period specified by Subtitle D can be extended or shortened by the governing regulatory agency on a site-specific basis. However, the decision to extend or shorten the post-closure care period should be based on whether the landfill is a threat to human health or the environment. Development and incorporation of a risk factors matrix and risk assessment module for assessing potential threats to human health and environment during the PCC period will allow more efficient management strategies for closed landfill sites. The use of a scientifically justifiable decision making methodology would also have significant economic benefits and will provide a measure of PCC liability for public understanding.

## **ACKNOWLEDGEMENTS**

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## **LIST OF ACRONYMS**

CMP	Corrugated metal pipe
EPA	Environmental Protection Agency
HDPE	High Density Polyethylene
LCRS	Leachate Collection and Removal System
LCS	Leachate Collection System
LPN	Liability Priority Number
MSW	Municipal Solid Waste
PCC	Post closure care
PE	Polyethylene
PVC	Polyvinyl Chloride
RCRA	Resource Conservation and Recovery Act

## **Abstract**

Subtitle D of the Resource Conservation and Recovery Act (RCRA) requires a post closure period of 30 years for non-hazardous wastes in landfills. Post closure care (PCC) activities under Subtitle D include leachate collection and treatment, groundwater monitoring, inspection and maintenance of the final cover, and monitoring to insure that landfill gas does not migrate off site or into on-site buildings. The decision to reduce PCC duration requires exploration the applicability of a performance based methodology to Florida landfills. PCC should be based on whether the landfill is a threat to human health or the environment. Performance of closed landfills has been evaluated through case study of PCC practices at closed Davie Landfill.

The landfill activity depends on a number of factors which includes variables that relate to operations both before and after the closure of a landfill cell. Therefore, PCC decisions should be based on location specific factors, operational factors, design factors, post closure performance, end use, and economic factors. For this study two methodologies are used. These are Decision Algorithm & Ranking Matrix System and Field Based Approach. Knowledge based decision algorithm and ranking method can be applied for the landfills in the absence of the appropriate monitoring data.

For the Field Base Approach all the data for the Davie Landfill were provided by Broward County Waste and Recycling Services Solid Waste Operations Division. Leachate trend, leachate vs. rainfall trend, gas generation, leachate vs. gas generation, gas vs. rainfall data were evaluated as a quantitative data. Qualities of leachate and groundwater data were evaluated for the data analysis and landfill performance assessment.

For this research risk analysis and monitoring to confirm evaluations or predictions are going to be the next steps of determining to shorten or extend the PCC period.

# **EXECUTIVE SUMMARY**

## **1. INTRODUCTION**

Subtitle D of the Resource Conservation and Recovery Act (RCRA) requires a post closure period of 30 years for non-hazardous wastes in landfills. Post closure care (PCC) activities under Subtitle D include leachate collection and treatment, groundwater monitoring, inspection and maintenance of the final cover, and monitoring to insure that landfill gas does not migrate off site or into on-site buildings. The decision to reduce PCC duration requires exploration the applicability of a performance based methodology to Florida landfills.

Methodology for closing landfills can include the performance based factors as well as end use considerations for potential threats to human health and the environment. The performance based decision making factors for ending PCC at landfills include (Morris, 2005):

- Quantification of landfill source characteristics (i.e., leachate and landfill gas);
- Definition of trends in concentrations and quantities at the source;
- Evaluation and prediction of the release of constituents for potential impacts to human health and the environment;
- Monitoring to confirm evaluations or predictions

Detailed analyses of performance data from case study landfills will allow development of a decision making framework suitable for Florida landfills and help quantify and compare the extent of stabilization being achieved over time

## **2. OBJECTIVES**

The decision to reduce PCC duration requires an objective and acceptable approach. The goal of the proposed project is to explore the applicability of a performance based methodology to Florida landfills with the potential to reduce the extent or duration PCC. The specific objectives of the project are to:

1. Evaluate post closure performance data from closed Florida landfill cells;
2. Analyze potential threats to human health and the environment based on end use of landfills;
3. Conduct an economic analysis of PCC options suitable for Florida landfills
4. Develop a PCC guidance document suitable for Florida landfill owners and operators.

## **3. METHODOLOGY**

Development of a systematic approach which can be used as a decision making tool to extend or shorten the PCC period or modify PCC should be based on whether the landfill is a threat to human health or the environment. These decisions require

technically sound and justifiable methods for analysis and interpretation of available data and information from closed landfill sites. It is important that a set of measures (i.e., metrics) is developed and used appropriately to evaluate the relative activity in closed landfills in terms of their overall stability and potential to be threat to human health or the environment.

The landfill activity depends on a number of factors which includes variables that relate to operations both before and after the closure of a landfill cell. Therefore, PCC decisions should be based on location specific factors, operational factors, design factors, post closure performance, end use, and economic factors. For this study two methodologies are used. These are Knowledge Based Decision Algorithm and Ranking Method and Field Based Approach. Based on the characteristics of the landfill design, knowledge base algorithm method can be applied to landfill in the absence of the appropriate monitoring data. The ranking method is preliminary weights of the decision parameters for liner design, leachate generation, gas generation, settlement, and surface water quality during PCC. Appropriate weight scales for parameters are being developed for the ranking. Based on the characteristics of the landfill design, a set of PCC liability priority numbers can be estimated for assessing the significance of the PCC liability of the landfill.

Field base approach is based on the evaluation of all the available data provided by the landfill site. For the Field Base Approach all the data for the Davie Landfill were provided by Broward County Waste and Recycling Services Solid Waste Operations Division. Leachate trend, leachate vs. rainfall trend, gas generation, lechate vs. gas generation, gas vs. rainfall data were evaluated as a quantitative data for landfill performance assessment.

#### **4. CONCLUSIONS**

During the year 1 of the study, time dependent changes in a landfill's structure and components are being analyzed using the available data and knowledge base from three case study landfills. The case study landfills selected include the Davie Landfill (also knows as Vista View Park), Munisport (also known as Biscayne Landings), and Alachua County Southwest Landfill. The main reasons for selecting these landfills for the purpose of evaluating PCC duration on the performance basis is data availability. These landfills are among the highest studied landfills in United States. They all have ample data on leachate quantity and quality, landfill gas, and groundwater monitoring, which plays a key role in PCC duration evaluation.

Quantity and quality of data available help in setting a trend between degradation of MSW and time, climate, moisture content of waste and waste type. The reports and documentation available for these landfills have been acquired and the research staff has been meeting with the technical personnel at the regulatory agencies. The knowledge base and data available on the case study landfills are currently being analyzed and integrated into the decision making algorithm to assess the suitability of the PCC options of the selected landfills relative to their end-use settings. The design and operational parameters are broken into detailed subcomponents (leachate, landfill gas, groundwater, cap, and end

use) and each subcomponent is analyzed from a time dependent performance perspective. The significance of each component on the overall integrity of the landfill is assessed based on anticipated time dependent changes. This analysis will allow the identification of landfill components which will require periodic upgrades to maintain their structural integrity during the PCC period as well as adequacy of the duration of the PCC period.

The decision algorithms and preliminary weights of the decisions parameters for liner design, leachate generation, gas generation, settlement, and surface water quality during PCC have been developed. Appropriate weight scales for parameters are being developed. Based on the characteristics of the landfill design, a set of PCC liability priority numbers can be estimated for assessing the significance of the PCC liability of the landfill. As an example, the sample algorithm for the liner type is presented below. Currently, the decision algorithm is being coded in visual basic as a user friendly computer based tool.

During Year 2 of the project, the potential treats to human health and the environment will be evaluated in the context of end use, level of post-closure care, and extent of stability of solid waste. Potential threats to human health and the environment will be correlated to the integrity of landfill components (i.e., leachate quality and quantity; gas composition and production; cover, side slope and liner design; site geology and hydrogeology; climate; potential receiving bodies; ecosystem and human exposure; and other site/location specific factors) from the risk perspective for ending the post closure care.

## **5. RESULTS**

During the year 1 of the study, time dependent changes in a landfill's structure and components are being analyzed using the available data and knowledge base from three case study landfills.

Quantity and quality of data available help in setting a trend between degradation of MSW and time, climate, moisture content of waste and waste type. The knowledge base and data available on the case study landfills are currently being analyzed and integrated into the decision making algorithm to assess the suitability of the PCC options of the selected landfills relative to their end-use settings. The design and operational parameters are broken into detailed subcomponents (leachate, landfill gas, groundwater, cap, and end use) and each subcomponent is analyzed from a time dependent performance perspective. The significance of each component on the overall integrity of the landfill is assessed based on anticipated time dependent changes. This analysis will allow the identification of landfill components which will require periodic upgrades to maintain their structural integrity during the PCC period as well as adequacy of the duration of the PCC period. Some field based results are listed below

Yearly Total Leachate vs. Rainfall figures shows us steady rainfall is slightly decreasing by the year.

When monthly leachate and rainfall data compared, it can be seen that there is some correlation based on the peaks. Leachate has periodic trends with some delay of the rainfall.

Inspection of the recent data records showed an unusual trend with no documented explanations. Interviewing of the engineer responsible for Davie Landfill site revealed that the meter that was used for measuring the leachate quantity was broken and a new meter had been installed in 2006. Reassessment of the data by plotting the rainfall versus leachate quantity clearly showed that the new meter had a different calibration scale from the previous meter that was used. The annual averages calculated using the new meter show the difference in calibration of this meter with the one that used previously.

The current landfill gas flow rate entering the enclosed flare is approximately 200 to 250 standard cubic feet per minute (scfm) with a methane concentration of approximately 40% to 50%. North mound only generates enough gas to operate the flare approximately 1 to 1.5 hours per day.

During the analyses of gas and, leachate data, it was observed that leachate and gas production rates over the years showed significant changes in the quantities immediately after the land use practices of the closed landfill changed. The monitoring data should be evaluated in view of the extend land use and regrading activities that took place over the years. There was a significant increase in gas flow immediately after the landfill closed in 2003. A significant increase can be seen in gas production immediately after the landfill was capped in 2004.

The decision algorithms and preliminary weights of the decisions parameters for liner design, leachate generation, gas generation, settlement, and surface water quality during PCC have been developed. Appropriate weight scales for parameters are being developed. Based on the characteristics of the landfill design, a set of PCC liability priority numbers can be estimated for assessing the significance of the PCC liability of the landfill.

## **LIST OF KEY WORDS**

Post Closure Care  
Landfill  
Leachate Collection System  
Liner Ranking  
Field Based Approach  
Geomembrane  
Geotextiles  
Liner

# 1. INTRODUCTION

Subtitle D of the Resource Conservation and Recovery Act (RCRA) requires a post closure period of 30 years for non-hazardous wastes in landfills. Post closure care (PCC) activities under Subtitle D include leachate collection and treatment, groundwater monitoring, inspection and maintenance of the final cover, and monitoring to insure that landfill gas does not migrate off site or into on-site buildings. According to solid waste facility regulations codified in 40 CFR §258.61(b), the 30-year PCC period specified by Subtitle D can be extended or shortened by the governing regulatory agency on a site-specific basis. However, the decision to extend or shorten the post-closure care period should be based on whether the landfill is a threat to human health or the environment (Morris et al., 2003).

Methodology for ending the PCC period for municipal solid waste (MSW) landfills can include performance based factors as well as end use considerations for potential threats to human health and the environment. A landfill is considered functionally stable when it no longer presents an unacceptable threat to human health and the environment. Currently, there are no specific technical criteria and metrics which can be used for systematic evaluation and comparison of relative stability of closed landfills; which, at the same time, allow an objective determination of the adequacy of the 30-year PCC period on a case-by-case basis. This makes it difficult for regulators to decide whether to extend or reduce the post-closure period. In addition, the proposed end-use of the closed landfills should be factored into the post-closure plans to evaluate the long-term environmental and public health issues and other community concerns. For example, if a closed landfill site is to be used as a park or a golf course, requirements and limitations for providing an irrigation system should be taken into account.

Methodology for closing landfills can include the performance based factors as well as end use considerations for potential threats to human health and the environment. The performance based decision making factors for ending PCC at landfills include (Morris, 2005):

- Quantification of landfill source characteristics (i.e., leachate and landfill gas);
- Definition of trends in concentrations and quantities at the source;
- Evaluation and prediction of the release of constituents for potential impacts to human health and the environment;
- Monitoring to confirm evaluations or predictions.

The landfill is an engineered system which should be developed with a scientific approach to designing, operating and closing in a way to optimize the post-closure care (PCC) costs. A closed landfill site can be reused for many purposes which serve the community needs (Vesilind et al., 2001, Tansel 1998). Post-closure care needs for MSW landfills include ground water and gas monitoring, leachate collection and treatment, gas recovery and management, and final cover maintenance (Vesilind et al., 2001; Reinhart and Townsend, 1997). Waste characteristics, climate, landfill design, and closure methods affect the rate and duration of leachate and gas production from a closed MSW

landfill site. The methodology for determining the PCC period should include both performance based factors as well as specific needs for selected end use to minimize potential threats to human health and the environment (Morris, 2005; Morris et al., 2003). RCRA rules also require landfill owners to prove that they funds required to maintain their landfills after closure and correct any environmental problems the landfill may cause. Issues that need to be incorporated into the financial assurance aspects of RCRA for MSW landfills should also include the duration of post-closure care, the amount of funding needed for future long-term care, financial assurances, and mechanisms to ensure that funds will be available exclusively for post-closure care and, if needed, ground water remediation (Lee, 2003; Anderson, 2004; Caldwell, 2004).

In a landfill, when the moisture content of the waste is reduced to about 20%, rate of gas production significantly slows (Christensen and Kjeldsen, 1989). While with a good quality cap design, it is possible to limit the moisture supply to a landfill, over time the cap may loose its integrity due to environmental and geotechnical stresses. Consequently, the cap requires periodic maintenance to prevent excessive amounts of moisture from entering the waste (Lee and Jones-Lee, 1993; Lee 2004). The implication that monitoring will be discontinued after 30 years because the landfill is stable and no longer represents a threat to the environment requires a scientific and systematic approach for monitoring performance of closed landfills (Barlaz, 2004; Barlaz et al., 2002). By implementing proper engineering measures during the operation of a landfill, the stabilization period of the MSW can be reduced significantly. Florida's climate promotes waste decomposition significantly faster than landfills located in other dryer parts of the United States. Detailed analyses of performance data from case study landfills will allow development of a decision making framework suitable for Florida landfills and help quantify and compare the extent of stabilization being achieved over time.

## **1.1 OBJECTIVES**

The decision to reduce PCC duration requires an objective and acceptable approach. The goal of the proposed project is to explore the applicability of a performance based methodology to Florida landfills with the potential to reduce the extent or duration PCC. The specific objectives of the project are to:

1. Evaluate post closure performance data from closed Florida landfill cells;
2. Analyze potential threats to human health and the environment based on end use of landfills;
3. Conduct an economic analysis of PCC options suitable for Florida landfills
4. Develop a PCC guidance document suitable for Florida landfill owners and operators.

## 1.2 METHODS

Development of a systematic approach which can be used as a decision making tool to extend or shorten the PCC period or modify PCC should be based on whether the landfill is a threat to human health or the environment. These decisions require technically sound and justifiable methods for analysis and interpretation of available data and information from closed landfill sites. It is important that a set of measures (i.e., metrics) is developed and used appropriately to evaluate the relative activity in closed landfills in terms of their overall stability and potential to be threat to human health or the environment. The indicators of landfill activity should be analyzed and interpreted in an integrated manner to develop an objective, compliant, informed and justifiable management decision. The general approach for development of a PCC period decision is presented in Figure 1.

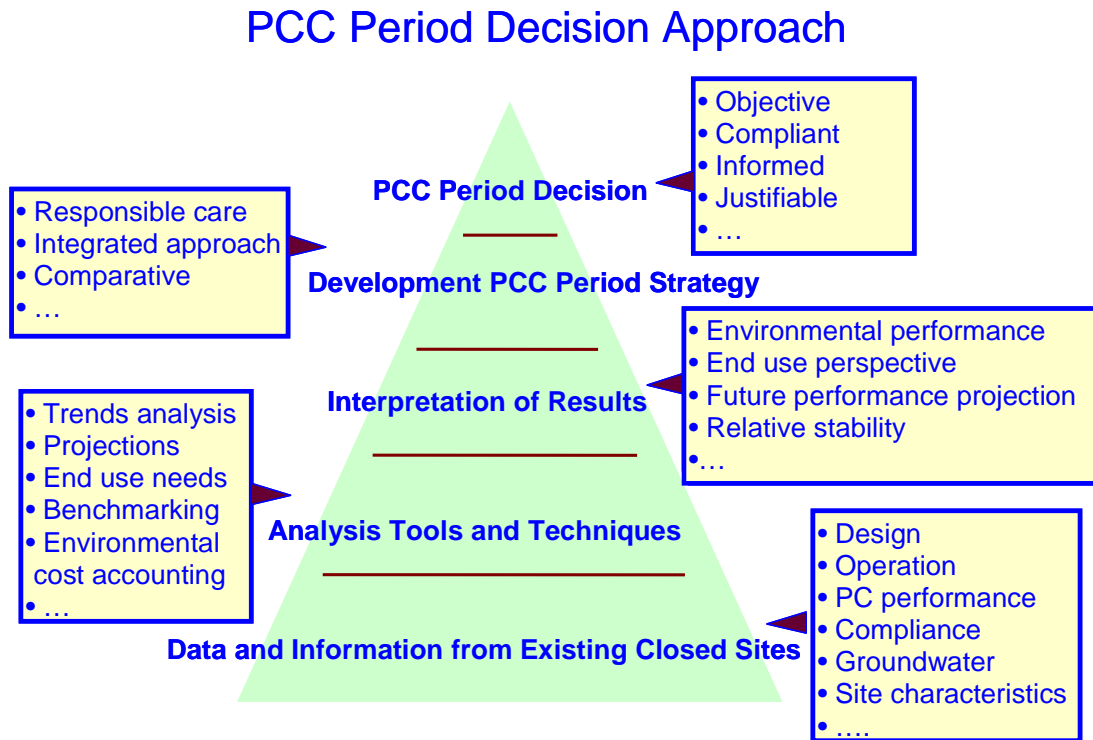


Figure 1. General approach and methodology for PCC period decision.

During this study, performance of closed landfills is being evaluated through case studies of PCC practices at closed Florida landfill cells. The potential treats to human health and the environment are evaluated in the context of end use and appropriate level of post-closure care. Evaluation of the potential threats to human health and the environment (i.e., leachate quality and quantity; gas composition and production; cover, side slope and liner design; site geology and hydrogeology; climate; potential receiving bodies; ecosystem and

human exposure; and other site/location specific factors) provide the scientific basis for development of a guidance document for ending or modifying post closure care.

The landfill activity depends on a number of factors which includes variables that relate to operations both before and after the closure of a landfill cell. Therefore, PCC decisions should be based on location specific factors, operational factors, design factors, post closure performance, end use, and economic factors as shown in Figure 2.

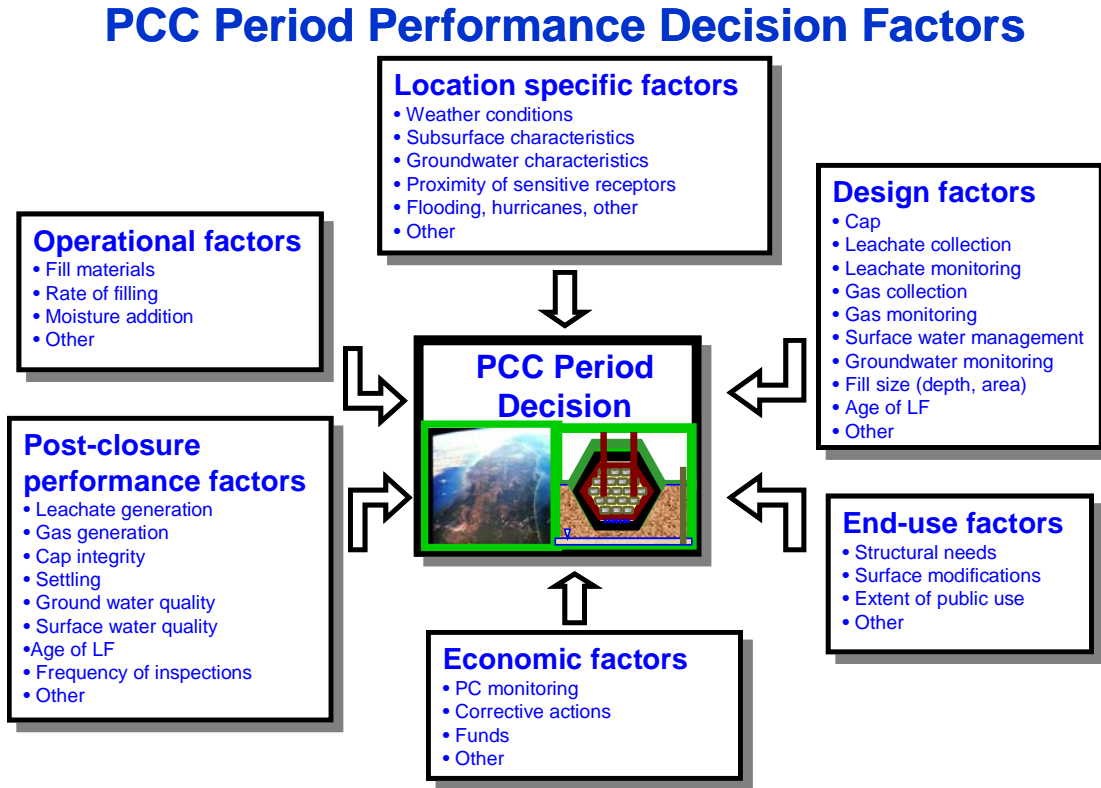


Figure 2. Examples of potential decision factors for PCC period.

The data from the case study landfills can be organized systematically for evaluation of the effect of each factor on the overall post closure performance of the landfill. The systematic approach to be followed for the analysis of available data from the case study landfills is shown in Figure 3.

# PCC Period Performance Analysis

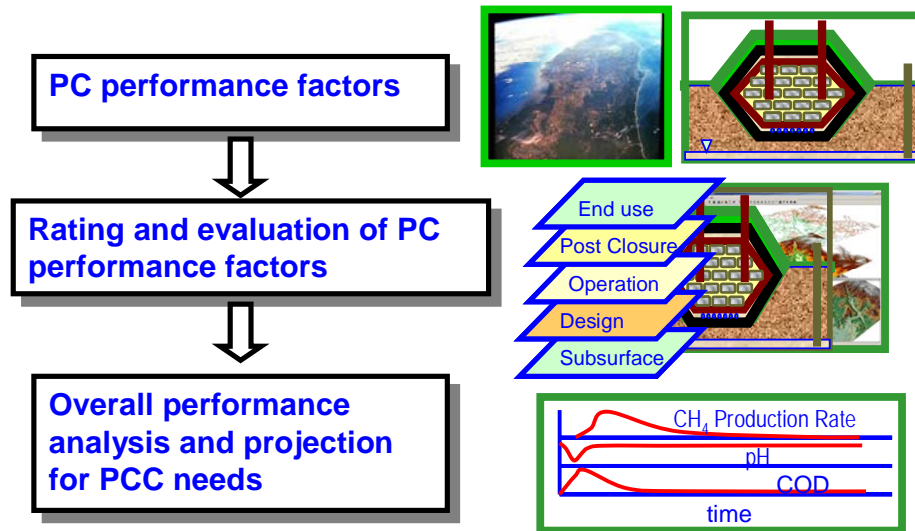


Figure 3. PCC Period performance analysis.

## 2. BACKGROUND

### 2.1 POST CLOSURE PERFORMANCE PARAMETERS

This section provides role of important design and operational parameters on the post closure performance of closed landfills.

#### 2.1.1 Liner

Landfill liners are designed and constructed to create a barrier between the waste and the environment and to drain the leachate to collection and treatment facilities. This is done to prevent the uncontrolled release of leachate into the environment. Liners may be described as single, composite, or double liners. Single liners consist of a clay liner, a geosynthetic clay liner, or a geomembrane. Composite liner systems consist of a geomembrane in combination with a clay liner and are required in municipal solid waste (MSW) landfills. The double liner systems consist of either two single liners, two composite liners, or a single and a composite liner. Double-liner systems are used in some municipal solid waste landfills and in all hazardous waste landfills.

#### 2.1.2 Leachate

Leachate is formed when water passes through the waste in the landfill cell. As the liquid moves through the landfill many organic and inorganic compounds, like heavy metals, are transported in the leachate. The amount of leachate produced is directly linked to the amount of precipitation around the landfill. The amount of liquid waste in the landfill also affects the quantity of leachate produced.

Leachate collection systems are commonly constructed with layered materials. A LCS mainly consists of the following components as shown in Figure 4.

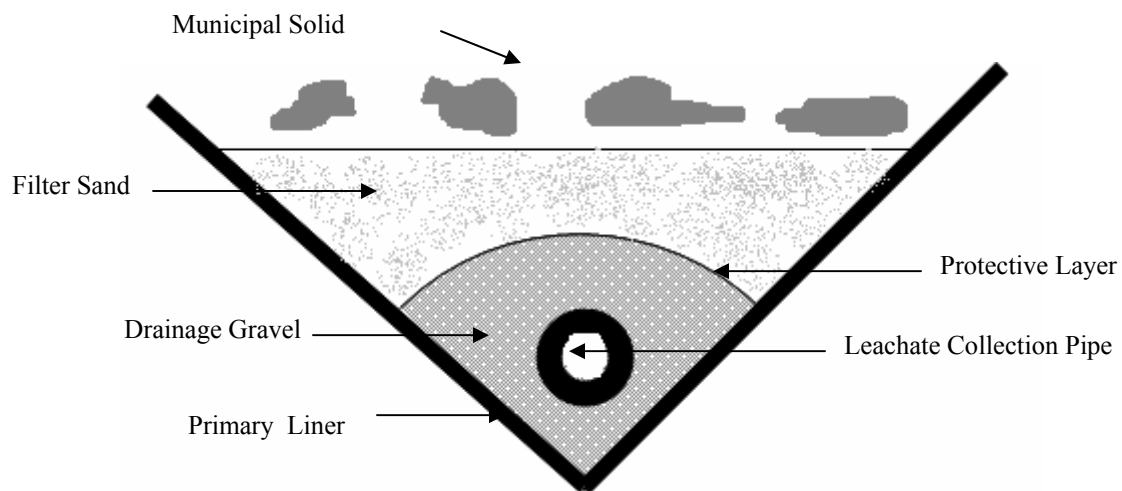


Figure 4. Components of leachate collection systems (adopted from Reinhart, 2000).

### 2.1.3 Gas

Fifty percent of the municipal solid waste in the landfill site gets broken down by bacteria for energy. This is done by aerobic or anaerobic fermentation. The degradable organic matter gets broken down into a stabilized organic residue (or compost), and water and carbon dioxide, the latter contributing to the composition of landfill gas. The waste quickly becomes anoxic due to the high oxygen demand for bacterial respiration in sanitary landfills. Anaerobic fermentation of organic matter will take place if sufficient moisture is present. With complete absence of oxygen, true anaerobic microorganisms, including methanogens, become established. Organic acids and hydrogen in the waste are then metabolized forming methane and carbon dioxide. If the methane migrates to areas of the landfill, which are operating under aerobic conditions, it may be oxidized to CO<sub>2</sub> by methanotrophic bacteria.

Landfill gas (LFG), is composed of 50-60% methane (CH<sub>4</sub>), 30-40% carbon dioxide (CO<sub>2</sub>), 10% Nitrogen and small amounts of non-methane volatile organic compounds (VOCs)

### 2.1.4 Cap

A cover or cap is an umbrella over the landfill to keep water out (to prevent leachate formation). It will generally consist of several sloped layers: clay or membrane liner (to prevent rain from intruding), overlain by a very permeable layer of sandy or gravelly soil (to promote rain runoff), overlain by topsoil in which vegetation can root (to stabilize the underlying layers of the cover). If the cover (cap) is not maintained, rain will enter the landfill resulting in buildup of leachate to the point where the bathtub overflows its sides and wastes enter the environment.

### 2.1.5 End Use

There are two types of End Uses.

- Passive uses such as Green space, wildlife or nature conservancy and hiking trails.
- Active uses such as sports fields, golf courses, industrial uses and transfer stations.

Table 1. Land use examples of closed landfills.

Land Uses
BMX Race Track, Model Airplane Field ,Little League Baseball Facility
Salt water sailing lake, golf course, wetlands, levees, amphitheater, & wildlife refuge
Recreation park, wildlife refuge and butterfly garden
Business Park and Golf Course, Ski Slopes
Passive Parkland and a small golf course
Soccer fields, tennis courts, boat launch, fishing area, amphitheater, sledding area
Public Works Storage Facility and Transfer Station

### 3. METHODOLOGY

For this study two methodologies are used. These are

- 1- Knowledge based decision algorithm and ranking system
- 2- Field based approach

#### 3.1 KNOWLEDGE BASED DECISION ALGORITHM AND RANKING SYSTEM

After the closure of a landfill, the owner is responsible for a minimum of 30 years to maintain the landfill. To ensure proper performance of the closed landfill, it is important that the owner/operator properly maintain the landfill and meet the obligations during the post-closure period. For this reason owner should monitor the surface water, ground water, gas and manage the leachate collection system. Many of the old landfills have no liners or liner in place does not meet today's regulatory requirements. The knowledge based decision algorithm and ranking method was developed to assess post closure performance of these unlined landfills in the absence of appropriate monitoring data.

##### 3.1.1 Post closure risk parameters associated with liner design

For assessing the landfill after closure, liner should be assessed as a first component. The liner effectively creates a bathtub in the ground. If the bottom liner fails, wastes can migrate directly to subsoils and groundwater. There are three types of liners: clay, plastic, and composite. The post closure concerns associated with these liners are summarized below.

**Clay liners:** Natural clay is often fractured and cracked. Organic chemicals such as benzene can diffuse through the clay landfill liner. Some chemicals can reduce the cation exchange capacity of the clay.

**Synthetic liners:** The most common landfill liners today are made of high density polyethylene (HDPE). A number of household chemicals can degrade HDPE, making it lose its strength or making it brittle. Not only will household chemicals, such as moth balls, degrade HDPE, but much more benign substances can cause it to develop stress cracks, such as, margarine, vinegar, ethyl alcohol, shoe polish, and peppermint oil.

**Composite liners:** Based on experiences, it has been observed that synthetic liners develop leaks. Additional leakage results from defects such as cracks, holes, and faulty seams. Studies show that a 10-acre landfill will have a leak rate somewhere between 0.2 and 10 gallons per day.

### **3.1.2 Algorithm Method**

The decision algorithm for liner, leachate generation, gas generation, settlement, and surface water quality during PCC period has been developed. Based on the characteristics of the landfill design, algorithm method can be applied to landfill. As an example, the sample algorithm steps for the liner type are explained below.

If a landfill has a no liner or a single liner such as clay or synthetic liner, due to their weakness, soil type should be investigated first. In general, there are three types of soils: loam, sand and clay. Sandy soils are light, usually holding water very poorly due to their low organic content. Loam is somewhat heavier than sandy soils, but also tends to be fairly free draining due to typically low organic content. Clay soils are not typically free draining, and water tends to take a long time to infiltrate. When wet, such soils tend to allow water to run-off.

Due to the weakness of the no liner and loam or sand soil type, next step should be considering the groundwater. Groundwater depth, proximity to the sensitive factors and groundwater direction such as upstream or downstream are the important factors that affect the ground water quality.

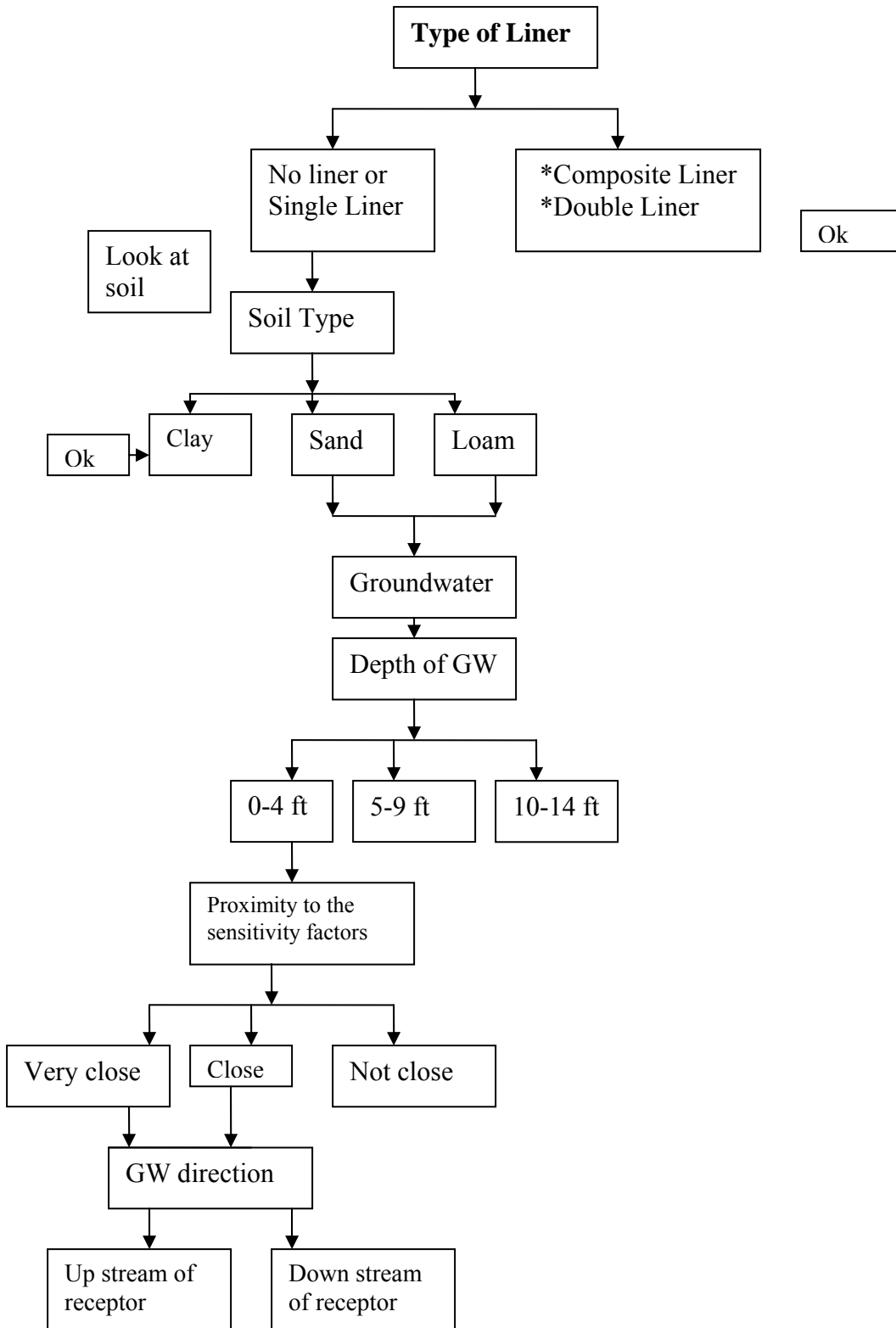


Figure 5. Post closure risk parameters associated with liner design.

### 3.1.3 Landfill Ranking

The knowledge based landfill ranking approach was developed based on evaluation of each component of the landfill. In this section, a sample ranking was presented for the liner. Liner performance ranking is based on type of liner, type of soil, depth to ground water, direction of groundwater, and proximity to sensitive receptors. Each factor was scaled to from 1 to 10, as 1 being the best and 10 being the worst case. In order to determine the best appropriate Landfill, Weighted Sum Method (USEPA) was used. This method is a quantitative method for screening and ranking options.

#### Liner Performance Ranking

##### Soil Types

0-10% Clay
0-10% Silt
80-100% Sand

**Sandy soils** are typically comprised of approximately 80 - 100% sand, 0 - 10% silt and 0 - 10% clay by volume. Sandy soils are light and typically very free draining, usually holding water very poorly due to very low organic content

10-30% Clay
30-50% Silt
25-50% Sand

**Loam soils** are typically comprised of approximately 25 - 50% sand, 30 - 50% silt and 10 - 30% clay by volume. Loam soils are somewhat heavier than sandy soils, but also tend to be fairly free draining, again, due to typically low organic content

50-100% Clay
0-45% Silt
0-45% Sand

**Clay soils** are typically comprised of approximately 0 - 45% sand, 0 - 45% silt and 50 - 100% clay by volume. Clay soils are not typically free draining, and water tends to take a long time to infiltrate. When wet, such soils tend to allow virtually all water to run-off.

Figure 6. Soil Types

Soil type ranking is based on each soils' permeability capacity.

Table 2. Soil type ranking.

Soil type	Sensitivity factor
Clay	1
Loam	5
Sand	10

Scale = 1 to 10, 1 is the best and 10 is the worst

### Rating for Types of Liner

Liner rating is based on type of liner used in landfill. Due to their weakness, for example landfill without liner was chosen the worst and it was given 10 as a rating.

Table 3. Rating for types of liner

Type Of Liner	Rating
No Liner	10
Single Liner	6
Single Synthetic	8
Composite ( Clay + Synthetic)	5
Double Clay	2
Double Synthetic	3

### Rating for Depth of Groundwater

Ratings are given based on the depth of groundwater from landfill.

Table 4. Rating for depth of groundwater.

Ground water Depth (ft)	Rating
0-2	10
2-4	9
4-6	8
6-8	7
8-10	6
>10	5

### Proximity to Sensitive Receptors

Sensitive receptors can be industrial, residential area around the landfill. Ranking is based on the distance of these receptors to landfill.

Table 5. Ranking for sensitive receptors.

Proximity (ft)	Rating
25-100	10
100-200	9
200-400	8
400-700	7
700-1000	6
>1000	5

### Ground Water Direction

Groundwater direction can be determined if it is towards the landfill or away the landfill.

### Liability Priority Number (LPN)

Liability Priority number is the total number of evaluation of the landfill. From all the ratings of type of liner, type of soil, depth of ground water, direction of groundwater, proximity to the sensitive factors give us LPN. LPN can be between 50 and 100000. The higher the number gives us the higher risk.

For a minimum  $\rightarrow 2 \times 1 \times 5 \times 5 \times 1 = 50$

For an Average  $\rightarrow 8 \times 5 \times 8 \times 7 \times 5 = 12600$

For a maximum  $\rightarrow 10 \times 10 \times 10 \times 10 \times 10 = 100000$

### Future

This method can be done for the each element of landfill as shown in the Table 6.

Table 6. Landfill Ranking

PCC Factor	LPN	Scaled LPN	Weight Factor	Final Number
Liner				
Cap				
Settlement				
Surface Water				
Leachate				
Ground Water				

## 3.2 FIELD BASED APPROACH

The data used in the analyses for the Davie Landfill were provided by Broward County Waste and Recycling Services Solid Waste Operations Division.

Leachate trend, leachate vs. rainfall trend, gas generation, lechate vs. gas generation, gas vs. rainfall data were evaluated as a quantitative data. Qualities of leachate and groundwater data were evaluated for the data analysis and landfill performance assessment.

## 4. CASE STUDY LANDFILLS

### 4.1 VISTA VIEW PARK (DAVIE LANDFILL) BROWARD COUNTY

#### 4.1.1 History

The Davie landfill is located at 4401 S.W. 142<sup>nd</sup> Avenue, Davie, Florida (Broward County). The site operated as a landfill from 1964 to 1987. It is a 209 acre parcel of land. After closing, a portion of the site (approximately 160 acres or around 78% of the land) was converted to a regional park, known as Vista View Park which opened to the public on July 2003.

Table 7. Chronicle history of Davie Landfill (Completion report Davie Landfill, 2003).

<b>Event</b>	<b>Date</b>
Incinerator and trash landfill (south mound) operations commence	1964
Unlined sludge lagoon created and operations begin	November 1971
Shutdown of incinerator due to excessive particulate matter emissions	June 1975
Landfills at subject site officially close - no longer accepting waste	December 1987
Solid Waste Post-Closure Permit issued by FDEP	February 1995
Broward County regional park, Vista View Park opened to the public	July 12, 2003

#### 4.1.2 Location Specific Factors

##### 4.1.2.1 Weather

Weather conditions such as temperature and average rainfall are important because they affect the performance of the landfill and they increase leachate among other undesired problems.

Other weather related considerations include potential impacts due to tornadoes and hurricanes. Hurricanes cause soil erosion and this affects the performance of the landfill components. It increases the possibility of leachate, caps wearing off and saturation of layers. For examples, the 2005 hurricane season was the most destructive in recent history for Broward County (Hurricanes Wilma and Katrina ) and in 1964 Hurricane Cleo passes through the Atlantic Coast including Broward County.

#### **4.1.2.2 Ground water**

The hydrogeological units that are present in the vicinity of the Davie Landfill Site are the surficial or water table aquifer, which is the Biscayne Aquifer and the artesian aquifer known as the Floridian Aquifer. The Biscayne is an unconfined aquifer, which is approximately 100 feet thick at the site and, the only groundwater source of potable water in Broward County. The Biscayne Aquifer consists of two hydraulically connected units. The upper Biscayne Aquifer is approximately 50 feet thick and consists of a series of interbedded sandy limestone, limestone and sandstone. The lower Biscayne Aquifer consists of approximately 50 feet of sandstone that contains large solution holes, which are at least partially filled with sand. The hydraulic conductivity of the upper unit is estimated at 300 gallons per day per foot (gpd/ft). The hydraulic conductivity of the lower unit is estimated at 10,000 gpd/ft.

#### **4.1.2.3 Sensitive Receptors:**

Sensitive receptors are areas located around the site that could be affected by any failure of the system. Sensitive receptors include:

- Oakhill Equestrian Park.
- Robbins Park.
- North New River Canal.
- South New River Canal.
- Camp Seminole of the South Florida Council of the Boys Scouts of America is located north of the landfill.
- Imagination farms (dairy farms) lies along the western, southern and most of the eastern boundaries of the landfill.
- A single-family residential development Sunshine ranch is also in the vicinity.
- Golf courses
- Other receptors around the vicinity of the landfill include banks, supermarkets among others; however, these receptors won't be as affected as the ones mentioned above.

#### **4.1.3 Design Factors**

The landfill area is comprised of two mounds, the south mound (trash landfill) and north mound (sanitary landfill). The south mound is unlined and accepted incinerator ash, yard trash, construction and demolition debris, and other trash. The focus of this discussion involves only the north mound, which accepted unprocessed municipal solid waste.

#### **4.1.3.1 Liner System**

The north mound is made up of 14 cells. Cells 1-4 are located in the northwest portion of the north mound. Cells 5-13 are located immediately adjacent to the eastern face of cells 1-4 and progress to the easternmost boundary of the north mound. Cell 14 is the southernmost cell of the north mound and also overlays cells 1-13 up to the final elevation.

Cells 1-4 were lined with a sprayed asphaltic liner and do not have a leachate collection system. Cells 5-13 are lined with a paved asphalt liner with a leachate collection system. A secondary bentonite clay liner was installed at an elevation of 55-60 feet. Cell 14 was constructed with a 60 mil HDPE liner and leachate collection system

#### **4.1.3.2 Cap**

In general, both the sanitary and trash landfill cover system consists of a two-foot thick limerock cover, which is compacted, in six-inch layers with six inches of vegetative cover soil. A total of 31,969 tons of lime rock were used as landfill cover material, and approximately 21,000 tons of the total were used for Cell No. 14. Two lifts of material, 1-foot thick, were spread and compacted to an in-place density of at least 98%. The final cover was sloped at a 2% grade towards the southwest corner of the sanitary landfill slopes on the cover are relatively flat on the crown of the landfill cells, with slopes generally 1 to 3%, with some areas that do not readily drain due to settlement. There were no signs of erosion and the vegetation was in good condition. There were no obstructions present on the cover system that would impede sheet flow off the cover into the drainage system. There were no areas of slides or sloughs. Landfills have settled uniformly approximately five feet since 1987 and there are no permanent settlement monuments on either of the mounds.

#### **4.1.3.3 Ground water**

Based on water level measurements taken in September and November 1999, that were reviewed in the July -December 1999 Semi-Annual Ground Water Report, the potentiometric surface elevation of the underlying aquifer ranged from approximately 4 feet in the northwest portion of the landfill to approximately 2.3 feet in the southeast portion of the landfill. This indicates a southeasterly groundwater flow direction on contour maps from 1978 and 1993. This is also the flow direction reported in the ROD.

The regional groundwater gradient is reported to be about 0.4 feet per mile. The C-1 1 canal has a direct effect on the groundwater flow in the Davie Landfill Site. During mostly seasonal periods of high stage the canal becomes a recharge source for the aquifer and influences groundwater flow in a northerly direction. During periods of low flows the canal acts as a discharge area for groundwater and enhances the southerly flow direction of the site. Therefore, fluctuations in groundwater at Davie Landfill Site are directly related to precipitation and pumping events in the area.

#### 4.1.3.4 Leachate System

The leachate collection system from the sanitary landfill drains into a main sump, where it is pumped through a leachate force main to the City of Sunrise wastewater treatment plant. Leachate samples, collected from the main sump, are analyzed for a comprehensive suite of parameters.

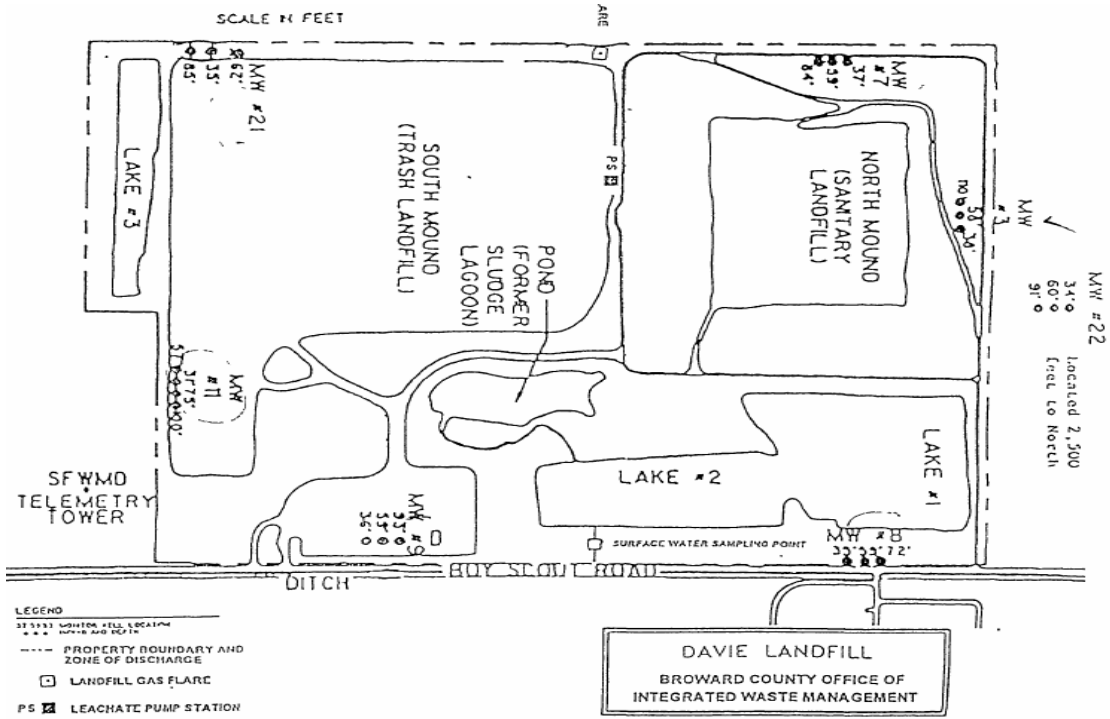


Figure 7. Leachate system. (Completion report Davie Landfill, 2003)

#### 4.1.3.5 Surface water

Davie Landfill Site is located between two drainage canals. The North New River Canal (L-36) is approximately three and a half miles to the north and the South New River Canal (C-11), which is approximately one-quarter mile to the south. To the east of the landfill is a north-south drainage ditch that drains into the C-11 Canal. This shallow ditch lies east of Boy Scout Road and to date has received no surface water runoff from landfill. All surface water runoff is channeled to one of the borrow lakes. Lakes 1, 2 and the pond are physically connected. The northern area of the site drains to lake numbers 1 and 2 and the southern area drains to lake number 3. There is a perimeter berm around the Davie Landfill Site that is designed to hold a 25-year, 72-hour storm event.

#### 4.1.4 Data analysis and landfill performance assessment

##### 4.1.4.1 Quantitative Data

##### Yearly Total Leachate

Leachate collection started in 1995. Leachate is measured by montly period. The yearly leachate collection data per years is shown in Figure 8.

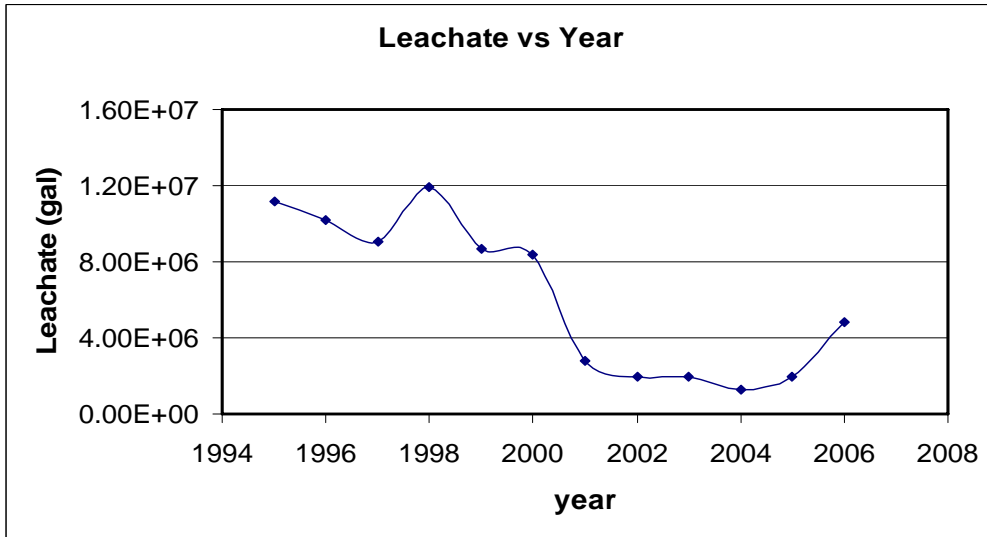


Figure 8. Yearly total leachate amount

##### Yearly Total Leachate vs. Rainfall

As shown in Figure 9, steady rainfall is slightly decreasing by the year.

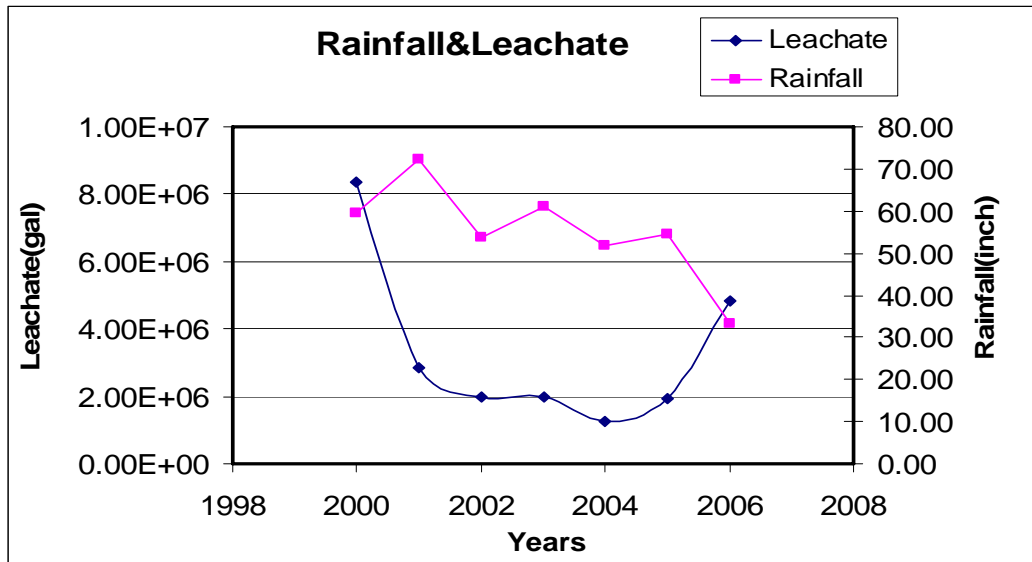


Figure 9. Yearly total leachate vs. rainfall.

## Monthly Total Leachate vs. Monthly Total Rainfall

When monthly leachate and rainfall data compared, it can be seen that there is some correlation based on the peaks. Leachate has periodic trends with some delay of the rainfall.

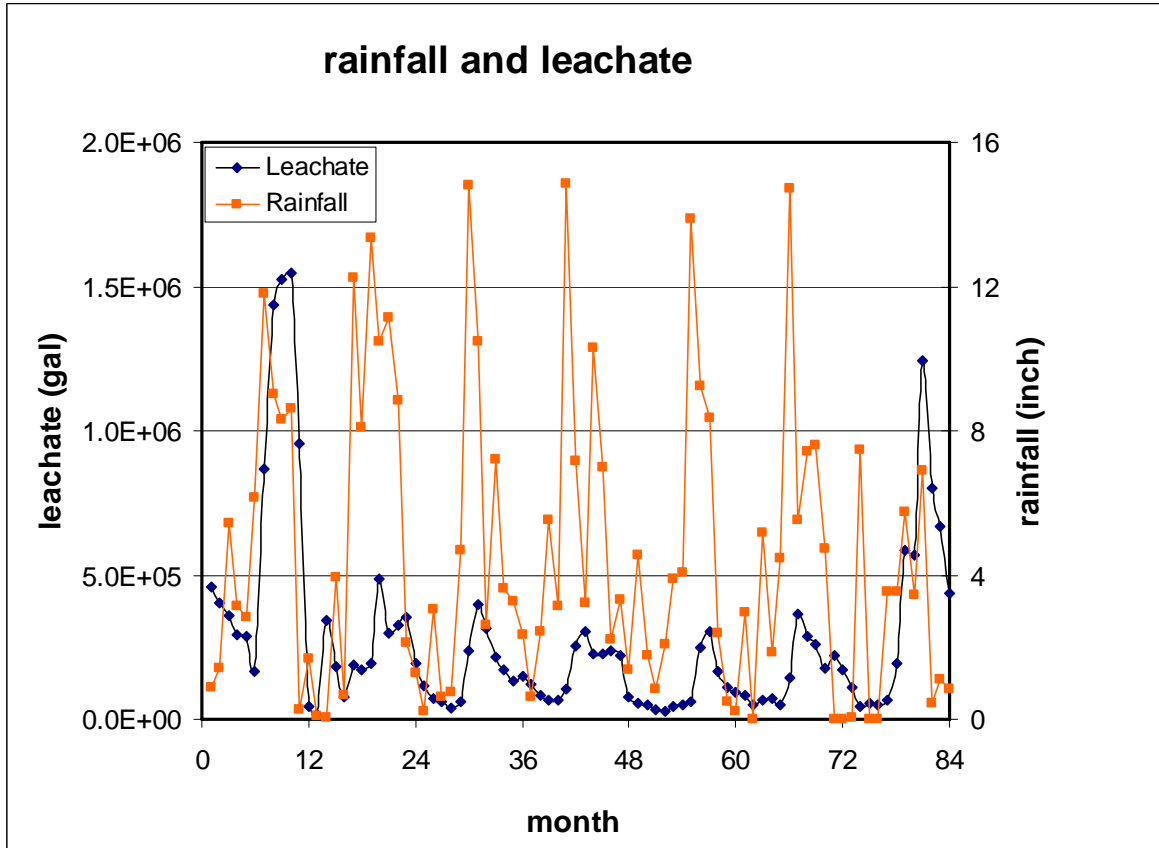


Figure 10. Monthly total leachate vs. monthly total rainfall.

## Average Rainfall vs. Average Leachate

Inspection of the recent data records showed an unusual trend with no documented explanations. Interviewing of the engineer responsible for Davie Landfill site revealed that the meter that was used for measuring the leachate quantity was broken and a new meter had been installed in 2006. Reassessment of the data by plotting the rainfall versus leachate quantity clearly showed that the new meter had a different calibration scale from the previous meter that was used. Figure 11. presents annual average data for rainfall versus leachate quantity. The annual averages calculated using the new meter show the difference in calibration of this meter with the one that used previously.

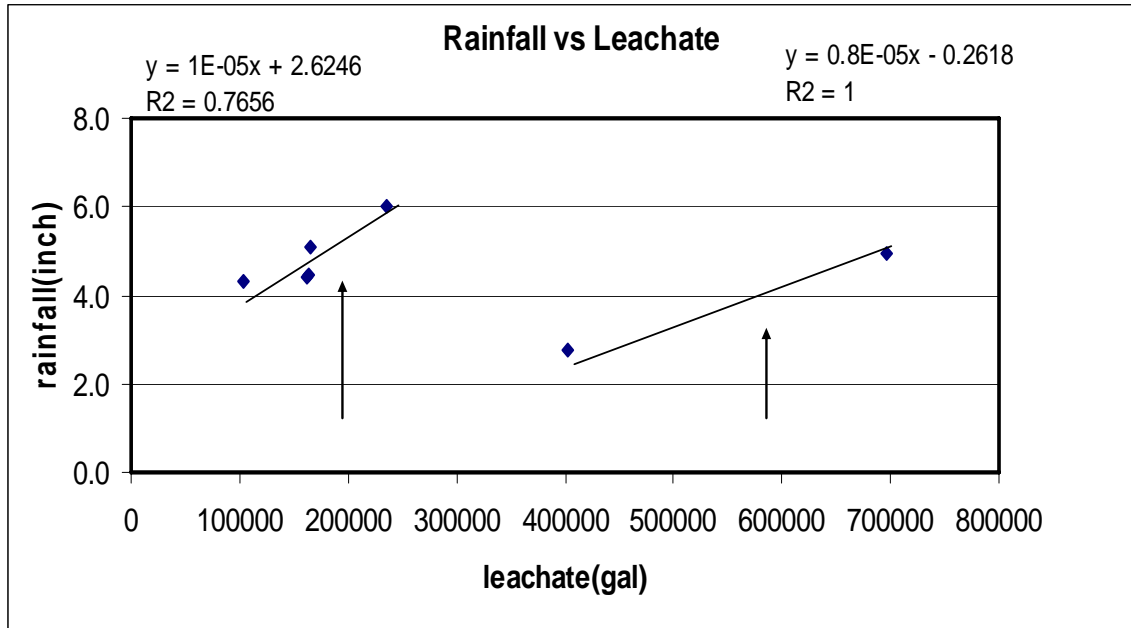


Figure 11. Average rainfall vs. average leachate.

### Yearly Average Gas Generation

The current landfill gas flow rate entering the enclosed flare is approximately 200 to 250 standard cubic feet per minute (scfm) with a methane concentration of approximately 40% to 50%. North mound only generates enough gas to operate the flare approximately 1 to 1.5 hours per day.

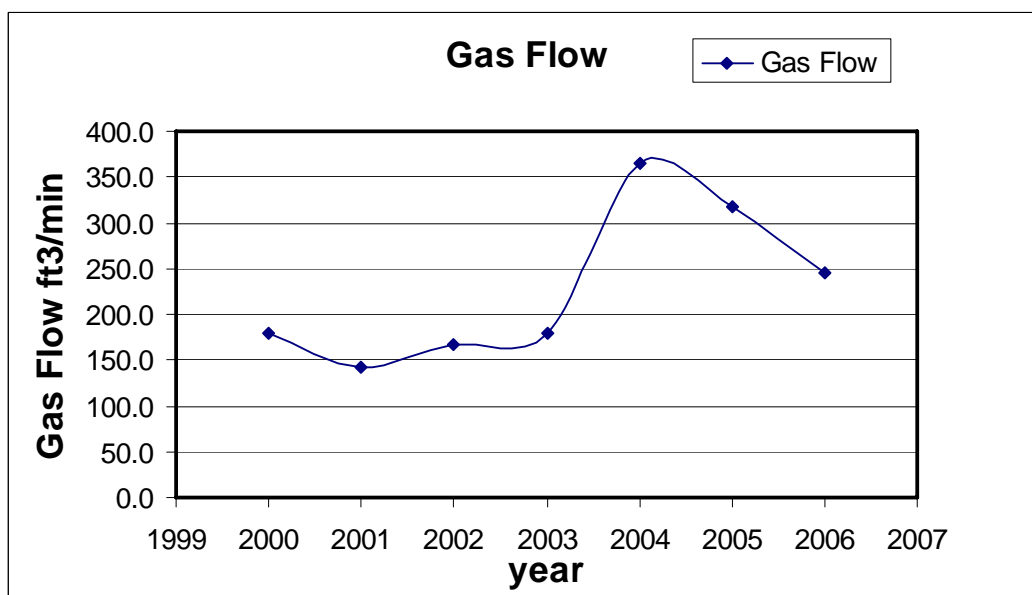


Figure 12. Yearly average gas generation.

### Average Leachate vs. Av. Gas Generation

During the analyses of gas and, leachate data, it was observed that leachate and gas production rates over the years showed significant changes in the quantities immediately after the land use practices of the closed landfill changed. The monitoring data should be evaluated in view of the extend land use and regrading activities that took place over the years. There was a significant increase in gas flow immediately after the landfill closed in 2003. As shown in Figure 13, a significant increase in gas production immediately after the landfill was capped in 2004.

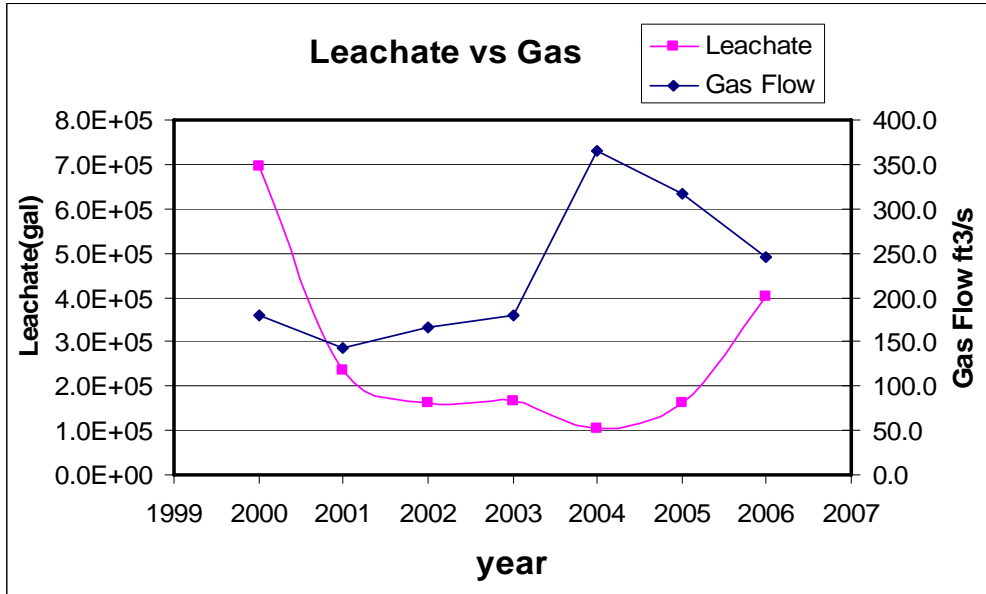


Figure 13. Average leachate vs. average gas generation

### Average Gas Generation vs. Average Rainfall

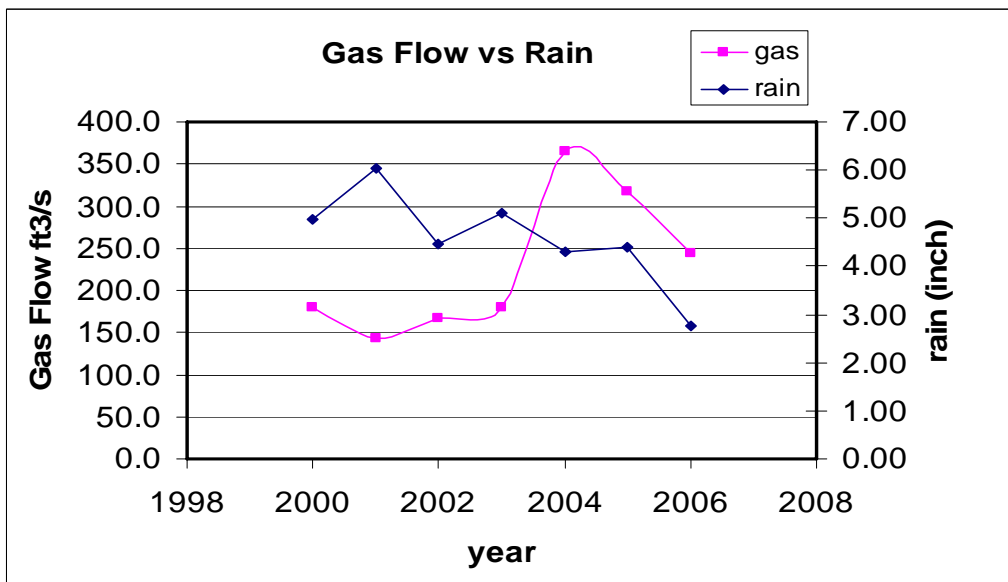


Figure 14. Average gas generation vs. average rainfall.

## **4.1.5 Post Closure Care**

### **4.1.5.1 Final Cover Construction**

Construction of the final cover for Cell No. 14 of the sanitary landfill began on July 25, 1989 and was completed on August 8, 1989.

### **4.1.5.2 Leachate collection and monitoring**

Leachate management system to prevent as much leachate as possible from reaching the groundwater and prevents any direct exposure to the leachate.

FDEP Post-closure monitoring permit requires that the leachate generated from the sanitary landfill be sampled semiannually (on April and October). The leachate collection system from the sanitary landfill drains into a main sump, where it is pumped through a leachate force main to the City of Sunrise wastewater treatment plant. The leachate samples, collected from the main sump, are analyzed for a comprehensive suite of parameters. The ROD does not require that the landfill leachate meet any specific cleanup criteria. Broward County keeps records of the leachate discharge volume and rainfall data on a monthly basis.

Currently at the site the leachate line is monitored at least twice per week for any unexplained pressure drops.

### **4.1.5.3 Gas collection and monitoring**

Landfill gas management system that actively collects gases produced by the landfill and eliminates them through an enclosed flare.

The sanitary landfill gas collection and control system maintenance activities consists of monthly inspection of 33 gas extraction wells and six trench well headers for damage to piping, fittings, hoses, clamps and valves on a monthly basis. Additionally, the enclosed flare is inspected and maintained on a monthly basis.

Surface methane monitoring is conducted on an annual basis. The sanitary landfill is inspected for evidence of stressed vegetation, cracks in the surface, and odors.

Monthly monitoring of gas pressure, gas composition, oxygen concentration and gas temperature at each gas extraction well/trench and flare are required to be recorded.

After 15 years of monitoring, the site is under intermittent gas monitoring schedule due to a limited amount of landfill gas being generated. FDEP approved this change.

#### **4.1.5.4 The cost for long term landfill**

The cost for long term care at the Davie Landfill is approximately \$300,000 per year. The site is comprised of 209 acres, which contains 116 acres (48-acre-north mound, 68-acre-south mound) of landfill space.

## **4.2 ALACHUA LANDFILL, ALACHUA COUNTY**

### **4.2.1 Introduction**

Evaluation of the Post Closure Care (PCC) duration for Southwest Landfill (SWLF), Alachua County, Florida is being conducted using performance based methodology, developed by Geosyntec Consultants. The methodology is comprised of following modules:

1. Leachate Module
2. Groundwater Module
3. Landfill Gas (LFG) Module and
4. Cap Module

The impact of each module component on the PCC duration of the SWLF is being analyzed. Currently, evaluation of the leachate module is almost complete. This report is a summary of leachate module analysis and its outcomes.

### **4.2.2 Leachate Module**

#### **4.2.2.1 Purpose**

The purpose of the leachate module is to evaluate leachate data from the Southwest Landfill (SWLF). SWLF is a Class I landfill, operated as a bioreactor. In 1988 waste acceptance began, while in the year 1999 it was closed. Since 1993, the landfill has been operated as a bioreactor, in collaboration with the University of Florida (UF).

The main objective of leachate module is to study variations in concentration of leachate contaminants and verify whether the current leachate management strategy can be optimized by reducing or discontinuing monitoring for some of the contaminants or whether leachate monitoring can be completely stopped.

Mostly, the contaminants considered for the study are Florida Department of Environmental Protection (FDEP) regulated parameters. Data collection is the first step in the leachate module. Detailed leachate monitoring data were obtained from 1993 up to 2006, courtesy of Jones & Edmunds, Associate who conducted monitoring at SWLF, and made it available for the above study. Changes in the contaminant concentration, before and after capping were studied and compared with Maximum Contaminant Levels (MCLs), to know their impact on human health and environment (HH&E). Along with current concentrations, future concentrations were also predicted from the statistical

model and compared with MCL set by FDEP. Mass of contaminants were also evaluated statistically.

On the whole, specific tasks of the leachate module are:

1. Review of historic leachate monitoring, data collection
2. Analyze the variation of contaminant concentration with time and compare with MCLs.
3. Estimate the statistical trend for the contaminant(s), if possible.
4. Analyze the trend and make suggestions regarding future concentrations and monitoring.
5. Discuss the impact of leachate monitoring on PCC, by suggesting whether monitoring for a given contaminant is necessary or can be stopped as it is not harmful to HH&E.

#### 4.2.2.2 Methodology

As mentioned earlier, for this task, leachate monitoring data from 1993 to 2006 are available. SWLF leachate is monitored about 200 contaminants. Most of the contaminants (175) are always below laboratory detection limit. Thus analysis is limited up to 25 parameters including BOD, COD and leachate flow.

Performance based methodology has categorized overall parameters into two types.

- a. **Decision parameters:** BOD, COD, Leachate flow and BOD mass (BOD concentration x Leachate Flow) are decision parameters. Before starting analysis of regulated parameters, a decreasing trend in any one of the decision parameters needs to be confirmed. BOD and COD are historically used in studies conducted on leachate concentrations over time (Gibbons et al., 2007). Statistically significant values are obtained for BOD concentration and mass (vs. time) ( $p < 0.05$ ). These values confirm the decreasing trend for decision parameters. Statistical software Minitab15 is used for statistical analysis and trend estimation purposes. Please see Appendix I for BOD mass (Figure 1) and BOD concentration (Figure 2) variations with time. Along with BOD concentrations and mass loadings, BOD: COD ratio was also analyzed (Figure 3, Appendix I) as it is a very helpful parameter, commonly used as an indicator of leachate maturity. It is seen that BOD to COD ratio has decreased below 0.1. This is an indication that leachate is approaching stable quality and implies that further biological decomposition of leachate will be very slow. On the other hand, the COD concentrations is fairly stable at 1500-2000 mg/L. Humic and fulvic acid concentrations building in the leachate can be one of the reasons behind this trend (Bataresh 2006). Total organic content (TOC) can also be analyzed along with COD, but TOC data were not analyzed because it is not monitored regularly.
- b. **Regulated parameters:** Once a decreasing trend in the decision parameters is confirmed, regulated parameters can be analyzed. These are FDEP regulated

contaminants, which are required to be monitored during a PCC duration of 30 years.

The following discusses target contaminants above laboratory detection limit which were analyzed in detail. For simplicity they are categorized in Table 8 .

Table 8. Categorized detect contaminants from SWFL leachate

<b>Contaminant</b>	<b>Monitoring Span</b>	<b>Total Monitoring Events</b>	<b>Detects</b>	<b>ND</b>	<b>% ND</b>	<b>MCL</b>	<b>Unit</b>
<b>METALS</b>							
<b>Antimony</b>	1993-2006	22	11	11	50.00	6	ug/L
<b>Arsenic</b>	1993-2006	29	27	2	6.90	50	ug/L
<b>Chromium</b>	1996 - 2006	27	23	4	14.81	100	ug/L
<b>Cobalt</b>	1996-2006	20	7	13	65.00	NA	ug/L
<b>Iron</b>	1993-2006	29	29	0	0.00	300	ug/L
<b>Nickel</b>	1993-2006	22	22	0	100.00	100	ug/L
<b>Sodium</b>	1993-2006	29	19	0	0.00	160	mg/L
<b>Vanadium</b>	1996-2006	20	19	1	5.00	NA	ug/L
<b>INORGANIC INDICATORS</b>							
<b>Chloride</b>	1993-2006	27	0	0.00	200	mg/L	
<b>Conductivity</b>	1993-2006	21	0	21	0.00	NA	-
<b>Dissolved Oxygen</b>	1993-2006	21	21	0	0.00	NA	mg/L
<b>Fluorene</b>		14	2	12	85.71	500 (H)	ug/L
<b>Sulfide</b>		12	5	7	58.33	NA	ug/L
<b>ORGANIC VOLATILE</b>							
<b>Acetone</b>	1996-2006	20	12	8	40.00	NA	-
<b>C-1,2 Dichloroethene</b>	1998-2005	15	7	8	53.33	NA	-
<b>Ethyl Benzene</b>	1993-2006	29	22	7	24.14	700	ug/L
<b>Napthalene</b>	1993-2006	14	10	4	28.57	100 (H)	ug/L
<b>Styrene</b>	1996-2006	20	7	13	65.00	100	ug/L
<b>Toluene</b>	1993-2006	29	25	4	13.79	1000	ug/L
<b>TDS</b>	1998-2006	29	29	0	0.00	500	mg/L
<b>Total Phenolics</b>	1993 - 1995	2	2	0	0.00	NA	ug/L
<b>Total Xylene</b>	1993-2004	27	27	0	0.00	10000	ug/L

### 4.2.3 Statistical Analysis and Recommendations

Contaminant concentrations in the leachate, monitoring date, waste age, and MCL concentrations are required for statistical analysis of regulated target parameters. In most cases, it is observed that data follow a normal or lognormal distribution. And hence linear or exponential trends are applicable to most of the target parameters respectively.

Before trend application, scatter plots of data, which gives an idea of scatter of concentration data over time, were analyzed and compared before and after the capping year with MCL concentrations. This task was followed by a normality/log-normality test, outlier check and trend estimation. Varying trends were observed with different types of contaminants.

For example, xylenes show a decreasing trend throughout the period of monitoring and are always below MCL (10,000 µg/L). In years 2005 and 2006, leachate production increased drastically, but xylene concentrations were still reducing. This continuous reducing trend and the fact that concentrations were below MCL, lead us to make a recommendation to discontinue monitoring for xylenes. Discontinued monitoring has to be preceded by reduced monitoring frequency, to check whether or not the contaminant is following earlier observed trends.

Another very common response observed is a decrease in concentrations after capping, especially in case of metals. Arsenic, chromium, cobalt and iron are showing decreased concentrations after capping but are dependant on leachate flow. And hence for metals, mass is also plotted against the age of the landfill. Years 2005 and 2006 showed increased mass of metal due to increased leachate production. And hence for metals continued monitoring is suggested along with leachate flow considerations. However, copper can be released from monitoring, as it is always below MCL.

Another important category is inorganic indicators, ammonia-N, chlorides, TDS are in this category. In the case of ammonia-N it is seen that concentration has reduced after capping, but concentrations are fairly constant after capping. As pH of leachate is always below 8, it can be said that ammonium nitrogen species can be in the form of ammonium ion, which may inhibit the degradation process, but it not as toxic as dissolved unionized ammonia, predominant at higher pH (pH level above 10) (Berge et. al, 2007). Continued monitoring for ammonia-N is recommended. Similarly, continued monitoring for chlorides is also recommended, as they are varying with the leachate production rate in the landfill and are present in concentrations above MCL.

### 4.2.4 Summary of Results

In the case of detection parameters, BOD and BOD mass show a reducing trend. BOD: COD ratio reaching below 0.1, indicating a biologically stable leachate. On the other hand, COD concentrations are fairly constant at a range of 1500-2000 mg/L. Around 90% of the regulated contaminants are below the laboratory detection limits throughout the monitoring events (1993-2006). The nondetects suggest that monitoring frequency for these

parameters can be reduced followed by discontinued monitoring if the same trend continues. Therefore, only 25 target parameters including detection parameters will need to be monitored. Organic contaminants behavior can be categorized into three groups, (1) most of the organic contaminants (e.g. xylene, toluene) follow a statistically significant decreasing trend and are below MCL, (2) have always been below MCL (e.g. styrene or naphthalene), or (3) are declining and approaching MCL values like acetone. It is only inorganic parameters (metals and non-metals), whose behavior needs to be monitored in the future. In the case of metals, copper is always BDL, which indicates that monitoring can be done less frequently, while arsenic, chromium, and iron show variations in mass and concentrations following leachate generation rate patterns, hence continued monitoring is suggested for them. Jones, Edmunds & Associates has kindly agreed to provide the contaminant concentrations from recent monitoring events, which are not included in this analysis. The data from recent monitoring events will be helpful in checking the estimated values for various trends from the past data of leachate modules.

# APPENDIX

## Trends for Decision Parameters for Alachua Landfill

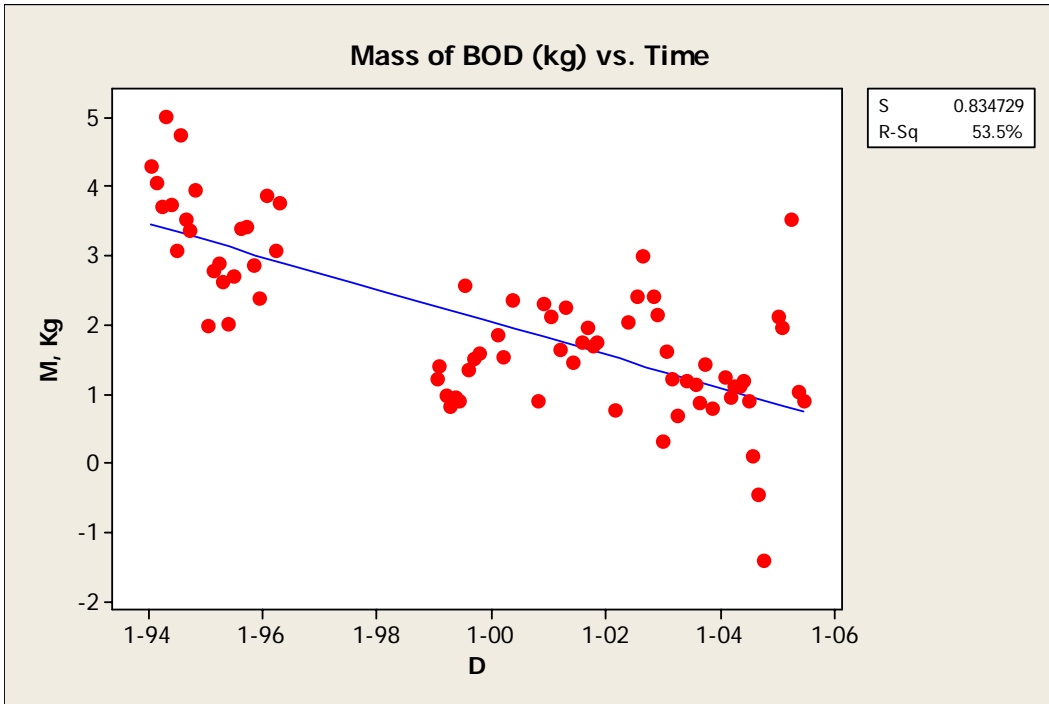


Figure 1. Trend for BOD Mass (Kg)

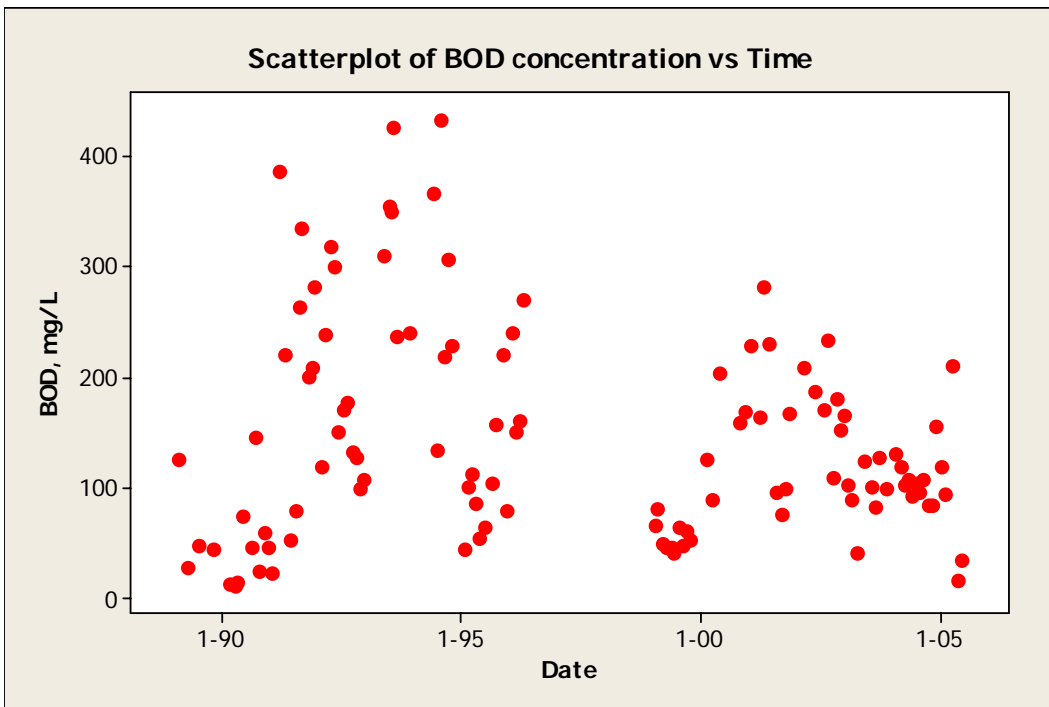


Figure 2. Trend for BOD Concentration (mg/L)

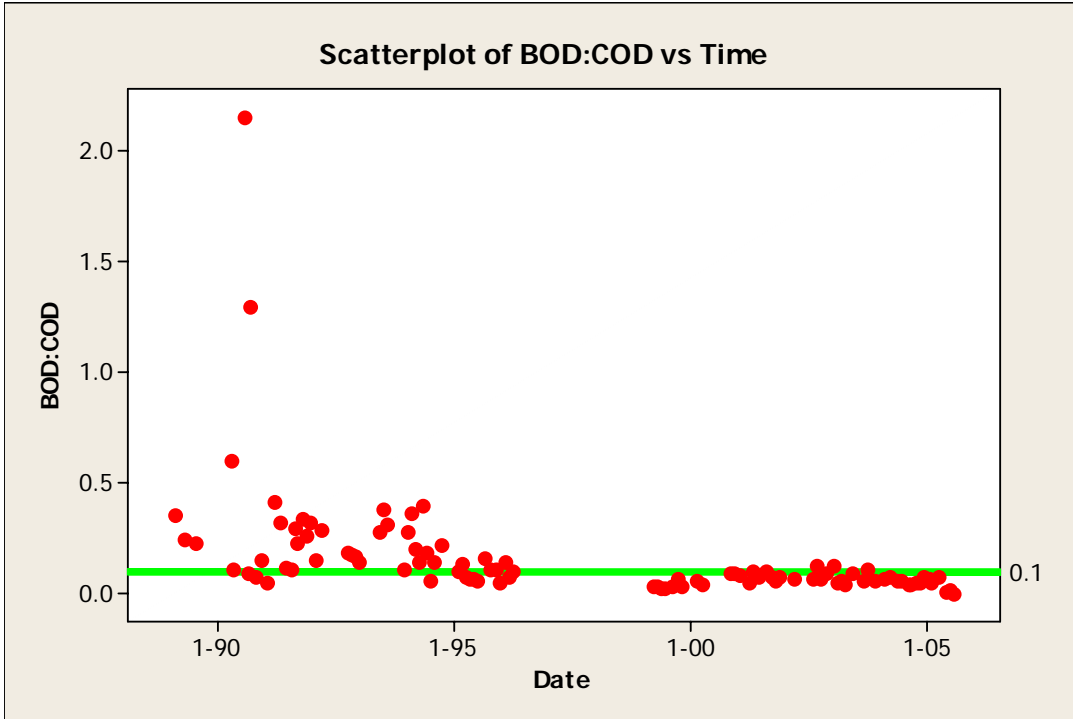


Figure 3. BOD: COD ratio vs. time

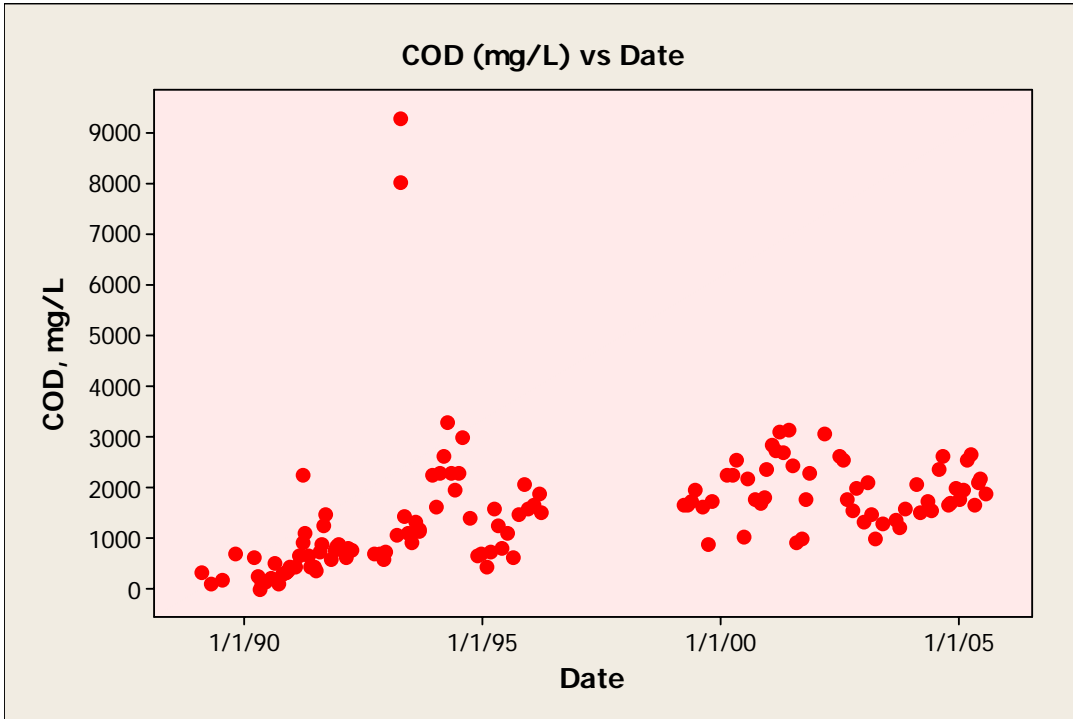


Figure 4. COD vs. Time

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