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FINAL TECHNICAL REPORT NO. 6

PHASE 2 STAGE 2C
SELECTION OF PREFERRED SITE

AIR QUALITY ASSESSMENT

SENES CONSULTANTS LIMITED

HALTON

ENVIRONMENTAL ASSESSMENT
LANDFILL COMPONENT OF
SOLID WASTE MANAGEMENT

JUNE 1985

SUMMARY

The overall Stage 2C study seeks to assess the suitability of six sites for a regional landfill facility. This Technical Report assesses the sites with respect to air quality using two major airborne emissions; dust and odour. The amount of these emissions will depend on 1 on-site activity and 2 local meteorology, and the impact of these emisions will depend on local meteorology and the 3 location of local residents relative to the landfilling operations.

Calculations of downwind dust concentrations were made following procedures outlined in the Ontario Environmental Protection Act. The calculated estimates indicated that suspended dust concentrations at the landfill boundary could result in levels being above the allowable maximum point of impingement concentration of 100 ug/m^3. However, levels from an existing landfill operation located in the Region do not appear to be a problem. Based on this information, the dust emission rates were assumed to be approximately 50% lower than the initial estimate due to mitigating factors that were not originally considered. This reduction results in suspended dust concentrations being below the regulated value of 100 ug/m^3 beyond 300 m from the landfill boundary.

dust could exceed max. allowable

Using an assumed odour level for the refuse, calculations of downwind odour concentration were made under a variety of atmospheric conditions. Only under the more stable conditions were off-property odours estimated to be detectable. Under these conditions, odour may be detected very close to the landfill and only on infrequent occasions.

In order to establish a ranking of sites, a dust-dosage relationship was developed which related the dust loading to nearby population levels. The sites are ranked based on the dust-dosage at 750 m, because beyond that distance the dust concentrations drop to background levels. The resulting analysis indicated that all sites could be made acceptable for landfill operations.

The ranking of sites from most to least suitable is:

Most suitable	A, E, F
	C, D
Least suitable	B

It is important to note that this ranking has been based on several broad assumptions. In particular, the detailed plan of operations will be developed during the approvals stage so that changes may occur to the conceptual landfill plans developed in Stage 2C. In addition, local population patterns may be affected once landfill operations are implemented.

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1.0 INTRODUCTION

Prediction of the dust and odour impact of a sanitary landfill operation is inherently difficult. The compilation of emission inventories requires knowledge of the size and type of machinery in use on-site, the pattern of trench digging and waste emplacement and the types and lengths of surfaces the trucks travel across.

At this stage in the site selection process (Stage 2C), a number of generalized assumptions regarding site parameters that would apply to any site have been made. Operating conditions for the selected landfill site will be finalized in a later stage when the details of the landfill design have been advanced to actually represent the preferred site. The working assumptions, however, are sufficient to evaluate and compare the sites on an equitable basis. The assumptions have been based on current operating conditions in Halton, information made available by other members of the study team and material contained in the Ontario Ministry of the Environment publication entitled "Guidelines for the Establishment, Operation, Management, Maintenance and Closure of Landfilling Sites in Ontario (MOE)", (undated).

MOE guidelines

On this basis, the following characteristics were used to define the proposed site for the air quality assessment. A site capacity of 11.3 x 10^6 yd^3 of refuse with an expected life of twenty years was used resulting in an average daily amount of waste to be disposed of 1,810 yd^3. Based on a cover to waste ratio of 1:4 indicated in Hydrogeologic/Hydrologic Assessment and Conceptual Design Technical Report (Hydrology Consultants), this waste will be covered by about 450 yd^3 of material. Data contained in the Transportation Assessment Technical Report (Giffels Associates Limited) indicate an annual daily average of 263 trucks will arrive at the landfill. Further details concerning operational assumptions are given in the appropriate sections of this report.

what type of trucks large?

2.0 PREDICTED EMISSIONS

The air quality assessment has been undertaken for airborne dust and odour. In addition to these aspects, litter can be an "airborne" contaminant that impacts the area surrounding a landfill. The dispersion of litter from a site is related to meteorological conditions and operating procedures (site maintenance). Under high wind conditions, uncovered refuse may be dispersed from any site and those sites which are adversely affected by odour and dust may also experience a litter problem. In terms of evaluating the most suitable site(s) for landfilling from an air quality perspective, the effects of odour and dust are considered sufficient and only those parameters have been used in the analysis. has not used litter in his analysis

litter can be an airborne contaminant

does he know anything about existing site maint.?

litter mitigation

Specific mitigating measures for litter control, different for those of either dust or odour, are required, however, and could include the establishment of litter screens (vegetation screens and or movable litter fences), the establishment of special procedures for "high wind" periods, and, perhaps, the establishment of litter patrols. These would be required regardless of which site is chosen.

The operations that will take place at the landfill are independent of location. Therefore, any constraints related to air quality will be as a result of factors such as the local topography or the proximity to local residences. However, it is still necessary to calculate the expected emission rates to ensure that air quality standards and criteria are not exceeded. In evaluating emissions from the landfill operation, standard engineering and operating mitigation measures that are currently in use in Halton or will be used at the new site (e.g., dust suppressants) are considered.

2.1 Dust

Dust is generated in two principal ways at landfilling operations. The first is the mechanical action of equipment on the ground. Examples of this type of source include:

1 - truck traffic on paved and unpaved roads,
2 - fill handling operations,
3 - loading and unloading trucks carrying fill,
4 - smoothing and grading cover materials.

The amount of dust generated by these actions is dependent on the properties of the soil, the amount of recent precipitation, the properties of the machine generating the dust (weight, number of wheels, etc.) and the activity level of that machinery.

The second process that generates dust is the action of wind on dry, suspendable soil. When the windspeed is high enough, smaller particles can be suspended if the soil is sufficiently dry. The amount of dust generated by this mechanism is dependent on the local meteorology (wind speed and precipitation), the properties of the soil and the amount of exposed soil.

Calculation of the amount of dust generated by machinery operations requires a knowledge of the type and quantity of machinery that will be used on site. The following equipment is currently in use at the active landfilling operation in Halton:

- 2 refuse compactors
- 1 bulldozer
- 1 tracked type loader
- 1 self-unloading scraper tractor

These were used in estimating the emissions from the proposed facility. In addition, it was assumed that two dump trucks would be used to move fill at the site.

Calculations of suspended dust emissions created by the landfill operation, traffic and wind erosion have been made and are summarized in Table 2.1. The estimated amount of dust generated without any suppression techniques being applied is presented in the first column entitled "Uncontrolled Emissions". With dust suppression applied, these values are reduced and presented in the second column entitled "Controlled Emissions (Using mitigation)".

Table 2.1

To mitigate against wind erosion, chemical suppressants and mulch can provide a large reduction of approximately 85 percent. However, wind erosion is not a large factor at any of these sites, and a more practical technique of watering the soil as needed was applied in the estimates to produce a 25 percent reduction. It has been assumed that, in the longer term, open areas will be revegetated providing a high degree of permanent suppression.

Traffic dust generated by vehicle movement over unpaved roads on site can be reduced by 50 percent with frequent watering (twice daily). With chemical suppressants, the road dust can be reduced by 75 percent. On paved roads, frequent sweeping or flushing with water can reduce dust emissions by 99 percent.

What chemicals + where applied?

Details of the emission rate calculations are presented in Appendix C.

2.2 Odour

The quantification of odour emission rates and, therefore, the impact of odour on receptors is a difficult procedure. The science has not developed as rapidly or to the same degree as that for the classical pollutants. The basic measure of odour is the odour unit (OU). One odour unit per cubic foot (ft^3) is the level at which most people would detect and respond to an odour.

Table 2.1

FUGITIVE DUST EMISSIONS

	Uncontrolled Emission lb/hr	Controlled Emissions (With Mitigation) (lb/hr)	(% suppression)
1. Excavation - scraper operation	49.2	49.2	0
2. Bulldozer operation	9.8 to 32.0	9.8 to 32.0	0
3. Road grading - on site	5.3	5.3	0
4. Cover fill			
a) Scraper operation[1]	12.3	12.3	0
b) . Front end loader	2.0	2.0	0
. Fill truck travel	58.2	14.6	75
. Unloading cover fill	4.6 to 22.2	4.6 to 22.2	0
5. Wind Erosion	2.1 to 14	1.6 to 10.5	25
6. Refuse truck - paved site road[2]	77.4	.77	99
7. Refuse truck - unpaved site road	85.5	21.4	75

Notes: 1. Cover fill operations would use either (a) or (b) but not both.

2. Assumes some carry-over of silt from unpaved to paved road.

To carry out an odour assessment, it was necessary to select an analysis carried out with a similar substance. Previous odour studies for raw sewage sludge have determined that surface odour generation rates range from 1 to 10 $OU/ft^2/min$ (Wilson, 1978). Realizing that although sewage sludge is not identical to municipal refuse, the sludge is malodourous and it is expected that the malodour of refuse would be in the same general range. Consequently, an odour generation rate of 2 $OU/ft^2/min.$, the geometric mean value for raw sewage sludge, is used for refuse in our calculations. Odour occurs as a result of exposed refuse. Since the characteristics of the refuse cannot be effectively altered, it is necessary to control odour by covering the odour-generating refuse. The most effective mitigation measure that can be applied is to cover the malodorous refuse as quickly as possible, and this is standard practice at a landfilling operation.

rapid cover over

client's expense

It is assumed that the maximum exposed area of refuse would be 500 m^2, about one day's exposed refuse. Thus, the total odour emission rate is estimated to be 180 odour units per second (OU/s).

It is also assumed that odour detection and the response to it would be very rapid, a few minutes or less. On this basis, the normal dispersion calculations used for estimating concentrations of regulated contaminants averaged over 10 minutes or a half hour would underestimate short term odour peaks. In order to get a reasonable estimate of the peak odour concentrations, the 10 minute average concentrations were multiplied by 10.

3.0 METEOROLOGY

- major influence on way dust & odour are dispersed

The local meteorology has a major influence on the way in which dust and odour are dispersed and transported from the landfilling operation to the receptor. All of the sites under consideration fall within the same general climatic zone (Brown, McKay, and Chapman, 1980), although their individual proximity to both Lake Ontario and the Niagara Escarpment will influence the microclimatic conditions at each site. Because meteorological data such as wind and precipitation information is so variable, average values established from long-term records at existing weather stations must be used. Within the timeframe of this stage of the process (Stage 2C), it was not possible to collect any relevant on-site meteorological data. Therefore, information from existing weather stations was used. The surrounding stations used in the analysis are: 1 for wind, Toronto (Lester B. Pearson) International Airport, Guelph, Valens (14 km NE of Galt), and Hamilton Royal Botanical Gardens; 2 for precipitation, Toronto (Lester B. Pearson) International Airport, Milton Kelso, Hamilton Royal Botannical Gardens, and Valens; and 3 for atmospheric stability, Toronto Downsview Airport.

3.1 Wind Speed and Direction

windspeed & direction are major deter. of dispersion & impact of dust & odours.

Wind speed and direction are major determinants of the dispersion and impact of dust and odours from a landfilling operation. High wind will result in the suspension and dispersion of dust from open areas, while lower wind speeds will result in poorer dilution of odours.

In general, the wind direction pattern is similar across Halton Region. Winds from the southwest through north are predominant and are stronger than winds from other directions, particularly in the winter.

Although atmospheric dilution is enhanced as wind speed increases, high winds can also erode loose material from dry exposed surfaces thereby contributing to dust levels in the air. Generally, 20 km/h is the wind velocity at which potential wind erosion starts (CDOH 1981). This 'start velocity' is the result of considerable experimental and field work in industrial and mining operations ~~carried out~~ in the United States. Wind data from a number of stations (Appendix A) were analyzed to obtain the number of hours in each month when wind velocity exceeded the erosion 'start velocity' of 20 km/h (Figure 3.1).

Minimum erosion potential occurs in August at all four stations with winds exceeding the 'start velocity' varying from 15% of the time at Toronto International Airport down to 2.5% of the time at Valens. Maximum erosion potential occurs in January with winds in excess of 20 km/h occurring 27% of the time at Toronto International Airport down to 22% of the time at Valens.

On an annual basis winds are greater than 20 km/h as follows:

Location	Annual Period Percent
Toronto International Airport	27.6
Guelph	18.9
Hamilton Royal Botanical Garden	15.2
Valens	13.4

An annual average value of 20% for the amount of the time wind speed is greater than 20 km/h, was used in calculations of wind erosion potential.

3.2 Precipitation

Natural control of dust occurs with any measurable (>0.01") precipitation. To assess the fraction of time when precipitation suppresses dusting due to wind erosion, and other dust generating activities, monthly precipitation records for a number of stations were analyzed (Appendix B). The results indicate that precipitation is measurable between 7 to 15 days per month (Figure 3.2). The stations further from Lake Ontario will have slightly more precipitation than those closer to the lake.

In the summer months, precipitation and, consequently, dust suppression occurs about a quarter of the time at all locations. In colder months, freezing and snow cover aid in providing dust suppression.

3.3 Atmospheric Stability

Stability is a measure of the tendency of the atmosphere to resist or enhance vertical motion. The stability of the atmosphere is an important factor in determining the dispersion of air pollutants. Surface meteorological observations are commonly used to prepare joint frequency distributions of wind speed and direction and atmospheric stability class (also referred to as a stability array or STAR data set). The stability class incorporated into such a STAR data set is estimated from observations of wind speed and net solar radiation. In turn, the net radiation is estimated from observations of cloud cover and solar insulation or estimated from solar altitude. STAR data sets are prepared by the Atmospheric Environment Service, on request for specific locations and time periods.

In Ontario, the atmosphere is of neutral stability the majority of the time. Thus, calculation procedures for criteria pollutants (i.e. suspended dust) are based on neutral and near neutral conditions.

Inversions are associated with stable atmospheric conditions and light winds. The occurrence of stable conditions is important in calculating potential odour occurrences because this atmospheric condition tends to inhibit the dispersal of air pollutants. To determine the frequency of occurrence of strong stable conditions (F stability) at the landfill sites, STAR data from the Toronto area were examined. STAR data for Hamilton airport indicated only a 6% frequency of "F" stability; thus the Toronto data was used as it indicated a greater frequency.

Table 3.1 (Toronto A) shows that strong stable conditions occur about 12% of the year (1050 hours). In any particular direction, the occurrence of these stable conditions is a small fraction of the total.

TABLE 3.1

ANNUAL

RELATIVE FREQUENCY DISTRIBUTION

SPEED (knots)

STATION - TORONTO
DOWNSVIEW - 1956-82

Direction	0-3	4-6	7-10	11-16	17-21	Greater than 21	Total
N	0.006429	0.004626	0.0	0.0	0.0	0.0	0.011055
NNE	0.003997	0.002158	0.0	0.0	0.0	0.0	0.006154
NE	0.004380	0.001548	0.0	0.0	0.0	0.0	0.005928
ENE	0.004273	0.001673	0.0	0.0	0.0	0.0	0.005945
E	0.004912	0.002357	0.0	0.0	0.0	0.0	0.007269
ESE	0.001763	0.000839	0.0	0.0	0.0	0.0	0.002603
SE	0.001561	0.000703	0.0	0.0	0.0	0.0	0.002263
SSE	0.001390	0.000603	0.0	0.0	0.0	0.0	0.001993
S	0.003428	0.002238	0.0	0.0	0.0	0.0	0.005667
SSW	0.003874	0.002873	0.0	0.0	0.0	0.0	0.006746
SW	0.005748	0.003924	0.0	0.0	0.0	0.0	0.009671
WSW	0.005300	0.003718	0.0	0.0	0.0	0.0	0.009018
W	0.007623	0.006523	0.0	0.0	0.0	0.0	0.014145
WNW	0.006402	0.004819	0.0	0.0	0.0	0.0	0.011221
NW	0.006583	0.004359	0.0	0.0	0.0	0.0	0.010942
NNW	0.005823	0.004918	0.0	0.0	0.0	0.0	0.010742
TOTAL :	0.073483	0.047879	0.0	0.0	0.0	0.0	0.010742

RELATIVE FREQUENCY OF OCCURRENCE OF F STABILITY = 0.121364
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH F STABILITY = 0.034672

FIGURE 3.1

WINDS IN EXCESS OF 20 km/h

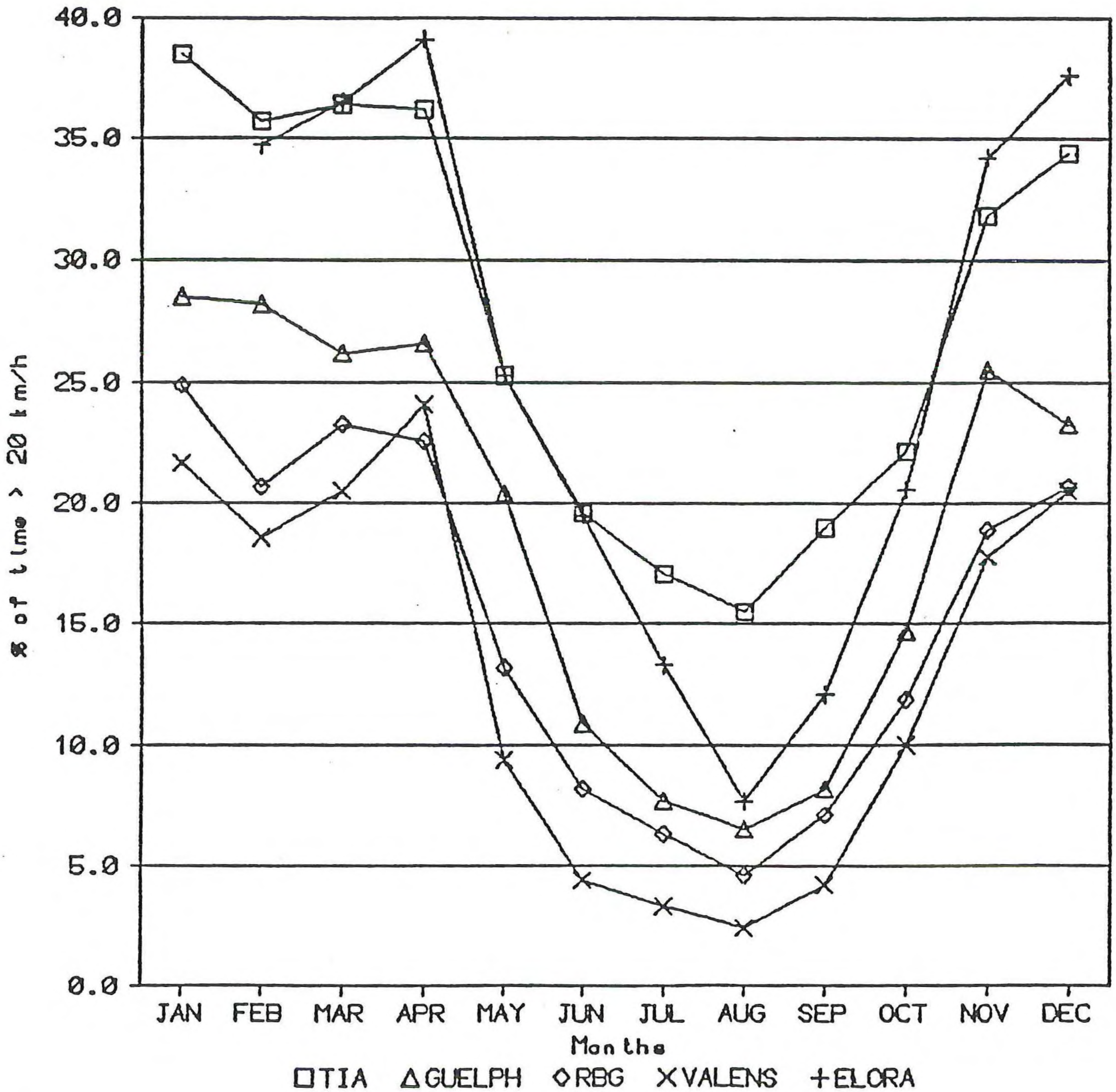
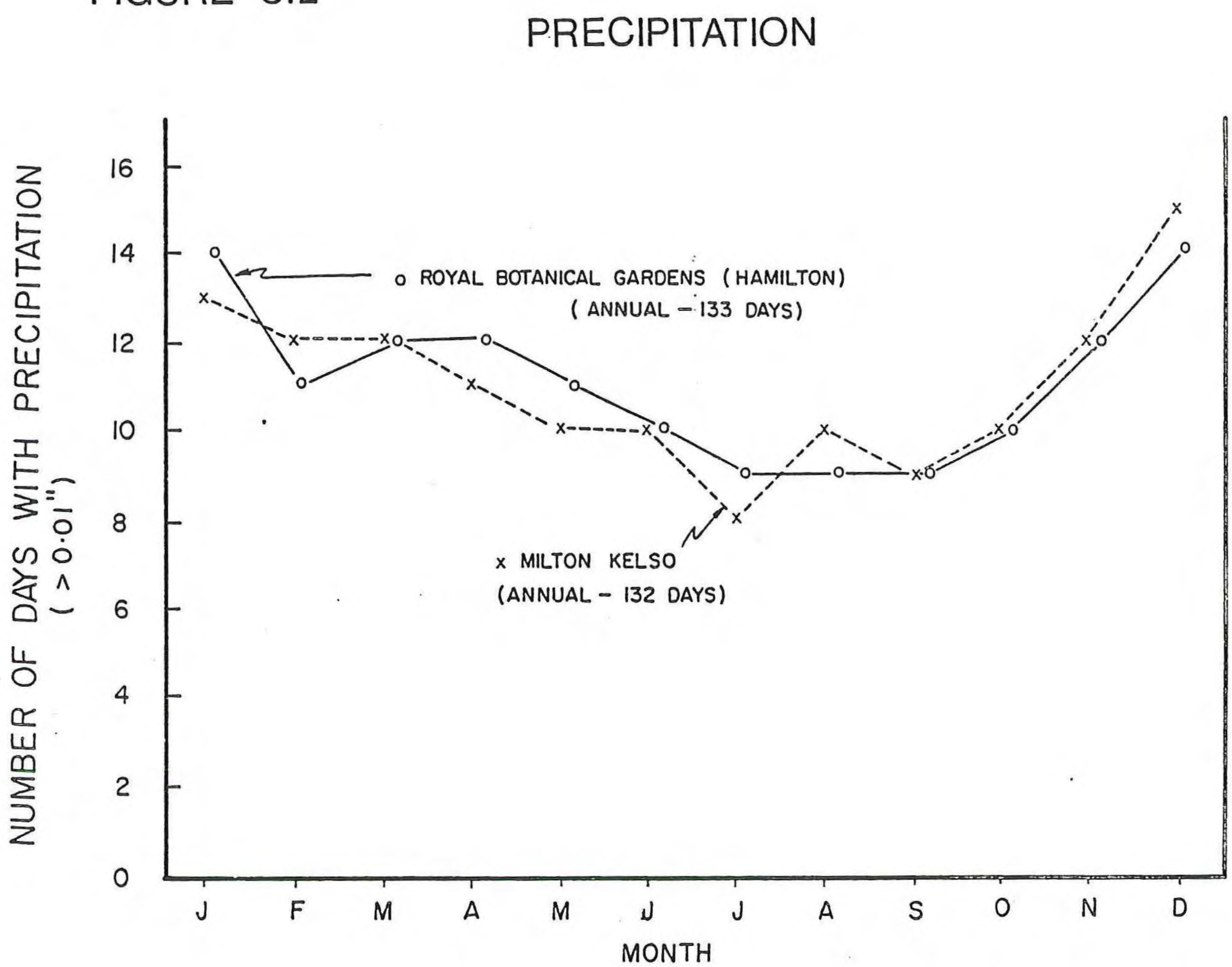
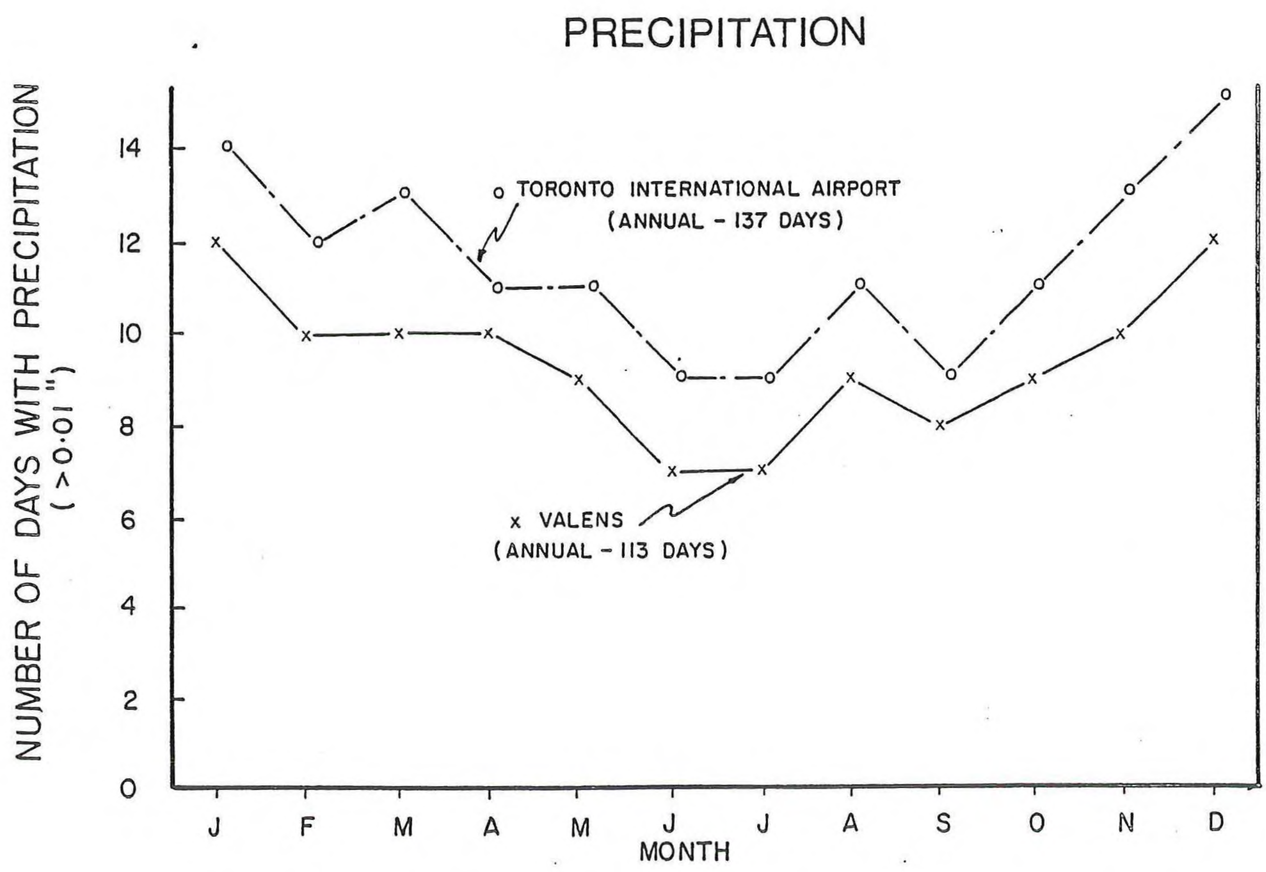


FIGURE 3.2


PRECIPITATION
NUMBER OF DAYS WITH PRECIPITATION
(> 0·01")
0
2
4
6
8
10
12
14
16
o ROYAL BOTANICAL GARDENS (HAMILTON)
(ANNUAL – 133 DAYS)
x MILTON KELSO
(ANNUAL – 132 DAYS)
J F M A M J J A S O N D
MONTH


PRECIPITATION
NUMBER OF DAYS WITH PRECIPITATION
(> 0·01")
0
2
4
6
8
10
12
14
o TORONTO INTERNATIONAL AIRPORT
(ANNUAL – 137 DAYS)
x VALENS
(ANNUAL – 113 DAYS)
J F M A M J J A S O N D
MONTH

4.0 ESTIMATED ATMOSPHERIC CONCENTRATIONS

Standard equations have been developed to determine the downwind concentration of a contaminant released at ground level (Turner 1969). These calculations calculate a 10 minute average concentration.

In Ontario, there is a prescribed procedure by which one calculates half-hour point of impingement concentration for criteria pollutants (MOE, 1982), including total suspended particulate matter (dusts). To obtain half-hour values, the concentrations calculated for 10 minute periods are multiplied by 0.6 for slightly unstable atmospheric conditions and by 0.8 for neutral stability conditions.

For odours, a short term peak value is obtained by multiplying the 10 minute average concentration by 10.

4.1 Suspended Particulate Matter - Dust

It has been estimated that approximately a 100 m by 600 m area (6 hectares) would be exposed to wind erosion with the 600 m axis located immediately next to a buffer zone. This is equivalent to the exposed soil associated with one year's generation of refuse and is expected to be the maximum amount of soil exposed prior to revegetation. Landfill activities are estimated to occur over a smaller area of about 100 m by 200 m.

Refuse truck traffic approaching and within the landfill site is estimated to travel a round-trip distance of 1600m on paved roads and 400m on unpaved roads.

Dispersion calculations have been carried out for the emissions outlined in Table 2.1 using prescribed procedures. The calculated downwind concentrations are shown in Fig. 4.1. Sample detailed calculations are presented in Appendix C.

1

The largest contributor to the off-site dust levels is the use of equipment in the landfill operation on-site (items 1, 2, 3 and 4 in Table 2.1). 2 Refuse truck traffic (items 6 and 7) is the next largest contributor and 3 wind erosion (item 5) is the smallest.

how come to this conclusion ?

Based on this analysis, the estimated suspended dust concentration at the landfill boundary could result in levels being above the allowable maximum point of impingement concentration of 100 ug/m^3.* However, boundary dust levels from the existing Burlington landfill operation do not appear to be a problem. Based on this information, we have assumed that dust emission rates could be approximately 50% lower than our theoretical estimates due to mitigating factors we have not considered. The ability to reduce the emission rates by 50% results in a new curve (Figure 4.2) showing that at distances greater than 300 m, the suspended dust concentrations would be well below the 100 ug/m^3 legal standard.

4.2 Odour

Calculations of downwind odour concentration from the landfill site based on the assumptions outlined in Section 2.2 were made for a variety of atmospheric stability conditions. Only under the more stable conditions were odours off-property estimated to be detectable. The detailed calculations are contained in Appendix C. The estimated off-property concentrations are presented in Figure 4.3 and show odours would be detected primarily under the most stable conditions at a downwind distance of about 130 meters and a windspeed of 1 m/s. Odour appears to be a localized potential problem and probably would not be detected off-property unless odour emission rates exceeded 2 O.U./ft^2/min.

This agrees with measurements from the "Community Odour Study at the Brock West Landfill", Ontario Research Foundation. Because the meteorological conditions under which odour is estimated to be detectable occur infrequently (17-124 hours per year depending on wind direction) odour is not expected to be a problem at any of the sites.

* g/m^3 - micrograms (suspended dust) per cubic metre of air

FIGURE 4.1 SUSPENDED DUST CONCENTRATION vs. DISTANCE - ESTIMATED

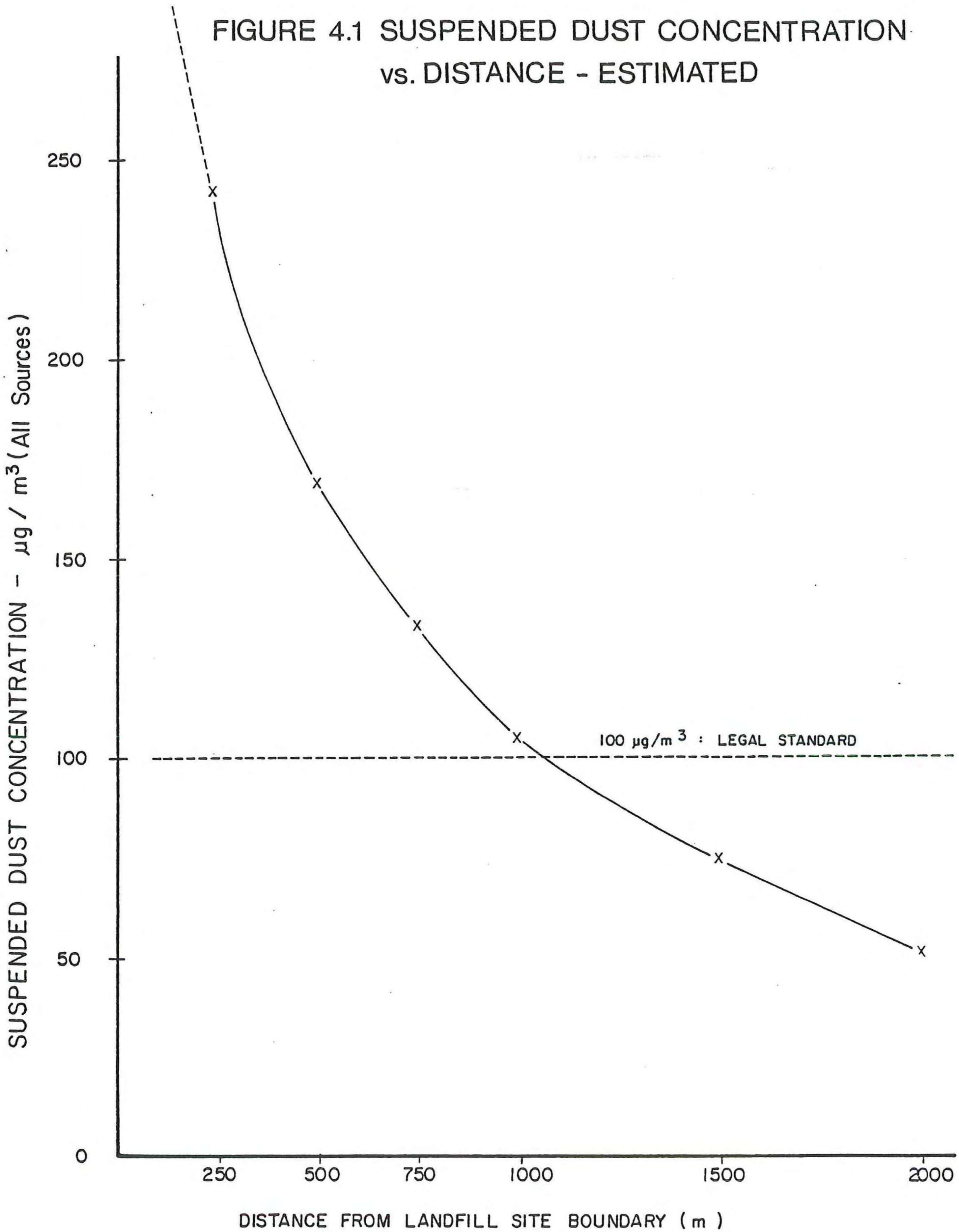


FIGURE 4.2 SUSPENDED DUST CONCENTRATION vs. DISTANCE - ESTIMATED

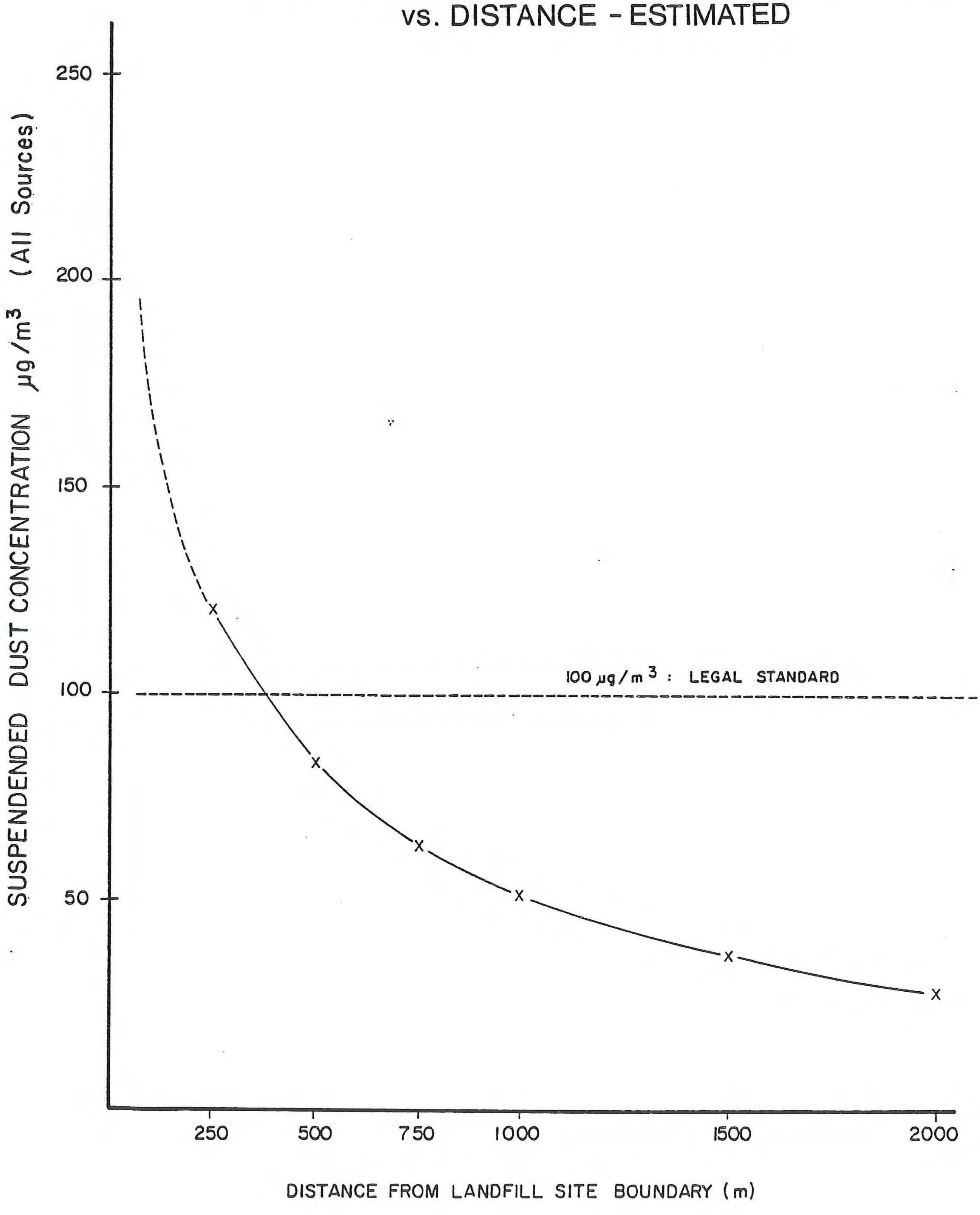
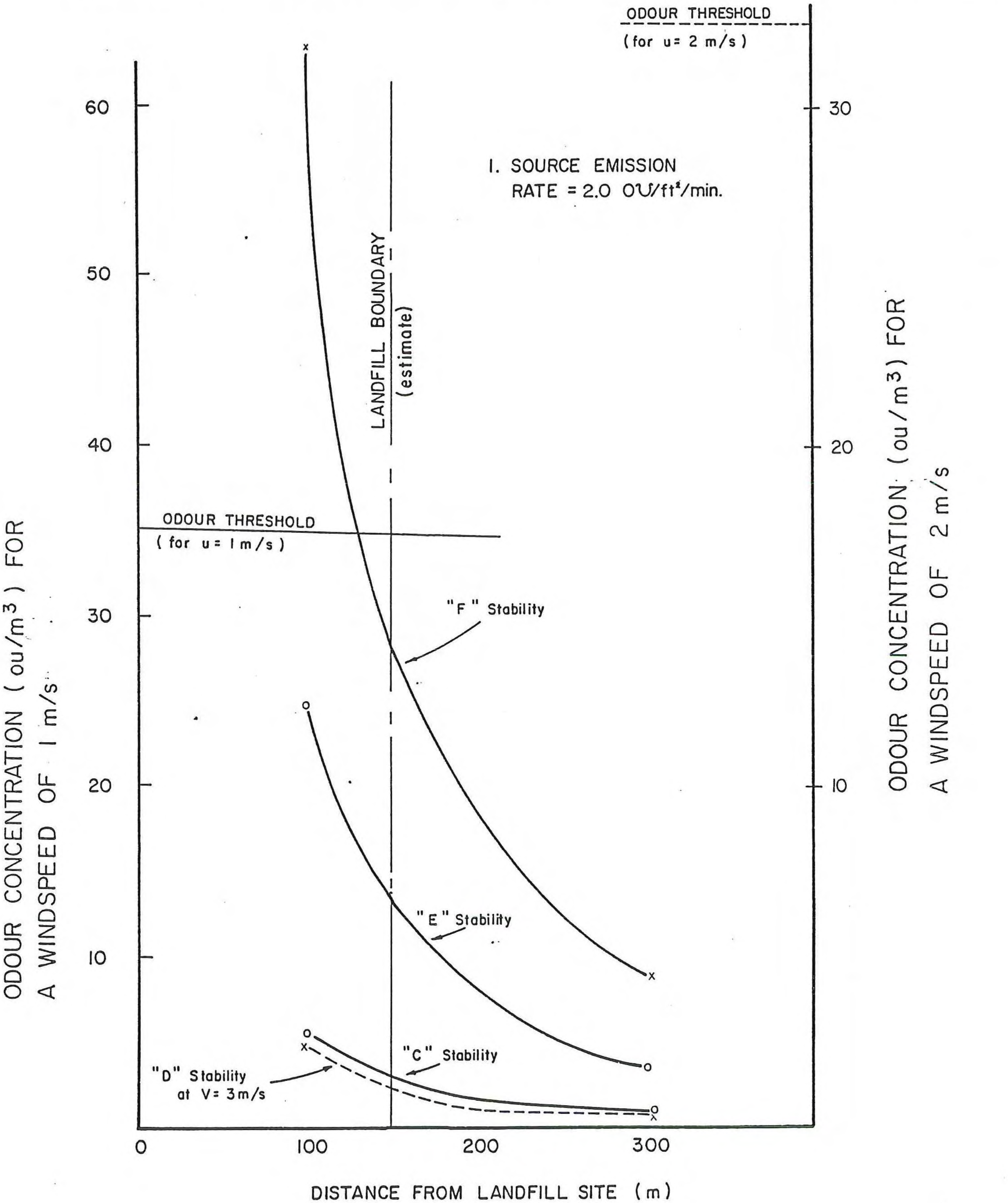


FIGURE 4.3 ODOUR CONCENTRATIONS vs. DOWNWIND DISTANCE



5.0 ASSESSMENT AND COMPARISON

There is no defined protocol in Ontario for the comparison and ranking of alternative sites based on air quality considerations. Thus, the methodology used in this report is one which we have developed and feel is appropriate for this situation.

Under the worst postulated atmospheric conditions, estimated detectable odour is not a problem beyond 130 metres from the source, and therefore cannot be used as an indicator.

In terms of meteorology, all of the Sites are quite similar since they are in a relatively restricted geographic area. The sites further from the lake will have slightly more precipitation than those closer to the lake resulting in slightly less potential for wind-erosion generated dust. This is not an important factor because wind-eroded dust is not a major dust source.

Of prime importance in analyzing the dust impact is the proximity of nearby residents to the landfilling operation. All of the Sites have residences located quite close to the site boundaries, and none is clearly superior on the basis of the nearest receptor. Thus, an evaluation criterion which accommodates a measure of the number of receptors at successive distances (a surrogate for dust level) is needed. The approach that has been taken is to develop a dust-dosage relationship which relates the number of residences at a particular distance from the facility to the expected dust level at that location. NB

The number of residences in specific bands at increasing distances (.25, .5, .75, 1.0, 1.5 and 2.0 km) from each site was determined for the Land Use and Planning Assessment Technical Report (Walker, Wright, Young Associates Limited). The dust concentration at a specific distance was calculated by summing dust from landfill operations, traffic and erosion (see Figure 4.2). From this curve, average dust concentrations for each band were taken. Curves of cumulative dosage versus distance for each site are shown on Figure 5.1.

At approximately 750m from the landfill site boundary, the half hour suspended dust concentrations are 64 micrograms per cubic metre. Averaged over a 24 hour period, the concentrations as measured by a high volume sampler used for determining background (suspended particulate concentrations) would be less because the wind's direction and speed are seldom the same for 24 hours. The average 24 hour suspended dust concentration is about 1/2 or less of the half hour value of 64. Such daily levels are typically measured in clean environments as background concentrations.

It is therefore important to note that beyond 750m the suspended dust concentration is similar to background levels. Thus, the increase in cumulative dust dose past 750m is essentially a result of an increase in population, not increasing dust levels. Therefore, the sites have been ranked based on the dust dose at 750m.

The results from Figure 5.1 indicate that the difference between the sites is not large (at 750 m) and, thus, all sites could be made acceptable for landfilling operations. The ranking of the sites, from most to least suitable is:

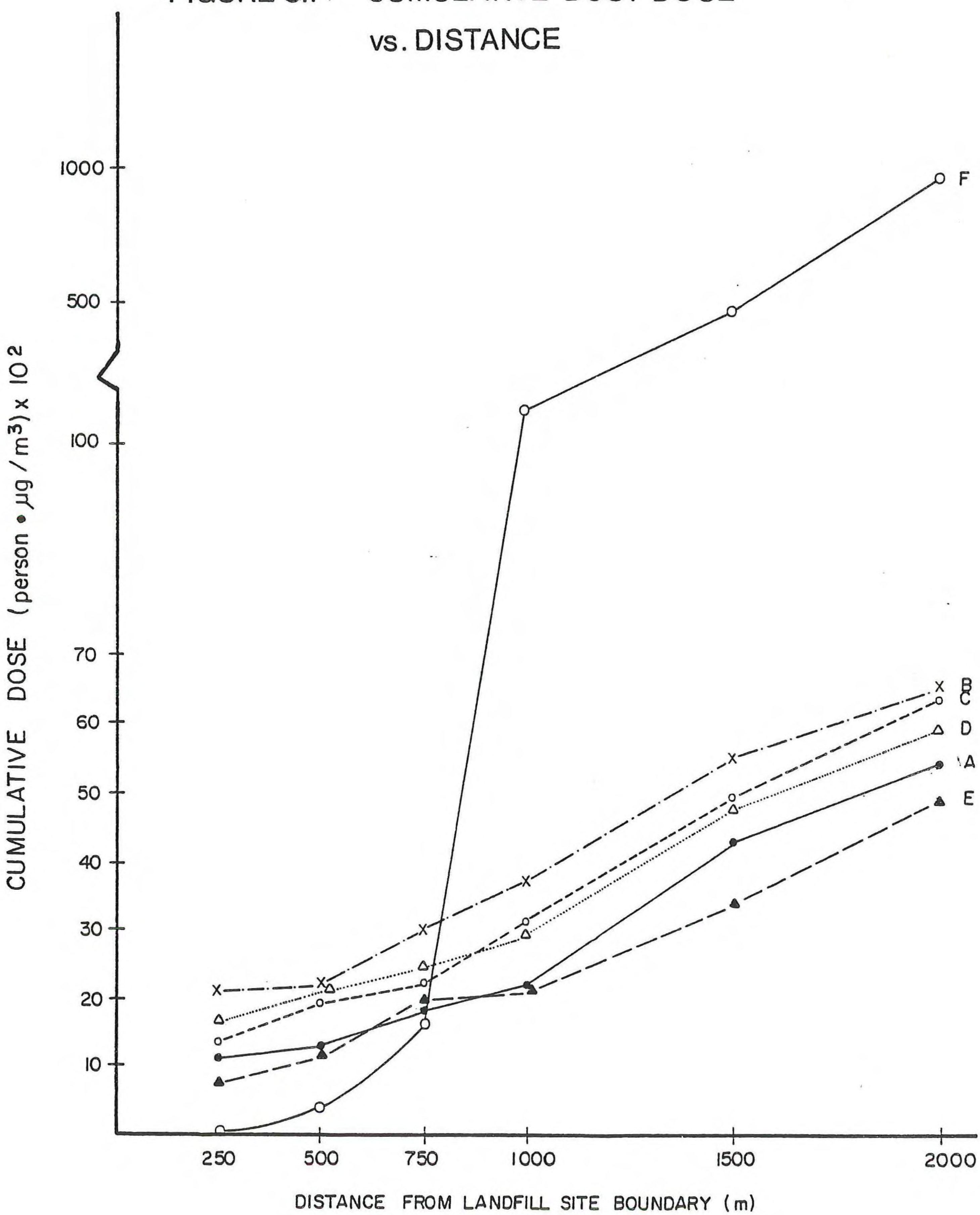
Rank	Site
Most suitable	A, E, F
	C, D
Least suitable	B

On an individual basis, the sites are ranked as follows:

Site F - 1; Site E - 2; Site A - 3; Site C - 4; Site D - 5; Site B - 6. It should be noted that the grouping of sites above reflects the relatively minor differences among these sites with respect to predicted dust and odour impacts.

It is important to note that this ranking has been based on several broad assumptions. In particular, the detailed plan of operations will be developed during the approvals stage so that changes may occur to the conceptual landfill plans developed in Stage 2C. In addition, local population patterns may be affected once landfill operations are implemented.

FIGURE 5.1 CUMULATIVE DUST DOSE vs. DISTANCE



APPENDIX A

WIND INFORMATION FOR SELECTED WEATHER STATIONS

TORONTO INTERNATIONAL AIRPORT

% time wind > 20 km/h

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
NNE	0.72	0.79	0.72	0.66	0.46	0.33	0.26	0.35	0.45	0.35	0.40	0.58	0.50
NE	0.83	0.64	0.67	0.43	0.26	0.10	0.11	0.17	0.09	0.24	0.30	0.79	0.39
ENE	1.0	0.93	1.2	1.0	0.57	0.19	0.15	0.08	0.19	0.35	0.53	1.1	0.61
E	1.4	2.2	4.2	4.1	2.0	0.72	0.41	0.43	0.73	1.2	1.3	1.4	1.7
ESE	1.0	0.72	1.1	1.0	0.81	0.40	0.23	0.28	0.38	0.72	1.1	1.3	0.75
SE	0.42	0.24	0.32	0.59	0.43	0.52	0.33	0.41	0.32	0.35	0.56	0.45	0.41
SSE	0.26	0.29	0.24	0.56	0.68	0.64	0.57	0.68	0.46	0.35	0.42	0.17	0.44
S	0.88	0.83	0.40	0.60	0.63	0.57	0.60	0.58	0.76	0.74	1.1	0.66	0.69
SSW	1.9	1.7	1.1	1.2	0.83	0.90	0.79	0.70	1.3	1.3	1.6	1.5	1.2
SW	4.3	2.3	2.1	2.4	1.8	1.8	1.5	1.6	2.0	2.4	3.3	4.3	2.5
WSW	7.1	3.8	2.7	2.1	1.7	1.8	1.5	1.4	1.5	2.4	5.2	5.5	3.0
W	5.7	5.9	5.8	5.2	3.4	2.7	2.8	2.0	2.9	3.3	5.8	5.4	4.2
WNW	3.6	3.8	4.7	4.7	3.4	2.5	2.4	1.9	2.4	2.3	3.4	2.8	3.2
NW	2.7	3.4	3.5	3.5	2.1	1.9	1.7	1.6	1.6	1.9	2.2	2.3	2.4
NNW	3.3	4.2	4.5	4.9	3.2	2.2	1.9	1.8	2.1	2.4	2.6	3.3	3.0
N	3.4	4.0	3.1	3.3	3.0	2.3	1.8	1.5	1.8	1.9	2.0	2.8	2.6
ANN	38.5	39.7	36.4	36.2	25.3	19.6	17.1	15.5	19.0	22.2	31.8	34.4	27.6

HAMILTON ROYAL BOTANICAL GARDENS

% time wind > 20 km/h

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
NE	3.0	2.8	6.0	5.5	2.3	1.1	0.5	0.5	1.6	2.1	2.9	3.7	2.7
E	0.5	0.4	0.1	0.3	0.2	0.1	0.1	0	0	0.1	0.4	0.8	0.2
SE	0.3	0.4	0.8	0.6	0.2	0.2	0.1	0.1	0.2	0.3	0.3	0.3	0.3
S	0.9	0.9	0.5	0.5	0.8	0.4	0.3	0.2	0.2	0.6	0.6	0.4	0.5
SW	14.4	9.3	7.1	6.5	4.3	3.1	2.3	1.7	2.7	4.8	9.0	9.8	6.3
W	2.2	3.2	3.0	3.3	2.2	1.2	0.9	0.8	0.7	1.4	2.2	1.6	1.9
NW	2.8	3.0	5.1	5.2	2.9	1.9	2.0	1.3	1.4	2.3	2.9	3.4	2.9
N	0.8	0.7	0.7	0.7	0.3	0.2	0.1	0	0.3	0.3	0.6	0.7	0.4
ANN	24.9	20.7	23.3	22.6	13.2	8.2	6.3	4.6	7.1	11.9	18.9	20.7	15.2

GUELPH

% time wind > 20 km/h

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
NE	1.4	0.7	1.0	1.5	0.7	0.3	0	0.1	0.2	0.2	1.1	1.6	0.7
E	3.2	1.6	5.7	4.9	2.8	1.0	0.2	0.2	0.4	0.8	1.7	2.4	2.1
SE	0.1	0.1	0.2	0.5	0.2	0	0.1	0	0	0.2	0.4	0.2	0.2
S	0.5	0.8	0.3	0.9	0.5	0.2	0.3	0.1	0.3	0.9	1.4	0.5	0.6
SW	7.1	4.6	3.5	3.9	3.5	2.9	1.6	1.1	1.9	4.1	4.4	3.7	3.5
W	11.1	12.2	9.0	7.4	7.0	3.1	2.3	2.1	2.3	5.3	9.5	8.6	6.6
NW	4.3	6.6	5.5	6.0	4.5	2.8	2.8	2.7	2.5	2.5	5.2	4.7	4.2
N	0.8	1.6	1.0	1.5	1.2	0.6	0.4	0.2	0.6	0.7	1.8	1.6	1.0
ANN	28.5	28.2	26.2	26.6	20.4	10.9	7.7	6.5	8.2	14.7	25.5	23.3	18.9

ELORA

% time wind > 20 km/h

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
NE	2.1	1.7	2.2	2.8	1.7	0.9	0.1	0.2	0.6	0.9	1.4	2.4	1.4
E	3.2	4.1	7.3	6.3	2.9	0.7	0.4	0.3	0.6	2.0	3.9	4.6	3.0
SE	1.6	0.6	1.1	1.0	1.5	1.1	0.2	0.2	0.5	1.2	1.2	1.3	1.0
S	1.4	1.2	0.9	1.3	1.4	1.2	0.4	0.3	0.7	1.4	2.0	1.0	1.1
SW	13.1	8.4	4.8	6.3	4.9	5.4	4.5	2.6	3.7	5.9	10.4	11.2	6.8
W	12.7	9.1	7.9	7.3	4.7	3.4	2.2	0.9	1.5	2.8	7.5	8.3	5.6
NW	6.1	7.2	11.0	12.4	6.8	5.7	4.9	2.9	4.2	5.8	5.9	7.6	6.6
N	0.6	2.4	1.3	1.7	1.4	1.1	0.6	0.3	0.3	0.6	1.9	1.2	1.1
ANN	40.8	34.7	36.5	39.1	25.3	19.5	13.3	7.7	12.1	20.6	34.2	37.6	26.6

FERGUS

% time wind > 20 km/h

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
NE	1.1	0.8	1.8	1.5	0.7	0.2	0	0.1	0.1	0.5	0.7	1.2	0.7
E	1.8	1.0	2.2	1.6	0.8	0.1	0	0.1	0.2	0.1	0.9	1.1	0.8
SE	1.9	1.3	2.6	2.5	1.4	0.6	0.1	0.1	0.4	1.2	2.3	1.9	1.3
S	0.6	0.5	0.6	0.7	0.4	0.4	0.1	0.1	0.3	0.6	0.9	0.4	0.5
SW	8.8	5.3	4.0	4.4	3.2	2.8	2.3	1.5	2.4	4.5	6.8	8.4	4.5
W	7.7	6.2	4.7	4.9	2.6	1.1	1.1	0.8	1.6	2.2	5.6	4.5	3.6
NW	6.5	8.2	8.7	9.2	6.3	4.8	3.7	3.6	3.9	5.6	6.9	6.3	6.1
N	0.1	0.2	0.2	0.1	0.0	0	0	0	0	0.1	0.2	0.1	0.1
ANN	28.5	23.5	24.8	24.9	15.4	10.0	7.3	6.3	8.9	14.8	24.3	23.9	17.6

VALENS

% time wind > 20 km/h

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
NE	3.2	2.6	3.7	3.9	2.2	0.4	0	0.3	0.9	1.2	1.3	2.3	1.9
E	0.7	1.3	2.0	2.6	0.3	0	0	0	0	0	1.3	0.8	0.8
SE	0.4	0	0	0	0	0	0.2	0	0	0	0.5	0.1	0.1
S	0.5	0.5	0.3	0.5	0.4	0.1	0	0	0.2	0.3	0.8	0.3	0.3
SW	12.3	9.6	6.7	6.6	3.4	2.2	2.1	1.9	2.2	5.8	9.7	12.6	6.5
W	1.3	1.5	1.7	1.2	0.2	0.1	0	0	0.1	0.2	0.6	0.5	0.6
NW	3.0	2.5	5.6	7.7	2.3	1.5	0.9	0.2	0.8	2.4	2.8	3.5	2.8
N	0.3	0.6	0.5	1.6	0.6	0.1	0.1	0	0	0.1	0.8	0.4	0.4
ANN	21.7	18.6	20.5	24.1	9.4	4.4	3.3	2.4	4.2	10.0	17.8	20.5	13.4

HAMILTON MARINE POLICE

% time wind > 20 km/h

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
NE	3.3	4.0	6.5	6.8	3.9	3.5	2.2	2.4	4.7	4.3	4.6	5.1	4.2
E	2.1	2.2	4.2	3.4	1.4	1.2	0.5	0.7	1.0	0.9	1.4	2.4	1.7
SE	0.2	0.3	0.4	0.2	0.2	0	0.1	0	0	0.2	0.7	0.7	0.3
S	0.1	0	0	0.2	0.1	0	0	0	0	0	0.2	0	0.1
SW	12.7	7.2	5.0	5.4	4.6	3.0	2.5	2.0	2.6	5.0	9.0	9.2	5.7
W	7.6	8.2	7.6	6.3	5.3	3.2	2.9	2.1	2.5	3.9	5.9	5.5	5.0
NW	3.8	4.2	6.9	6.7	3.4	3.3	3.5	2.6	2.8	4.1	4.4	4.5	4.1
N	0.8	0.9	0.5	0.8	0.8	0.5	0.2	0.2	0.7	0.4	0.6	0.8	0.6
ANN	30.6	27.0	31.1	29.8	19.7	14.7	11.9	10.0	14.3	18.8	26.8	28.2	21.7

APPENDIX B

PRECIPITATION INFORMATION FOR SELECTED WEATHER STATIONS

MEAN TOTAL PRECIPITATION (mm)

	ANN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Milton Kelso	874.9	72.7	65.9	72.3	79.2	68.0	72.9	57.7	88.4	72.2	68.0	77.2	80.4
Hornby	837.6	69.3	53.8	66.6	73.1	72.7	71.4	65.5	91.9	69.7	63.4	70.5	69.7
Trafalgar Marine	822.5	60.2	64.4	73.0	74.5	67.9	69.3	63.6	80.5	75.2	63.7	66.2	64.0
Erindale	811.0	59.3	52.2	63.9	74.5	69.9	70.5	70.7	76.4	71.2	66.0	68.0	68.4
Millgrove	842.8	59.3	53.2	68.4	76.1	71.0	73.3	71.2	87.3	75.6	69.6	66.2	71.6
Elora	835.9	58.3	48.9	74.1	70.2	77.6	86.9	73.0	72.1	71.3	66.3	65.7	71.5
Fergus	922.5	70.8	57.6	75.0	79.1	78.5	86.0	74.9	83.8	77.4	78.4	81.4	79.6
Guelph	833.3	56.3	50.5	62.5	73.9	72.7	70.6	82.4	81.5	63.4	73.4	74.9	71.2
Hamilton RBG	838.9	65.5	53.6	75.3	77.4	69.9	67.7	67.0	81.1	73.0	68.7	65.8	73.9
Aldershot	860.2	58.8	58.9	71.3	80.8	74.4	72.2	75.4	87.4	66.1	73.3	69.9	71.7
Burlington TS	822.0	69.8	55.7	65.7	81.9	66.6	67.3	68.2	77.3	73.6	62.1	61.4	72.4
Burlington Fire HQ	778.2	57.2	42.1	58.0	73.9	68.8	68.7	75.2	72.6	71.9	69.5	58.2	62.1
Burlington	776.7	54.3	50.5	67.3	72.2	63.1	64.3	73.6	76.5	60.7	70.9	60.9	62.4
Oakville	799.3	57.1	49.8	59.0	74.9	72.1	65.8	69.1	82.1	73.2	65.7	64.6	65.4
Oakville SWWPCF	764.7	55.1	43.5	62.9	72.0	59.6	69.8	65.0	79.8	73.1	64.8	56.4	62.7
Clarkson	804.6	60.0	57.6	68.6	74.3	61.8	69.8	65.6	81.6	66.5	60.8	67.3	70.7
Valens		58.6	55.4										

NUMBER OF DAYS WITH MEASURABLE PRECIPITATION

	ANN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Milton Kelso	132	13	12	12	11	10	10	8	10	9	10	12	15
Hornby	118	11	9	11	10	10	9	8	9	8	10	11	12
Trafalgar Marine	111	10	8	9	11	9	8	8	8	9	10	11	10
Erindale	133	13	10	11	11	12	11	9	10	10	10	12	14
Millgrove	98	8	7	8	9	9	8	7	8	7	8	9	10
Elora	158	19	16	14	13	12	10	9	11	10	11	14	19
Fergus	148	17	13	13	12	11	10	9	10	11	12	14	16
Guelph	140	15	12	12	12	11	10	9	10	10	10	13	16
Hamilton RBG	133	14	11	12	12	11	10	9	9	9	10	12	14
Aldershot	115	10	9	11	11	10	8	8	8	8	9	11	12
Burlington TS	112	10	8	10	11	10	8	8	9	8	9	10	11
Burlington Fire HQ	106	9	6	9	10	11	9	8	8	8	9	10	9
Burlington	100	9	8	10	9	9	8	7	8	7	7	8	10
Oakville	120	11	10	10	12	11	8	8	9	8	9	11	13
Oakville SWWPCF	122	11	9	12	12	10	10	9	8	10	10	11	10
Clarkson	97	10	8	8	8	8	8	7	7	8	7	8	10
Valens	113	12	10	10	10	9	7	7	9	8	9	10	12
Tor. Int. Air.	137	14	12	13	11	11	9	9	10	9	11	13	15

APPENDIX C

EMISSION FACTORS
SUSPENDED DUST - SAMPLE CALCULATION
MALODOUR - SAMPLE CALCULATION

EMISSION FACTORS (T.S.P. $\leq 30\ \mu m$)

Topsoil Handling

- a) Removal by scraper = 0.058 lb/T

  b) Hauling by scraper = $2.7 \times 10^{-5}(s)^{1.3}(W)^{2.4}$

  where s = silt = 7.2-25.2% (16.4 mean)

  W = weight = 36-70 tons (53.8 mean)

  c) Unloading by scraper = 0.04 lb/T

  d) Storage (all exposed areas) = 0.38 T/acre·year

- Pickup and dump into truck by shovel/front end loader (capacity 2.5-8 yd^3)

  = 0.037 lb/yd^3 = 0.022 kg/m^3

- (1) Bulldozing (overburden)

  $$\text{Emission factor} = \frac{5.7\ (s)^{1.2}}{(M)^{1.3}} \frac{lb}{hr}$$

  where s = material silt content (%) ≅ 8% default

  M = material moisture content (%) ≅ 7-8% default

  (2) 32 lb/dozer hour

- (1) Grading = $0.040\ (S)^{2.5}$ lb/VMT

  where S = mean vehicle speed = 7.1 mph (11.4 kph)

  (2) u = 32 lb/hr/grader

- Haul trucks = $0.0067\ (w)^{3.4}(L)^{0.2}$ lb/VMT

  where w = mean number of wheels, G.M. = 8

  L = road surface silt loading (g/m^2) = 40.8 g/m^2

- (1) Batch drop $$E = \frac{k(0.00090)\left(\frac{s}{5}\right)\left(\frac{u}{2.2}\right)\left(\frac{H}{1.5}\right)}{\left(\frac{M}{2}\right)^2\left(\frac{Y}{4.6}\right)^{1/3}} \frac{kg}{Mg}$$

  where k = particle size multiplier = 0.73 $\leq 30\ \mu m$

  s = material silt content = 7-15%

  u = mean wind speed, m/s

  H = drop height, assume 1.5 m

  M = material moisture content (.25-0.7)

  Y = dumping capacity m^3

  (2) Batch drop 0.12 kg/mg (T.S.P.) (0.24 lb/ton)

- Wind Erosion (seeded land, stripped overburden, graded overburden)

  (1) E.F. = 0.38 T/acre·year (0.85 Mg/hectare·year)

  (2) $$E = 1.9\left(\frac{s}{1.5}\right)\left(\frac{365-p}{235}\right)\left(\frac{f}{15}\right) \text{ kg/day/hectare}$$

Emission factors (continued)

where s = silt content (aggregate)

p = number of days with ≥ .25 mm precipitation (measurable)

f = frequency of time that unobstructed wind speed exceeds 5.4 m/s (12 mph)(20 kph) at the mean pile height

(3) E = 3.9 kg/hectare/day

Unpaved Roads

- Haul trucks E.F. = 33 lb/VMT
- Vehicle travel on unpaved roads

  Heavy duty vehicle E.F. 14.7 kg/VKT (52 lb/VMT)
- $E = k(5.9)\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right)$ lb/VMT

  where k = particle size multiplier (dimensionless) (0.8 ≤ 30 μm)

  S = mean vehicle speed, mph (13-40)

  s = silt content of road surface, % (4-20)

  W = mean vehicle weight (tons) (3-157)

  w = mean number of wheels (4-13)

  p = number of days with measurable precipitation

Paved Roads

- $E = k(0.090)I\left(\frac{4}{n}\right)\left(\frac{s}{10}\right)\left(\frac{L}{1000}\right)\left(\frac{W}{3}\right)^{0.7}$ lb/VMT

  where k = as above (0.86)

  I = augmentation factor for industrial road = 7 when travelling on unpaved bed

  = 3.5 unpaved shoulder

  n = number of traffic lanes (2)

  s = surface silt content (%) (5-92)

  L = surface dust loading (lb/mile) (149-7,100)

  W = average weight of vehicle (tons) (3-13)

MALODOUR - SAMPLE CALCULATION

I Malodourous area = 500 m^2 = 5379 ft^2

II Odour generation rate = $\frac{2 \text{ O.U.}}{ft^2 \text{ min}} \times 5379 \text{ } ft^2$

$= 10{,}758 \text{ O.U./min}$

$= 179.3 \text{ O.U./sec}$, say 180 O.U./sec

III Odour threshold = $\frac{1 \text{ O.U.}}{ft^3} = \frac{1 \text{ O.U.}}{ft^3} \times \frac{35.31 \text{ } ft^3}{m^3} = \frac{35.31 \text{ O.U.}}{m^3}$

IV Concentration at 100 m downwind:

$$\chi = \frac{Q \times \text{safety factor}}{\pi \times u \times \sigma_y \sigma_z}$$ where $u = 1$ m/s, $\sigma_y \sigma_z = 9 \text{ } m^2$ (at 100 m)

$$= \frac{180 \times 10}{\pi \times 1 \times 9}$$

$= 63.7 \text{ O.U.}/m^3$ (1.8 times threshold)

Concentration at 200 m downwind:

$$\chi = \frac{Q \times \text{safety factor}}{\pi \times u \times \sigma_y \sigma_z}$$

$$= \frac{180 \times 10}{\pi \times 1 \times 32}$$

$= 17.9 \text{ O.U.}/m^3$ (½ threshold)

SUSPENDED DUST - SAMPLE CALCULATION

Erosion

Exposed Area = 600 m x 100 m

For wind perpendicular to 600 m axis, lateral dispersion standard deviation

$$\sigma_y \cong \frac{600}{4.3} = 400 \text{ m}$$

For σ_{y_c} = 400 m, distance to virtual point source

$x \cong 910$ m, say 900 m

Distance from virtual source to property line is

x =	900 m
plus buffer =	100 m
	1000 m

∴ For "C" stability, windspeed of 5.4 m/s (u)

$$\frac{\chi u}{Q} = \frac{5 \times 10^{-5}}{m^2} \text{ at } 1000 \text{ m}$$

Concentration $\chi = 5 \times 10^{-5} \times \frac{Q}{u}(f)$ where Q = emission rate
f = averaging time

$$\chi = 5 \times 10^{-5} \times \frac{2.1}{5.4} \times 0.6 \times 10^6$$

Concentration χ = 11.7 micrograms per cubic metre
(at 1000 m downwind)

APPENDIX D

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