

**CENTRAL OKANAGAN REGIONAL  
DISTRICT  
WESTSIDE LANDFILL OPERATIONS  
AND CLOSURE PLAN**

1993

Prepared by:

**REID CROWTHER & PARTNERS LTD.**  
201, 3275 Lakeshore Road  
Kelowna, BC  
V1W 3S9

Telephone: 762-3727

Facsimile: 762-7789

July 1993

File: 39439  
3-005CGL



Reid  
Crowther

Please refer to file 39439-4(b)  
1-010CGL

September 1, 1993

Regional District of Central Okanagan  
540 Groves Avenue  
Kelowna, B.C. V1Y 4Y7

Attention: Mr. H. Hettinga, P. Eng.

Dear Sir:

RE: Westside Landfill Operations and Closure Plan

Attached are three copies of the above-noted report in final form. This volume is a compilation of the preceding interim reports. In addition, the drawings are included on the enclosed diskettes.

Also enclosed, are Terms of Reference for the Phase 2 Hydrogeological Study. Reid Crowther can perform the administrative and management aspects of the assignment including tendering, evaluation, liaison, and coordination. We are also in a position to assist in the coordination. We are also in a position to assist in the leachate aspects of the additional work. We estimate that we can perform these duties for a fee of approximately \$4,000 to \$5,000, which we outline as follows:

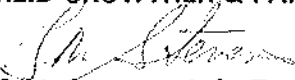
- |   |               |
|---|---------------|
| ▪ Tendering Services  | \$ 500        |
| ▪ Co-ordination and Project Management                        | 1,000         |
| ▪ On-site Services<br>(overviews and leachate-related issues) | 1,500 - 2,500 |
| ▪ Reports (tie-in into previous reports)                      | 1,000         |

If you find this arrangement acceptable, and you have approved the Terms of Reference, we would like to meet with you to formalize the arrangements. A draft copy of the Terms of Reference has also been sent to the Ministry of Environment for their comments.

We've enjoyed working on this assignment and look forward to serving you again in the future. We wish to thank the staff of the Regional District, in particular Mr. Charlie Cameron, and the employees at the landfill for their assistance during the project. As always, if you have any questions, please do not hesitate to call.

Yours very truly,

**REID CROWTHER & PARTNERS LTD.**

  
G.M. Stevens, A.Sc.T.  
Environmental Engineering Division  
CGL:lt

Reid Crowther & Partners Ltd.

Consulting Engineers

201 - 3275 Lakeshore Road, Kelowna, British Columbia V1W 3S9, Phone: (604) 762-3727, Fax: (604) 762-7789



# WESTSIDE LANDFILL OPERATIONS AND CLOSURE PLAN

## TABLE OF CONTENTS

<b>SECTION 1.0</b>	<b>INTRODUCTION</b>	
	General	1 - 1
	Background	1 - 1
	Assignment	1 - 1
	Methodology	1 - 2
<b>SECTION 2.0</b>	<b>WASTE CHARACTERIZATION AND QUANTIFICATION</b>	
	Introduction	2 - 1
	Waste Characteristics	2 - 1
	Waste Quantification	2 - 3
	Summary	2 - 6
<b>SECTION 3.0</b>	<b>PRESENT OPERATIONS</b>	
	Site	3 - 1
	Operations	3 - 1
	Site Capacity	3 - 3
<b>SECTION 4.0</b>	<b>REDUCTION STRATEGIES</b>	
	Recycling	4 - 1
	Composting	4 - 2
	Compaction	4 - 4
<b>SECTION 5.0</b>	<b>PROJECTIONS AND LANDFILL OPERATIONS</b>	
	Introduction	5 - 1
	Waste Segregation	5 - 1
	Acceptable Wastes	5 - 2
	Waste Reductions	5 - 2
	Contract	5 - 5
	Operations	5 - 5
	Operation Stages	5 - 8
	Drainage	5 - 10
	End Use	5 - 12
<b>SECTION 6.0</b>	<b>LANDFILL LEACHATE</b>	
	Introduction	6 - 1
	Treatment Implications	6 - 2
	Leachate Generation	6 - 3
	Collection and Treatment Options	6 - 6
<b>SECTION 7.0</b>	<b>LANDFILL GAS</b>	
	Introduction	7 - 1
	Estimation of Quantity	7 - 2
	Testing Landfill Gas	7 - 3
	Control	7 - 4



# WESTSIDE LANDFILL OPERATIONS AND CLOSURE PLAN

## TABLE OF CONTENTS cont'd

<b>SECTION 8.0</b>	<b>DETAILED DESIGN</b>	
	Equipment	8 - 1
	Staff	8 - 3
	Filling Procedure	8 - 4
	Daily Cover	8 - 5
	Final Cover	8 - 5
	Access Road	8 - 5
	Internal Transfer	8 - 7
	Environmental Concerns	8 - 8
<b>SECTION 9.0</b>	<b>OPERATIONS PLAN</b>	
	Introduction	9 - 1
	Waste Cell Construction	9 - 1
	Fill Progression	9 - 2
	Daily and Intermediate Cover	9 - 2
	Final Cover	9 - 3
	Prohibited Wastes	9 - 3
	On-Site Transfer Station	9 - 5
	Waste Segregation	9 - 6
	Safety	9 - 6
	Landfill Gas Monitoring	9 - 6
	Groundwater Monitoring	9 - 7
	Control Strategies	9 - 7
	Staff	9 - 11
	Inspections	9 - 12
	Records	9 - 13
	Annual Report	9 - 14
<b>SECTION 10.0</b>	<b>CONTINGENCY PLAN</b>	
	Introduction	10 - 1
	Unauthorized Waste Dumping	10 - 1
	Accidents	10 - 2
	Leachate Migration	10 - 2
<b>SECTION 11.0</b>	<b>CLOSURE PLAN</b>	
	Introduction	11 - 1
	End Use	11 - 1
	Climate	11 - 2
	Landfill Geometry	11 - 2
	Remaining Capacity of Landfill	11 - 2
	Final Cover	11 - 2
	Cap Construction	11 - 3
	Irrigation	11 - 6
	Landfill Closure Implementation	11 - 7
	Post-Closure Program	10 - 7



# WESTSIDE LANDFILL OPERATIONS AND CLOSURE PLAN

## TABLE OF CONTENTS cont'd

<b>APPENDIX A</b>	Permit
<b>APPENDIX B</b>	Capacity/Lifespan Estimate Tables
<b>APPENDIX C</b>	Client List
<b>APPENDIX D</b>	Operations Contract
<b>APPENDIX E</b>	Drainage Map
<b>APPENDIX F</b>	Soil And Groundwater Conditions
<b>APPENDIX G</b>	In-situ Density Tests
<b>APPENDIX H</b>	Equipment Hourly Cost Estimate
<b>APPENDIX I</b>	Leachate Analysis
<b>APPENDIX J</b>	Stage 2 Hydrogeological Proposal
<b>APPENDIX K</b>	Gas Monitoring Report
<b>APPENDIX L</b>	Proposed Fill Progression From 545m
<b>APPENDIX M</b>	Management of Specific Special Wastes

### TABLES

2-1	Waste Composition in British Columbia	2 - 2
2-2	Waste Density Estimates	2 - 3
2-3	Westside Landfill Waste Quantity	2 - 4
2-4	Glenmore Landfill Waste Quantity	2 - 5
2-5	Base 1992 Parameters	2 - 6
5-1	Recyclable Materials	5 - 3
5-2	Estimated Divertible Quantities	5 - 4
5-3	Landfill Operations Stages	5 - 10
5-4	Landfill Life Expectancy	5 - 10
6-1	Typical Composition of Landfill Leachate	6 - 1
7-1	Major Components of Landfill Gas	7 - 2
7-2	Trace Components of Landfill Gas	7 - 2
8-1	Equipment Owning and Operating Costs	8 - 3
8-2	Leachate Analysis	8 - 9

### FIGURES

		Follows Page
1.1	Westside Landfill Service Area	1 - 2
3.1	Proposed Final Contours	3 - 3
5.1	Proposed Cell Configuration	5 - 12
5.2	Surface Settlement	5 - 12
5.3	Stage 1 Proposed Contours	5 - 12
5.4	Stage 1 Fill Sequence	5 - 12
5.5	Stage 2 Road Alignment Options	5 - 12
5.6	Ditch Cross Sections	5 - 12
7.1	Typical Gas Monitoring Well	7 - 5
7.2	Vents	7 - 5
7.3	Typical Well Type Gas Burner	7 - 5
8.1	Proposed Road Alignments	8 - 11
8.2	Typical Leachate Collection Trench	8 - 11
8.3	Gas Collection System Conceptual Plan	8 - 11



**SECTION 1.0**  
**INTRODUCTION**



## **SECTION 1.0 INTRODUCTION**

### **1.1 GENERAL**

Reid Crowther & Partners Ltd. was retained by the Central Okanagan Regional District (CORD) to prepare an Operations and Closure Plan for the Westside Landfill. This Report is the assimilation of the four previous draft reports.

### **1.2 BACKGROUND**

The Westside Landfill has been operated by the CORD since the late 1960's. It is located approximately 2.5 km north of downtown Westbank at the junction of Shannon Lake Road and Asquith Road. The site serves the Electoral Areas 'G' and 'H', which include Westbank and Lakeview Heights, (Figure 1.1) a total estimated population of 17,000. It operates under Permit number PR-2102, issued in November 1973 and amended in September 1976 (included as Appendix A). The day-to-day operation is undertaken by a private operator under contract to the Regional District. The current contractor is Serwa Bulldozing of Kelowna, whose agreement expires in early 1993.

### **1.3 ASSIGNMENT**

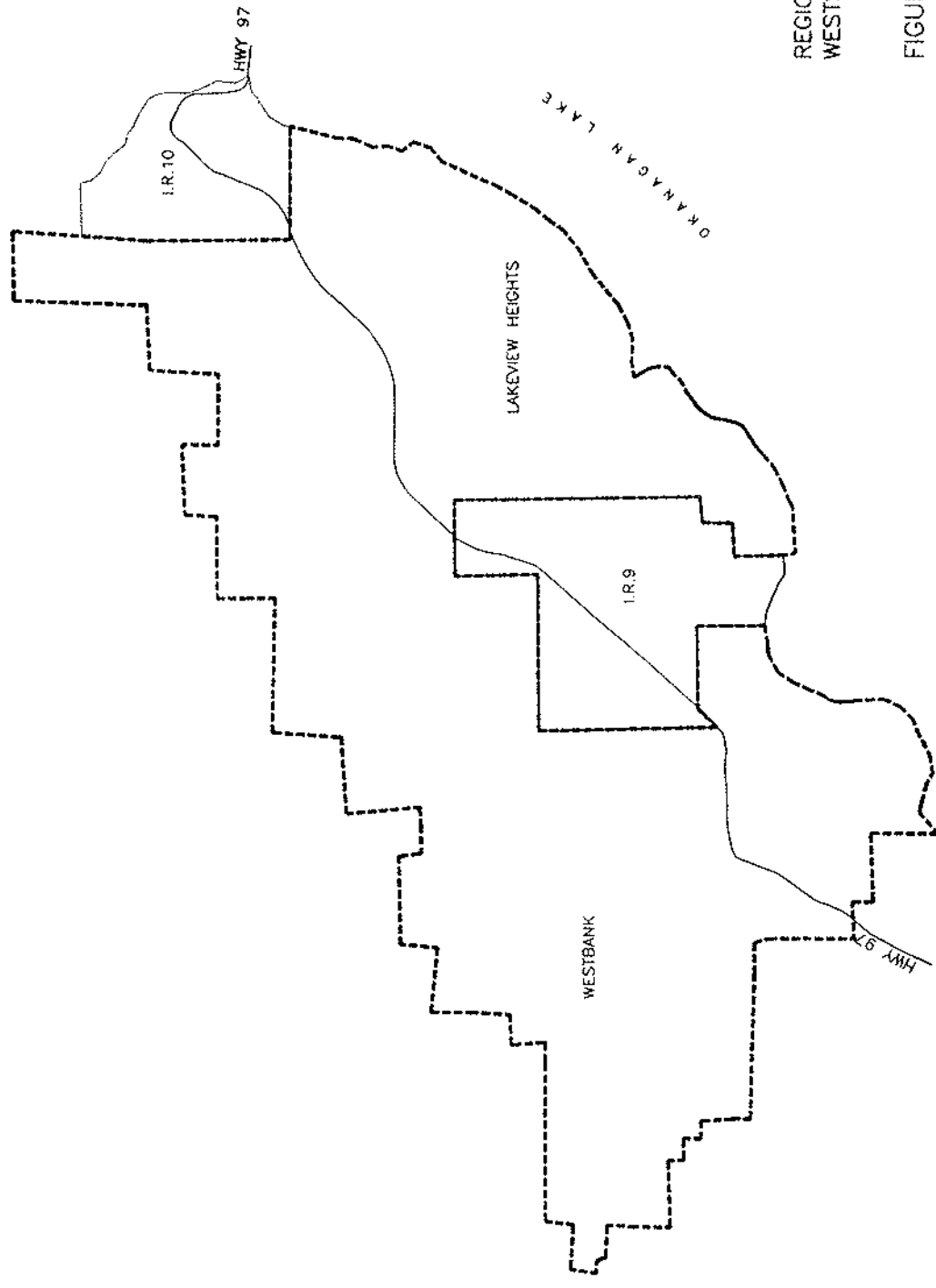
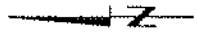
The principal objectives of the assignment are to:

- make projections on future demands on the landfill;
- study the present infrastructure and operations;
- recommend improvements to the site operations if necessary;
- investigate and mitigate environmental impacts; and
- produce operating, closure, and end use plans.

## 1.4 METHODOLOGY

To meet the project's objectives, the study has been divided into five stages as follows:

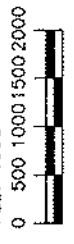
- Stage 1 - Investigation and Research. A wide variety of data has to be collected, collated, and distilled into a format appropriate for use in the planning phase of the project. This information includes documents pertinent to landfilling in the region such as the CORD's Solid Waste Management Plan and the Glenmore Landfill Operations Plan, existing and proposed landfill topographical mapping, the Official Community Plan, operations contracts, permits, waste characteristics and quantities, and population projections. Included in this stage are interviews with CORD, Ministry of Environment, and operations personnel staff.
- Stage 2 - Predesign. The Predesign phase will evaluate the existing landfill infrastructure and operations to identify shortcomings. Preliminary geotechnical work will form the basis for detailed investigations in later stages. Estimates of gas and leachate production will allow management options to be developed.
- Stage 3 - Design. Plans for proposed improvements will be made where appropriate, including surface water diversion, leachate and gas management, access roads, and equipment improvements. Final geometry of the landfill will be established, along with a program to monitor and mitigate environmental impacts of leachate, gas, odours, and the like. Cost estimates for all aspects of the operation will be prepared.
- Stage 4 - Operations Plan. All the procedures necessary to achieve the goals set in the previous stages will be laid out in an Operations Plan, which will optimize the remaining capacity of the site.
- Stage 5 - Closure Plan. This stage will undertake the design of an adequate cap to prevent infiltration. A step-by-step manual similar to the Operations Plan will provide details of the closure procedures. Finally, an End Use Plan will briefly assess potential uses of the site once all landfilling operations have ceased.



REGIONAL DISTRICT OF CENTRAL OKANAGAN  
WESTSIDE LANDFILL SERVICE AREA

FIGURE 1.1

FEB. 1993





**SECTION 2.0**  
**WASTE CHARACTERIZATION AND QUANTIFICATION**



## SECTION 2.0 WASTE CHARACTERIZATION AND QUANTIFICATION

### 2.1 INTRODUCTION

In order to plan for the future operations at the landfill and determine its remaining life, an estimate of the quantity of waste deposited each year needs to be made. Population, weight records, historical data, and waste composition analyses have been used to determine a base value from which to estimate future demand.

### 2.2 WASTE CHARACTERISTICS

#### 2.2.1 Waste Composition

Knowledge of waste composition allows development of strategies to reduce, recycle, recover and manage waste. For example, knowing the quantity of glass bottles in the waste stream would give some indication of the feasibility and effectiveness of a deposit/return system.

In 1990 during the development of a British Columbia Ministry of Environment-commissioned manual for conducting waste composition surveys, four British Columbia communities were studied. The results of those studies is shown in Column A in Table 2 - 1.

The exact values of waste composition at the Westside Landfill cannot be easily determined, nor is it necessary to do so. Composition varies with the day of the week, the time of the year, and the area of collection. Determining the exact composition on one truck, or on one day, is of limited value since it is unreasonable to expect all trucks or all days will be the same. It is therefore proposed to use typical values found in other sources.

Table 2 - 1 illustrates that variability from site to site, but it also shows that the ranges of each component are roughly within a certain range (paper 30% to 40%, organics 25% to 35%).

One difference that stands out is the percentage of construction and demolition waste present in the Kelowna stream. This value is on the order of twice the

amount found in other areas, and can be attributed to the development boom that has been occurring in the Okanagan.

**TABLE 2 - 1**  
**WASTE COMPOSITION IN BRITISH COLUMBIA**

Category	Waste Composition (%)		
	A	B	C
Paper	31.8	36.2	35.0
Glass	5.4	4.2	6.0
Metal	5.5	5.2	6.0
Plastic	7.1	8.2	6.0
Leather	0.3		
Rubber	1.5		
Organic	32.4	24.9	25.0
Textiles	2.3	1.7	
Brown Goods	0.9		
Bulky Goods	1.3	2.4	
Construction/Demolition	4.5	7.6	15.0
Residue	3.9		
Household Hazardous	2.0	0.2	
White Goods	0.9		
Other	0.1	9.4	7.0
<b>TOTAL</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

A) Average from Maple Ridge, Kamloops, Castlegar, Slokan Valley (Gartner Lee, 1991)

B) Estimated Residential and Industrial-Commercial-Institutional waste for B.C. (Proctor & Redfern, 1992)

C) Suggested values for Kelowna from CORD Solid Waste Management Plan (UMA/Gartner Lee/Recycling Development Corp, 1990)

The Solid Waste Management Plan suggested the numbers in Column C be used for planning purposes in the Central Okanagan. As they appear to be close to those found elsewhere, they will be used throughout this document.

### 2.2.2 Waste Density

The overall density of the waste is needed to estimate the approximate volume of the waste in the landfill. The 1991 Gartner Lee report gives estimates of the densities each component of the stream as it was received (uncompacted) at the disposal sites they surveyed. Table 2 - 2 presents those estimates.

**TABLE 2 - 2**  
**WASTE DENSITY ESTIMATES**

Category	Average Density (kg/m <sup>3</sup> )
Paper	122
Glass	308
Metal	115
Plastic	54
Organic	484
Construction/Demolition <sup>a</sup>	300

a) RCPL estimate.

Factoring these component densities into the overall composition in Column C of Table 2 - 1, and assuming the "Other" category of 7% is comprised of scrap metal and white goods that are placed separately from the other 93%, the overall density of the waste as deposited at the working face (excluding cover material) is estimated to be approximately 250 kg/m<sup>3</sup>.

Compaction of the waste should be practiced. This decreases the overall volume landfilled, and thereby increases the mass capacity of the landfill. Compacting the waste also increases stability. The degree of compaction depends on the method used. Compaction at the Westside Landfill is performed by driving a bulldozer over the working area.

## **2.3 WASTE QUANTIFICATION**

### **2.3.1 Population Projections**

The Westside Sanitary Landfill serves the communities of Westbank and Lakeview Heights, which comprise Electoral Areas 'G' and 'H' of the Central Okanagan Regional District (CORD). As with the Okanagan Valley in general, these areas are experiencing rapid growth. Increased migration has led to a development boom. The rate of population growth is the major factor affecting the operational life of the landfill.

From the CORD Solid Waste Management Plan, the 1992 population of Areas 'G' and 'H' was approximately 17,000. The annual growth rate of the Electoral Areas was assumed to be 2.75%. To cover the possibility of higher or lower growth in

forecasting future waste generation, a range of growth rates have been chosen: 2.0%, 2.75%, and 4.0% per year.

### 2.3.2 Historical Data

Reports are available from the province of British Columbia and other areas which present typical solid waste generation rates. These rates typically range from 500 to 900 kgs per person per annum. A study undertaken at the Glenmore Landfill in Kelowna determined a generation rate of 1,200 kgs per person per annum. This value is rather high, and has been attributed to the development boom and the resultant increase in demolition waste.

### 2.3.3 Waste Mass

A scale was installed at the gate of the landfill in January of 1992. From January 30 to October 30, 1992, approximately 12,850 tonnes of waste were disposed of at the site (Table 2 - 3).

**TABLE 2 - 3**  
**WESTSIDE LANDFILL WASTE QUANTITY**

Type of Waste	Total Weight (tonnes)
Residential (private vehicles)	3 500
Commercial <sup>a</sup>	9 300
Park Waste	50
<b>TOTAL</b>	<b>12 850</b>

a) Includes contractor pick-ups of residential waste

From the Glenmore Landfill Operations Plan, monthly weights received at that landfill were given (see Table 2 - 4). The period of February to October accounted for approximately 78% of the total for the twelve month period. Assuming the Westside Landfill to follow the same pattern, and applying this factor to the nine months of Westside data, it is estimated that 16,500 tonnes of solid waste entered the landfill in 1992.

### 2.3.4 Waste Volume

Using the density estimate from Section 2.1.2 of 250 kg/m<sup>3</sup> and a total mass of 16,500 tonnes, the volume of waste as received at the site in 1992 is estimated at

66,000m<sup>3</sup>. Cover material, as estimated by the operation staff, contributed an additional 12,000m<sup>3</sup> (uncompacted).

### 2.3.5 Generation Rate

Given the estimated 1992 population of 17,000, the waste generation rate in 1992 is approximately 970 kg per person per annum. This value will be used as the base 1992 generation rate.

The Ministry of Environment has set goals of 30% solid waste reduction by 1995, and a 50% reduction by 2000. In Stage 1, tables and graphs were presented for each population curve (see Section 5.0, Stage 1).

More detailed examination in Stage 2 led to a revision of both the ultimate capacity of the site and the cover to waste ratio. New projections are made in Section 5.0 based on the tables in Appendix B.

**TABLE 2 - 4**  
**GLENMORE LANDFILL WASTE QUANTITY**

Month	Weight (tonnes)	Percent of Total
Jan	7,096	7.26
Feb	7,101	7.26
Mar	8,579	8.78
Apr	8,558	8.75
May	10,538	10.78
Jun	9,130	9.34
Jul	7,976	8.16
Aug	9,368	9.58
Sep	7,578	7.75
Oct	7,897	8.08
Nov	7,729	7.91
Dec	6,213	6.36
<b>TOTAL</b>	<b>97 763</b>	<b>100.00</b>

Appliances and scrap metal are periodically salvaged from the site, however, information on the quantity that has been removed from the landfill will not be available until early 1993, so this factor can not be accounted for with precision.

## 2.4 SUMMARY

The previous section addressed the quantity of waste estimated to enter the landfill. The base (1992) values selected for use in this study are summarized in Table 2 - 5.

**TABLE 2 - 5**  
**BASE 1992 PARAMETERS**

Description	Units	Value
Density	kg/m <sup>3</sup>	250
Population	persons	17 000
Waste Mass	tonnes	16 500
Waste Volume	m <sup>3</sup>	66 000
Generation Rate	kg/cap/yr	970

**SECTION 3.0**  
**PRESENT OPERATIONS**



## **SECTION 3.0 PRESENT OPERATIONS**

### **3.1 SITE**

The Westside Landfill is located northwest of the intersection of Shannon Lake Road and Asquith Road, approximately 2.5 km north of downtown Westbank. The elevation of the site is about 520m. Shannon Lake is situated 0.5 km to the northeast, and Westbank Creek 1 km to the west.

Land use around the site consists of rangeland, agriculture, rural residential, and residential.

### **3.2 OPERATIONS**

#### **3.2.1 Collection**

There is no single contractor for refuse collection in the area. Residents and businesses contract the work out on an individual basis, or do the task themselves. As of August 1992, there were approximately 200 commercial customers using the landfill, including landscapers, construction contractors, and private refuse collectors. In addition, a large number of private citizens haul their own waste in their own vehicles. The number of customers using the landfill per day varies from 50 to over 400. The commercial client list is included as Appendix C.

#### **3.2.2 Operation**

The landfill is supervised by the Central Okanagan Regional District (CORD), but the actual work is performed by a private contractor. The operations contract is currently held by Serwa Bulldozing Co. Ltd. who have been working the site since 1988. The contract expired in 1991 when it was renewed for an additional two years. The contract is reproduced in Appendix D.

The site is open to the public six days per week, from 9:00 a.m. to 4:00 p.m. On Wednesdays, only commercial disposal is permitted.

The contractor is responsible for all facets of the operation. They maintain a D6 bulldozer for the purpose of digging trenches, compacting refuse, and excavating cover material; a rubber-tired three-yard front end loader for moving and loading material; and a twelve-yard dump truck for moving cover material to the working face. The one operator on site operates all three machines.

Both public and commercial users dump at the same working face to facilitate daily compaction and covering. The working area is covered daily with cover material, except during the summer when it may be covered more frequently. The operator estimates between 20 and 30 twelve-yard truckloads of cover material are used per week.

Old appliances (white goods) and derelict vehicles are separated from the main waste stream and stored close to the entry gate. This material is periodically removed from the site by salvage companies.

A weigh-scale was installed in January 1992. Prior to this date, approximate tonnages were assumed for each commercial vehicle type, and public self-deliveries were counted and multiplied by an assumed weight per vehicle to reach an annual figure. In 1990 the annual tonnage was estimated at nearly 22,000 tonnes; extrapolated scale data for the first nine months after its installation is less than 17,000 tonnes (see Section 2.3.3).

### **3.2.3 Environmental Concerns**

The Ministry of Environment records indicate the presence of four dug wells and three drilled wells 1,000m down gradient to the south. There are also six dug wells and four drilled wells less than 500m down-slope to the northeast. Golder Associates performed a preliminary geotechnical investigation on the site in October 1992 to assess possible effects of leachate. The potential for subsurface gas migration will be confirmed in the gas assessment to be performed during a later stage.

### 3.3 SITE CAPACITY

Stage 1 provided a preliminary estimate based on existing data and maps of close to 1.8 M m<sup>3</sup>. More detailed analysis has revised this estimate down to just over 900,000m<sup>3</sup> (see Section 5.7). This is a result of less area being available than previously thought, keeping fill away from reserves of cover material around the perimeter of the site, and maintaining at least 50m setbacks from all property lines. Figure 3.1 shows a proposed contour with side slopes of 25% and a maximum elevation of 565m. Once this volume has been landfilled, the site has to be closed. The rate at which this volume is filled depends on the quantity of waste and the degree of compaction reached.

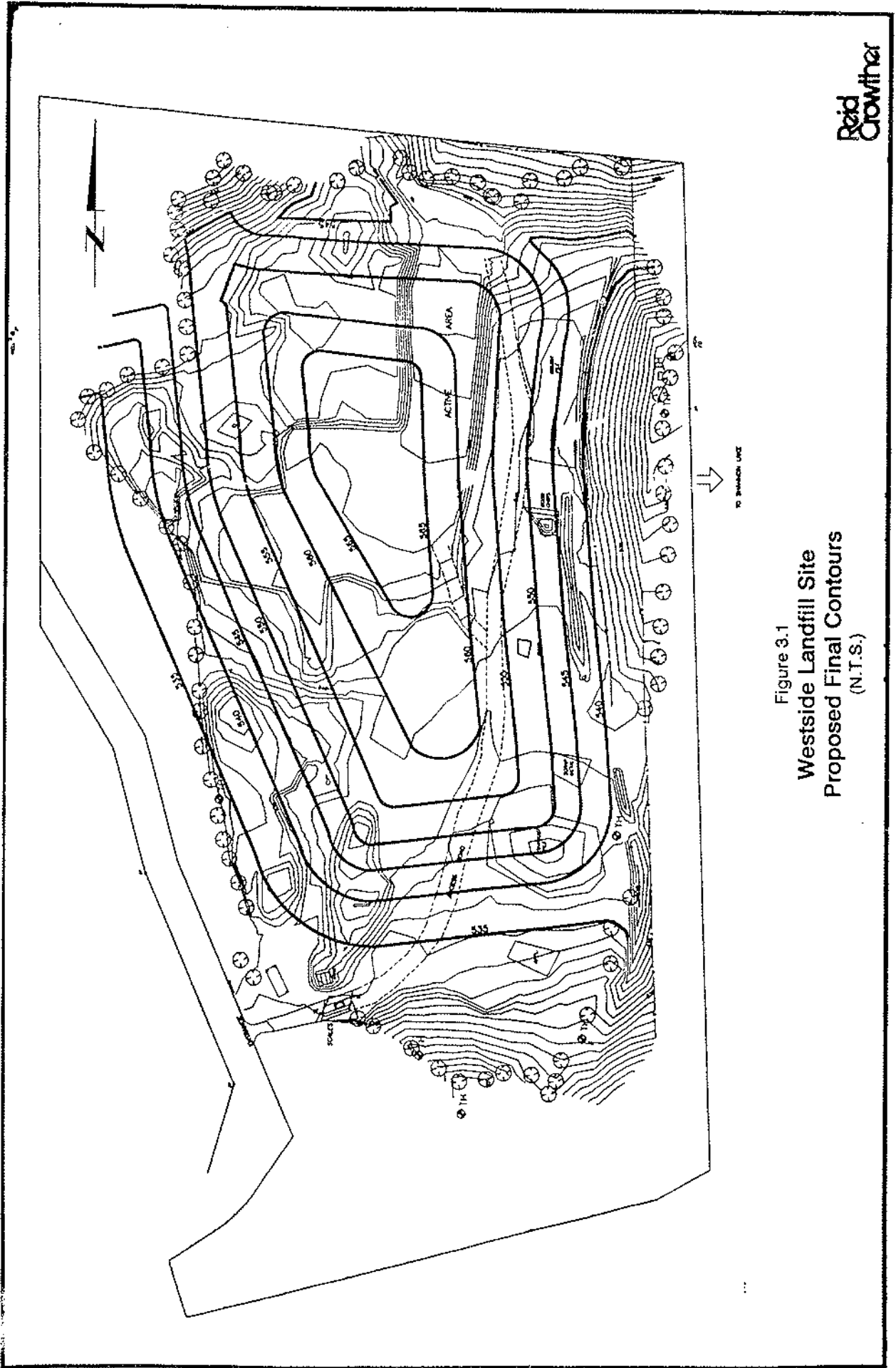


Figure 3.1  
 Westside Landfill Site  
 Proposed Final Contours  
 (N.T.S.)

**SECTION 4.0**  
**REDUCTION STRATEGIES**



## **SECTION 4.0 REDUCTION STRATEGIES**

### **4.1 RECYCLING**

#### **4.1.1 Introduction**

One way of reducing the volume of waste is to divert it from the main stream for re-use. The success of a recycling program depends mainly on the market for the material - if the demand is not there, the price is too low, or the product is contaminated, it cannot be recycled. Public education is vital to a recycling program to ensure all the "rules" are followed. The following presents a few important characteristics of commonly recycled materials that must be considered.

#### **4.1.2 Glass**

Glass can be recycled almost indefinitely as long as the colours remain separate - green, brown, and clear glass cannot be mixed. In addition, certain types of glass cannot be recycled. Small pieces of light bulbs, automobile head lights, and ceramic dishes can render an entire batch of glass useless for recycling.

#### **4.1.3 Paper**

There is a growing market for paper as new products using recycled paper are devised. One example is wall board used in construction. Recycling does not, however, save as many trees as commonly believed. In the U.S., 28% of paper is made from recovered paper, 27% from lumber mill trimmings, and a major part of the remainder from trees especially planted for paper production.

A ban on paper is being introduced in September of 1993.

#### **4.1.4 Metal**

Metal is an easily recyclable material, however, markets may be limited in some areas.

#### **4.1.5 Plastic**

Even though many plastics look alike, there are many different types, and due to the differing properties of their constituents they must be separated before being processed. To assist in this, many containers are stamped with a numerical code which identifies the type of plastic. The most recycled plastics are polyethylene terephthalate (PETE) and high density polyethylene (HDPE).

#### **4.1.6 Applicability**

The potential of reduction through recycling programs in the Central Okanagan is addressed in Section 6.0.

### **4.2 COMPOSTING**

#### **4.2.1 Introduction**

Composting is a controlled biological process for converting organic solid wastes into a stable humus-like product. Composting can be classified by oxygen usage (aerobic and anaerobic), temperature (mesophilic and thermophilic), and technological approach (open or windrow and mechanical or enclosed).

Aerobic composting involves aerobic microbes, thus oxygen must be provided during the process. Anaerobic composting occurs in the absence of oxygen. The aerobic process is generally characterized by high temperatures, low odour generation, and relatively rapid decomposition. Anaerobic composting occurs at lower temperatures, produces odour-generating reduced compounds, and proceeds at slower rates. The advantages of aerobic composting are the characteristics described above; high temperatures, low odours, and rapid rates, while the advantage of anaerobic composting is that it requires very little attention.

Mesophilic composting occurs at intermediate temperatures (15°C to 40°C), which in most cases is the ambient temperature. Thermophilic composting occurs at higher temperatures (45°C to 65°C). In practice, most processes span the two ranges.

Open, or "windrow" systems are those in which the entire process is carried out in the open, the material generally stacked in elongated windrows. In mechanical

systems, the majority of the initial stage takes place in an enclosed unit. In most mechanical systems, the material is windrowed towards the end to allow the product to mature.

#### **4.2.2 Process**

The composting process involves three steps: sorting, grinding, and composting.

Sorting is necessary to remove material such as tin cans, miscellaneous metals, glass, and ceramics that would damage grinding mechanisms. Ferrous metals are removed magnetically, and other materials either mechanically or by hand.

Grinding the refuse makes the material more susceptible to decomposition, entrains air, and gives a homogeneous consistency.

Immediately after the material is stacked in windrows or placed in a digester, bacterial activity begins at an accelerated rate. Excess energy released by the microorganisms results in a rapid rise in temperature. The material is usually self-insulating, and the elevated temperature is maintained relatively steadily until the readily degradable material has broken down. Once this has occurred, biological activity declines, accompanied by a corresponding drop in temperature.

The net result is the partial stabilization of the material. It is desirable to attain a degree of stability so that the material will not give rise to nuisances while stored. Final stabilization occurs when the compost product is used to fertilize soil.

Depending on the "purity" of the initial material a volume reduction of 65% (garden debris) to 30% (municipal refuse containing relatively large amounts of paper).

The end product is used as a mulch or soil conditioner in agriculture or gardening, and in land reclamation as a replacement for lost topsoil. There is also potential for its use in reclaiming lands covered with mine tailings.

### **4.3 COMPACTION**

While not reducing the quantity of waste being placed in a landfill, increasing the degree of compaction reduces the volume, and hence, the gives a corresponding

increase in landfill life. Compaction is performed at the working face by a Caterpillar D6 bulldozer. The estimates for landfill life expectancy given in the Stage 1 report assumed compaction is not diligently performed, and the as-received density was used for the purpose of capacity calculation. A D6 caterpillar can compact relatively thin lifts to densities of about 500 kg/m<sup>3</sup>. Assuming the similar equipment to that presently on site will continue to be used, this density value will be used.

**SECTION 5.0**  
**PROJECTIONS AND LANDFILL OPERATIONS**



## SECTION 5.0 PROJECTIONS AND LANDFILL OPERATIONS

### 5.1 INTRODUCTION

The Stage 1 report presented preliminary projections based on existing practices and data. This Section makes projections based on revised information, realistic waste reductions, and implementing recommended improvements in operation.

### 5.2 WASTE SEGREGATION

Existing segregation involves recycling bins at the entrance, and stockpiles on the site for white goods, scrap metal, tires, and brush. The stockpiles are close to the access road, making access easy for salvagers. However if the stockpiles remain where they presently are, available landfill capacity is decreased as they are inside the boundary of the proposed final landfill configuration. The practice of stockpiling derelict vehicles should be carefully evaluated. In the short term, this waste could continue to be accepted, provided the vehicles are free of hazardous substances such as oil, brake and transmission fluid, and the like. In the long term, however, space limitations at the site may preclude old vehicles being placed at the landfill. There is no segregation at the working face; all waste that is placed at the site is placed at a single working area, regardless of type.

Improvements to the present system could be realized if more segregation was performed. Enhancing segregation has the following advantages:

- Separation of inert wastes such as construction debris which would not require daily and intermediate cover, and by placing them separately from those that do, the cover material reserve could be used more efficiently. In addition, these wastes would not generate odours and draw pests, and such impacts on neighbouring residents could be lessened by placing this waste as a buffer between the development and the rest of the landfill.
- A specific area on a horizontal survey grid on each level should be set aside for controlled wastes (see next section) in order to provide a precise record

of its location in the future. Costs can be offset by increased fees for these wastes.

### **5.3 ACCEPTABLE WASTES**

The landfill should not accept hazardous and prohibited wastes such as corrosive or radioactive wastes, petroleum, and industrial chemicals. Liquid waste and septic tank pumpings are not accepted. The stockpiling of derelict vehicles should be reevaluated.

Controlled wastes may be accepted if certain procedures are followed. Waste asbestos, for example, would need to be double-bagged to retain dust. According to the CCME Guidelines for the Management of Biomedical Waste in Canada, only microbiology laboratory waste and waste sharps can be landfilled, and only if first decontaminated by an acceptable sterilization treatment (e.g. autoclaving), packaged in approved containers, and accompanied by a manifest. These controlled wastes should be placed in a specially prepared trench and immediately covered with soil to ensure that operations machinery and personnel, and other traffic do not come into direct contact with the waste.

Wood waste should continue to be accepted, and used as a cover material supplement. Brush, which is presently stockpiled in the northeast, should be chipped. A small chipper should be adequate for this task. This will reduce its volume and fire risk. The chipped product could also be used as cover supplement.

Due to the proximity of residential development and the direction of the prevailing winds to the northeast, open burning of wood wastes should not be permitted.

### **5.4 WASTE REDUCTIONS**

Table 5-1 presents the quantity of recyclable material in the waste stream based on the waste compositions presented in Section 2.0. The fractions of types of papers, plastics, and metals were estimated from the Ministry of Environment (MOE) Municipal Solid Waste Composition Studies.

**TABLE 5 - 1**  
**RECYCLABLE MATERIALS**

Description	Estimated Fraction, %	Tonnes*
Newsprint	8-10	1500
Cardboard	5	850
Fine Paper	2	350
Tin Cans	3.5	600
HDPE	1	170
PET	<0.1	10
Glass	6	1000
Total		4560

\* Based on 1992 total of 16500 tonnes

Ideally, if all of this material could be diverted, the result would be an approximate 25% reduction in waste entering the landfill. However, the actual recovery of these materials is dependent mainly on marketability and public participation. Marketability depends on demand and quality of the material; small amounts of foreign material can render an entire batch useless. Public participation depends on education and convenience. Curbside collection methods such as "Blue Boxes" are convenient and encourage high participation, but it is difficult to maintain a high standard of quality in material. Staffed satellite stations allow tighter control of the materials deposited, but are less convenient to use, and are more costly.

In the Kelowna area, recyclable material is handled by KEREDA, which runs the local satellite recycling stations and sells the products to brokers and recycling companies. They have a five-year contract for newsprint, and are in the process of negotiating a five-year contract for cardboard, and have the capacity to sell more than they are presently receiving. Glass, on the other hand, is not as marketable; about 60% of the glass they handle is green glass, of which there is an oversupply. The remaining 40% is clear and miscellaneous glass, which is in some demand. Plastics are the least saleable; the demand in some overseas markets, notably Korea, is high, but there is virtually none in North America. Shipping costs for plastics can be as high as \$800/tonne, hence profits are extremely low or nonexistent. KEREDA deals exclusively with HDPE milk jugs and ice cream pails, which, because they can be easily dyed any colour, have a wide range of uses.

A 10 to 15% weight reduction could be achieved given an approximate 50% participation rate in waste diversion of the materials described in Table 5-1 assuming that the material is strictly segregated and markets remain relatively stable. In addition, approximately 25% of residential waste (the organic fraction) is compostable. Extrapolating from Table 2-3, this amounts to 1100 tonnes out of the estimated 4,500 tonnes brought in by private vehicles in 1992, that could be diverted from the landfill by implementing a composting program. Combining the recycling and organic weight reduction results in an estimated 22% reduction in landfilled weight. Factoring in improved compaction could reduce the volume placed in the landfill by 50% or more.

**TABLE 5 - 2**  
**ESTIMATED DIVERTIBLE QUANTITIES**

Description	Tonnes (1992)	Fraction (%)
Recyclables	2500 <sup>a</sup>	15
Residential Organics	1100	7
Remainder	12900	78
Total	16500	100

\* Assuming 50% participation

In order to optimize the use of cover material, it should be possible to place construction waste separately from the main refuse stream. This would reduce the quantity requiring daily and intermediate cover by a further 15%. Adding this to the 10 to 15% recovered recyclables provides a 25 to 30% reduction in material requiring cover. This reduction should be phased in over a period of several years in the quantity/capacity calculations.

The tables presented in Appendix B combine a 15% weight reduction spread over three years, the separation of construction/demolition waste, and improved compaction, resulting in an approximate 50% overall reduction in volume.

## **5.5 CONTRACT**

The present contract (Appendix D) is one which has been in effect from 1988, with a two year extension granted in 1991 with provisions made to increase the hourly rate at 3% per year. The Regional District was sufficiently satisfied with the contract at the time of extension that it was not re-tendered.

The present contract provides for one operator to run three pieces of equipment: the dump truck, the loader, and the bulldozer. While this is economical in terms of operating costs, it is less efficient and some of the procedures (compaction, cover/wood mixing) may not be consistently performed. As compacting the waste in place has a significant effect on the operational life of the site, the extended life may be worth additional cost, and it may be worthwhile to consider having two equipment operators on the site. Section 2 f i could be amended to specify a minimum compaction of  $500 \text{ kg/m}^3$ , cover is to be comprised of a 70:30 earth/woodwaste ratio, and a waste to cover ratio of 22%, using the ramp method with 0.15m of daily cover and 0.30m of intermediate cover.

It is recommended that a program be initiated to measure the actual in-situ densities at the site in order to determine the level of compaction that is presently being achieved. Using the Regional District's backhoe, the cost of such a test would be on the order of \$500 to \$1,000. This information could then be used to assess the improvements that could be made with better compaction equipment.

Depending on the Regional District's continued satisfaction with the present arrangement, the contract could be further extended, with the above-mentioned amendments made. The present contract is very inexpensive, so there is room to add equipment and staff and still operate economically.

## **5.6 OPERATIONS**

### **5.6.1 General**

Placing the refuse in thin lifts and consistent compaction of the wastes would make more efficient use of the ultimate capacity of the site. Assuming the D6 caterpillar will continue to be used, an in situ density of about  $500 \text{ kg/m}^3$  should be easily attainable. This figure will be used for the purposes of calculation.

Employing the ramp method of filling (Figure 5.1), where the waste is placed on the sloping face of previous cells, the ratio of cover to waste can be minimized. Regulations require 0.15m of daily cover, and where no further waste will be placed for at least 30 days, 0.30m of intermediate cover is required. Placing 0.15m of cover on the face as daily cover and 0.30m on the top as intermediate cover, the ratio of cover to waste is approximately 0.22:1 by volume, provided the waste is properly compacted. The final cover, or cap, should have some impermeable material such as clay or silt incorporated in order to increase its resistance to water infiltration.

The present highest elevation of the working area of the site is about 545m. The site should first be filled to reach a site wide elevation of 545m from which filling would progress to the ultimate contour. This level would be relatively flat, but a minimum slope of at least 2% should be maintained to drain precipitation off of the site. Guidelines state that the fill should not be any closer than 50m from the site boundary. A landscaped berm should be provided along the eastern side as a barrier to the neighbouring development.

The sides of the waste should slope between 25 and 33% to allow for adequate drainage while maintaining stability of the final cap. Filling should be kept away from the south and west sides, which hold reserves of cover material. In order to keep operations away from the gatehouse/scale area, the southernmost limit of the fill should be at about the 535m contour which crosses the site from east to west.

The capacity of the depressions at the north end of the site is approximately 67,000m<sup>3</sup> to fill up to an elevation of 545m, 55,000m<sup>3</sup> of which would be waste, the rest cover. This is on the order of 21 months capacity at the present rate of disposal. If reductions are realized, this period could be longer. This provides time to implement the removal of the appliance and metal stockpiles, and construction of the new road. The present road can be used while filling areas A and B. Next fill area should be the southern half of the site, which slopes down to an elevation of 535m at its southern boundary. This area has an estimated volume of 150,000m<sup>3</sup>. The existing road can then be progressively closed as filling proceeds.

The total estimated capacity of Stage 1 is 215,000m<sup>3</sup>.

### **5.6.2 Cell Configuration**

Waste should be deposited in ramps, along the face of previous cells at a slope of 4:1. The waste should be placed in thin lifts of 0.6m, and compacted to at least 500 kg/m<sup>3</sup> (D6 can accomplish this level of compaction). The width of the cell should be at least three times the width of the compactor so that it is able to cover the entire waste area with its tracks. Cell sequence should be such that a face covered with only daily cover is used as the base of a subsequent cell within 30 days wherever possible. This is so that intermediate cover will not have to be applied to the majority of the cell surface. Intermediate cover should be placed on the top of the cell immediately, as this part would not be further covered until the next level is begun (see Figure 5.1).

### **5.6.3 Final Elevation**

The site should be filled as high as possible in order to maximize the capacity of the landfill. Settling will occur as the material in the fill compresses (magnitude of future settling is unknown but could be estimated to average 30% after five years. (See Figure 5.2). If large expanses of flat area are present, these could settle into concave depressions; if the cap loses its integrity, water trapped in the depressions will enter the waste material, leading to leachate production. By having most of the material sloped at least 4:1, settlement may flatten the slope, but no depressions should form, and drainage will continue. By filling at a slope of 4:1, the final profile will be relatively flat and the site will be more amenable to use as a park after it is closed.

### **5.6.4 Road Alignment**

The present road can be used to service Stage 1. Once 545m elevation is reached across the site, a new road will have to be constructed. There are two options for its alignment (see Figure 5.5):

- along the south and extending northward along the eastern boundary;
- turning north 90° just past the scale and extending along the west boundary.

The first option allows smoother traffic flow as there is no sharp corner to negotiate. It can also reach an elevation of 565m at a grade of about 5%. The

disadvantage is that it extends along the boundary where there is residential development.

The second option has several disadvantages. The 90° corner will have an effect on traffic flow, the grade required to reach 565m will have to be steeper, on the order of 7.5% to 10%, and a rock outcrop near the scale will have to be blasted and excavated. A major advantage is that as the road is on the western side of the landfill, it will keep traffic away from the neighbouring development for a majority of the time. Because of the sensitivity of the area residents to the landfill, this is a very important consideration.

Another advantage of the second option is that the alignment heads in a generally northeast direction, and filling from it will thus progress from the windward side of the site. This will provide a windbreak and allow odours to dissipate over the site.

The present use of trees around the perimeter should be maintained as a visual and sound barrier. The filling operation should not encroach on these areas.

## **5.7 OPERATION STAGES**

### **5.7.1 Introduction**

The future operation at the Westside Landfill can be divided into two stages. The first fills the site up to a relatively flat common elevation (sloped at a minimum of 2% to facilitate drainage), using the present road. Any cover material found to lie under the footprint of the proposed final contours will be excavated, stockpiled, and used during this stage. The second stage will begin filling with the ramp method from the Stage 1 elevation. A new road will be built as each level of the second stage is reached. The closure date of the site would depend on the ultimate elevation chosen. The maximum elevation is about 565m (see Figure 3.1).

### **5.7.2 Stage 1**

Stage 1 involves filling the landfill up to its present highest elevation of 545m (see Figure 5.3). Figure 5.4 shows three areas, A, B, and C. Areas A and B are to be filled first, working from the present active area. Area A should be used for inert wastes such as construction debris, as it borders the neighbouring development; area B should be used for the household and commercial wastes which require daily

cover. This will keep much of the activity in a more remote part of the site. The present access road can be used while these areas are being filled. The brush pile and woodchip pile will have to be moved in order to work in area A.

After areas A and B are brought up to 545m, area C will be filled from north to south. Preparations to construct the new road should be undertaken during this phase. The sawdust pile will have to be relocated. The appliance stockpile can likely remain, as it is outside the proposed filling area. As mentioned earlier, the stockpiling of automobiles may have to be discontinued.

The estimated capacity is 25,000m<sup>3</sup> in A, 42,000m<sup>3</sup> in B, and 150,000m<sup>3</sup> in area C. Total Stage 1 capacity is therefore an estimated 215,000m<sup>3</sup>. Referring to the tables in Appendix B, area B will be filled prior to area A if A is used exclusively for inert wastes. The northwest corner of area C would then be opened before area A is closed.

Any cover material encountered in these areas should be excavated and stockpiled prior to waste being placed.

### **5.7.3 Stage 2**

Stage 2 consists of filling from an elevation of 545m to the closure of the site. Given the final profile of the site to be a pyramid with 4:1 side slopes, and minimum 50m setback from the site property lines, the ultimate elevation appears to be 565m (see Figure 3.1).

For the purposes of estimating intermediate volumes and time intervals, Stage 2 is divided into six substages, 2 a through 2 f. Each of these stages accounts for a 3.3m change in elevation, which corresponds to the height of a waste cell (3m) and its associated daily and intermediate cover (0.3m). Table 5-3 presents the volume of each of these stages and Table 5-4 presents estimates of the date each is reached. This breakdown also gives an indication of landfill life expectancy as a function of ultimate elevation.

**TABLE 5-3  
LANDFILL OPERATION STAGES**

Stage	Start Elev'n	End Elev'n	Volume (m <sup>3</sup> )	Volume (m <sup>3</sup> )
1	present	545.0	215 000	215 000
2a	545.0	548.3	231 000	446 000
2b	548.3	551.6	161 500	607 500
2c	551.6	554.9	115 000	722 500
2d	554.9	558.2	94 500	817 000
2e	558.2	561.5	55 600	872 600
2f	561.5	564.8	34 000	906 600

Note: 25% side slope, no benches, minimum 50m setback from site boundary

**TABLE 5-4  
LANDFILL LIFE EXPECTANCY**

Stage	Volume (m <sup>3</sup> )	Completion Date at Growth Rate:		
		2%	2.75%	4%
1	215 000	May 1998	Apr 1998	Jan 1998
2a	446 000	Dec 2003	Jun 2003	Dec 2002
2b	607 500	Jul 2007	Oct 2006	Oct 2005
2c	722 500	Dec 2009	Jan 2009	Sep 2007
2d	817 000	Oct 2011	Aug 2010	Mar 2009
2e	872 600	Nov 2012	Aug 2011	Dec 2009
2f	906 600	Jun 2013	Mar 2012	Jun 2010

Note: month given solely to provide indication of relative time spans, and is not intended to be a precise estimate of the time of stage completion. Refer to Appendix B.

## 5.8 DRAINAGE

### 5.8.1 Existing Topography

The areas under consideration include the landfill site, upstream runoff areas, and the downstream drainage routes. In general, the land in this area slopes to the southeast. The catchment area was defined, and runoff and channel sections and locations established (see map, Appendix E).

### 5.8.2 Design Criteria

The drainage calculations used the following parameters:

- Storm data from City of Kelowna I.D.F. curve;
- Flows estimated for 1:100 year return period;
- Runoff coefficients of 0.25 for grassed, undeveloped and natural areas, and 0.90 for impervious surfaces;
- Channel sections sized according to Manning's Equation for open channel flow, 3:1 side slope, 2% grade, with 0.5m freeboard.

Natural (pre-development) runoff from the area follows a certain route and concentrates at a certain rate. Upon completion of filling of the site, regrading, levelling, etc., the runoff volume, concentration, and routing would be equivalent to pre-development conditions.

### 5.8.3 Existing Runoff

Given an estimated landfill site area of 12.5 ha, the estimated peak runoff from a 1:100 year event would be 0.40 m<sup>3</sup>/s. The estimated drainage area contributing to runoff from above is 17.25 ha. The estimated peak runoff from a 1:100 year event is 0.54m<sup>3</sup>/s.

Fig 5.7 shows two alternative ditch sections to handle these flows, assuming  $n = 0.050$  and slope of 2%. It is proposed to build two drainage ditches, the first draining to the east to an existing ditch which flows through the gravel pit into an unnamed creek and on to Okanagan Lake, and the second draining to the south through a natural draw and into an small unnamed lake at elevation 458m. This lake either drains to/recharges groundwater or overflows to Westbank Creek.

The ditches should match the long term development of the area. It is premature at this time to set a location for them other than the site perimeter. In areas where the slopes exceed 5%, an erosion protection liner may be required.

## 5.9 END USE

According to the Land Use Map included in the Westbank Official Community Plan (Bylaw 347, Schedule 'C'), the landfill site is situated in an area zoned for schools, institutions, and utilities on the western half, and low density residential on the eastern side. The neighbouring land is agricultural, recreation and conservation, or undesignated.

Section 10 of the community plan defines "hazardous areas" and outlines restrictions in such areas. Section 10-3 bars development and subdivision on lands subject to unstable soil conditions. Landfills continue to settle for many years after closure, and this site would therefore fall into this category. Section 10-5 states that areas with slopes exceeding 20% are generally considered unsuitable for development without a practical and sound professionally prepared design.

It appears the best use for the site would be recreational. After the landfill is closed, its use will be dictated by constraints imposed by its physical shape and its structure. Its pyramidal shape rules out any uses that require flat surfaces, such as golf courses. Because it is made out of garbage, it will continue to settle over time, and therefore no structures can be built on it. The integrity of the cap must be maintained, so no long-rooted plants should be planted. Grasses, small shrubs, and shallow-rooted evergreens are acceptable. The site is most suitable as a passive park area that could be used as a picnic area, playground, or toboggan park.

The area at the entrance could remain as a recycling depot and/or transfer station.

FIGURE 5.1  
PROPOSED CELL CONFIGURATION  
NTS

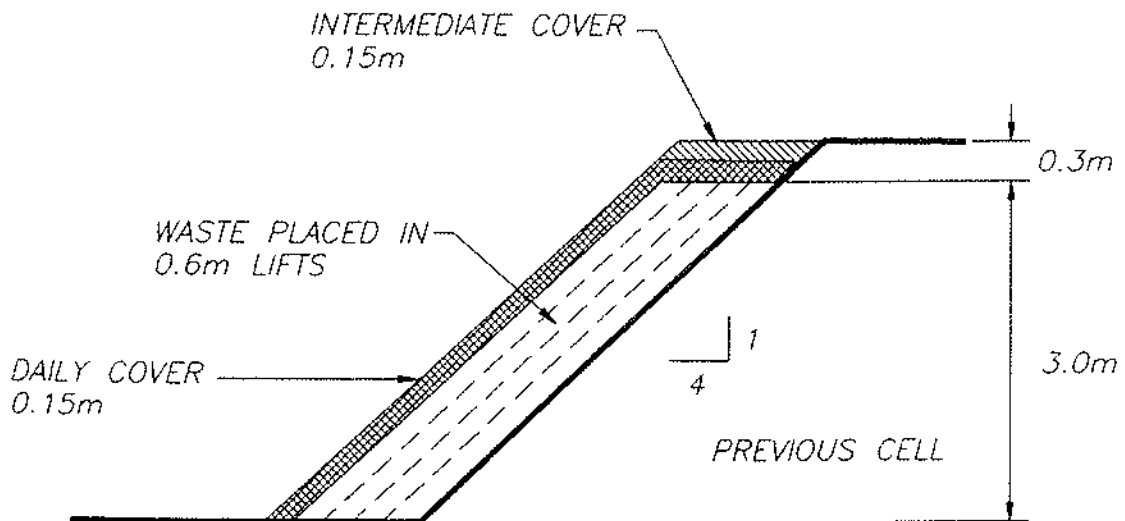
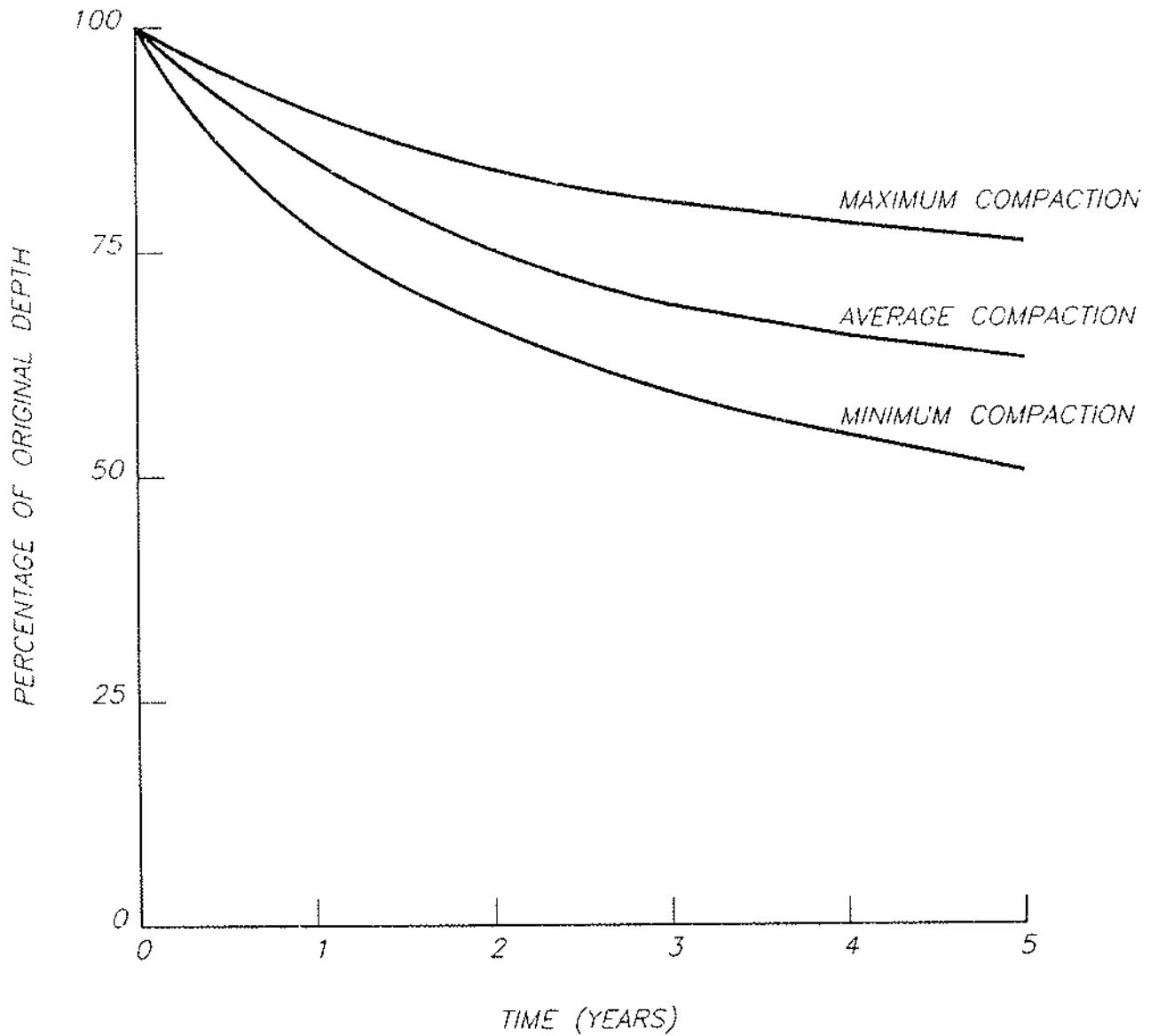


FIGURE 5.2  
SURFACE SETTLEMENT  
NTS



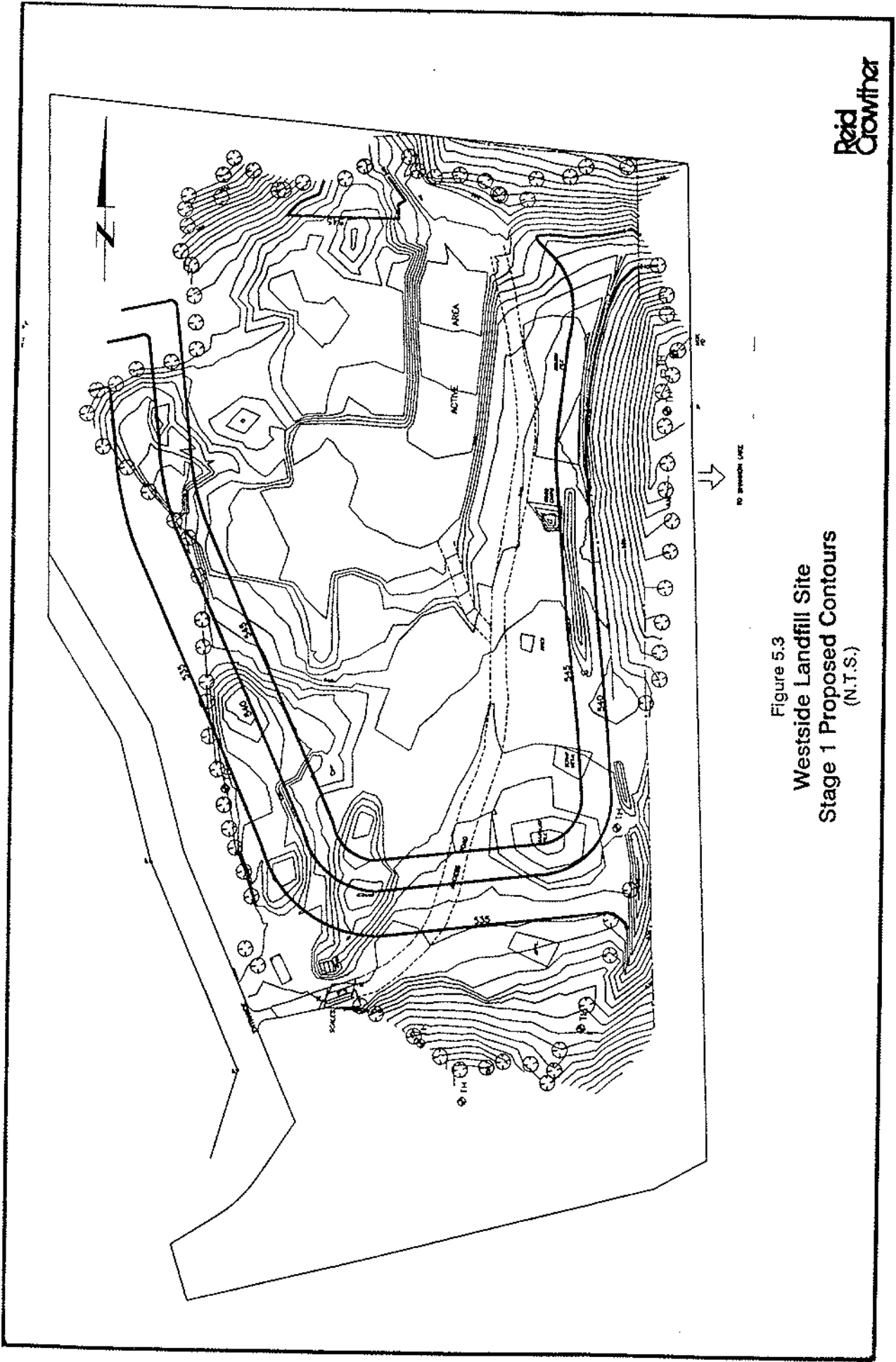


Figure 5.3  
 Westside Landfill Site  
 Stage 1 Proposed Contours  
 (N.T.S.)

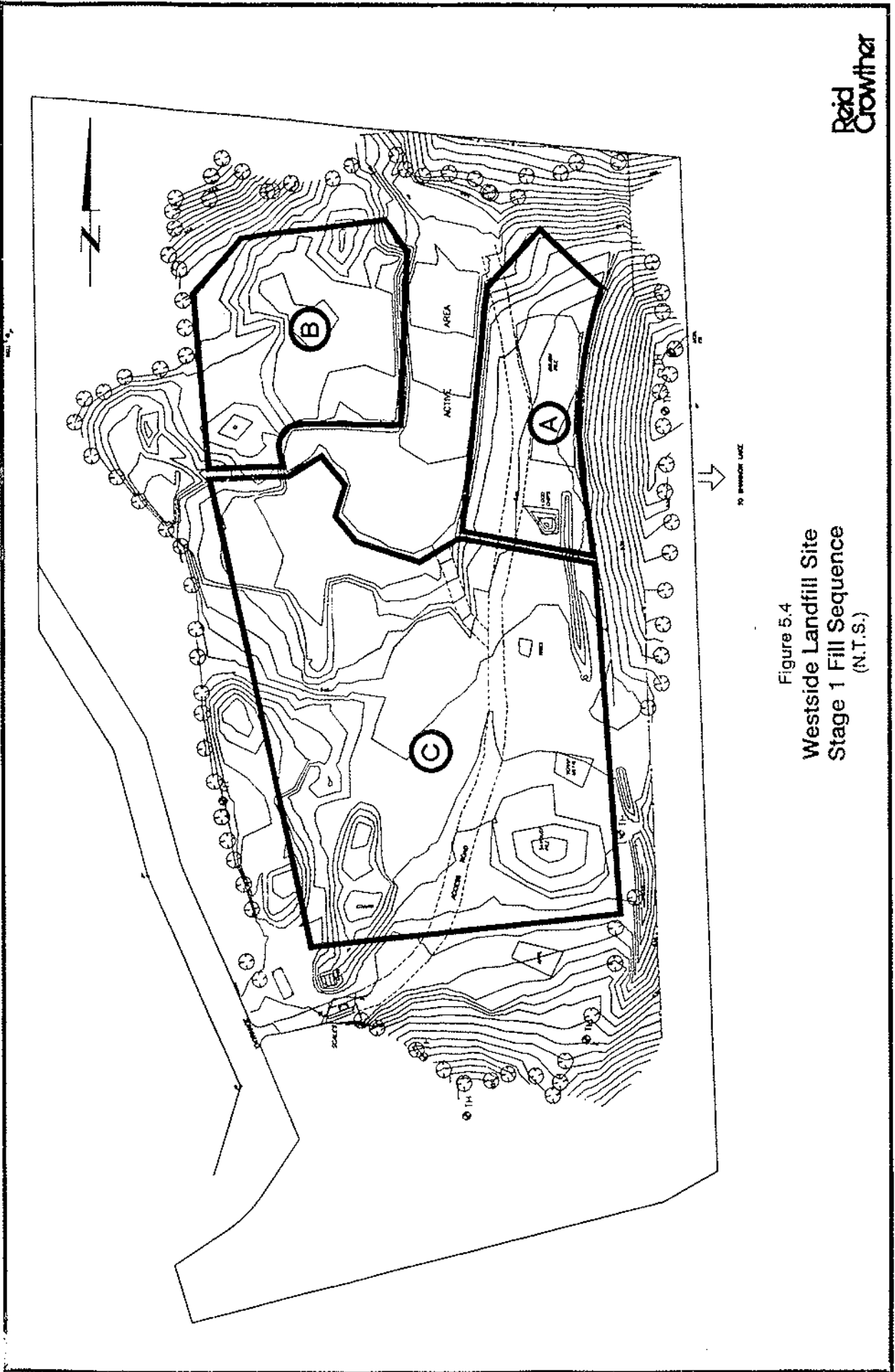
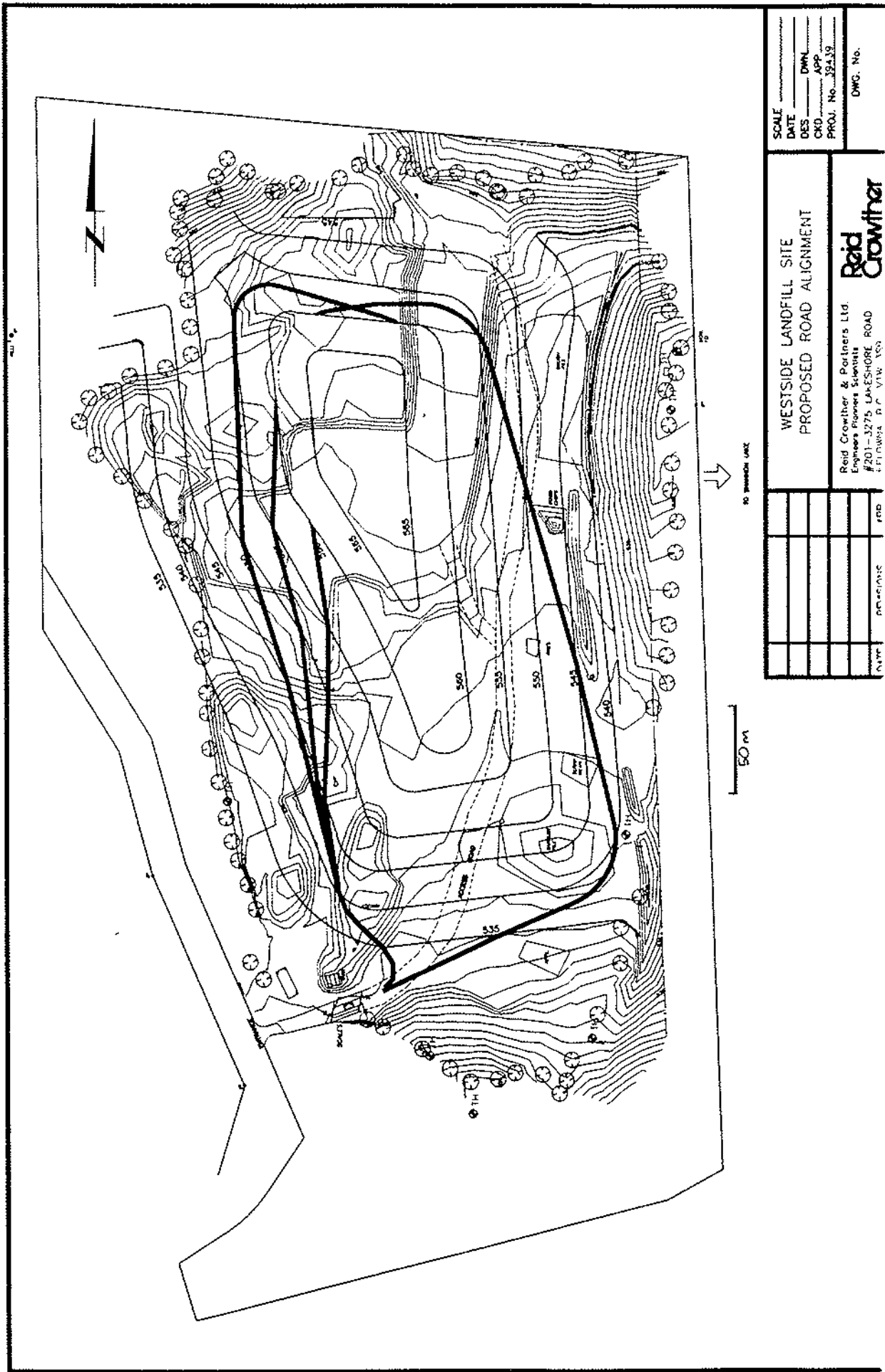


Figure 5.4  
 Westside Landfill Site  
 Stage 1 Fill Sequence  
 (N.T.S.)

Figure 5.5



SCALE	_____
DATE	_____
DES	DWN
CHKD	APP
PROJ. No.	39439
DWG. No.	_____

WESTSIDE LANDFILL SITE	
PROPOSED ROAD ALIGNMENT	
Reid Crowther & Partners Ltd. Engineers Planners Scientists #201-3275 LAKESHORE ROAD FLORENCE, B.C. V1W 1G3	
DATE	_____
BY	_____
CHECKED	_____
DATE	_____

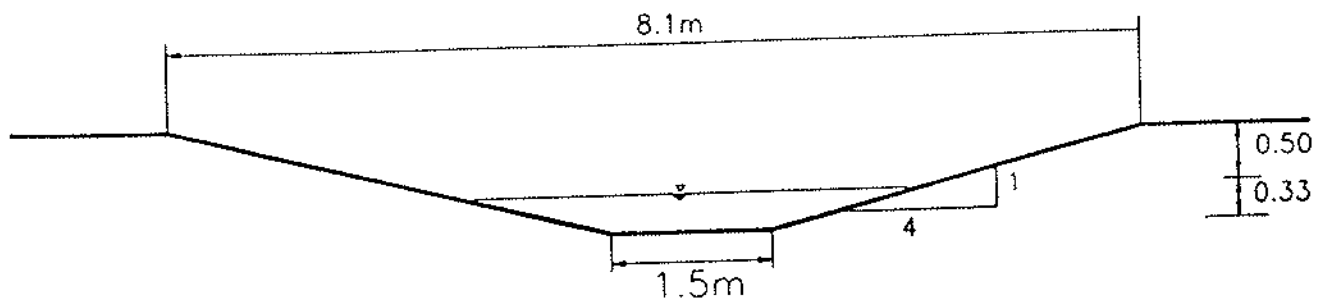
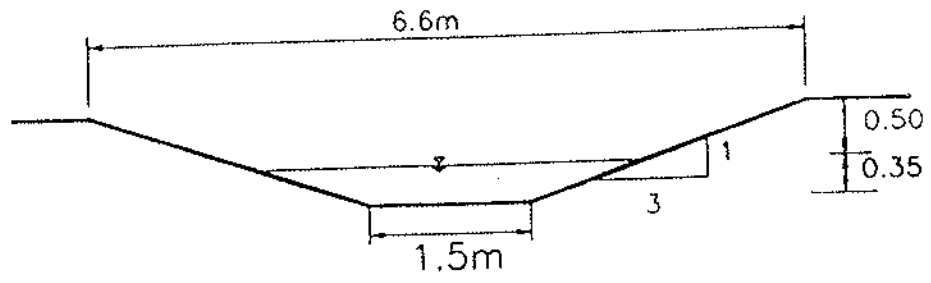


Figure 5.6  
Ditch Cross Sections  
N.T.S.

**SECTION 6.0**  
**LANDFILL LEACHATE**



## SECTION 6.0 LANDFILL LEACHATE

### 6.1 INTRODUCTION

Under the acidic conditions of biological waste decomposition, water percolating through the landfill extracts organic and inorganic compounds from the waste. This leachate is typically high in BOD, ammonia, alkalinity, and metals (see Table 6-1). If it migrates away from the landfill it has the potential to contaminate any ground or surface water it contacts, and is therefore a major concern associated with most landfills.

TABLE 6 - 1  
TYPICAL COMPOSITION OF LANDFILL LEACHATE

Constituent	Value (mg/L) <sup>a</sup>
Biochemical Oxygen Demand	10 000
Total Organic Carbon	6 000
Chemical Oxygen Demand	18 000
Total Suspended Solids	500
Organic Nitrogen	200
Ammonia Nitrogen	200
Nitrate	25
Total Phosphorus	30
Ortho Phosphorus	20
Alkalinity as CaCO <sub>3</sub>	3 000
pH	6
Total Hardness as CaCO <sub>3</sub>	3 500
Calcium	1 000
Magnesium	250
Potassium	300
Sodium	500
Chloride	500
Sulphate	300
Total Iron	60

a) Range of concentrations extreme. Typical values intended only as a guide.

Composition of leachate is highly variable, and depends on the variations unique to each landfill. These variations include refuse composition, type of cover material, infiltration control, density, moisture content, landfill age, and climate.

In general, landfilled waste undergoes decomposition in three stages. The first stage is aerobic decomposition, lasting up to one year, until the oxygen has been depleted. The second stage is anaerobic decomposition involving facultative microorganisms. This stage begins after all the oxygen has been consumed, and can last many years. During this stage, the microorganisms hydrolyze and ferment proteins, carbohydrates, and lipids into simpler compounds such as volatile fatty acids (VFAs) and alcohols. The BOD can exceed 10,000 mg/L, the BOD:COD (an indicator of the proportion of readily biodegradable organics) is greater than 0.7, the ammonia nitrogen concentration is 500 to 1,000 mg/L, and the pH is around 5 or 6. This acidic environment promotes further dissolution, especially of metals. Leachate generated under anaerobic conditions may therefore contain high levels of iron, manganese, zinc, calcium, magnesium, sulphate, and chloride.

The third stage occurs when an equilibrium is reached between acidogenic and methanogenic bacteria. High molecular weight refractory organics such as humic and fulvic acids, methane, and carbon dioxide are produced during this stage.

As the landfill ages, the pH rises to neutral or alkaline, the BOD:COD ratio drops to 0.1 as biodegradable organics are consumed, and the metals are precipitated or absorbed (except iron and manganese which remain soluble under anaerobic conditions). Organic nitrogen is converted to  $\text{NH}_4^+/\text{NH}_3$ , and the proportion of low molecular weight to high molecular weight organics decreases.

Due to the heterogeneous nature of their environments, most large landfills will have all three stages of decomposition occurring simultaneously in varying degrees.

## **6.2 TREATMENT IMPLICATIONS**

The variability in composition and strength of leachate make prediction of leachate characteristics difficult and has the following implications:

- thorough treatment may require biological, chemical, and physical unit processes;
- a given treatment at a given landfill may not be transferable to another site;
- treatment systems must be sufficiently flexible to respond to short- and long term fluctuations in both quality and quantity.

## **6.3 LEACHATE GENERATION**

### **6.3.1 General**

Although leachate composition is difficult to predict, one consistent characteristic is that it has high concentrations of dissolved organic and inorganic compounds, and is therefore a potentially hazardous pollutant. The main process which affects leachate characteristics is the biological decomposition of the waste. Factors which influence this process are beginning to be understood in sufficient detail to enable some degree of control. These factors include temperature, moisture, waste composition, and oxygen availability and percolation rates (both functions of waste compaction).

### **6.3.2 Temperature**

Temperature effects the rate of microbial growth. Above 40°C, thermophilic bacteria are active and decomposition rates are at a maximum. Between 20°C and 40°C mesophilic organisms predominate, and below 20°C psychrophilic organisms are active and the reactions proceed at minimal rates. After oxygen is depleted and conditions become anaerobic, temperatures fall and become controlled by ambient conditions.

### **6.3.4 Moisture**

The main source of moisture is precipitation. Because water transports nutrients and provides the medium for biochemical reactions, dry conditions will reduce the activity of the majority of the microorganisms, resulting in a longer stabilization times. Once the moisture content of the waste exceeds its field capacity, it begins to flow, carrying nutrients to other areas of the fill, leading to increased biological activity in those areas. Leachate production and percolation thus occur after the refuse mass has reached saturation.

Mean annual flow rates of leachate range from 10% to 25% of the precipitation rate. Seasonal variations are more difficult to predict and may be as much as 4 or 5 times the average flowrate. Annual average leachate production is commonly estimated by performing a water balance on precipitation, storage, evapotranspiration, and infiltration. Contaminant concentrations in the leachate is inversely proportional to the quantity produced; high levels of precipitation coupled

with porous soils create large amounts of weak leachate, and landfills with low infiltration rates will generate lesser quantities which will be more concentrated. The optimum moisture content for microbial decomposition has been reported as being in the 60% range. Excessive moisture (greater than 70%) limits oxygen diffusion, thus inhibiting aerobic processes, and insufficient moisture (less than 25%) inhibits microbial growth in general. The overall moisture content of as-received waste at landfills typically ranges from a low of 15 or 20% to a high of 30 to 40%. Typical average moisture contents of 25% are indicated by various sources.

### **6.3.5 Waste Composition**

The main source of many contaminants present in leachate is the readily biodegradable waste fraction which includes food, grass, and leaves. Because solid waste composition varies widely both with time and area, no simple model can be formulated to accurately predict leachate characteristics. For example, some decomposition products may be water soluble, although the original material was not, or a high proportion of sugars and starches (readily biodegradable) to cellulose (less biodegradable) will lead to stronger leachate. Furthermore, because of the refractory nature of some wastes, leachate chemical characteristics will change with time.

The composition of landfilled waste can be changed by new waste management policies and programs. Landfill diversion initiatives such as backyard and centralized composting will result in a decrease in the proportion of biodegradable waste in landfills and a subsequent reduction in leachate strength should occur.

Another typical leachate characteristic is high iron concentration arising from the ready dissolution of ferrous metals. Blue box recycling programs which divert some of these metals should lead to lower iron concentrations in leachates from newer landfills compared with that from long established landfills.

The nature and quantity of industrial waste in landfills can have an effect on leachate constituents, particularly metals. These wastes can be either detrimental or beneficial to landfill stabilization, depending on the amount landfilled and its reactivity.

### 6.3.6 Waste Compaction

In-place refuse densities are increasing with improvements in compaction technology. Leachate constituents will be affected by slower percolation rates and lower oxygen availabilities through a more compacted material. It is expected that such landfills will take longer to stabilize than will landfills with less compacted fill. In addition, leachate quantity is a function of refuse density. An increase in density from less than  $400 \text{ kg/m}^3$  to about  $600 \text{ kg/m}^3$  could decrease total leachate volume from about 50% of the annual precipitation volume to about 15%.

Increased compaction will also decrease available moisture, affecting the microbial activity as discussed above.

### 6.3.7 Summary

Factors affecting leachate generation are known, and data on leachate characteristics is available from various full-scale and test landfills. Predicting leachate characteristics is difficult as a result of multiple stages of decomposition occurring simultaneously in a landfill and from the effects of each given volume of waste undergoing the different stages of decomposition. The predominant variables affecting leachate appear to be the moisture content of the waste, the biodegradability of the waste, and other environmental variables which moderate biological waste degradation.

The effect of leachate on the environment depends mainly on the permeability of the soils and the proximity to ground and surface waters. The impacts can be lessened by:

- designing the landfill to provide adequate separation from potable water, lining the landfill to divert and collect the leachate, and treating the leachate prior to discharge;
- providing impermeable daily, intermediate, and final cover material to reduce the quantity of external water permitted to percolate through the waste;
- separating readily biodegradable and hazardous wastes at their sources, thereby preventing their entry into the landfill.

#### **6.4 COLLECTION AND TREATMENT OPTIONS**

There are two options for leachate collection; interception trenches on the down gradient side of the landfill, or pumped wells distributed throughout the site. Contingent on the results of the hydrogeological investigation into the groundwater flow regime, it appears that the simplest and most effective method of collection would be an interception ditch traversing one or both of the downhill sides of the site (east or south). The leachate would then flow by gravity to a storage/treatment facility, and would either be treated on-site (rotating biological contactors are well suited to leachate treatment), trucked away and treated at an off-site facility, diverted into the sewage collection system, or recycled back through the landfill before treatment. Golder Associates' preliminary summary of borehole testing is included in Appendix F.

**SECTION 7.0**  
**LANDFILL GAS**



## SECTION 7.0 LANDFILL GAS

### 7.1 INTRODUCTION

As the organic waste undergoes decomposition, a gas consisting of approximately 50% methane (CH<sub>4</sub>) and 50% carbon dioxide (CO<sub>2</sub>) and other trace compounds is generated (Table 7-1). Initially, while conditions are still aerobic, the fraction of carbon dioxide is greater, but as the landfill ages, and the oxygen is depleted, anaerobic processes create more and more methane. The gas permeates through the landfill cover and is eventually released to the atmosphere. It can also migrate laterally. Gas generation depends on the quantity and type of waste landfilled, the proportion of biodegradable material, and the local climatic conditions.

The main hazard associated with landfill gas is its explosive potential; methane is explosive at concentrations between 5 and 15 percent. In addition, it contains many toxic trace constituents (Table 7-2) which may present some hazard to health. The amounts of these compounds in landfill gas are not generally harmful in the low concentrations and short exposure times that most persons encounter them, longer exposure times could be a health risk, although there is no conclusive evidence of this.

Another concern is methane's role in global warming. Over the past several years, methane has been extensively studied in this regard and has been identified as a major agent in the "Greenhouse Effect". One methane molecule is about 20 times as effective in radiative forcing as a molecule of carbon dioxide.

Other effects are related to methane. These include a possible increases in atmospheric hydrocarbons, sulphur dioxide, methyl chloride, and ammonia due to reaction with free hydroxyl radicals, increases in tropospheric water vapour which further enhance the greenhouse effect, and increases in tropospheric ozone.

Landfills are thought to be a major source of human-produced methane, estimated to account for between 7 and 20% of the total global anthropogenic methane emission.

**Table 7-1. MAJOR COMPONENTS OF LANDFILL GAS**

Constituent	Fraction(%)
Methane	55.0
Carbon Dioxide	40.0
Nitrogen	4.9
Oxygen	0.1

**Table 7-2 TRACE COMPONENTS OF LANDFILL GAS**

Acetone	Ethylbenzene
Benzene	Ethyl Dibromide
Benzyl Chloride	Ethyleneimine
Butanone-2	Ethyl Toluene-4
Carbon Tetrachloride	Freon-114
Chlorobenzene	Hexanone-2
Chloroethane	Methyl Mercaptan
Chloroform	Methylene Chloride
Dichlorobenzene-1,4	Methyl-2-Pentanone-4
Dichloroethane-1,1	Toluene
Dichloroethane-1,2	Trichloroethane-1,1,1
Dichloroethene-1,1	Trichloroethene
Dimethyl Disulphide	Trimethylbenzene-1,2,4
Dimethyl Sulphide	Vinyl Chloride
Dioxane-1,4	Xylenes

## 7.2 ESTIMATION OF LANDFILL GAS QUANTITY

The quantity of landfill gas produced in a given landfill varies greatly depending on a large number of factors, the most important of which are:

- type of waste;
- moisture content;
- pH of waste and leachate;
- type and porosity of capping material;
- temperature;
- barometric pressure changes.

Predicting the quantity of landfill gas and the concentrations of its constituents is not an exact science. A number of models have been developed, the best known of which are the Palos Verdes, the Sheldon-Arleta, and the Scholl Canyon models. A major drawback of these models is that they were developed on the characteristics of landfills in regions with significantly different climates than British Columbia. While the Scholl Canyon model was developed for determining gas quantities produced in Canadian landfills, it has been found to overestimate the rate at which landfill gas production decreases over time.

The model to be used on this project will be one developed by E.H. Hanson & Associates, who have extensive experience with British Columbia landfills. This model uses the quantity of municipal refuse placed each year and determines the rise and decline of gas generation for each subsequent year. The model employs experience to determine peak methane generation, a steady state condition, and then a decline over a period of twenty years. The gas generation rates are then combined into a mass curve to determine total gas generation in a given year. If future refuse placement predictions can be made, long range gas generation forecasts can be made. The model gives a reasonably conservative estimate of methane generation. Special factors such as type of waste, moisture content, and the like can be accounted for by modifying the peak generation quantity.

### **7.3 TESTING LANDFILL GAS**

There are a number of methods available to test for the presence and quantity of landfill gas, as well as the zones of migration. They include:

- rod probing;
- extraction testing.

Rod probing involves driving a slim rod up to three feet into the fill with a slide hammer. The rod is then removed and a subsurface sample of gas is extracted and tested. Rod probes are a cost-effective method of establishing the presence of methane in soil, and are instrumental in detecting burial zones and confirming the presence of old landfills in cases where records are unavailable.

Extraction testing involves the withdrawal of gas from slotted wells by vacuum. This provides data not obtainable through rod probes and static testing alone. Figure 7.1 shows a typical gas testing well. Like static testing extraction testing gives information on the gas contents at any time, but also provides data on the rate of gas production and its migration potential. Extraction tests are performed to estimate the relative porosity of the fill and the approximate steady state gas production in the vicinity of the well.

As the test begins, the immediate contents of the well are withdrawn and the gases in the vicinity of the well are tested. Within the first minute, the initial samples are tested and recorded along with flow rates and suction pressure. As the extraction proceeds, the contents of the gas usually varies; generally, the methane percentage slowly drops until a stable withdrawal rate and methane content are reached. This may occur within a few hours and represents a short term balance between air intrusion and void space storage. As the extraction continues, the methane content may continue to recede until a new stable rate is attained. This value, combined with the radius of influence of the well, allows calculation of the long term steady state production capability of the area. Extraction tests also provide information on any anomalies such as abnormally high or low generation rates.

The gas is analyzed either by portable instruments or, if a more accurate determination of its content is required, by a laboratory equipped with a gas chromatography machine.

#### **7.4 CONTROL**

Landfill gas can be controlled by:

- passive venting;
- active venting and flaring;
- active collection and burning to generate steam or electricity.

The first option is discouraged, because the methane and trace contaminants are not destroyed, and the third is preferable over the second, due to the savings on power bills. Venting is done by installing vents made of materials (such as gravel) that are more permeable than the surrounding soil. Passive vents allow the gas to escape

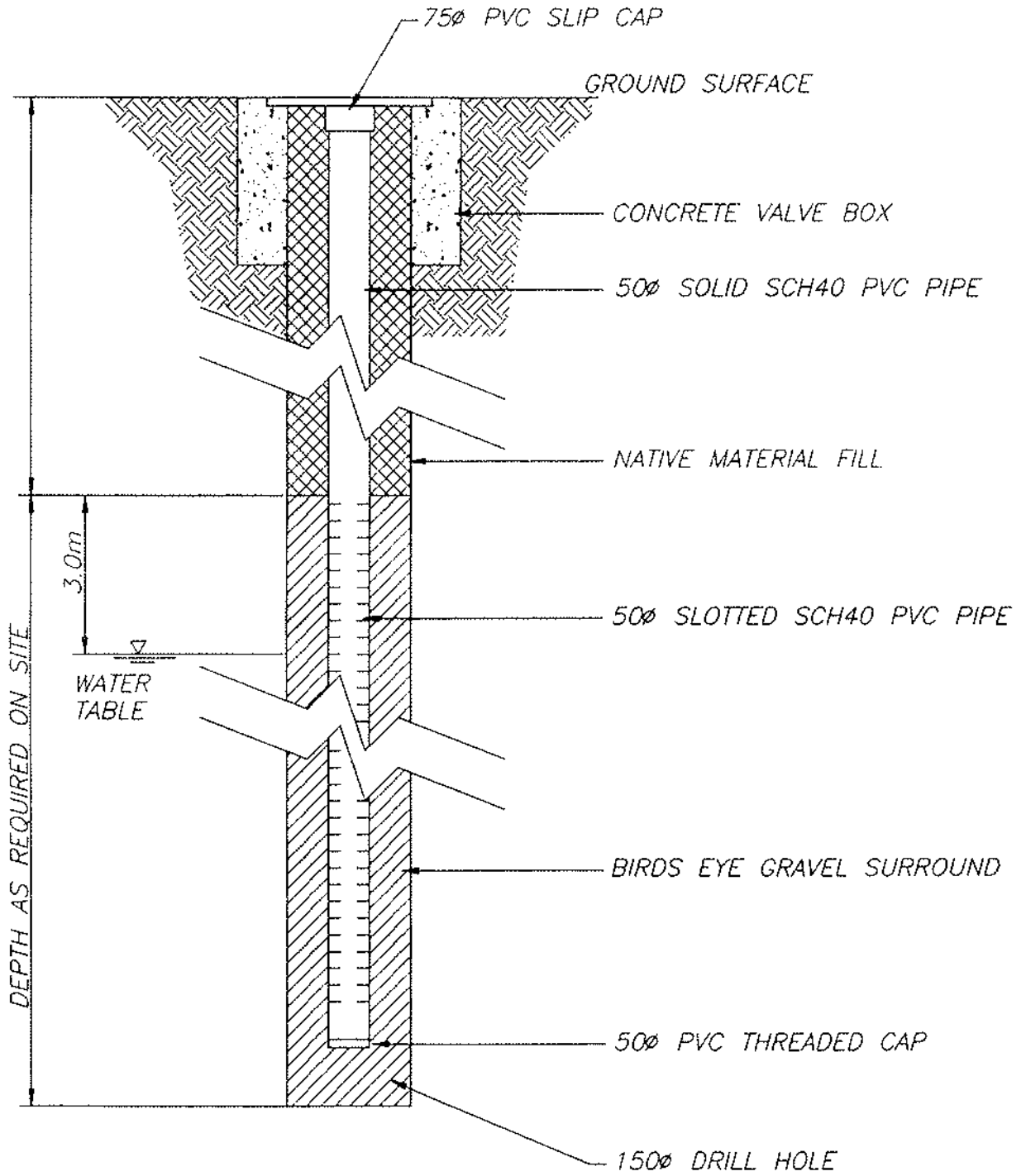
naturally, whereas active venting involves the use of blowers to apply a vacuum to extract the gas. Typical vents used to control the lateral movement of gases are shown in Figure 7.2. The gas would then be blown into a flare and burned. As long as the flare burns at a sufficiently hot temperature, most of the methane and toxic trace compounds will be destroyed. A typical burner is shown in Figure 7.3.

Such a system is not always completely successful at halting migration of gas off the site. In such cases, air barriers are used. An air barrier consists of a row of wells along the landfill boundary, preferably outside the refuse, into which air is blown. The air pressure in the soil stops the progress of any migrating gases.

With proper venting, methane is easily controlled. Carbon dioxide, however, has a density about 2.8 times that of methane and 1.5 times that of air, and tends to remain concentrated in the lower zones of the landfill. If it reaches the groundwater, it combines with the water to form carbonic acid, lowering the pH. Control of the downward movement of dense gases can be accomplished by perforated pipes installed in a gravel layer at the bottom of the landfill. The gas then vents laterally or through a vertical well.

The impacts of landfill gas are evaluated on a site-specific basis to decide on the appropriate measures. A landfill gas assessment was carried out at Westside Landfill and the report is presented in Appendix K.

FIGURE 7.1  
TYPICAL WELL  
NTS



NOTE: 3.0m OF SLOTTED  
PIPE MUST EXTEND  
ABOVE THE WATER  
TABLE FOR GAS  
SAMPLING.

FIGURE 7.2  
VENTS  
NTS

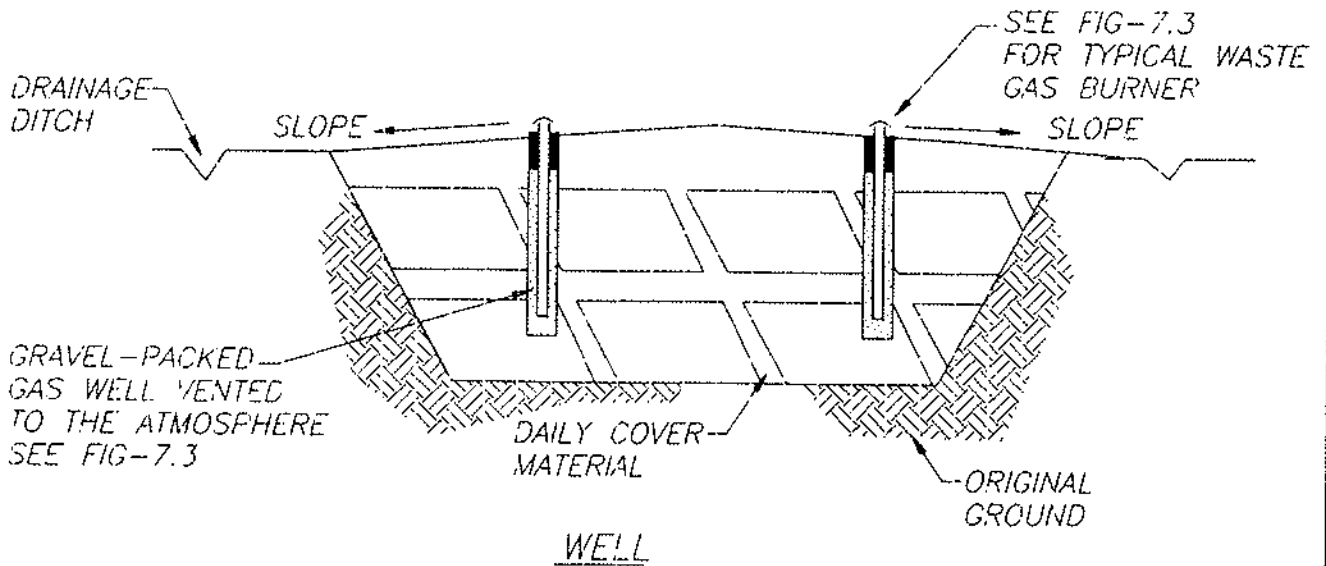
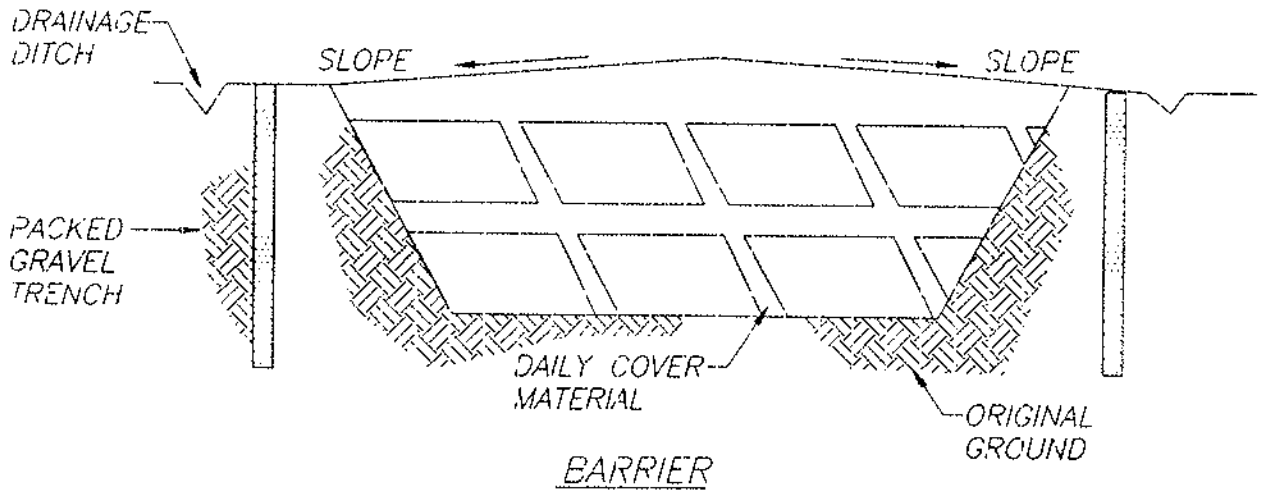
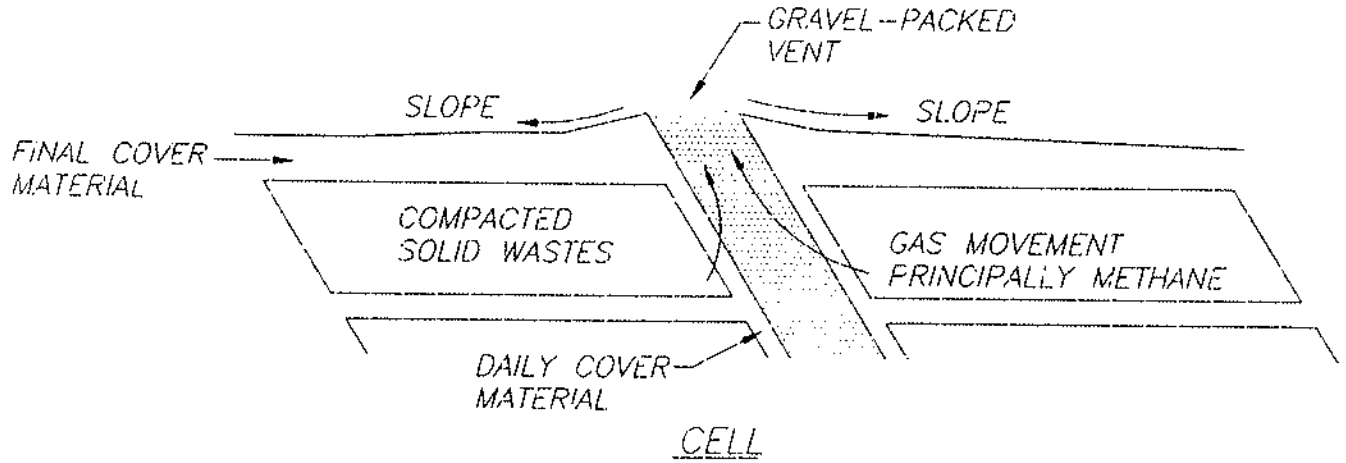
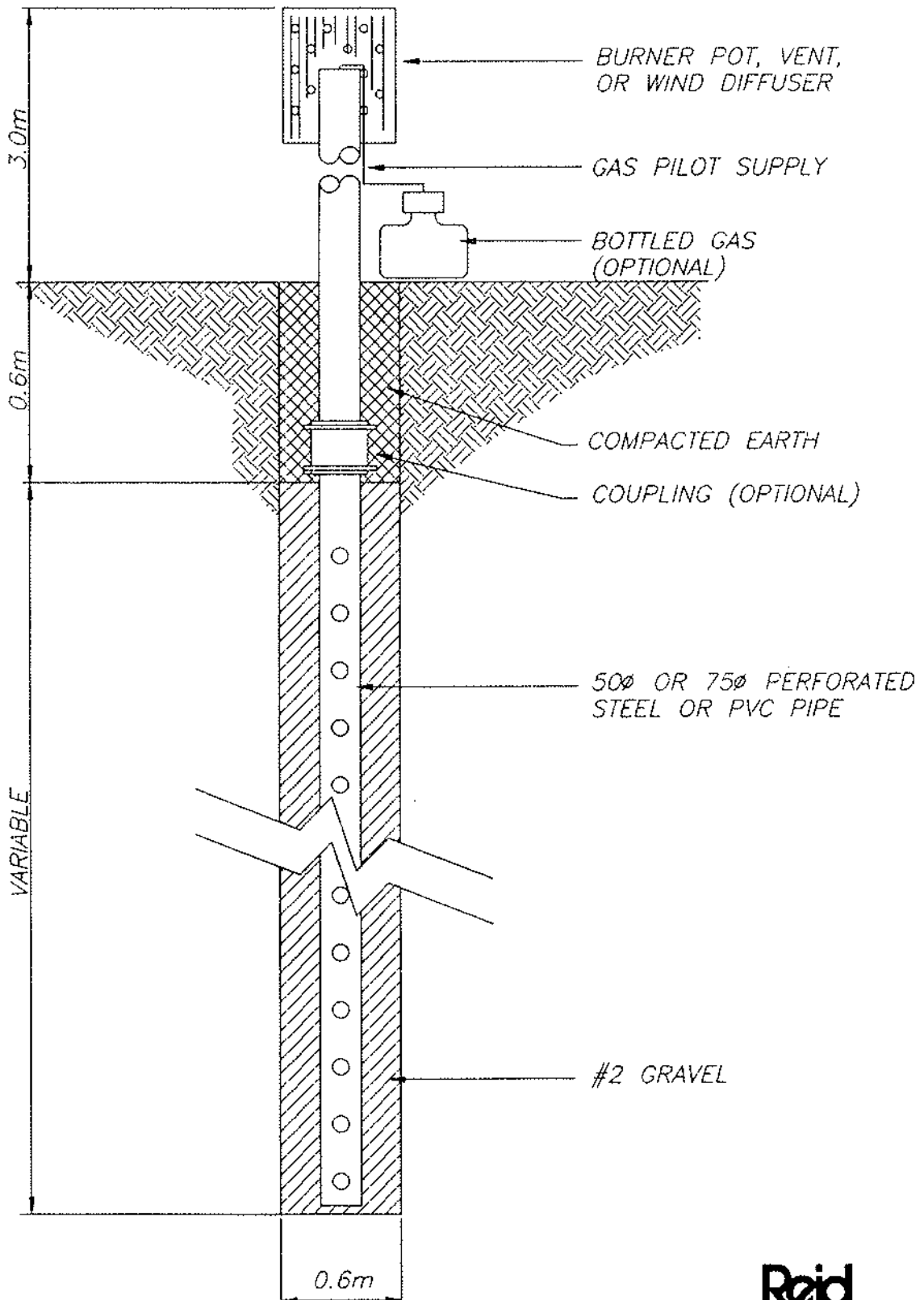


FIGURE 7.3  
WELLTYPE WASTE GAS BURNER  
NTS



**SECTION 8.0**  
**DETAILED DESIGN**



## SECTION 8.0 DETAILED DESIGN

### 8.1 EQUIPMENT

Two essential pieces of equipment for landfill operation are a compactor and a material mover to spread and compact waste, and to transport and place cover material. The cost of this equipment is the largest component of the cost of a landfilling operation.

#### 8.1.1 Compactor

Compaction can be performed by a specialized steel-wheeled compactor or a tracked crawler tractor.

Steel-wheeled compactors are able to achieve higher densities and therefore increase the weight capacity of a given site, however, they perform best on flat surfaces, and should never operate on a slope steeper than 4:1. As the Westside Landfill will be filled in ramps at a slope of 4:1, a steel-wheeled compactor will not be able to perform optimally at this site, and should not be considered.

A tracked crawler tractor is better suited to compacting on slopes up to 3:1. The D6 presently used is able to achieve densities on the order of 500kg/m<sup>3</sup> on which the life-expectancy calculations for this site were based (see Appendix G). A bulldozer is a versatile machine and will be more widely used at a relatively small operation like the Westside Landfill in secondary applications such as site-clearing and road building, in addition to its primary role in waste spreading and compacting.

A Caterpillar D6H WDA (Waste Disposal Application) tractor or equivalent should be used. The D6, weighing approximately 15,000kg, exerts sufficient pressure to achieve the desired density. WDA tractors are configured for landfill use, with elevated drive sprockets, trash blades, and debris shielding on the tanks, lights, etc.

The approximate purchase price of a D6H WDA is \$330,000, and that of a comparable compactor, the Caterpillar 936, is \$275,000.

### **8.1.2 Material Transport**

For transporting cover material from the stockpile or borrow area, a rubber tired front end loader is required. Over the next 5 years, requirement for cover is estimated at approximately 6000m<sup>3</sup>/yr or about 17m<sup>3</sup> per day. The present loader is a Caterpillar 966C with a bucket capacity of 3.1m<sup>3</sup>. The maximum recommended distance that a wheel loader should haul material is 185m, and as the cover material reserve is farther than this for much of the site, the advantage a large loader which can carry a larger quantity per trip is not as important. A smaller machine with a lower capital and operating cost can load a dump truck at the cover material source for transport to the working face very efficiently. A 1.0 to 1.5m<sup>3</sup> loader such as a Caterpillar 910E or 916 can handle an estimated average of 109m<sup>3</sup> to 180m<sup>3</sup> per hour, which is more than adequate at this site.

The approximate purchase prices of a 910E and a 916 loader are \$100,000 and \$112,000 respectively. The purchase price of a new 950F (equivalent to the old 966C) is about \$210,000.

### **8.1.3 Dump Truck**

A dump truck is required to move cover material from the stockpile or borrow area to the working face. A 4m<sup>3</sup> capacity single-axle truck would be adequate. The cost would be about \$40,000.

### **8.1.4 Other Equipment**

Equipment for specialized or rarely performed duties (road building, trench digging, drilling etc) can be rented when needed. This equipment may include road graders, backhoes, and the like.

### **8.1.5 Ownership and Operating Costs**

The decision whether to purchase and operate the equipment or whether to contract the operation should be based on the estimated hourly cost of the landfill equipment. An estimate table provided in the Caterpillar Performance Handbook returned values of \$90/hr for the D6H and \$44/hr for the 916 including wages for two operators (see Appendix H). The cost of the dumptruck would be about

\$10/hr. The dumptruck could be operated by the loader operator, so wages are not included in this figure.

The above costs assume a worst case in which the residual value of the equipment is depreciated to zero. If the machines could be sold for 50% of their new price at the end of the ownership period, the costs would fall to \$74/hr and \$38/hr (including operators) for the D6 and 916 respectively. Table 8-1 illustrates costs depending on three resale conditions: zero, 25, and 50 percent residual value.

**TABLE 8-1  
EQUIPMENT OWNING AND OPERATING COSTS**

Machine	Delivered Price	Residual Value	Hourly Cost
916 Loader	112,000	0	44
		28,000	41
		56,000	38
D6H Tractor	330,000	0	90
		82,500	82
		165,000	73

Note: all units in 1993 dollars.

## 8.2 STAFF

The following would be an minimum staff: manager, gate attendant, spotter, dozer operator, and loader operator.

The Manager would be responsible for assuring that plans and specifications are adhered to, security of the site, safety of users and employees, preparation and administration of budgets, preparation of reports, regulatory compliance, dealing with the public, and making decisions pertaining to operation, employees, scheduling, and the like. Salary including benefits would be about \$50,000/yr.

The Gate Attendant operates the scales and keeps related records, inspects loads, directs vehicles to pertinent areas. Salary including benefits would be about \$36,000/yr.

The Spotter would control traffic at the face in order to keep dumping within the area defined as the active face, clean up litter, and do relief work where necessary. Salary including benefits would be about \$32,000/yr.

The Bulldozer Operator would be responsible for spreading and compacting the waste and cover, and miscellaneous sitework such as road, berm, and ditch construction. Salary, including benefits would be about \$40,000/yr.

The Loader Operator would be responsible for excavating and loading cover material, and hauling it to the active face. Salary including benefits would be about \$40,000/yr.

In addition, provision should be made for part-time relief workers, say two workers half time at \$16,000/yr each.

The total salary for the above would be approximately \$150,000 per annum (Equipment operators' wages have been included in equipment operating costs).

If an internal transfer station is incorporated into the operation (see below), an additional employee would be required.

### **8.3 FILLING PROCEDURE**

As outlined in Section 5.0, the operation can continue with present practice until a relatively flat base at an approximate elevation of 545m is reached. A berm should be built to an adequate height along the southern edge and filling against this berm should proceed from this end of the site in a generally northerly direction.

Waste should be deposited at the base of the berm, or previous cell, and pushed up the slope. Downhill spreading of waste should not be practiced, as the tractor may lose stability. The waste should be spread to a depth of no more than 600mm and compacted. Three to five passes over the waste will achieve the level of compaction required. More than five passes give little increase in compaction. The cell should be at least three times the width of the compactor, or 6m wide, to allow full coverage of the waste by its tracks.

#### **8.4 DAILY COVER**

There is no particular specification for daily cover in terms of permeability, etc, as its purpose is a temporary barrier to wind, erosion, and vectors. In order to conserve cover material and stretch projected reserves to their maximum, it should be specified that cover be comprised of a 30:70 wood waste to earth ratio.

Daily cover should be applied to the face at the end of each day to a depth of 150mm. If the area is to remain inactive for more than thirty days, an additional 150mm of cover should be applied.

Initial estimates show adequate reserves of cover material on the site, therefore the cost of excavating material and disposing (using) it on site is included in the operating cost of the equipment.

#### **8.5 FINAL COVER**

Final cover should meet certain requirements for permeability, moisture content, size gradation, and vegetation. These will be addressed in the closure plan (Stage 5).

#### **8.6 ACCESS ROAD**

There are four proposed road alignments to serve the second phase of the landfill operation (see Figure 8.1). Option A, along the east side of the site, allows a gentler grade of about 5% over the entire length as well as a smoother traffic flow from the entrance. The disadvantages are, however, its length (over 550m) and that it follows a route along the developed eastern boundary of the site. This could lead to neighbouring residents being exposed to more traffic noise.

The other options follow a route along the western side of the site. This route is shorter at between 250m and 450m, depending on the grade, but would be steeper than 5%. An attractive aspect of this alignment is its relative remoteness from the neighbouring developments, thereby having less likelihood of noise complaints. A right angle turn would be required from the existing access road about 25 m past the gate house, and the first 50m or so would be graded at about 10%. A further obstacle is a small hill about 100m long rising to an elevation of about 542m.

Approximately 650m<sup>3</sup> of material would have to be excavated from this outcrop to allow the road to pass through. Testwork should be undertaken to determine the geology of this outcrop.

Provision should be made during operation of the landfill to place satisfactory material such as fill and demolition waste under the areas where the road is to be built. The road should be 7-8m wide to allow two lanes of traffic, and graded to allow passenger vehicle access. Speed limits should be set at 15km/h to reduce dust.

For comparison purposes, the cost of road construction with 300mm of pit run and 150mm of crushed gravel, and 8m wide is assumed to be on the order of \$55,000 per kilometre, although the actual cost may be less through use of suitable material found on-site. Excavation and on-site disposal of rock would cost on the order of \$10 to \$20 per cubic metre assuming the worst case and the abovementioned outcrop is comprised of rock and has to be blasted.

Using an average excavation cost of \$15/m<sup>3</sup> and \$55,000/km the road costs for the various options are as follows.

- Road along eastern boundary, 5% grade, no excavation required, length 550m: \$30,000;
- Road along western boundary, 5% grade, excavation required, length 450m: \$35,000;
- Road along western boundary, 7.5% grade, excavation required, length 350m: \$30,000;
- Road along western boundary, 5% grade, excavation required, length 250m: \$24,000.

It is recommended that the third option be followed, as traffic is kept to the areas remotest from neighbouring residents, filling is done from the windward side of the site, and the length and grade are not excessive.

It should be noted that the road will be built in stages of 50m to 100m at a time as each level of cells is completed, so the aforementioned costs will not be incurred as a lump sum.

## **8.7 INTERNAL TRANSFER**

Decreasing the traffic at the working face would improve control of waste placement and result in more efficient use of cover and equipment. Traffic reduction could be realized by providing a transfer station for the private vehicles trucks that bring in small quantities of waste. From Table 2-3 and Section 2.3.3, private vehicles bring in approximately 4500 tonnes per year, or 13 tonnes per day. At  $250 \text{ kg/m}^3$ , this translates to about  $50\text{m}^3/\text{day}$  on average. Two  $30\text{m}^3$  bins would be needed to allow unloading to continue while one is emptied at the working face.

The bin would be located with its top flush with the area on which the vehicles would back up to unload. There would be room for two vehicles to unload simultaneously, and space provided for additional vehicles to wait. The bin would sit on a concrete pad against a retaining wall. This facility could be located in the area near the present appliance stockpile.

The cost of the facility is estimated to be about \$64,000. The cost of a truck to haul the bins would be about \$90,000.

## **8.8 ENVIRONMENTAL CONCERNS**

The major concerns are drainage, leachate migration, and gas generation. Recommendations as to specific programs to monitor these parameters have to await the completion of the hydrogeological study and receipt of the final report on the gas conditions. Monitoring programs are included in Sections 9.0 and 11.0.

### **8.8.1 Drainage**

Drainage ditches as described in Section 5.8 would be placed along the western and northern edges of the site. The northern ditch would be about 350m in length, and the western ditch about 450m in length. A culvert to cross Asquith Road would be required.

A ditch with a bottom width of 1.5m and 3:1 side slopes would cost on the order of \$15/m. Total excavation cost would be approximately \$12,000. In areas where the slope exceeds 5%, erosion protection should be provided. An estimated 200m of the ditch may require this protection. At a cost of  $\$18/\text{m}^2$ , and about  $7\text{m}^2$  per

lineal metre of ditch, approximately 1400m<sup>2</sup> of riprap would be needed, at a cost of \$25,000.

A 450mm concrete culvert would cost \$90/m to supply and install. Approximately 10m would be required, for a total of \$900. Repaving the road would cost \$400-500.

### **8.8.2 Leachate**

Preliminary investigation has found very little leachate is likely being generated. A sample was taken from one borehole (BH1) and analysed. Table 8-2 presents some of the results and compares the values to the Drinking Water Standard and to typical leachate values found in literature. The complete results are included as Appendix I.

Three options for the collection and treatment of leachate have been examined. Until the detailed hydrogeological investigation is carried out, no specific recommendations can be made. Volume, flow direction, and other characteristics of the leachate will be determined during the hydrogeological study. The Proposal for this study is included as Appendix J.

A typical leachate collection system would consist of a perforated pipe laid in a trench filled with drain rock and lined with a geotextile to screen out fines (Figure 8.2 shows a typical section) to collect the leachate and convey it to a common low point. Depending on the volume and flow regime, the trench would extend along either the south side along Asquith Road, the east along Shannon Lake Road, or both.

**TABLE 8-2  
LEACHATE ANALYSIS**

Parameter	Measured Level	Drinking Water	Typical Leachate
Barium	0.18	1.0	
Calcium	300	200	1000
Copper	0.014	1.0	
Iron	21.2	0.3	60
Potassium	6.2		300
Magnesium	165	150	250
Manganese	8.6	0.05	
Sodium	110	200	500
Lead	0.032	0.01	
Chloride	315	250	500
Ammonia Nitrogen	1.6		200
Total Phosphorus	1.15		30
pH	7.0	6.5-8.5	6
Alkalinity	1440		3000
Colour	45	15	
Dissolved Solids	2110	500	
COD	337		18000
BOD	36		10000
Total Hardness	1430	500	3500
Phenol	0.16	0.002	

Note: all units in mg/L except colour and pH. See Appendix I for details.

From the low point, the leachate could be either discharged directly to the sewer, depending on the treatment plant's capability to handle the load and volume. There is a manhole MH20 at the intersection of Asquith and Shannon Lake Roads which would be a suitable tie in-point.

If direct discharge to sewer is not permitted, the leachate can either be treated by a package plant, or simply recycled back through the landfill. A pump would be required in either case. The package plant could, for example, consist of a rotating biological contactor located within the property limits of the site. The effluent from this facility could then be discharged to the sewer, again to the manhole at Asquith and Shannon Lake Roads.

Recycling the leachate would involve pumping to a holding tank, tanker truck, or sprinkler system and applying it directly to the landfill surface. This could be a supplemental dust control system on the roads, or used to wet down the active face to control windblown litter.

Again, the specific details of the leachate collection and treatment will have to await results of the second stage of the hydrogeological study.

### 8.8.3 Gas

Preliminary measurements carried out by E.H.Hanson and Associates to determine gas emissions from the three boreholes BH1, BH2, and BH3, showed negligible quantities. The report is included in Appendix K, and it appears at this stage that gas will not be a major concern, however, the site should continue to be monitored.

While the landfill is operating, it is recommended that three or four wells be drilled in the refuse itself for the purpose of monitoring gas production on a seasonal basis. Using a portable gas detector, landfill staff would go out four times per year and measure the methane level in each well. The recommended gas monitor is a Scott D-15 methane/natural gas detector, which costs about \$850. Two standard gas cylinders (2.5% methane and 55% methane) necessary to calibrate the detector would cost about \$300 each, and regulators \$400 each. Initial capital outlay is thus about \$2500, with \$600 every three years to replace the cylinders.

Figure 8.3 shows a conceptual plan for a gas collection system, should one prove necessary. Extraction wells placed on a 30-40m grid connect to headers which conduct the gas to a flare for burning (direct venting to the atmosphere is recommended against in the Landfill Guidelines). The flare would be located where there is easy vehicle and electrical supply access, good visibility of the flare stack, and easy connection to the collection system. The system would consist of approximately 2000m of pipe and 53 extraction wells. In addition, ten to twelve monitoring wells evenly spaced around the perimeter would be required to measure off-site migration.

The cost of design, installation, and start-up of such a collection system would be approximately \$6500 per well. The concept presented has 53 wells, and would therefore cost about \$350,000.

These collection systems are typically installed after closure of the site. Depending on how bad the odour or gas emissions are, nothing may have to be done during the operating life of the site. The wells could be installed as each area is completed (in the case of this fill progression, from the outside in). If gas problems occur during operation, the wells could be installed and then covered or extended as subsequent

lifts are deposited on top of them. If the wells are covered, new wells would have to be installed, and if they are extended, there is a risk of losing or breaking them during subsequent filling operations. A third option would be to install horizontal collectors as the refuse is being deposited, but the effectiveness of such a system is not as high, and potentially dangerous situations can occur due to excessive air being drawn into the system (subsurface fires, etc). The easiest and most effective way is to install the system post-closure.

Figure 8.1

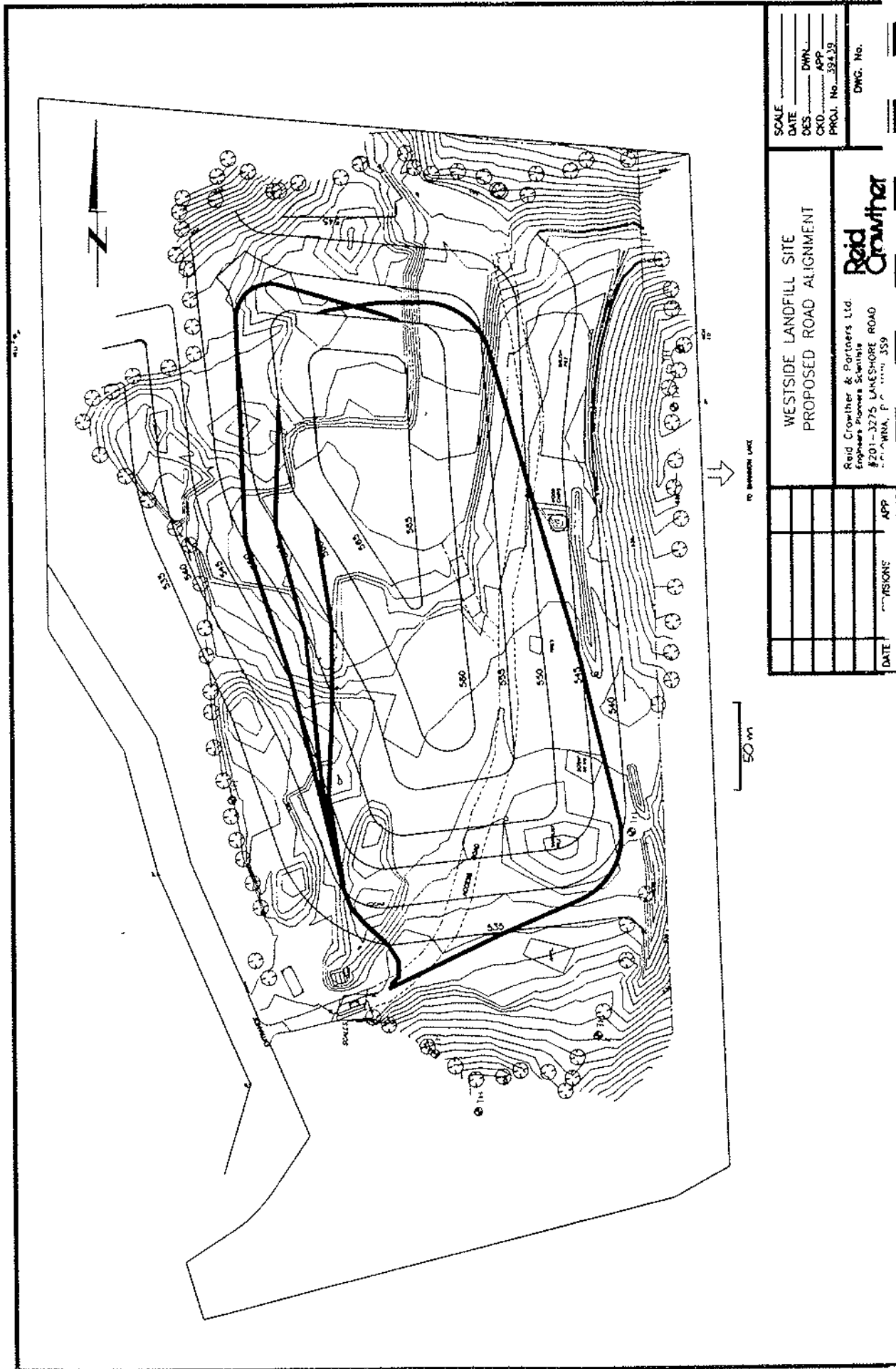
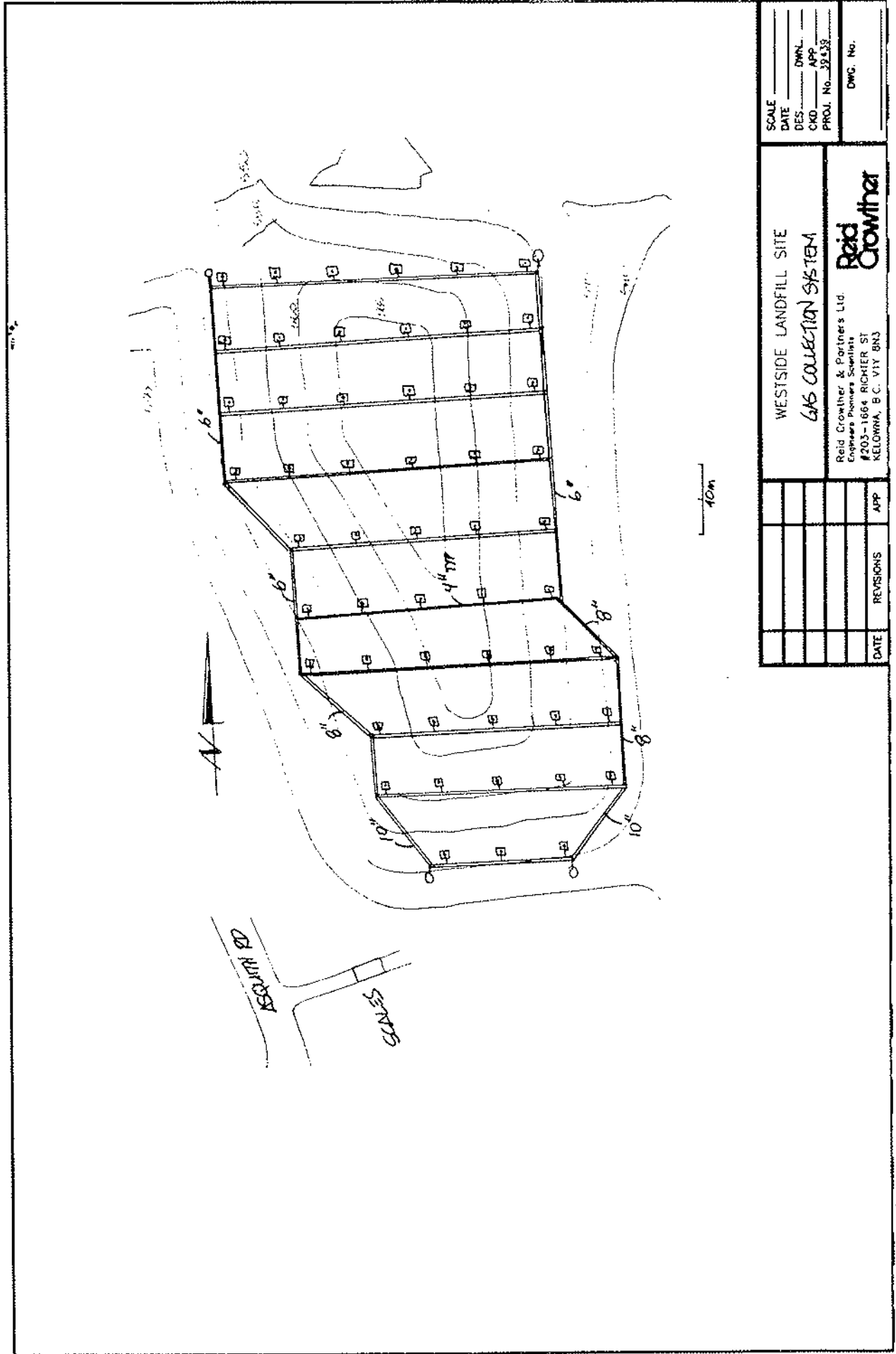




Figure 8.3



**SECTION 9.0**  
**OPERATIONS PLAN**



## SECTION 9.0 OPERATIONS PLAN

### 9.1 INTRODUCTION

This section outlines procedures to maximize site capacity, allow efficient use of cover material, maintain safe conditions and practices, and monitor environmental impacts.

The material in this section is also included in a separate volume entitled "Westside Landfill Operations Manual", which provides details of sampling procedures, etc.

### 9.2 WASTE CELL CONSTRUCTION

Waste should be deposited at the base of the face. The width of the cell should be three times the width of the dozer to allow complete compaction of the waste. For a Caterpillar D6 tractor, this would mean a cell width of about 6m. The dozer would spread the waste by pushing it up the face, and then compact it by making a minimum of three passes over the entire surface of the cell. No more than five passes should be made, as generally there is no increased compaction with this equipment.

To assess the effectiveness of compaction, the density of the landfilled waste should be measured. Every one or two months, the in-situ density should be estimated by excavating and weighing a measured volume of waste from a previous cell.

Given a cell width of 6m, length (up slope) of 12m and 47 tonnes per day (maximum projected mass in 2002) compacted to  $500\text{kg/m}^3$ , the depth of each cell would be about 1.3m, or two 0.6m layers of compacted waste.

Cells should be sequenced such that subsequent waste placement takes place within 30 days, thereby minimizing intermediate cover requirements. This involves placing less than 30 cells side-by-side before starting the next row, as described in Section 9.3.

While the northern half of the site is being filled, the stockpiles of separated materials (metals, wood, etc) will be placed at the southern end. As the lift approaches completion, these stockpiles moved to the next lift.

An area should be designated for the placement of waste during wet periods when access to the active area may not be possible.

The route that traffic takes from the permanent road to the working face should be varied to prevent one area from becoming more compacted than surrounding areas, to decrease the probability of differential settling.

### **9.3 FILL PROGRESSION**

As each lift is started, a berm should be constructed against which filling can proceed. The berm should be 3 to 3.3m high and 24m wide at the base to provide a ramp slope of 4:1. The berm can be constructed of waste.

Appendix L shows the progression of fill. The berm should be constructed along the eastern limit of the fill area. Waste is then placed along the berm from north to south for about 100m; upon reaching the end (Cell 16), cell 17 is to be placed on top of cell 1, cell 18 on cell 2 until reaching cell 32. The process is repeated until the western limit of the fill area is reached. In this way, no cell remains exposed (except at the top) for more than 30 days, thus reducing intermediate cover requirements.

In addition to providing a surface against which waste can be placed, the berm provides a visual and sound barrier to the neighbouring residences.

### **9.4 DAILY AND INTERMEDIATE COVER**

Regulations state that landfilled waste be covered at the end of each day's operation. The primary functions of daily cover are to reduce odours, fire risk, litter, and unsightliness. 150mm (6 in) of compacted soil will meet these requirements. Intermediate cover is added to areas which will be left exposed for a longer period of time (30 days in BC) and is comprised of 300mm of compacted soil (including the daily cover). The primary function of intermediate cover is to provide additional resistance to moisture entering the fill.

During the first phase (the placement of waste up to elevation 545m), any reserves of cover material within the boundary of the ultimate fill footprint should be identified and excavated prior to waste deposition, and stockpiled for later use. Any terms of reference for further hydrogeological work could include delineating areas of such material. Once the second Stage (placement of waste above 545m) begins, other sources of cover material will have to be used.

There are two reserves of cover material within the boundary of the landfill site, but outside the the fill area. Initial estimates of the available quantity of material run as high as 150,000m<sup>3</sup>, which, if accurate, is adequate to serve up to the projected closure date of the site (see Section 5.0). Augmenting the cover with wood waste will decrease the quantity of this cover material required.

Based on projections for the next ten years, approximately 15m<sup>3</sup> to 19m<sup>3</sup> of cover material will need to be placed each day of operation. A large quantity of the material should be excavated (one or two week's worth for example), and moved to the vicinity of the working face. Cover would then be placed at the toe of the cell by the loader and spread by the dozer. In this manner long distance hauls from the source need only be undertaken once or twice a month. The dozer operator will drive the dump truck during the stockpiling operation.

A large stockpile should be prepared prior to winter to eliminate the need to excavate in frozen ground.

## **9.5 FINAL COVER**

Final cover should be placed on the outside slope of the landfill while other areas are being filled. This allows the cost and effort involved in placing final cover to be spread out over time. Aspects of the final cover are presented in Section 11.0.

## **9.6 PROHIBITED WASTES**

There are certain materials which are not to be co-disposed of with municipal solid waste. These are:

- Bulk liquids and semi-solid sludges which contain free liquid;

- Liquid or semi-solid wastes, such as septage, sewage treatment sludge, and the like;
- Automobiles, white goods , other large metallic objects, and tires, where other options for the handling of such wastes are available or feasible;
- Biomedical wastes;
- Dead animals, or slaughter house, fish hatchery, farming, and cannery wastes and byproducts; and
- Special wastes as defined in the Special Waste Regulation.

In the absence of any alternative, the landfilling of these wastes may be approved provided they are buried in dedicated locations, thus avoiding co-disposal. In this event, the specific location shall be surveyed and recorded in case corrective or further action pertaining to the management of these wastes is warranted in the future. Automobiles, white goods, and other large metallic objects can be stockpiled at the site, awaiting ultimate disposal for their salvage value as scrap metal.

An exception to the Special Waste prohibition exists for asbestos, waste oil, and pest control product wastes and containers. Asbestos may be landfilled provided it is properly handled, packaged or otherwise contained, and immediately covered with 500mm of cover. Waste oil may be used in road construction or repair, dust suppression, or fuel, provided it meets certain specifications. Pest control product containers may be landfilled provided they are properly cleaned prior to disposal. The details pertaining to the above exceptions are included as Appendix M.

All staff should be aware of and trained to spot suspicious wastes which may be hazardous or prohibited. Some indications to watch for are:

- hazardous placards or markings;
- liquids;
- powders and dusts;

- sludges;
- bright or unusual colours;
- drums or commercial sized containers;
- chemical odours.

If any suspicions arise the following actions must be taken when possible:

- use protective equipment;
- question driver and/or source;
- review manifest if available;
- segregate the waste in question.

It is then the responsibility of the manager to contact the appropriate agency(s) and determine what action needs to be taken.

## **9.7 ON-SITE TRANSFER STATION**

An on-site transfer station for loads brought in by cars and small trucks would decrease on-site traffic and allow better control of waste placement at the face, resulting in more efficient compaction and use of cover material.

The transfer station should be located close to the gates and have sufficient capacity so that only needs to be emptied once per day. As described in Section 8.0, two 30m<sup>3</sup> bins should accommodate one day's capacity, on average.

The handling of the bins should be contracted out; the purchase and maintenance of a large truck specifically to move two bins once per day would not be economical. A waste handling contractor would come on to the site once per day, move the bins up to the face and dump them, and return them to the station. The site dump truck could also be modified to handle the bins.

In the event of a higher than average influx of small loads which fill the bins before their scheduled dumping, it would be permissible to allow these vehicles to the face.

## **9.8 WASTE SEGREGATION**

Several types of waste will be segregated at the landfill for the purpose of recycling or to meet specific landfilling requirements. Metals, white goods and perhaps other materials will be separated and stored in designated areas for recycling, either in existing recycling programs, for which the landfill can serve as a depot, or available for removal by individuals, organizations, or businesses who can find use for this material. These stockpiles should be kept as remote as possible from the active area so as not to interfere with normal operations.

Wood and construction debris will be used as cover and berm/road material respectively. It is recommended a chipper be purchased for reducing wood wastes to chips suitable for use as daily and intermediate cover. The area designated for the wood waste should be near the cover stockpile, and have reserve space so that other suitable cover materials that may be brought to the site, such as excavated soil from construction projects, can be stockpiled there also.

The recycling depot at the entrance to the landfill should remain.

## **9.9 SAFETY**

All workers shall conduct themselves according to the rules set out in the Workers' Compensation Board's Industrial Health and Safety Regulations. A copy of these regulations should be kept on the site.

As the landfill will have less than twenty employees, a formalized safety program may not be required (IH&S Regs, Section 4.02). However, informal regular (monthly) meetings to discuss health and safety matters should be held. The purpose of such meetings will be to correct unsafe conditions and maintain awareness and interest in safety among the staff. Records of the meetings should be kept. The program should be coordinated between Regional District and the Contractor's employees.

## **9.10 LANDFILL GAS MONITORING**

A gas monitoring program should be implemented as outlined in the report prepared by E.H. Hanson and Associates, i.e., three wells should be placed in the body of

the refuse itself and checked three or four times per year for gas levels. In this way, the effect of changing conditions and increased age of the waste can be assessed. If this program finds an increase in gas production, then plans for a collection and management system will be considered.

Monitoring can be performed by landfill or Regional District staff, or an independent consultant. If the Regional District elects to do it, a portable gas detector with attached probe and two cylinders of standard gas for calibration will be required. A gas sampling procedure is described in the "Operations Manual".

## **9.11 GROUNDWATER MONITORING**

The purpose of groundwater monitoring is to detect effects of leachate migrating from the landfill through sampling and analysis of groundwater both on and off the site. The sampling should be performed at least once per month.

Although this work could be performed by landfill staff, it may be more efficient and economical to have the sampling contracted out to the analytical laboratory or other specialist.

If the sampling is undertaken by landfill staff, a procedure is included in the "Operations Manual".

## **9.12 CONTROL STRATEGIES**

### **9.12.1 Odour Control**

Odour is to be primarily controlled by daily cover. The landfill should publish information that any waste likely to produce offensive or strong odours should be securely double-bagged or otherwise contained prior to being brought to the site. However, if uncontained odourous material is received, it should be covered immediately with 150mm of cover material.

### **9.12.2 Noise Control**

The tree buffer and berm constructed along the eastern edge of the site will reduce noise levels in the adjacent residential areas. Signs should be posted at the active area stating that vehicles should not idle their motors while waiting. Noise levels

should be measured at the boundaries of the site to document compliance with any noise guidelines or regulations. The hours of operation should be restricted to between 9 AM and 4 PM.

### **9.12.3 Litter Control**

Litter is controlled by compacting the waste, minimizing the working area, and applying cover at appropriate intervals. Portable litter fencing should be placed in the vicinity of the working face. Incoming loads should be properly covered (ie under a tarpaulin or bagged), and if not, a penalty in the form of an increased tipping fee should be imposed. A regular (frequency determined by wind conditions, amount of waste susceptible to producing litter, etc.) cleanup of litter over the entire site should be made. With the introduction of a paper ban, the potential for windblown litter should diminish.

### **9.12.4 Dust Control**

Dust is caused by traffic, earth moving, dumping activities, and wind. Dust can be mitigated by paving roads, wetting roads, strictly enforced speed limits, timing earth moving activities to minimize impacts (ie during times of relatively calm conditions), and use of cover and vegetation. Paving the road would be expensive and is not recommended, nor is wetting the road recommended because of the desire to keep water out of the fill. Speed limits and reducing activity during winds should adequately control dust.

### **9.12.5 Vector And Wildlife Control**

Municipal solid waste is a source of food which attracts animals and insects, many of which animals act as vectors through which diseases can be transmitted. Other animals such as birds create a nuisance, and yet others, bears in particular, present a safety hazard.

Keeping the active area relatively small and properly covered will help deter rats, gulls, and insects. Birds can be discouraged further by overhead wires and noisemakers, although overhead wires may complicate equipment operation and waste placement, and noisemakers would be unsuitable because of the proximity of residences.

If bears are found on the site, they should not be approached as their behaviour can be unpredictable. If it is necessary to remove a bear, the task should be handled by the local Conservation Officer Service (Kelowna telephone number 861-7670).

#### **9.12.6 Fire Control**

There are two types of fires which occur at landfills: surface and subsurface fires. Fires can be extinguished by removing combustible materials, and/or oxygen. In the case of surface fires, both of these are relatively easy to accomplish; however, in subsurface fires, combustible materials may not be easily removable and oxygen not readily eliminated or hindered, so are more difficult to control.

A major deficiency at the site is the lack of an adequate water supply; for this reason, measures must be taken to prevent fires from occurring. Adopting the following measures will minimize fire hazards:

- smoking will not be permitted at the working face.
- Open burning will not to be permitted. Controlled burning of wood residues (stumps, brush, wood chips, etc) will also forbidden as the landfill receives more than 10,000 tonnes of waste per year and is within 2 km of permanently occupied residences.
- Fire extinguishers should be placed in all structures and vehicles.
- Good waste compaction will be practiced to hinder oxygen transfer.
- Hot loads containing ashes or coal should be watched for, isolated, and extinguished. Metal containers should be provided near the entrance for these types of wastes.
- All waste will be covered on a daily basis; and
- The active area will be minimized.

Air can make its way below ground several ways: cracks in the cover, inadequate cover, wind impact, and atmospheric diffusion. Subsurface piping (a gas collection system, if present, for example) can crack and allow air into the surrounding fill. Active intrusion can occur by excessive gas extraction pulling air through the fill,

which, combined with the heat of decaying putrescent material, can lead to spontaneous combustion.

Underground fires can be prevented by eliminating or minimizing air intrusion into the fill. Good compaction minimizes air space, and a maintaining a sufficient thickness of cover and repairing it when necessary minimizes air transport into the waste. In addition, use of effective well-bore seals, and proper flow control through gas extraction systems if present, prevents air from being pulled below ground.

If a subsurface fire is suspected, local ground temperatures should be measured. A thermometer for this purpose should be kept on the site. The area of elevated temperature should be delineated and the surrounding area inspected for cracks, fissures, erosion, etc.

Elevated gas temperatures, along with evidence of soot and elevated carbon monoxide levels in any wells in the area may also indicate fire. Another indication may be smoke and/or vapours rising from the surface (best seen in the early morning). Extreme caution must be observed in the vicinity of a suspected subsurface fire, as the ground may subside or collapse. The area should be barricaded, equipment removed and kept away, and the fire department called.

If the fire is shallow, the area should be carefully excavated and the combustible material removed. When temperatures in the surrounding area have returned to background levels, the void should be backfilled with inert material and the cover restored. Ground temperature monitoring should continue to be monitored to ensure that the fire is indeed out.

In the case of deep fires (which cannot be easily excavated), restricting oxygen access is the only option. This is achieved by repairing cover, reducing well extraction rates in the vicinity (if applicable), filling in any subsidence. Ground temperature should be monitored to determine if the fire is diminishing. Only as a last resort should water be injected into the fire zone.

In the case of surface fires, the fire department should be summoned. In the case of small fires, landfill employees should attempt to put out the blaze with fire extinguishers, if it is considered safe to do so. The bulldozer or loader may also be used to dig out and/or cover the burning material.

An extinguished landfill fire should be monitored for several days after it has been put out in case it re-ignites.

If evacuation of the area is warranted, the RCMP should be called (Emergency telephone number 911, non-emergency telephone number 762-3300).

### **9.13 STAFF**

The following are responsibilities and duties which are important to an efficient landfilling operation. They are broken into job titles for convenience, but are not necessarily performed by separate people.

#### **Manager**

The Manager is responsible for:

- compliance with the Operating Certificate, operations plan, contingency plan, etc;
- direction and supervision of staff;
- liaison between the contractor and Regional District;
- Inspection, record-keeping, and reporting requirements; and
- Implementation of repairs, corrective actions, modifications, etc.

It is not necessary that the Manager be at the site full-time, but should visit every day and be readily available by telephone or pager should matters requiring his attention arise. It is expected a Regional District employee working as manager would devote at least one quarter time to the job.

#### **Gate Attendant**

The Gate Attendant screens incoming vehicles, records the number of loads, records the type and weight of each load, collects the tipping fee, directs traffic to the active area, recycling facility, or the internal transfer station (if applicable). This would be a full time position.

### **Spotter**

The Spotter directs traffic at the face and ensures waste is placed within the limits of the active cell width, assesses thickness of the waste layer, and performs litter control.

### **Transfer Station Attendant**

If this option is pursued, someone will be needed to supervise the unloading of private vehicles with small loads at the transfer station, and to maintain cleanliness of the area.

### **Dozer Operator**

The job of the Dozer Operator is to spread the refuse that has been deposited in the cell and compact it in 600mm (2ft) lifts. At the end of the day, the operator must also spread and compact sufficient cover material onto that day's working area. This employee would also drive the dump truck during cover stockpiling.

### **Loader Operator**

The job of the Loader Operator is to excavate cover, load the dump truck, and move cover material from the stockpile to the face from where the Dozer Operator can spread it up the ramp. This employee could also take on some of the other responsibilities, as the loader is not expected to be used full-time.

Some of the jobs described could be combined and performed by one person. For example, the Loader Operator could also act as Spotter, as the loader will not be running full-time. Consultations with present and future contractors should address the division of labour.

## **9.14 INSPECTIONS**

Regular inspections of the site should be carried out to ensure compliance with requirements and this operation plan. These inspections should be scheduled monthly to coordinate with the safety meeting described in Section 9.9. Safety

inspections can be carried out by a qualified safety officer from the Regional District or from among the landfill staff. Compliance inspections will assess compliance with design and specification standards.

As a minimum, items subject to inspection are:

- Site access - access control (fence, gates, signs, gate house), procedures for receiving waste, and road;
- Scale;
- Fire protection equipment;
- Litter control;
- Application of cover material;
- Adherence to fill progression plan;
- Dust, noise, vector and wildlife, and odour control;
- Water and gas monitoring wells; and
- Record keeping procedures.

## **9.15 RECORDS**

The following records should be kept both on-site and at the Regional District's Office:

- Number of daily loads, and weight of each load;
- Total daily weight of waste;
- Daily quantity of cover material used;
- Any special or hazardous waste admitted to the site, as well as its location;
- Volume of material placed as determined by regular (annual or semiannual) surveys;

- Results of in-situ density measurements;
- Results of gas and water monitoring programs;
- Accident and fire reports;
- Copy of permit and Operating Certificate;
- Copy of Operations Contract;
- Inspection records;
- Operation Plan; and
- Contingency plan.
- Minutes of employee meetings.

#### **9.16 ANNUAL REPORT**

An annual report should be prepared each year, either by the manager or at the direction of the manager, which contains the following:

- Total tonnage and volume placed during the preceding year;
- Approved design volume and remaining capacity;
- Operational plan for the upcoming year;
- Operation and maintenance expenditures;
- Environmental monitoring data (gas, leachate, water quality) and interpretation, as well as any quantities of leachate and/or gas collected, treated, and disposed of;
- Any variations from approved plans and specifications; and
- An up-to-date contingency plan.

**SECTION 10.0**  
**CONTINGENCY PLAN**



## **SECTION 10.0 CONTINGENCY PLAN**

### **10.1 INTRODUCTION**

The contingency plan outlines procedures to be followed in the event of irregular situations which may occur. The three situations discussed in this plan are unauthorized waste dumping, accidents, and leachate migration.

### **10.2 UNAUTHORIZED WASTE DUMPING**

Unauthorized waste dumping refers to prohibited waste as defined in Section 9.6 which are illegally dumped at the landfill. Although landfill users will be informed of which wastes are specifically prohibited, there may be situations where such materials are knowingly or inadvertently taken to the landfill for disposal. It is likely that the Dozer Operator will spot prohibited waste during spreading and compaction of the waste. Liquids, sludges, powders, chemical containers, food processing waste or large bulky wastes will alert the operator to take action. In addition, strong and/or unusual odours may also indicate the presence of prohibited waste.

When the operator determines that prohibited or suspicious wastes have been received at the active area, the following procedure is recommended.

- Shut down dozer;
- Report situation to Gate Attendant;
- Identify the vehicle(s) known or suspected of transporting the waste to the landfill, if possible;
- If the waste can be identified, and is not considered an immediate health or environment hazard, and if the source of the waste can be identified, those responsible for sending the waste to the landfill should be contacted, and instructed to make arrangements to collect the waste. The waste will then be removed from the active area for collection by the responsible party.

- If a prohibited waste cannot be identified or traced, and is believed to pose a health or environment hazard, qualified personnel should be called to investigate the waste. The purpose of the investigation will be to identify the waste through visual inspection or sampling and analysis, to determine safe handling and disposal procedures. The Ministry of Environment should be informed of the incident. The waste should then be removed and disposed of in an appropriate manner. It may be necessary to move the active area to a new location pending removal of the waste.

### **10.3 ACCIDENTS**

It is recommended that all staff be trained in health and safety procedures and instructed in procedures to follow in the event of an accident. Staff must be knowledgeable of the type of accidents that can occur at landfills, including exposure to prohibited wastes which may create an immediate health hazard. However, it is likely that the greatest risk will be that of physical injury due to equipment operation, and all staff must be aware of procedures to follow should a serious accident occur. These procedures involve rapid response in contacting emergency medical personnel or hotlines and reaching a hospital. Staff must know which agencies are to be contacted, where telephone numbers are posted on the site, routes to hospitals, and what actions need to be taken to assist emergency personnel or to facilitate emergency response. Landfill staff will be required to attend appropriate health and safety courses to learn the correct procedures. Documents outlining such procedures should be kept at the site.

### **10.4 LEACHATE MIGRATION**

Leachate migration will be detected through ground and surface water monitoring. Results of the monitoring are to be compared to the appropriate water quality criteria, as well as levels of the same parameters found in upgradient wells.

If an excursion to the water quality criteria occurs, its significance should be assessed to determine the appropriate course of action. The assessment of the deterioration of water quality is to be discussed with the Ministry.

If it is determined that the source of contamination is leachate migration from the landfill and that continued leachate migration will present a significant threat to downgradient ground or surface water, the first course of action is to attempt to locate the source of the leachate within the landfill, if possible. Should the source be located, a limited leachate containment, collection, and disposal system should be developed. This system would consist of a collection trench excavated on the downgradient side of the landfill, lined with an impermeable material to contain the leachate and granular material to permit drainage to a collection point such as a sump or holding tank. Leachate thus collected will be stored until removed for disposal. The appropriate disposal option will be determined based on leachate characteristics but could involve on-site treatment or off-site treatment at a municipal wastewater treatment plant. Such a system could be expanded to collect leachate from the entire landfill should future incidents occur. The method of on-site treatment, if chosen, should be satisfactory to the Ministry's policy on Best Available Control Technology.

Should it be determined that the water quality excursions originate from the landfill are a concern, but not a concentrations that warrant immediate action, an expanded monitoring program should be implemented. This expanded program would involve a greater sampling frequency and analytical program limited to the parameters which exceed the water quality criteria. The purpose of the expanded monitoring program is to establish whether leachate generation is worsening and requiring corrective measures, or only temporary (in that location in the landfill) and may dissipate following the placement of additional lifts and cover material.

Should water quality excursions occur, other provisions for control of ground or surface water infiltration to the waste should be examined, including the redirection of off-site ground or surface water, the use of cover material with lower permeability, greater compactive effort on cover material, and improved surface water management during the operation of the landfill.

Moreover, an investigation into the potential impact of leachate migration on ground and surface water resources downgradient of the landfill may be beneficial to determine more accurate information regarding natural attenuation mechanisms or estimates of contaminant concentrations at specific locations or receptors. Such investigation will involve a hydrological and hydrogeological characterization of the

area. This information can be used to devise corrective actions that are commensurate with the threat to downgradient resources.

**SECTION 11.0**  
**CLOSURE PLAN**



## **SECTION 11.0 CLOSURE PLAN**

### **11.1 INTRODUCTION**

Closure will involve the construction of an impermeable cap over the landfill, and the maintenance of a surface water management system. During the post-closure period, programs will be implemented to monitor the site for up to 25 years.

### **11.2 END USE**

According to the Land Use Map included in the Westbank Official Community Plan (Bylaw 347, Schedule 'C'), the landfill site is situated in an area zoned for schools, institutions, and utilities on the western half, and low density residential on the eastern side. The neighbouring land is agricultural, recreation and conservation, or undesignated.

Section 10 of the community plan defines "hazardous areas" and outlines restrictions in such areas. Section 10-3 bars development and subdivision on lands subject to unstable soil conditions. Landfills continue to settle for many years after closure, and this site would therefore fall into this category. Section 10-5 states that areas with slopes exceeding 20% are generally considered unsuitable for development without a practical and sound professionally prepared design.

It appears the best use for the site would be recreational. After the landfill is closed, its use will be dictated by constraints imposed by its physical shape and its structure. Its pyramidal shape rules out any uses that require flat surfaces, such as golf courses. Because it is made out of garbage, it will continue to settle over time, and therefore no structures can be built on it. The integrity of the cap must be maintained, so no long-rooted plants should be planted. Grasses, small shrubs, and shallow-rooted evergreens are acceptable. The site is most suitable as a passive park area that could be used as a picnic area, playground, or toboggan park.

The area at the entrance could remain as a recycling depot and/or transfer station.

### **11.3 CLIMATE**

The climate of the region is semi-arid experiencing less than 400mm of precipitation per year (mean annual). About 75% of the precipitation is rainfall, one half of which usually occurs in the months of May, June, July, and August. Mean precipitation between 1959 and 1990 was recorded as 280mm for rain and 105mm for snow.

### **11.4 LANDFILL GEOMETRY**

The ultimate geometry of the landfill is dependent on slope stability considerations, surface drainage requirements, setback requirements, and maximum desired elevation. A truncated pyramid with a side slope of 1:4 and top plateau sloped at 4% was chosen. This geometry provides good drainage and ensures slope stability.

The cap will need a vegetative cover to anchor the impermeable layer and prevent erosion due to wind and water.

### **11.5 REMAINING CAPACITY OF LANDFILL**

It is anticipated that the landfill has a remaining capacity of approximately 900,000m<sup>3</sup>, or some 305,000 tonnes of waste (excluding cover material). Depending on the population growth rate, this capacity may be reached sometime between 2010 and 2013.

### **11.6 FINAL COVER**

#### **11.6.1 General**

The most critical aspect of landfill closure is the design and construction of the final cap, which protects the waste from the elements, minimizes leachate production, controls gas emissions, prevents the spread of litter, and discourages vectors.

According to the BC Landfill Criteria, a sanitary landfill requires a minimum of 1000mm of low-permeability compacted soil plus at least 150mm of vegetated topsoil as a final cover. The maximum recommended permeability is  $1 \times 10^{-5}$ cm/sec, although a more permeable material may be approved if leachate

generation is low. The Landfill Criteria also state that provisions for a gas collection and recovery system must be incorporated into the final cover if required, based on results of the gas monitoring program.

### **11.6.2 Soil Barrier Layer**

This layer is generally made up of a clayey or silty clay soil. Specific soil properties that are important to consider when selecting a soil for the barrier layer: permeability, plasticity, and grain size distribution. When locating a borrow source for the barrier soil, the following guidelines should be considered:

*Permeability* -  $1 \times 10^{-7}$  cm/sec is generally regarded as the maximum acceptable limit in many jurisdictions. The BC Criteria allows up to  $1 \times 10^{-5}$  cm/sec, but soils of higher permeability may be approved based on the potential for leachate generation. Given the relatively dry climate of this area, a more permeable soil may be sufficient. The choice will be dependent on the results of further hydrogeological study.

*Plasticity* - Atterberg Limits (Liquid Limit and Plasticity Index) provides an indication of the plasticity of the soil. For soil barriers, clays of medium plasticity are preferred. Therefore, the Liquid Limit should be between 20% and 30%, and the Plasticity Index between 10% and 20%.

*Grain Size Distribution* - Soils with a size fraction of 40% to 50% less than 0.074mm and with a clay content of 25% or more are preferred.

## **11.7 CAP CONSTRUCTION**

### **11.7.1 Introduction**

Quality Assurance/Quality Control (QA/QC) procedures will be required during construction of the final cover to ensure that its performance will be satisfactory. QA/QC procedures include testing programs for both the soil as obtained from the borrow source and as constructed into the cap.

### 11.7.2 Barrier Layer

The soil selected for the barrier layer cover must provide a permeability of no greater than  $1 \times 10^{-5}$  cm/s when recompacted for the barrier layer. Following confirmation (through site investigation to characterize soil stratigraphy and permeability testing of samples obtained from the borrow site) that there is a sufficient quantity of soil having a permeability that meets this criterion, the following QA/QC testing program should be implemented during development of the borrow source:

- Moisture-density curves every 5000m<sup>3</sup>;
- Permeability tests of remolded samples every 10000m<sup>3</sup>;
- Atterberg Limits every 5000m<sup>3</sup>; and
- Grain size distribution every 5000m<sup>3</sup>.

The results of these tests will be used to establish the design parameters to be used in construction of the final cover.

It will be important to mix and blend the soil to produce a homogeneous mixture; this can be effectively achieved by excavating the soil with a scraper. It may also be necessary to break up large clods of soil, screen the soil to remove large stones (> 50mm), and adjust the moisture content of the soil. The latter is important with respect to achieving the desired permeability by ensuring that the moisture content and density of the recompacted soil is maintained within set ranges (based on the moisture-density curve). The processed soil will then be stockpiled for transport to the landfill.

The soil will be placed over the existing cover at the landfill in 250mm lifts and compacted with a sheepsfoot roller. The required compactive effort will be predetermined through testing. The lift should then be smooth rolled. Prior to placing the next lift, the following QA/QC tests should be performed:

- Permeability tests (2 per hectare);
- Density and moisture content tests (10 per hectare); and

- Atterberg Limits and grain size distribution tests (1 per hectare).

Only if the lift meets the levels set for the above parameters can the next lift be constructed. If not, the lift must be reconstructed and recompact until the design values are achieved.

This procedure is to be followed until the required depth of 1000mm of recompact material is placed. Upon completion, the topsoil layer (150mm) can be spread and seeded.

### **11.7.3 Vegetative Cover**

The vegetative cover anchors and protects the final cover against erosion and plays an important role in minimizing surface water infiltration through the action of evapotranspiration. The vegetative cover also enhances the aesthetics of the site which is of particular importance for an end use involving a natural or park concept.

The selection of vegetative cover is governed by a number of factors, the most significant that it thrive in the environment into which it is placed with a minimum of maintenance. Generally, native vegetation is the best choice, especially in a semi-arid area like the Okanagan Valley. A native vegetation will likely not require an irrigation system for survival, which would be a major maintenance concern over the post-closure period.

Another important consideration is that the vegetation not have a deep root system which could damage the soil barrier layer. Finally, it must be able to survive with minimal nutrient additions while at the same time being able to compete with undesirable species which may appear over the course of time.

A qualified horticulturist should be consulted to suggest suitable seed mixtures and to identify nutrient and irrigation requirements, if needed.

### **11.7.4 Construction Supervision**

Construction supervision should be provided by personnel experienced in similar projects, and who possess a complete understanding of the plans and the specifications for closure of the landfill. The construction supervision would involve:

- coordination of all construction activities;
- liaison with all contractors and the Regional District;
- monitoring progress of construction in relation to the construction schedule;
- approval of progress payments to contractors;
- overall quality control of construction in relation to plans and specifications;
- preparation of progress reports and Quality Assurance/Quality Control (QA/QC) documentation;
- implementation of the QA/QC plan and coordination with the soils analytical laboratory;
- inspection of construction activities and preparation of daily inspection reports;
- sample collection for analysis as specified in QA/QC plan;
- performing any required in-situ soil testing as specified in QA/QC plan;
- surveying for construction and as-built information; and
- quantity estimates for construction progress reports.

## **11.8 IRRIGATION**

An irrigation system is generally required for two reasons; to provide water to establish and maintain vegetation, and to maintain an equilibrium moisture content in the barrier layer. Use of native vegetation should preclude the need for irrigation for the former reason; depending on the permeability requirements and the moisture-density relationship determined for the barrier layer material, an irrigation system may or may not be required for the latter reason.

There are two options for irrigation systems. The first is a conventional underground system buried at minimal depth with sprinklers spaced every 15m or so. A disadvantage of underground irrigation is the stress to which it will be subjected as settlement occurs. This could lead to difficult-to-repair leaks which would be detrimental to the cap.

An above-ground system would be easier to maintain and install, and may be more suitable in the initial stages if closure is undertaken over a period of years.

The frequency of irrigation would depend on the amount of drying that occurs in the cap. The soil-moisture tension should be monitored with tensiometers, which should be permanently installed in various locations over the cap. Should these tensiometers indicate excessive drying, the irrigation system would be activated.

The present lack of adequate water must be addressed before an irrigation system can be designed.

## **11.9 LANDFILL CLOSURE IMPLEMENTATION**

### **11.9.1 Fill Progression Plan**

During the life of the landfill, the fill progression plan will serve as a guide for the placement of waste on an annual basis. Adherence to this plan is essential in establishing the necessary minimum slopes to provide effective surface drainage.

### **11.9.2 Surface Water Management System**

Perimeter drainage ditches are to be constructed at the toe of the slopes, integral with the final cap. These ditches will convey surface water runoff collected from the landfill to natural drainage, as outlined in Section 5.0.

## **11.10 POST-CLOSURE PROGRAM**

### **11.10.1 Introduction**

Once the cap and surface water management system have been constructed, a long-term maintenance and monitoring program will be required, as the potential for leachate and gas generation will persist for many years, and the safeguards placed

during the closure must remain intact to minimize the effects. This "post-closure" plan outlines required inspections, maintenance activities, repair procedures, and monitoring programs for the site.

The post-closure program will extend for a period of not less than 25 years. During this time, the Regional District, or any future responsible authority, must commit to maintaining the cap and the surface water management system, and the monitoring gas, ground, and surface water. No site development or use that would interfere with these systems will be permitted.

### **11.10.2 Inspections**

Regular (perhaps four per year) inspections are to be performed, with additional inspections to take place after severe storms. At a minimum, these inspection should include:

- *Cap Inspection:* The cap shall be inspected for evidence of: cap failure; water ponding due to settlement; erosion; leachate breakouts; distressed vegetation; undesirable vegetation; desiccation cracking; and burrowing animals.
- *Surface Water Management System:* For evidence of damage caused by erosion, blockage due to siltation, and presence of leachate.
- *Groundwater Monitoring Wells:* Check exposed well, casing, cap, and lock for damage.
- *Irrigation System (if required):* Check condition and operation of the irrigation system.
- *Gas Collection System (if required):* Check condition and operation of vent piping, headers, and recovery system, as applicable.
- *Miscellaneous:* Check access road, fence, and landscaping for damage or maintenance needs.

### 11.10.3 Maintenance and Repair

Limited maintenance will be required at the landfill during the post-closure period. Specific needs will be determined during the inspections. Typical maintenance activities to be expected are:

- Irrigation of the cap to support the vegetation and to moisten the barrier layer to prevent cracking and maintain low permeability (may not be required);
- Re-seeding the cap;
- Cutting vegetative cover;
- Removing undesirable species of vegetation;
- Applying fertilizers to the vegetative cover;
- Regrading ditches and removing deposited soil;
- Upkeep of irrigation system; and
- Regrading of the access road.

Surface erosion, burrowing animals, and desiccation cracking may cause minor damage, which generally would not require reconstruction to repair. Eroded areas will require replacement of topsoil and reseeding; a biodegradable erosion mat would subsequently be placed on top of the repaired area. All holes left by burrowing animals should be filled with a bentonite slurry or grout, covered with topsoil, and reseeded, after it is certain that the animals have been relocated. Cracks in the cap would be repaired by injection of a bentonite slurry or grout up to the surface.

Cap damage caused by severe erosion or settlement would require reconstruction. This would involve excavation of the cap and perhaps the underlying foundation layers and upper layers of the waste in the general vicinity of the failed area.

Cap repair would begin by placing general fill up to the surrounding foundation layer, and then compacting it to provide a suitable base on which to construct the cap. The cap would be reconstructed using construction methods in accordance

with the design parameters and QA/QC plan followed during the initial construction of the cap. All pertinent QA/QC testing would be conducted to certify that the reconstructed cap meets performance standards established for the original cap. Finally, the reconstructed area would be covered with degradable erosion matting and reseeded.

#### **11.10.4 Surface Water Monitoring**

Surface water and sediments collected in the drainage ditches are to be monitored for leachate breakouts through the cap. Samples are to be taken based on the results of site inspections, in particular where there is evidence of cap failure.

#### **11.10.5 Groundwater Monitoring**

Groundwater monitoring over the post-closure period is essential for protection of health and the environment. Any contaminant migration from the landfill caused by leachate or the entry of waste liquid must be identified before a serious problem is created for groundwater users and Shannon Lake. Monitoring will provide information on the nature and extent of any contamination, as well as providing information for the determination of potential remediation methods.

#### **11.10.6 Water Quality Parameters**

Ground and surface water should be analysed for:

- metals (at a minimum: lead chromium, cadmium, nickel, zinc, mercury, arsenic, aluminum, selenium, antimony, beryllium, barium, silver, thallium, iron, manganese);
- chloride;
- colour;
- total organic carbon;
- sulfate;
- alkalinity;
- total hardness;

- turbidity;
- biochemical oxygen demand;
- nitrate;
- total Kjeldahl nitrogen;
- volatile and semi-volatile organic compounds;
- chemical oxygen demand;
- total dissolved solids;
- ammonia;
- pH;
- specific conductivity;
- cyanide; and
- phenols.

The initial analyses should be comprehensive, including all of the above parameters, to indicate which are present at significant levels and which are important indicators; for reasons of economy and time, subsequent analyses should be made for only those parameters so chosen. A complete analysis could be performed on a less frequent interval, perhaps once per year, to track the other parameters.

Results of all surface water and sediment analyses should be documented and submitted to the Ministry of Environment. If a health or environmental hazard is posed by the presence of contaminated water or sediment, a remediation plan will be devised and implemented.

