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**REVISED
WITNESS STATEMENT
OF
RALPH E. CRYSLER, P. Eng.**

In the matter of the Consolidated Hearing for the Environmental Assessment of Proposed Halton Region Landfill Component of Solid Waste Management.

A. ROLE AND RESPONSIBILITIES

I am a Professional Engineer registered to practice in the Provinces of Ontario and Alberta. My resume is attached and lists my qualification and experience in considerable detail. I am presently employed by **Trow Hydrology Consultants Ltd.** as Manager of Environmental Services. I have held this position since February of 1984.

As stated in the Introduction to Final Technical Report No. 7 of Phase 2, Stage 2C, "it was **Hydrology Consultants'** task to conduct preliminary hydrogeologic-hydrologic assessments and to prepare generic conceptual site development plans for Candidate Sites A, B, C, D, E and F". Using the general engineering criteria set forth in Section 1.6 of that report, it was my responsibility to prepare conceptual plans for each site, recognizing the hydrogeologic constraints and the leachate control methods determined by others. It was my responsibility to determine, in general, how surface water was to be handled and how collected leachate would be handled on-site or off-site. The level of design was sufficient to permit a basic comparison among sites.

In the Technical Studies for Sites D and F (referred to as EPA Level of Detail). **Trow Hydrology Consultants Ltd.** was responsible for hydrogeologic studies and engineering designs. The results of these studies and designs are described in the Design and Operations Reports. In this phase of the work, I was responsible for the design of surface water control features. Although this work was done under my direction, I was not able to provide direct supervision or review of all of that work. Subsequent to the completion of the Design and Operation Reports, I have reviewed that earlier work and have directed and participated in additional analyses to clarify a number of details and to satisfy myself as to the adequacy of the design.

B. HYDROLOGIC METHODS

All runoff calculations (i.e., calculation of stream flow and ditch flow) were undertaken using the Rational Formula which relates stream discharge to rainfall intensity, drainage area and basin characteristics. This is a method which has been in use for many years and which is considered to be reasonably accurate for drainage areas of less than 25 square kilometers (i.e., 25,000 ha). The rainfall intensity was determined from Intensity-Duration-Frequency (IDF) Curves produced by Environment Canada. For Site F, curves from two nearby stations (Burlington Fire Headquarters and Hamilton RBG) were averaged. For Site D, curves are available for four nearby stations: Hornby, Burlington Fire Head Quarters, Oakville SE OWRC, and Hamilton RBG. The Hornby curves are based on a relatively short period of record and are classed only as estimated for frequencies in excess of ten years. Hence, although the Hornby station is quite close to Site D, it could not be used reliably by itself and it was decided to average the four sets of curves.

The "Time of Concentration", which is a watershed characteristic used in conjunction with the IDF Curves, has been the subject of much research. We investigated four common formulae for the Time of Concentration: Kirpich, Airport, Bransby-Williams and SCS. In the pre-development conditions at Site F, the SCS method consistently gave high readings and the other three were reasonably close with Kirpich being on the low side. (Note that high Times of Concentration give lower or less severe flow figures.) In the post-development situation, the Airport formula gave the highest figures followed by the SCS method. MTC Hydrology Section[1] recommends the use of either the Airport or the Bransby-Williams formula in Southern Ontario, depending on site conditions. In the case of Site F, the Bransby-Williams criteria most closely suited the site and it was decided to use that formula exclusively.

For Site D, it was found in all cases that SCS was high and Kirpich was low. Considering the site conditions, it was decided to average the Bransby-Williams and the Airport values.

The runoff coefficient was developed from standard tables published by several references.[2,3,4] Drainage areas were delineated and measured on the 1:2000 mapping prepared for this study. Stream gradients and valley slopes were interpreted from the same mapping.

In a response (January 13, 1986) to a request from Walker Wright and Young, the City of Burlington advised that they would require on-site channels to be designed for the 5-year storm (Q5). If retention or flood control ponds were to be used, those ponds would have to be designed for the 25-year storm (Q25) and checked for the 100-year storm (Q100).

In a letter dated February 17, 1986, the Halton Region Conservation Authority advised the consultants to the City of Burlington that any channel works undertaken in connection with the Bayview Park would have to be protected from erosion during the fifty year storm, but could be sized for some smaller flow (i.e., overtopping would be accepted, but not erosion).

Based on these two directives, it was originally decided to investigate the sites only for Q25. This was the basis for the designs set forth in the Design and Operations Report for Site F, dated September, 1986. In the later review, and additional analyses, the designs were checked for Q100 as well as for Q25. In addition, the Site D plans included a major stream diversion. This diversion was checked for the Regional Storm.

C. SITE F INVESTIGATIONS

C.1 Site Description

The Site Description is found in the Design and Operations Report for Site F. Site F is situated almost entirely on the western portion of the Indian Creek watershed. The northernmost edge and the southwestern part of the site drain north and west, respectively, into Falcon Creek. The surface relief of the site can be described as being extensively dissected by ravines.

At present, there are three stream channels that drain from the northern part of the site, and two that drain the southeastern part, south of the Bayview site (formerly the Bayview Landfill). These five streams cross under the North Service Road and Highway 403 at three points. The most easterly stream crosses under the North Service Road at the King Road intersection. The other stream that drains the area south of the Bayview site crosses under the North Service Road about 230 m west of King Road. The three stream channels draining the northern part of the site flow through a single box culvert under the North Service Road about 430 m west of King Road. South of Highway 403, this stream swings to the east and joins the flow from the adjacent channel.

The stream channels draining from the northern part of the site each flow over three distinct types of terrain. The northern part of the site is relatively flat table land and the channel gradients are less than four percent. In the main part of the site, channel gradients are as high as eight percent in gullies having side slopes as steep as 55%. In the southern part of the site, the stream gradients range from about three to five percent with relatively low side gradients.

In many reaches, the channel is obstructed with windfalls and other debris. The middle stream draining from the north has two dams on it, about 100 m apart. These dams were apparently constructed prior to 1935 and the ponds behind them have been so silted up that little storage capacity remains.

All streams on Site F are considered to be ephemeral. It should be noted that part of the existing Regional Landfill Site drains to the east into Indian Creek as well as east and south into Falcon Creek. The Bayview Park Site drains, in part, to the west and south into three of the Indian Creek streams.

C.2 Site Development

The proposed development of Site F has been described in the Revised Design and Operations Report for Site F. The development will affect the existing surface drainage patterns in several ways, as follows:

i) The two more westerly stream channels that drain from the northern part of the site will be completely removed as the site is excavated for the landfill.

ii) The northern half of the third stream channel draining from the north (and which receives drainage from Bayview) will also be removed by the landfill operation.

iii) The runoff from the entire area of the Site F landfill will be collected into perimeter ditches that will lead through retention ponds to the box culvert under the North Service Road.

iv) A portion of the runoff from the southwest corner of the site that now drains to Falcon Creek will be redirected to the east and will discharge through the South Retention Pond to Indian Creek. This diversion will add 4.6 ha. to the drainage basin of Indian Creek.

v) The northern portion of the ditch on the east side of Site F will also receive some runoff from the Bayview Site. This ditch will pass through the East Retention Pond and discharge into the remaining southern portion of the most easterly of the three existing streams. A part of this work has already been done by the City of Burlington in connection with their remedial work at the Bayview Site.

vi) The southern portion of the ditch that receives surface runoff from the east side of the landfill will be separated from the northern portion, and will drain to the South Retention Pond.

vii) The ditch on the west side of the landfill will also drain to the South Retention Pond.

viii) The drainage from the east side of the Regional Landfill is now collected in a separate ditch leading to Falcon Creek. This will not be changed.

ix) The two existing streams that drain the area south of the Bayview Site will not be affected by the development.

C.3 Hydrologic Calculations

This section will present the results of the various hydrologic calculations, and will discuss the significance of those results. As set out in Section C-2, the two streams south of the Bayview Park will not be affected by the development, and hence, they are not considered in these calculations. The area draining to Falcon Creek will be slightly reduced, and there will be no adverse impacts. Hence, Falcon Creek was not considered in these calculations.

The three existing streams that will be affected by the development all pass under Highway 403 in one large concrete box culvert some 430 m west of King Road. In total, these three stream channels now drain an area of 76.8 ha. In the pre-development condition, the peak flows off the property passing through the box culvert under the North Service Road and Highway 403 will be:

Q25 - 4.22 cms (cubic metres per second)
Q100 - 5.14 cms

In the post-development condition, the area draining through the box culvert will increase slightly to a total of 81.4 ha. mostly because of the diversion from Falcon creek. The drainage ditches will, in general, be gabion lined to prevent erosion. In addition, the channel will be stepped to limit the maximum channel gradient to one percent. The discharge exiting the property through the box culvert in the post-development condition was first computed without any retention ponds. These post-development flows are shown below, together with the pre-development flows for comparison. It should be noted that the original design of the ditches, as reported in the Design and Operations Report, was very conservative. So much freeboard had been allowed that the ditches were found to have adequate capacity for Q100.

	Pre-Development	Post-Development	% Increase
Q25	4.22 cms	4.78 cms	13.3
Q100	5.14 cms	5.81 cms	13.0

As this increase in flow was considered to be excessive, it was decided to use retention ponds. Two ponds will exist in the post-development condition. These are shown on the drawings in the Design and Operation Report.

Both the 25 and 100 year design storms were routed through these ponds. Since the Time of Concentration to the culvert under Highway 403 was relatively short at about 51 minutes, it was decided to route both a 51 minute and a three hour duration storm through the retention ponds. The 51 minute duration storm will quantify larger peak flows with a smaller total volume of water required to pass through the ponds while the three hour duration storm will quantify a smaller peak flow but a larger overall volume of water. It should be noted that the ponds used in this analysis are somewhat modified as to size and outfall characteristics from those shown on the drawings that accompany the original Design and Operations Report. The following table summarizes our findings.

			Post Development			
Storm	Duration	Pre-Development	No Ponds	% Increase	With Ponds	% Increase
Q25	51 min.	4.22 cms	4.78 cms	13.3	2.28 cms	-47.0
Q25	3 hr.	1.77 cms	1.98 cms	13.1	1.77 cms	0
Q100	51 min.	5.14 cms	5.81 cms	13.0	2.59 cms	-49.6
Q100	3 hr.	2.20 cms	2.47 cms	13.3	2.09 cms	-5.0

With the retention ponds in place, the design flows leaving the property are actually less than the pre-development flows.

As described in the Design and Operations Report, a third retention pond. the West Retention Pond, will be constructed and used during the first half of the site development. This pond will be removed during the second half of the work and will be replaced by the South Retention Pond. The East Retention Pond will be constructed at the beginning of the site development. In this way, retention ponds will be in place from the beginning to control the runoff from the site. The temporary West Retention Pond is also intended to assist in retaining the existing conditions of the south part of the site until it is disturbed for landfilling. Otherwise the South Pond could be built at once.

The design to date has established the size, gradient and location of the ditches. They will require lining or protection to prevent erosion under all conditions. The details of such lining or protection will be settled in the final design and the preparation of working drawings. In the same way, the exact location and size of channel steps is a matter, normally, of final design and is not addressed here.

Site drainage from within the working area has been described in the revised Design and Operations Report.

C.4 Summary

The results of these analyses have shown that discharges from the property will be less after development than before development. This has been shown to be the case for both the 25 year and the 100 year storms.

It is agreed that the channels will have to be protected from erosion at all flows. Details of the erosion protection are deferred until final design.

In the revised analyses, it was found desirable to re-size the ponds. This has been done and their locations determined. The outlet pipes have been sized to obtain the required impoundment-discharge relationships. The size and location of the detention ponds are indicated on the drawings.

D. SITE D INVESTIGATION

D.1 Site Description

The site description is found on page 17 of the Design and Operations Report for Site D, dated September, 1986. The proposed site lies on a drainage divide between the Bronte Creek and the Sixteen Mile (or Oakville) Creek watersheds. Although both of these main creeks have their headwaters on or above the escarpment, the drainage courses crossing Site D all rise below the escarpment and are all ephemeral streams.

D.1.1 Bronte Creek Tributaries

A tributary of a branch of Bronte Creek rises north of Britannia Road and flows (intermittently) through Site D. It exits the site through a concrete box culvert under the First Line and drains to the west, past the CNR tracks and across Tremaine Road to join the much larger branch of Bronte Creek. Upstream of the First Line box culvert, this tributary drains a total of 273.6 hectares of agricultural land, of which 67.3 ha are on Site D. Upstream of Site D, the stream channel is poorly defined, and for much of its length is little more than a shallow swale. Residents along First Line report frequent floodings and overtopping of the road adjacent to the box culvert (personal communication).

The extreme southwest corner of Site D drains to Bronte Creek through a 450 mm steel culvert under First Line. This culvert drains an area of 3.8 ha. The flow through this culvert joins the flow from the concrete box culvert upstream of the CNR tracks.

D.1.2 Sixteen Mile Creek Tributaries

A minor tributary of a branch of Sixteen Mile Creek crosses through the northeast corner of Site D and joins the branch about 400 m downstream of the site. This larger branch drains an area extending above Steeles Avenue into the built-up area of Milton. The combined flow then passes under Highway 25 in a large concrete culvert. The minor branch drains about 26.7 ha upstream of Site D and about 16.4 ha of Site D. At the point of confluence with the larger branch, the total combined drainage area amounts to 518.1 ha. The tributary crossing the corner of Site D does not have a defined channel.

An area of about 38.6 ha, most of which is on Site D, drains eastward through two culverts under Highway 25 directly to the branch of Sixteen Mile Creek. A further area of 13.8 ha along the southern limit of the site drains southward toward Sixteen Mile Creek. Neither of these last mentioned areas contains any defined creek channels.

D.2 Site Development

The proposed development of Site D has been described in the Design and Operations Report. The development will affect the existing surface drainage patterns in several ways, as follows:

i) The tributary of Bronte Creek that drains from the north will be directed into a shaped and graded channel as it enters the site. The channel will flow westward adjacent to the north boundary and then southward between the screening berm and First Line and will discharge under First Line through the existing concrete box culvert.

ii) The small tributary of Bronte Creek at the extreme southwest corner of the property will not be affected by the development.

iii) The tributary of Sixteen Mile Creek that crosses the northeast corner of the site will be diverted around the actual working area in minor ditches.

iv) That area of the site that drains to the east directly across Highway 25 will be, essentially, untouched. The site access road passes through this area and will require minor roadside ditches.

v) Part of that area at the south of the site that drains southward to Sixteen Mile Creek will be within the working area. The runoff from this affected area will be redirected to the west through the site drainage system to join the flow to Bronte Creek.

vi) The surface runoff from the actual working area will be collected in ditches and discharged from the site through retention ponds. The ditches will drain a total of 52.5 ha. to Bronte Creek and 15.3 ha. to Sixteen Mile Creek.

vii) These various diversions and the distribution of runoff from the landfill itself affect the total drainage areas of the two principal tributaries that cross the property. The pre-development and post-development drainage areas of these two tributaries, measured at the point where they leave the site are:

	Bronte Creek	**Sixteen Mile Creek**
Pre-Development	273.6 ha	43.1 ha
Post-Development	258.8 ha	58.4 ha

D.3 Hydraulic Calculations

This section will present the results of the various hydrologic calculations and will discuss the significance of those results. As set out in Section D.2 above, the flow of only two streams (Items (i) and (ii) of Section D.2) leaving the property will be affected by the development. Hence the calculations and this discussion are restricted to those two streams.

D.3.1 Bronte Creek Tributary

As stated earlier, the tributary of Bronte Creek that traverses the site now drains a total area of 273.6 ha before exiting the property under First Line. In the pre-development condition, it was found that the 25 year flow (Q25) exiting the property would be 6.33 cubic metres per second (cms). This flow is directed through a concrete box culvert, 2.4 m wide by 1.2 m high. A check of the culvert capacity showed that its inlet would surcharge (i.e. overtop) and the nearby road would be overtopped at a flow of 5.34 cms which is about the ten year flow (Q10). Immediately north of the culvert, there is a long sag in the road grade. At Q25, it was found that a length of about 300 m of road would be flooded to a depth of about 0.1 m.

A similar calculation showed that the 100-year flood (Q100) would be 7.95 cms, and the road would be overtopped for a length of about 350 m to a maximum depth of slightly less than 0.2 m. This means that under existing conditions, the water level at First Line will rise by only 0.2 m as flows increase from Q10 to Q100 despite the very low capacity of the concrete box culvert, because of the very long sag in the road.

Downstream of the culvert under First Line, the stream channel has been straightened, widened and deepened by the property owner. This channel improvement apparently extends only to his downstream property line in a woodlot midway between First Line and the railway tracks. We are advised by the residents (personal communication) that flooding of their land is not infrequent and they attribute this to a lack of adequate downstream outlet.

The CNR tracks are approximately parallel to First Line and about midway between First Line and Tremaine Road. The MNR 1:10,000 mapping indicates that the railroad embankment where it crosses the Bronte Creek tributary has a top elevation of 182.5 m ASL (above sea level). By comparison, the elevation of First Line at the box culvert is shown to be 182.0 m ASL. This means that the railroad embankment is higher than First Line. The tributary flows through the embankment in two 1500 mm round steel culverts. Since these two culverts have approximately the same capacity as the upstream concrete box culvert, it is reasonable to expect some considerable damming of water by the embankment. However, the mapping and field reconnaissance indicate that overland flow would occur parallel to the embankment to discharge through other culverts both north and south of the tributary itself, thus relieving some of the possible flooding of the properties between the tracks and First Line. Based on available mapping, it would appear that this relief flow could occur at water levels of about 181.0 m ASL, or about one metre below the First Line, and one and a half metres below the top of the railroad embankment.

In the post-development situation, the flow from the area upstream of the site is diverted in a new channel around the screening berm. The discharge of the drainage from the actual landfill area joins the upstream flow shortly before the combined flow passes under the First Line. The flow from upstream is essentially unchanged for the pre-development flow, but the flow from the landfill area will be increased. Without a retention pond, the pre-development and post development flows at the First Line culvert are:

	Pre-Development	Post-Development	% Increase
Q10	5.55 cms	5.83 cms	5.0
Q25	6.33 cms	6.65 cms	5.1
Q100	7.95 cms	8.46 cms	6.4

It was considered that these increases were too great, and a retention pond was added to the landfill drainage system. When the various flows are routed through the retention pond, the post-development flows are reduced to the following:

	Pre-Development	Post-Development	% Increase
Q25	6.33 cms	6.39 cms	1.0
Q100	7.95 cms	8.07 cms	1.5

The effect of these very modest increases in peak flows will be mitigated very quickly by additional tributary flows downstream. A rough calculation indicates that at the CNR tracks the increases will be reduced to 0.67% for Q25 and 1.0% for Q100. At Tremaine Road the increases would be further reduced to 0.5% for Q25 and 0.85% for Q100. Downstream of Tremaine Road, the tributary joins a much larger branch and the effects of the flow increase will be negligible.

The diversion channel was also checked for the Regional Storm. This storm is so large that the pre-development and post-development flows are unchanged.

The diversion channel has been sized such that the water depth at the downstream end, in all storms, will be below the road level if it were not for the constraint of the existing concrete culvert. This means that if, or when, the capacity of the culvert under First Line is increased, the diversion channel will be correctly sized. In the interim, the existing flow restriction at First Line will cause a backup of water and there will be some greater depth of water in the diversion channel. The channel banks could be set high enough to contain this greater depth. An alternative would be to allow the diversion channel to overtop its west bank to retain the present situation of road overtopping.

The original design of the diversion channel was very conservative. So much freeboard had been allowed that the Regional storm can be accommodated with no change in design.

D.3.2 Sixteen Mile Creek Tributary

As stated earlier, that tributary of Sixteen Mile Creek which crosses the northeast corner of the site drains a total of 43.1 ha before exiting the site. In the pre-development condition it was found that the flows off the site would be:

Q25 - 1.58 cms
Q100 - 1.98 cms

Where the tributary joins the larger channel, some 400 m downstream (and upstream of Highway 25), the combined pre-development flows were determined to be:

Q25 - 10.71 cms
Q100 - 13.09 cms

In the post-development condition, there will be an increased area draining to this tributary because of on-site grading and drainage. This will result in increased flows at the site boundary as follows:

	Pre-Development	Post-Development	% Increase
Q25	1.58 cms	2.60 cms	64.6
Q100	1.98 cms	3.22 cms	62.6

However, 400 m downstream, the tributary joins the larger branch and the increase in the combined flow is much less apparent, as follows:

	Pre-Development	Post-Development	% Increase
Q25	10.71 cms	10.94 cms	2.1
Q100	13.09 cms	13.38 cms	2.2

If these very modest increases a short distance downstream, or the larger increases at the property boundary are not acceptable, the flows can be routed through a retention pond on site, as shown on the Site Plans. This will result in flows as follows:

	At Site Boundary			At Downstream Confluence		
	Pre-Development	Post-Development	% Increase	Pre-Development	Post-Development	% Increase
Q25	1.58 cms	1.55 cms	-1.9	10.71 cms	10.71 cms	0.0
Q100	1.98 cms	1.95 cms	-1.5	13.09 cms	13.09 cms	0.0

D.3.3 Erosion and Scour Control

It will, of course, be necessary to protect all of these man-made channels from scour and erosion during various storm events. It will also be necessary to prevent scour and meanders during the low flow conditions. The form of that scour protection will be determined during the final design stage.

D.3.4 On-Site Storm Drainage

Storm drainage from within the working area has been described on page 68 of the Design and Operations Report for Site D, dated September, 1986, and is not repeated here.

D.4 Summary

Based on our calculations, as described in the Design and Operations Report for Site D, dated September, 1986, and as further expanded above, the design of the Bronte Creek Diversion and of the on-site drainage ditches and retention ponds will result in insignificant increases in flow from the site under all storm conditions.

Since the increases in peak flow are insignificant, there can be no problems of increased downstream erosion or flooding resulting from the proposed development.

Ralph E. Crysler, P. Eng.,
Manager, Environmental Services

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REFERENCES

1. **MTC Drainage Manual**; Chapter B, Design Flood Estimation for Small Watersheds, Drainage and Hydrology Section, Highway Design Office, Ontario Ministry of Transportation and Communications, 1984.

2. **Handbook of Applied Hydrology;** Van Te Chow, Chapter 21, First Edition.

3. **Applied Hydrology and Sedimentation for Disturbed Areas;** B.J. Barfield, R.C. Warner and C.T. Hoan, Oaklahoma Technical Press, 1981.

4. **SCS National Engineering Handbook;** Section 4, Hydrology, Soil Conservation Service, U.S. Department of Agriculture.

GLOSSARY

Intensity-Duration-Frequence Curves
Curves expressing rainfall intensities (measured in millimeters per hour) for specified durations (measured in minutes or hours) and frequencies (measured in years of the return period). These curves are developed from historical rainfall data recorded at meteorological stations.

100-Year Storm
Refers to the storm that is considered to occur on average once in one hundred years. Similarly, the 50-year storm or the 25-year storm will occur, on average, once in 50 years or 25 years respectively.

Q100 is the computed flow that would occur in a stream channel or ditch as a result of the 100-year storm. Q50, Q25, etc., signify the stream flow resulting for the 50-year or 25-year storm, respectively.

Regional Storm
A very high intensity storm which has been designated by the Province of Ontario and which results in the Regional Flood.

Gradient
Refers to slope, as in a stream channel or ditch. If it is expressed as a percentage, it is equivalent to metres of fall (or rise) per hundred metres of length.