Still Creek Stewardship Society

Final Report

Renfrew Ravine Hydrology And Geotechnical Study

September 2008

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October 20, 2008

Shannon Campbell
Still Creek Stewardship Society
3939 Pine Street
Burnaby, BC
V5G 1Z3

Dear Ms. Campbell:

RE: RENFREW RAVINE PARK – RENFREW COMMUNITY PARK
Submission of Final Report
Our File 2511.001-120

We are pleased to submit fifteen (15) copies of the final Renfrew Ravine Park – Renfrew Community Park Hydrology and Geotechnical Study.

We understand that there will likely be ongoing review and use of this document by the City of Vancouver, Vancouver Parks, and Metro Vancouver. We would be happy to attend future meetings or work with the Stewardship Society in any further work on Still Creek or in the Renfrew Ravine.

Please call me at (604) 293-3259 if you have any questions.

Yours truly,

KERR WOOD LEIDAL ASSOCIATES LTD.

Original signed by:

David Matsubara, M.Eng., P.Eng.
Project Manager

/dtm
Encl.

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Still Creek Stewardship Society

Final Report

Renfrew Ravine Hydrology And Geotechnical Study

September 2008

KWL File No. 2511.001

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STATEMENT OF LIMITATIONS

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the Still Creek Stewardship Society for the Renfrew Ravine Hydrology and Geotechnical Study. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Section 1

Introduction

1. INTRODUCTION

1.1 SITE DESCRIPTION

Renfrew Ravine Park and Renfrew Community Park are located in Vancouver between Renfrew Street / Atlin Street (between 25th and 29th Avenue) and Nootka Street, and 19th Avenue and 29th Avenue. 22nd Avenue and the Boyd Diversion separate the two parks. The upstream extent of the open channel of Still Creek is located within these parks, which constitute some of the only remaining undeveloped land in the Still Creek watershed. Renfrew Ravine Park is an undeveloped treed ravine while Renfrew Community Park has been more extensively landscaped. Still Creek flows in a mostly natural channel through the ravine although sections of the creek are culverted and some banks are protected. The creek flows in a largely manmade channel through Renfrew Community Park before entering another culvert that takes it out of the study area.

1.2 PROJECT PURPOSE

Two recent studies have been prepared regarding management and enhancement of Still Creek. These studies are:

- Lees + Associates, Karen Hurley + Associates, Dayton + Knight Engineers, Hudema Consulting Group, 2002. *Still Creek Rehabilitation and Enhancement Study*. Report prepared for City of Vancouver Community Services Planning Department; and

- City of Burnaby, City of Vancouver, Greater Vancouver Regional District, 2007. *From Pipe Dreams to Healthy Streams – The Integrated Stormwater Management Plan for the Still Creek Watershed.*

The 2002 "Enhancement Study" is a broad planning document that develops conceptual plans for reaches of the Still Creek corridor based on available information, existing knowledge, current work in the area of watercourse enhancement, objectives of the City of Vancouver and consultation processes. This document provides comprehensive documentation of a vision for Still Creek.

The 2007 Integrated Stormwater Management document (ISMP) further developed the concepts from the 2002 study under a regional framework developed and administered by Metro Vancouver. While the initial Enhancement Study was quite broad in most aspects, the ISMP further developed specific ideas surrounding stormwater management, water quality, and aquatic life and habitat. Both of these documents recognize the need for additional specific engineering studies (including geotechnical and hydrological) for implementation of management objectives.

To move the specific objectives in the Renfrew corridor forward, the 2007-2008 Vancouver Board of Parks and Recreation (Park Board) Capital Plan approved funding for studies for park renewal for both Renfrew Ravine Park and Renfrew Community Park. Under the current capital plan, a management plan will be developed by the Park Board for both parks. In collaboration with the Park Board, City of Vancouver Engineering and Metro Vancouver, the Still Creek Stewardship Society (SCSS) obtained grant funding for baseline studies for the future park management plans. The SCSS has retained Kerr Wood Leidal Associates (KWL) to conduct a hydrology and geotechnical study that will provide information for development of the management plan.

The work program for this project is summarized in Table 1-1.

Table 1-1: Work Program

TASK	DESCRIPTION
1. Project Initiation	• Make contractual arrangements with Still Creek Stewardship Society. • Obtain existing survey data of Renfrew Ravine/Community Park, and other relevant background data. • Obtain and review available air photography, and previous maps.
2. Survey / Fieldwork	• Conduct a topographic survey of Renfrew Ravine and Renfrew Community Park.
3. Terrain Mapping Analysis	• Terrain mapping including digital transfer of airphoto interpretations and preparation of terrain map. • Assessment of slope instability.
4. Hydrology and Water Quality	• Review available information concerning hydrology. • Collect flow measurements at several times during the project to estimate average flows and possible variation. • Obtain stage data from Metro Vancouver for the Renfrew culvert stage recorder and review data to estimate low flows and high flows. • Review local gauged data from other systems for flow estimate. • Scope the level of effort for a detailed rainfall-runoff calibrated model. • Review available water quality data (City of Vancouver/City of Burnaby). • Conduct preliminary water quality assessment including: - Dissolved oxygen, turbidity, conductivity, chemical oxygen demand, biochemical oxygen demand, nutrients, dissolved metals, metalloids, heavy metals. • Suggest future monitoring program.
5. Draft Report	• Summarize analysis in draft report, including figures. • Submit draft report to Still Creek Stewardship Society for review.

TASK	DESCRIPTION
6. Project Completion	• Incorporate feedback into draft report. • Finalize report and submit to Still Creek Stewardship Society.

1.3 PROJECT TEAM

The primary project team includes:

- David Matsubara, M.Eng., P.Eng., Project Manager;
- Erica Ellis, M.Sc., G.I.T., Fluvial Geomorphologist; and
- Martin Zaleski, PG, Engineering Geologist (BGC Engineering).

KWL has retained BGC Engineering to conduct the terrain mapping analysis.

Shannon Campbell of the SCSS provided overall project management, with technical input from Dr. June Ryder. Other project proponents included the following staff from the Park Board, City of Vancouver, and Metro Vancouver:

- Kate Davis-Johnson – Park Board Manager of Park Development and Planning;
- Debra Barnes – Park Board Project Manager;
- Steve McTaggart – City of Vancouver Engineering;
- Neil McCreedy – City of Vancouver Environment; and
- Mark Wellman – Metro Vancouver Drainage Engineering.

Funding for this study was provided in a grant to the Still Creek Stewardship Society by the Real Estate Foundation of BC.

Section 2

Terrain Mapping

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2. TERRAIN MAPPING

2.1 PURPOSE FOR TERRAIN MAPPING

The 2002 Enhancement Study specifically identified the possibility of slope instability and the need for detailed geotechnical assessments for the implementation of a number of potential stormwater management concepts. The current objectives for the Renfrew Ravine and Renfrew Community Park include provision of access and interpretative areas that could include pathways, boardwalks, and viewing platforms. More ambitious secondary goals include potential construction of stormwater treatment facilities, fish habitat structures, channel restructuring, and aesthetic stream features. Based on the limited available terrain mapping, interpretation, and other geotechnical information, the SCSS identified detailed terrain mapping as the first step in the park planning process.

2.2 TERRAIN MAPPING

Terrain mapping is a classification system used to describe landforms, surficial materials and geomorphological processes. For this project, terrain mapping and interpretation for a terrain classification system were used to provide a relative level of slope instability. This information is intended to be used to guide management and enhancement activities in the parks. In particular, the mapping identifies geotechnical features that could constrain potential park land use and activities, as well as landforms and features that indicate past or ongoing slope instability.

The terrain mapping should not be confused with detailed geotechnical investigation, testing and analysis. Whereas terrain mapping could be used to help site low complexity structures such as trails and public amenities, terrain mapping is not a substitute for geotechnical engineering for larger structures, especially those that might impound water, or result in further steepening of slopes. The complete BGC Engineering report is provided in Appendix B. This report, complete with the terrain map figures, should be read in its entirety; the following summary is provided merely as an introduction and summary of BGC's findings.

2.3 TERRAIN MAPPING METHODOLOGY

The BGC terrain mapping program combines all available information including historical aerial photographs, ground surveys and photogrammetric contour information provided by the Park Board and City of Vancouver respectively, and geotechnical investigations available for the Skytrain site to the south of the site. The field program included traversing of the slopes in both parks and surveying topography in Renfrew Ravine Park.

Terrain interpretation was conducted using a five class rating system in which higher number stability classes are associated with higher potential terrain instability. The study area was divided into polygons that are described in terms of surficial material, geomorphological process, stratigraphic units, surface expression and slope steepness. Based on observations and measurements, each terrain polygon was classified with respect to stability using the following classes:

- **I – Stable**: includes gently sloping (<15%) areas underlain by active floodplains, rock, glaciofluvial deposits, till and mixed glacial drift. Rock inclined at up to 50% is also considered stable;

- **II – Probably Stable**: includes flat-lying (<15%) glaciolacustrine deposits, fills, and saturated active fluvial deposits. Glaciofluvial deposits, till and mixed glacial drift inclined at up to 30%, are included, and rock at up to 70% is also included;

- **III – Potentially Unstable**: glaciolacustrine deposits, fill, and other glacial deposits that are saturated or gullied, that are inclined at up to 30%, are included. Other glacial deposits that are not saturated or gullied can be inclined up to 50%, and rock may exceed 70%;

- **IV – Probably Unstable**: glaciolacustrine deposits, other saturated glacial deposits, and fills inclined up to 50% are included. Other glacial deposits may be inclined up to 70% if they are not saturated or gullied. Any slopes showing evidence of creep fall into this category; and

- **V – Unstable**: fill and glaciolacustrine deposits exceeding 50% gradient, and all other glacial deposits exceeding 70% gradient, are included. All rapid mass movement source and deposition areas are included, including thick deposits of colluvium. Any saturated ground in excess of 50% gradient is included.

A complete discussion of the terrain mapping is provided in the BGC report (Appendix B).

2.4 SUMMARY OF RESULTS

While the complete BGC report is provided in Appendix B, a colour coded figures showing the terrain mapping results are provided in Figures 2-1, 2-2, and 2-3.

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Still Creek Stewardship Society
Renfrew Ravine Hydrology and Geotechnical Study

Project No.	Date
2511.001	August 2008

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Renfrew Community Park Terrain Map

Figure 2-1

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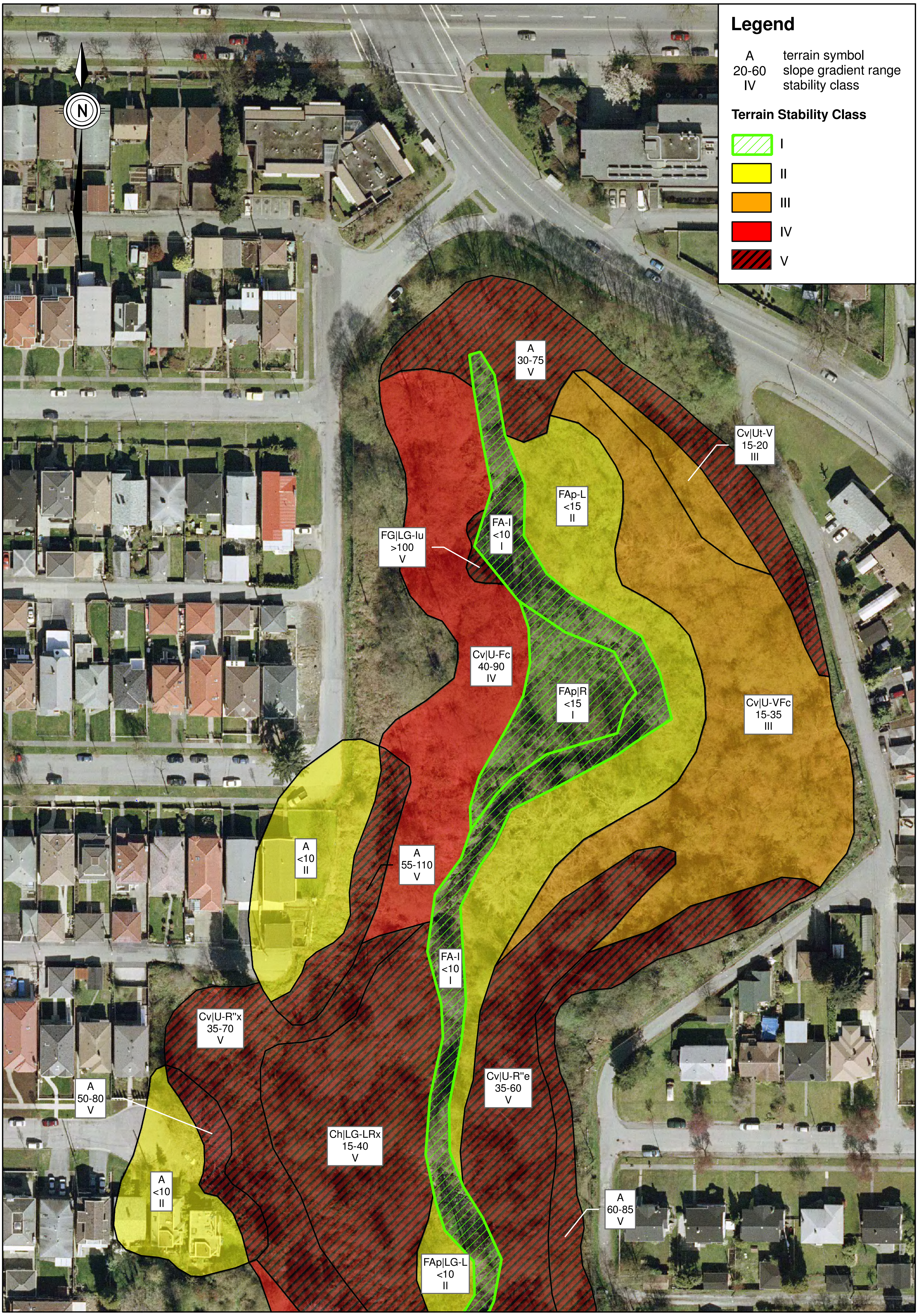

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Renfrew Ravine Hydrology and Geotechnical Study

Project No.	Date
2511.001	August 2008

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Scale 1:1,000

Renfrew Ravine Park Terrain Map (North)

Figure 2-2

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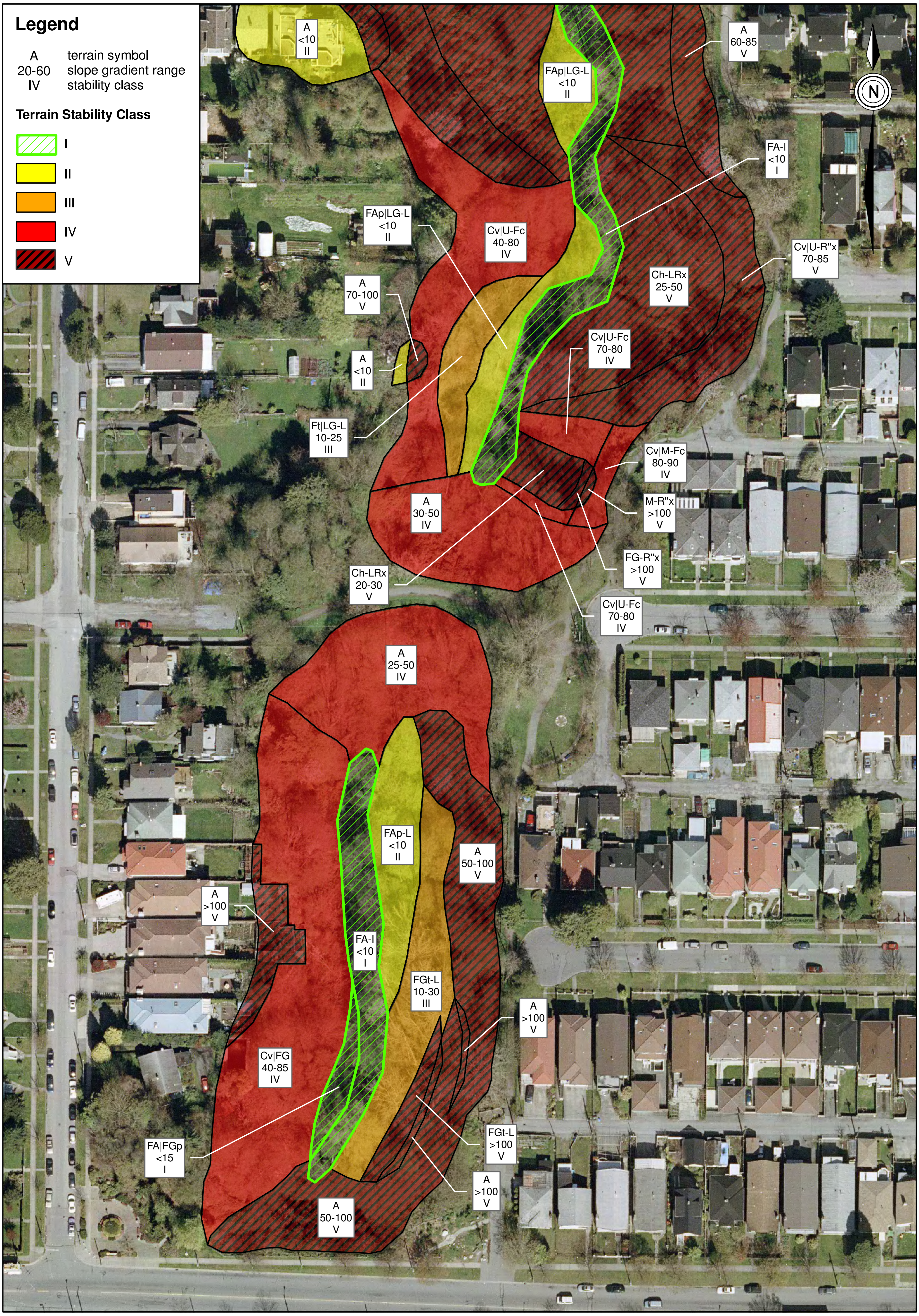

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Renfrew Ravine Hydrology and Geotechnical Study

Project No.	Date
2511.001	August 2008

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Scale 1:1,000

Renfrew Ravine Park Terrain Map (South)

Figure 2-3

Section 3

Hydrology

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3. HYDROLOGY

3.1 STILL CREEK WATERSHED

Renfrew Ravine Park and Renfrew Community Park are located in the headwaters of the Still Creek watershed, which is delineated in Figure 3-1. Most of the upper watershed is located within the City of Vancouver, with a small portion extending into the City of Burnaby. The total drainage area upstream of the park is about 5.58 km^2.

As shown in Figure 3-1, the upper watershed is almost completely developed. Notable green spaces in the upper watershed include the northern portion of Central Park in Burnaby and Killarney Park and a few other smaller fields. The major pipes of the stormsewer network are shown on Figure 3-1 in blue, and indicate how precipitation is normally conveyed from the Vancouver streets to the first open channel section of Still Creek at the Renfrew Ravine. The underground piping and aerial photos were provided to the project by the City of Vancouver Engineering department with approval from the Park Board. Of note, the catchment immediately to the south of the upper Still Creek catchment is the Vivian Creek catchment, which flows to the Fraser River and does have small populations of resident Cutthroat Trout in the Fraserview Golf Course.

Figure 3-2 provides a detailed view of Renfrew Ravine Park and Renfrew Community Park, with the neighbouring stormsewer and combined sewer system. As can be seen from both Figures 3-1 and 3-2, all of the catchment upstream of Still Creek is dedicated stormsewer; however, there are some isolated sections of combined sewer near the Kingsway corridor and a small portion of combined sewer adjacent to Renfrew Ravine Park. The combined mains in the upper watershed appear to be isolated from the stormwater mains although cross-connection issues have been noted in parts of the Still Creek watershed[1].

Inspection of the GIS piping information and field investigations confirmed the two stormsewer outfalls to Still Creek, one on the east bank of Renfrew Ravine from 26th Avenue and the other on the east bank of Renfrew Community Park at 20th Avenue. The combined sewer system on the west bank of the Renfrew Ravine is reported to drain to the northwest, which is consistent with field observations and the general topography. The redirection of this combined sewer catchment to the northwest effectively reduces the catchment area that might otherwise be directed into Still Creek downstream of Renfrew Ravine Park.

Combined sewers were commonly constructed in the mid 1900s, whereby precipitation collected both from streets or building lots would be conveyed in the same pipes as

[1] From Pipe Dreams to Healthy Streams: A Vision for the Still Creek Watershed (The Integrated Stormwater Management Plan for the Still Creek Watershed). January 2007.

domestic sanitary sewage. The practice of the late 1900s and currently is to construct independent sanitary sewers and stormwater sewers to better limit the cost of sewage treatment and some of the environmental issues associated with combined sewer overflows. The City of Vancouver, along with other older municipalities such as the City of Burnaby, has been actively separating combined sewers. In the event that the combined sewer west of Renfrew Ravine is separated in the future, the City of Vancouver could consider implementing some best management practices to both attenuate peak flows and address water quality if directed to Still Creek.

At the upstream end of Renfrew Ravine, the contributing watershed discharges to Still Creek through a circular concrete pipe, measured in the field to be about 1.8 m in diameter. This pipe captures discharges from the 5.58 km^2 upper watershed, which can be roughly divided into two sub-catchments on either side of Kingsway. The western sub-catchment is referred to as the Rhodes Trunk catchment and the eastern sub-catchment, the Collingwood Trunk catchment.

3.2 HYDROMETRIC MONITORING

Metro Vancouver is responsible for much of the operation and management of Still Creek as regional drainage infrastructure. The Water Survey of Canada at one time maintained hydrometric (creek flow monitoring) stations on Still Creek at Gilmore Avenue between 1958 and 1978. Metro Vancouver as part of a management plan for the Brunette River basin (including Still Creek) undertook development of a hydrometric program on Still Creek and various tributaries[2]. These hydrometric stations include:

- Still Creek at Douglas Road;
- Deer Lake Brook at Canada Way;
- Stoney Creek at Government Road;
- Eagle Creek at Winston Street; and
- Still Creek at 22nd Avenue.

In the upper reaches of Still Creek, Metro Vancouver has an automatic stage recorder at the outlet of the box culvert downstream of 22nd Avenue, in Renfrew Community Park. Based on discussions with Metro Vancouver, this station has some available data; however, there have been recent technical problems with the station and Metro Vancouver is still developing a rating curve for this station. Don Maurer of Metro Vancouver was contacted during the project; however, no reliable data could be provided for the project.

[2] December 1998. *Greater Vancouver Regional District Still Creek – Brunette River Floodplain Mapping*. Technical Report.

The Still Creek at 22nd Avenue station is the newest of the monitoring stations and is reported to have been installed in 2007. The other stations have been in place since the 1998 floodplain mapping work was conducted, or from previous programs.

Hydrometric data is also collected on Beecher Creek on behalf of a local streamkeeper group. KWL worked with the streamkeeper group to establish the gauge, which collects flow, stream temperature, and conductivity. This data is reported in a real-time web interface on the KWL Emerald system (www.kwlemerald.com).

UPPER STILL CREEK DISCHARGE AND STAGE MEASUREMENTS

As part of the KWL work program for the current project, discharge and stage measurements were conducted in Renfrew Community Park. Discharge was measured just upstream of a pedestrian bridge, at a relatively uniform section. Stage was measured at the outlet of the box culvert near 22nd Avenue (Metro Vancouver station). The intent of this work was to determine some characteristic discharges and develop preliminary data to assess the Metro Vancouver data. Discharge and stage measurements are summarized in Table 3-1.

Table 3-1: Stage and Discharge Measurements

Date	Discharge (L/s)	Stage (m)
November 23, 2007	70	0.03
December 14, 2007	240	0.07
February 15, 2008	370	0.065
March 3, 2008	1390	0.2

Note: Discharge measured about 9 m upstream of a pedestrian bridge in Renfrew Community Park. Stage measured in the box culvert outlet at the upstream end of the park.

The November 2007 flow is the lowest flow measured in the course of this study: about 69 L/s (note: 1000 L/s = 1 m^3/s). It is possible that summer baseflow may be less than what was measured in November. Baseflow rates for the Lower Mainland range from about 1 $L/s/km^2$ to 5 $L/s/km^2$, which translates to a range of about 6 L/s to 28 L/s for Still Creek at 29th Avenue.

The measurements on December 14th and on February 15th indicate very similar stages in the box culvert but differing discharges downstream in the channel. This indicates some uncertainty in the stage or discharge measurement on these dates, which could be confirmed with additional stage and discharge measurements, or stages could be confirmed from the Metro Vancouver station. This also shows that measurement of very small stage ranges is difficult, and measurements are prone to error without very well established measurement methods.

Measurements on February 15, 2008, and March 3, 2008 were made following heavy precipitation. The culvert used for stage measurements is a 1.8 m by 1.8 m (6’ by 6’) concrete box design, at a gradient of 2.5%. As indicated in Table 3-1, the depth of flow in the culvert is quite shallow and relatively minor changes in stage may result in larger changes in discharge, as can be seen between the December and February measurements. While the measurements provide some initial benchmark data, data collected to this point do not permit the development of a reliable stage-discharge curve.

3.3 PEAK FLOW ESTIMATES

For the purposes of this report, a number of methods were employed to estimate peak flows including:

- rainfall-runoff modelling;
- derivation of unit peak flows from other urbanized catchments; and
- hydraulic modelling of creek and culvert sections.

These methods are described below.

RAINFALL-RUNOFF MODELLING

A lumped rainfall-driven hydraulic SWMM model was used to estimate the 100-year return period discharge for Still Creek at 29th Avenue. The catchment area at 29th Avenue is approximately 558 ha (5.58 km^2) and is estimated to be about 65% impervious area. Input rainfall data were derived from Metro Vancouver station VA04 (Renfrew Elementary School). Model results for the 100-year return period 2-hour storm yield an estimated peak flow of 27 m^3/s. It should be noted that the KWL model is uncalibrated.

In comparison, peak flow results from 1998 GVRD calibrated rainfall-runoff modelling are generally lower[3]. The estimated 200-year return period 2 hour storm peak flow is 19 m^3/s after scaling to the drainage area of the upper watershed. The GVRD model has been calibrated based on longer records lower down in the watershed. Therefore, the calibrated model results may not capture the expected quicker hydrologic response of the upper watershed.

REGIONAL ANALYSIS

Water Survey of Canada (WSC) data were obtained for local small and urbanized catchments. There are only two regional stations that meet these requirements with sufficiently long records for analysis:

- WSC 08GA061: Mackay Creek at Montroyal Boulevard (area = 3.63 km^2); and
- WSC 08GA065: Noons Creek at Meridian Substation Road (area = 2.59 km^2).

[3] December 1998. Greater Vancouver Regional District Still Creek – Brunette River Floodplain Mapping. Technical Report.

Two additional WSC stations with larger and less urbanized catchments were included in the analysis for comparison:

- WSC 08GA047: Roberts Creek at Roberts Creek (area = 32.6 km^2); and
- WSC 08GA060: Chapman Creek above Sechelt Diversion (area = 64.5 km^2).

KWL operates a number of hydrometric stations in the Metro Vancouver region, and peak flow data from these stations were also reviewed for this project. Catchments are generally small (1 km^2 to 11 km^2) and highly urbanized. Most of the stations are located in Surrey, with records lengths of between 7 and 12 years. Some stations are located in North Vancouver and Burnaby but these records are generally much shorter.

The regional peak flow data show a relatively strong relation between drainage area and mean annual flood (instantaneous). Based on this relation, the mean annual instantaneous flood for Still Creek at 29th Avenue is estimated to be about 10 m^3/s.

WSC and longer regional instantaneous peak flow data were used in a flow frequency analysis to estimate the range of regional unit peak flows for return periods of between 1.25 years and 20 years. Return period peak flows were estimated using Environment Canada's Consolidated Frequency Analysis software (CFA v.3.1) to fit the Generalized Extreme Value, Three-parameter Log-normal and Log Pearson Type III frequency distributions to the observed data. Unless significant lack of fit was observed, the results from all three distributions were averaged.

Figure 3-3 presents estimated unit peak flows (m^3/s/km^2) from the WSC stations and the KWL stations as well as from the rainfall-runoff modelling, for comparison. As shown in the plot, there is considerable variation in estimated unit peak flows even among stations with smaller drainage areas. Noons Creek appears to be an outlier, consistently indicating unit peak flows that range from 1.5 to 2.5 higher than the other stations. Both of the WSC stations with larger drainage areas plot near the lower end of the range as would be expected. The KWL rainfall-runoff model result is very similar to the estimated unit peak flow for Mackay Creek, while the GVRD modelling results tend to fall closer to Chapman Creek. Based on the estimated regional unit peak flows, the range of peak flows for Still Creek at 29th Avenue is summarized in Table 3-2.

Table 3-2: Estimated Peak Flows From Regional Analysis

Return Period (yr)	Estimated Range of Peak Instantaneous Flow (m^3/s)
1.25	3 to 8
2	4 to 11
5	6 to 15
10	8 to 18
20	10 to 21
50	12 to 24
100	14 to 29

HYDRAULIC ANALYSIS

Simplified hydraulic analysis was conducted for a creek and culvert cross-section in order to evaluate flow conveyance capacity at high flow conditions. The first approach was to relate high water marks measured in the field with flood discharge at the inlet of the 22nd Avenue culvert using CulvertMaster v.1.0. High water marks are assumed to correspond to heavy rainfall events in fall 2007. The following input parameters were used:

- concrete box culvert;
- 1.83 m by 1.83 m;
- 127.5 m long; and
- 2.5% gradient.

Model results indicate that the culvert is inlet-controlled. Based on the measured high water marks at about 1.4 m above the inlet, this headwater elevation corresponds to a discharge of about 4 m^3/s. If it is assumed that the culvert is flowing full, the estimated discharge increases to about 6 m^3/s.

Creek profile and cross-sections measured in Renfrew Ravine Park and Renfrew Community Park were used to estimate bankfull discharge using FlowMaster. Channel conveyance at bankfull was estimated for sections in Renfrew Ravine Park, and a high water mark was used to estimate the corresponding discharge in Renfrew Community Park. The 1.8 m diameter culvert at 27th Avenue was also assessed. Hydraulic modelling results are summarized in Table 3-3.

Table 3-3: Hydraulic Modelling Results

Location	Condition	Estimated Discharge (m^3/s)
Renfrew Community Park, about 9 m upstream of the wooden pedestrian bridge.	High water mark (about 0.9 m above the bed).	8 to 18
Renfrew Ravine, upstream of the 22nd Avenue culvert.[1]	Bankfull (top of bank to top of bank).	8 to 30
Inlet of 27th Avenue culvert midway in Renfrew Ravine	Theoretical capacity to the top of the culvert at inlet	6
Inlet of 22nd Avenue culvert, at downstream end of Renfrew Ravine Park.	High water marks (about 1.4 m above the invert).	4

Note:
1. Water levels at this section could be influenced by backwater effects from the 22nd Ave culvert and are not considered for peak flow analysis.

The assessment of high water marks in the channel should be considered carefully. Without developing a more rigorous hydraulic model, it is difficult to assess the effect of backwater effects, downstream hydraulic constrictions, and channel roughness on the flood profile. Therefore, the lower bound may be an estimate of the actual discharge in Still Creek, while the upper bound would represent a channel capacity in the absence of flow obstructions such as culverts. Overall, the Still Creek channel has higher conveyance capacity than the culverted sections and higher water levels are probably due to capacity limitations at culvert inlets.

Other high water marks were noted in the field including evidence of overbank flows at the culvert inlet located at the downstream end of Renfrew Community Park. High water marks in Renfrew Ravine Park generally indicate that recent floods have overtopped channel banks, especially in the narrow protected bank sections.

It is also important to recognize that the peak flow at 29th Avenue is restricted by the conveyance capacity of the upstream stormsewer network, which discharges from a 1.8 m diameter concrete pipe. Under the assumption that the stormsewer is at capacity, based on the outfall size it would be expected from pipe area and exit velocity that discharge could be as high as 15 m^3/s for velocities of about 5 m/s. It is possible that while the upstream catchment is capable of generating discharges in excess of 20 m^3/s at 29th Avenue, there may be limitations in the stormsewer system that would change the character of flood hydrology in upper Still Creek. This work would have to be confirmed with a detailed network analysis.

Discussions with the Metro Vancouver also indicated that the culvert at the downstream end of Renfrew Community Park (near Renfrew Street) has been sufficiently blocked in the past so that backwatering occurred to such an extent that water overtopped the ravine slope. An indication of this phenomenon was seen in the field (as shown in Photos 15, 16, and 17 of Appendix A). While there is likely a limited ability for the upstream catchment to convey the floods in excess of 10 to 20-year return period, the potential for blocking of culverts could cause flooding that would exceed inundation depths expected for the flood discharge.

3.4 SUMMARY

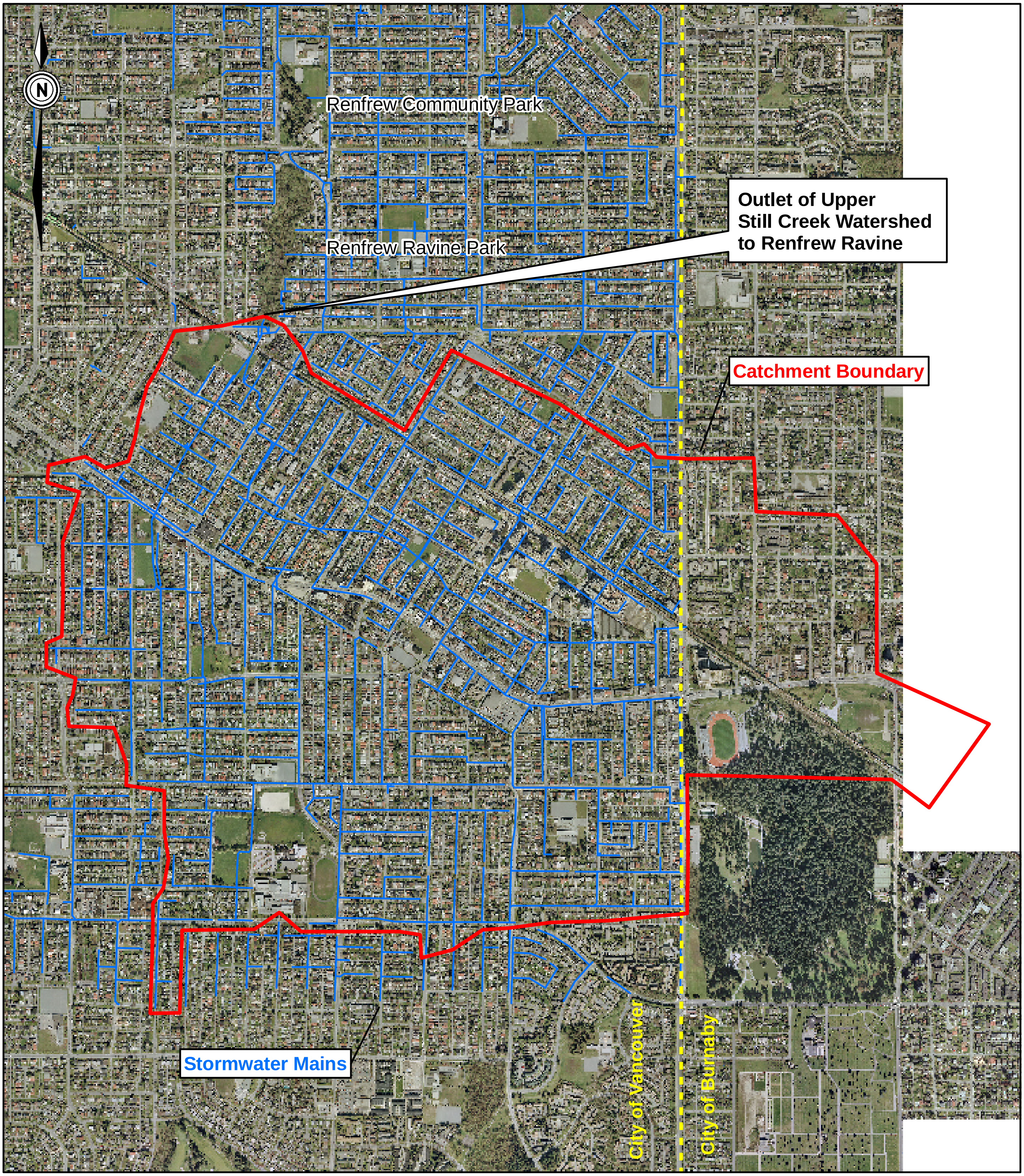
The results of the hydrological assessment for Still Creek between 29th Avenue and 20th Avenue may be summarized as:

- low flow (or base flow derived from groundwater) is expected to be in the range of 70 L/s;
- the mean annual flood flow for the Still Creek at the Renfrew Ravine based on catchment size and regional measurements is about 10 m^3/s;
- the capacity of the 27th Avenue and 22nd Avenue culverts without headwatering (1.8 m water depth) is 6 m^3/s and 11 m^3/s respectively;
- potential 100-year return period instantaneous unit flow rates in the 5.58 km^2 catchment are expected to range between 3.5 $m^3/s/km^2$ and 4.5 $m^3/s/km^2$, with a conservative estimate of a peak instantaneous flow of 25 m^3/s;
- the peak expected flow from the 29th Avenue stormsewer outfall is expected to be less than 20 m^3/s;

- discharges above 6 m^3/s would cause very high water (> 2 m) upstream of the 27th Avenue culvert;
- discharges above 11 m^3/s would cause very high water (> 2 m) upstream of the 22nd Avenue culvert; and
- backwatering and limited overbank flooding is expected at the 20th Avenue culvert due to losses from woody debris caught on the debris trap and limitations in capacity.

The peak flow analysis on Still Creek indicates that there is inherent uncertainty in the hydrological estimates. It should be noted that as the peak flow estimates are not based on physical measurements, they will have a higher degree of associated uncertainty. Therefore, as Metro Vancouver further develops data on Still Creek, it may be possible to reduce the uncertainty associated with these estimates.

Furthermore, the current infrastructure acts to attenuate flows in parts of Renfrew Ravine Park and Renfrew Community Park. Future channel or culvert upgrading or daylighting should consider how potential flooding could be affected by infrastructure changes. Presently, flood risk is highest at the upstream ends of culverts where entrance losses could result in high backwater.



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Scale in Metres

Upper Still Creek Watershed

Figure 3-1

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Renfrew Ravine Hydrology and Geotechnical Study

Project No.	Date
2511.001	February 2008

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Scale in Metres

Upper Still Creek Infrastructure

Figure 3-2

Map Document: (Q:\2500-2599\2511-001\430-GIS\MXDs\2511-001Fig3-2.mxd)
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Regional Unit Peak Flow Analysis

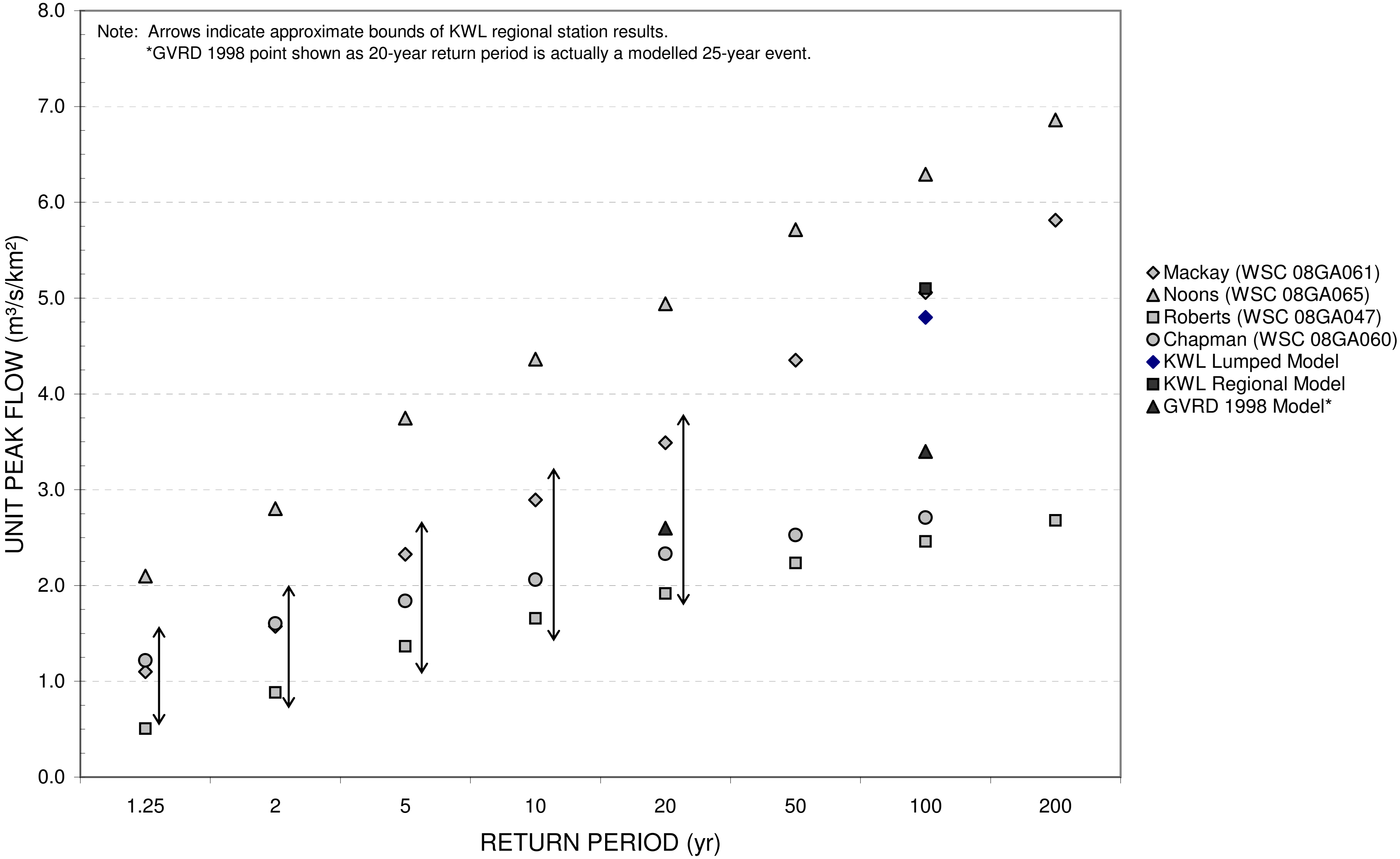

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Figure 3-3

Section 4

Water and Soil Quality

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4. WATER AND SOIL QUALITY

4.1 BACKGROUND

The 2002 Enhancement Study references and supports previous British Columbia Institute of Technology (BCIT) conclusions that urban runoff is likely to have conveyed contaminants that may have contaminated soil in Renfrew Ravine. The report also recommends further water and soil quality testing to determine feasibility of future enhancements.

The 2007 ISMP Support Document 1 – Environment also summarizes reports of poor water quality found in the Still Creek system in a study prepared by BCIT[4]. The results include:

- high dissolved metals loadings including eight metals exceeding the criteria for aquatic life or recreation;
- high fecal coliform counts that correlate positively with discharge;
- nutrients (phosphorus and nitrogen) concentrations increased with discharge;
- polycyclic aromatic hydrocarbons (PAHs) in suspended solids were two to three orders of magnitude higher than other parts of the Fraser River system; and
- other contaminants including: dioxins/furans, PCBs, organochlorine pesticides, and DDT were higher that neighbouring systems and/or exceeded the guidelines for water quality for protection of aquatic life or recreation.

Based on the previous observations, a limited water and soil quality testing program was implemented to determine site specific water and soil quality data. The SCSS has begun to undertake a monthly water quality sampling program using a handheld probe to collect temperature, pH, dissolved oxygen, and conductivity. Therefore, the sampling program for this study was implemented to address other contaminants and physical/chemical water properties with comparable quality standards or guidelines.

4.2 WATER AND SOIL SAMPLING

WATER

Water quality samples were collected on February 20 and March 3, 2008. Samples were collected at the 22nd Avenue culvert outlet in Renfrew Community Park. Table 4-1 summarizes the sample results. Discharge on February 20th was not directly measured, but the discharge can be estimated at about 100 L/s based on stage measurements at the culvert and based on physical observations, which represents a typical low flow. The

[4] BCIT, 1998 Still Creek Inventory, Issues and Opportunities. Draft Report prepared for the City of Burnaby.

March 3 sampling date was timed to coincide with a higher flow period and the discharge is estimated to be about 1.4 m^3/s.

The following table illustrates some of the primary test results for water quality. A detailed list is provided in Table 4-3 and 4-4 and in Appendix C.

Table 4-1: Still Creek Water Quality Sampling Results

Water Quality Parameter	Sampling Results Feb. 20, 2008	Sampling Results Mar. 3, 2008
BOD mg/L (biochemical oxygen demand)	<10	<10
TSS mg/L (total suspended solids)	8	56
Low Molecular Weight PAH (µg/L) (polycyclic aromatic hydrocarbons)	0.2	0.38
High Molecular Weight PAH(µg/L) (polycyclic aromatic hydrocarbons)	0.06	0.88
Fecal coliform (MPN/100ml)	<1	**>2400**
Total Aluminum (mg/L)	0.292	1.5
Total Arsenic (mg/L)	0.006	0.013
Total Chromium (mg/L)	<0.001	0.004
Total Copper (mg/L)	**0.007**	**0.0221**
Total Iron (mg/L)	0.773	**1.83**
Total Lead (mg/L)	0.0017	0.0111
Total Manganese (mg/L)	0.058	1.02
Total Selenium (mg/L)	0.0001	0.0001
Total Zinc (mg/L)	0.016	**0.055**

As can be seen from the table above, the concentrations for most parameters are quite low with some parameters below detectable levels. It can also been seen that the water quality is strongly linked to discharge, and almost all parameter concentrations increased with discharge. Most notably fecal coliform concentrations increased dramatically from a non-detectable value to substantially higher number (bolded above). This very high number of organisms is indicative of cross-connected sanitary sewers in the Still Creek catchment.

The other values which either exceed the Canadian Council of Ministers of the Environment (CCME; Federal) Guidelines for Protection of Aquatic Life, or the BC Water Quality Guidelines include: copper, iron, and zinc. In Table 4-3, all measured dissolved metals are compared with the Federal and Provincial Guidelines. The metals with higher concentrations only slightly exceed the guidelines for the protection for aquatic life and do not exceed regulated values under the provincial contaminated sites regulation.

Based on the water quality testing, the concentrations of dissolved metals and hydrocarbons would allow aquatic life, which is seen in a number of urban streams. Of greater concern, the large number of fecal coliforms during storm events indicate that there could be health issues associated with recreation in and around Still Creek during higher flow events.

SOIL

Two soil samples were collected from the active channel in Renfrew Ravine Park on February 20, 2008. Samples were collected in deposits of fine sediment adjacent to the wetted channel. The purpose of the soil testing was to provide some baseline data and determine the potential severity of previous conclusions regarding soil contamination. Results are summarized in Table 4-2 and displayed in detail in Table 4-4.

Table 4-2: Still Creek Soil Quality Sampling Results

Sample Parameter	Sample 1 (near 25th Ave)	Sample 2 (upstream of 27th Ave)
LEPH (mg/kg) (Low Molecular Weight Extractable Petroleum Hydrocarbons)	<100	<100
HEPH (mg/kg) (High Molecular Weight Extractable Petroleum Hydrocarbons)	348	219
Total Antimony (mg/kg)	1.8	1.2
Total Barium (mg/kg)	102	25.6
Total Cobalt (mg/kg)	5.7	5.3
Total Molybdenum (mg/kg)	1.2	4.3
Total Nickel (mg/kg)	14.3	34.5
Total Tin (mg/kg)	3.1	**153**
Total Vanadium (mg/kg)	34	34

The soil sampling results are compared with the BC Contaminated Sites Regulation (CSR) concentrations for metals and PAHs. In general, like the water sampling results, most of the higher concentrations including aluminum, iron, magnesium, phosphorus, potassium, and sodium are not regulated under the CSR, but do show some indication that these metals are either present in the soil or that stormwater is likely conveying metals or compounds, which are evident in silt and fine sand of the creek bed.

Metals and hydrocarbons are typically found in fine soils (silts and clays). Both samples were taken from the active channel in areas where there was higher potential for silts and clays, but soils were still quite sandy. Any future sampling should investigate floodplain areas where there would be a potential for substantial deposition of finer suspended sediment. Of the metals and PAH tested, only tin at the upstream site exceeded Urban Park and Residential Land use concentrations. This is not surprising, given that a small particle of tin could result in a high concentration. Since Still Creek collects almost

6 km^2 of urban watershed and there is some fill evident in the area, it is likely that some metals would be present.

4.3 FUTURE PROGRAMS

Future sampling programs could include continuation of the current sampling program; however, a number of parameters could be added if desired to further test parameters in the CCME and BC Water Quality Guidelines. These could include: nutrients (ammonia, nitrate and phosphorus), other metals and pesticides.

In addition, we would recommend the short or long term deployment of a water quality measuring instrument. A multimetric instrument could be utilized to collect temperature, pH, conductivity, dissolved oxygen, and a number of other parameters on a continuous basis. This type of data would be correlated with stream discharge to determine the actual effects of stormwater discharge on the system versus what can be captured in spot samples on a monthly or more frequent basis. Continuous data would start to provide the information necessary to determine whether most aquatic life can survive regular higher flows with respect to water chemistry. These types of instruments can be rented on a weekly or monthly basis to capture one or more storm events.

Soil sampling in floodplain areas could provide additional information to characterize the extent of possible soil contamination. This is not a high priority at this time but could be considered prior to any major earthworks project.

4.4 SUMMARY

The initial water and soil quality data did not show high levels of contaminants, and the parameters measured generally meet the BC Water Quality Guidelines for Protection of Aquatic Life and Recreation during low flow conditions. The soil testing data also did not exceed general Urban and Residential criteria under the CSR, with the exception of tin.

Given that there is very little opportunity for storage or ponding of water in the Renfrew reaches of Still Creek, there may be a net benefit to water and soil quality as the reach is primarily a zone of transport rather than deposition. During low flow, water quality appears sufficient to support aquatic life such as resident species of Cutthroat trout or other fish if sufficient habitat were available.

However, if this reach were to be used for potential stormwater treatment (i.e. removal of fine sediments), there would limited opportunity for other park use or habitat enhancements. Large scale sedimentation facilities would also accumulate contaminants that are bound to the fine sediments, thus requiring ongoing management and maintenance.

Table 4-3: Still Creek Water Quality Sampling Results

Date:		Regulation or Guideline					Feb 20/08	Mar 03/08
		BC Water Quality Guidelines			CCME Guidelines	Notes		
Maxxam Job #:							**A807269**	**A809198**
	Units	**Wildlife / Livestock**	**Recreational**	**Freshwater Aquatic Life**	**Freshwater Aquatic Life**			
BOD_5	mg/L	-	-	-	-	general indicator parameter	<10	<10
Total Hardness ($CaCO_3$)	mg/L	-	-	-	-	general indicator parameter	80.7	20
TSS	mg/L	background+ 20 or 20% > background	-	background+ 25 or 10% > background	background+ 25 or 10% > background	(a)	8	56
ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)								
Maxxam ID							I89914	J03005
Sampling Date							20/02/2008 9:40	03/03/2008 0:00
COC Number							F77636	F62484
	Units							
Total Metals								
Total Aluminum (Al)	mg/L	500	-	-	5-100	(a)	0.292	1.5
Total Antimony (Sb)	mg/L				-		<0.0005	0.0013
Total Arsenic (As)	mg/L	25	-	5	0.005	(a)	0.0006	0.0018
Total Barium (Ba)	mg/L	-	-	1	-	(b)	0.025	0.023
Total Beryllium (Be)	mg/L	0.001	-	0.0053	-	(b)	<0.0001	<0.0001
Total Bismuth (Bi)	mg/L	-	-	-	-		<0.001	<0.001
Total Boron (B)	mg/L	5	-	1.2	-	(a)	0.019	0.011
Total Cadmium (Cd)	mg/L	80	-	10EXP{0.86[log(hardness)] - 3.2}	0.000017	(b)	**0.00003**	**0.00013**
Total Calcium (Ca)	mg/L	-	-	-	-		23.9	6.31
Total Chromium (Cr)	mg/L	-	-	-	-	(b)	<0.001	0.004
Total Cobalt (Co)	mg/L	1000	-	0.9	-	(a)	<0.0005	0.0007
Total Copper (Cu)	mg/L	300	1000	(0.094*hardness+2)	0.002-0.004	(a)	**0.007**	**0.0221**
Total Iron (Fe)	mg/L	-	-	1.0	0.3	(f)	0.773	**1.83**
Total Lead (Pb)	mg/L	100	50	$e^{(1.273\ln(hardness)-1.460)}$	0.001-0.007	(a)	0.0017	0.0111
Total Magnesium (Mg)	mg/L	-	-	-	-		5.14	1.02
Total Manganese (Mn)	mg/L	-	-	0.0044(hard.)+0.605	-	(a) (c)	0.058	0.056
Total Mercury (Hg)	mg/L				0.000026		<0.00002	<0.00002
Total Molybdenum (Mo)	mg/L	0.05	-	2	0.073	(a)	0.001	<0.001
Total Nickel (Ni)	mg/L	1		0.025 (hard.=0-60) 0.065 (hard.=60-120) 0.110 (hard.=120-180) 0.150 (hard.>180)	0.025-0.150	(b)	<0.001	0.002
Total Potassium (K)	mg/L	-	-	373	-	(b)	2.41	0.86
Total Selenium (Se)	mg/L	4	-	2	0.001	(a), (c)	<0.0001	0.0001
Total Silicon (Si)	mg/L	-	-	-	-		7.8	3.1
Total Silver (Ag)	mg/L	2000	5000	7.5 +0.75(H-90)	0.0001	(a), (c)	<0.00002	0.00003
Total Sodium (Na)	mg/L	-	-	-	-		17.1	3.75
Total Strontium (Sr)	mg/L	-	-	-	-		0.148	0.03
Total Sulphur (S)	mg/L	-	-	-	-		5	<3
Total Thallium (Tl)	mg/L			0.3	0.0008	(b), (h)	<0.00005	<0.00005
Total Tin (Sn)	mg/L	-	-	-	-		<0.005	<0.005
Total Titanium (Ti)	mg/L	-	-	2	-	(b)	0.012	0.061
Total Uranium (U)	mg/L	200	-	300	-	(b)	0.0001	<0.0001
Total Vanadium (V)	mg/L	100	-	6	-		<0.005	<0.005
Total Zinc (Zn)	mg/L	2000	5000	7.5 +0.75(H-90)	0.03	(a), (c)	0.016	**0.055**
Total Zirconium (Zr)	mg/L	-	-	-	-		<0.0005	<0.0005

Notes:
(a) Value from "British Columbia Approved Water Quality Guidelines - 2006 Edition" http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html
(b) Value from "A Compendium of Working Water Quality Guidelines for British Columbia" http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html
(c) Value for average 30-day fresh water aquatic life. Higher peak or instantaneous values are accepted (values not provided here)
(d) Freshwater aquatic life value is dependant on chloride. Value provided is the minimum.
(e) pH may be outside of this value if it is not statistically different from background pH values.
(f) Draft guideline Oct 25, 2007. http://www.env.gov.bc.ca/wat/wq/homesubs/draft_reports/iron_draft_oct07.pdf
(g) Can be pH dependent below pH 6.5
(h) Referenced from Ontario guideline
(i) Value is commonly accepted, but not legal, requirement of the Fisheries Act

Table 4-4: Still Creek Soil Quality Sampling Results

Date:		Regulation or Guideline			Feb 20/08	Feb 20/08
		BC Contaminated Sites Regulation (a)		Notes		
Maxxam Job #:					A807269	A807269
	Units	Urban Park	Residential		ZEN Ravine 1	ZEN Ravine 2
Maxxam ID					I89915	I89916
Sampling Date					20/02/2008 10:30	20/02/2008 10:45
COC Number					F77636	F77636
RESULTS OF CHEMICAL ANALYSIS OF SOIL						
Moisture	%				22.6	20.3
TOTAL PETROLEUM HYDROCARBONS (SOIL)						
Surrogate Recovery						
O-TERPHENYL (sur.)	%				96	98
CSR/CCME Metals - SOIL						
Total Aluminum (Al)	mg/kg				8910	7190
Total Antimony (Sb)	mg/kg	20	20	(a)	1.8	1.2
Total Arsenic (As)	mg/kg				6.7	4.1
Total Barium (Ba)	mg/kg	500	500	(a)	102	25.6
Total Beryllium (Be)	mg/kg	4	4	(a)	0.1	0.2
Total Bismuth (Bi)	mg/kg				0.1	<0.1
Total Cadmium (Cd)	mg/kg				0.41	<0.2 (1)
Total Chromium (Cr)	mg/kg				25	55
Total Cobalt (Co)	mg/kg	50	50	(a)	5.7	5.3
Total Copper (Cu)	mg/kg				61.7	31.6
Total Iron (Fe)	mg/kg				18300	15000
Total Lead (Pb)	mg/kg				54.6	60.6
Total Magnesium (Mg)	mg/kg				4130	4030
Total Manganese (Mn)	mg/kg				217	191
Total Mercury (Hg)	mg/kg				<0.05	<0.05
Total Molybdenum (Mo)	mg/kg	10	10	(a)	1.2	4.3
Total Nickel (Ni)	mg/kg	100	100	(a)	14.3	34.5
Total Phosphorus (P)	mg/kg				593	316
Total Potassium (K)	mg/kg				422	374
Total Selenium (Se)	mg/kg	3	3	(a)	<0.5	<0.5
Total Silver (Ag)	mg/kg	20	20	(a)	0.13	0.05
Total Sodium (Na)	mg/kg				231	183
Total Strontium (Sr)	mg/kg				23.1	17.6
Total Thallium (Tl)	mg/kg				<0.05	<0.05
Total Tin (Sn)	mg/kg	50	50	(a)	3.1	153
Total Titanium (Ti)	mg/kg				407	389
Total Vanadium (V)	mg/kg	200	200	(a)	34	34
Total Zinc (Zn)	mg/kg				189	88
Total Zirconium (Zr)	mg/kg				<0.5	0.6

Notes:
(a) Value from "BC Environmental Management Act - Contaminated Sites Regulation - Schedule 4 - Generic Numerical Soil Standards"; B.C. Reg. 239/2007, July 1, 2007

TOTAL PAH - SURFACE WATER

Date:		BC Water Quality Guidelines			Notes	Feb 20/08	Mar 03/08
		Fresh Water (chronic)	Fresh Water (phototoxic)	Sediments (Fresh Water)			
Maxxam ID						I89914	J03003
Sampling Date						20/02/2008 9:40	03/03/2008 12:00
COC Number						F77636 (b)	F62484
Polycyclic Aromatics							
Low Molecular Weight PAH`s	ug/L					0.2	0.38
High Molecular Weight PAH`s	ug/L					0.06	0.88
Total PAH	ug/L					0.2	1.3
Naphthalene		1 ug/L	NR	0.01 ug/g	(a)	0.05	0.03
2-Methylnaphthalene		NR	NR	NR	(a)	0.06	0.03
Quinoline	ug/L					<0.1	0.06
Acenaphthylene	ug/L					<0.02	0.01
Acenaphthene		6 ug/L	NR	0.15 ug/g	(a)	<0.02	0.014
Fluorene	ug/L	12 ug/L	NR	0.2 ug/g	(a)	0.03	0.03
Phenanthrene	ug/L	0.3 ug/L	NR	0.04 ug/g	(a)	0.05	0.16
Anthracene	ug/L	4 ug/L	0.1 ug/L	0.6 ug/g	(a)	<0.02	0.05
Acridine	ug/L	3 ug/L	0.05 ug/L	1ug/g	(a)	<0.1	<0.05
Fluoranthene	ug/L	4 ug/L	0.2 ug/L	2 ug/g	(a)	0.02	0.019
Pyrene	ug/L	NR	0.02 ug/L	NR	(a)	0.04	0.02
Benzo(a)anthracene	ug/L	0.1 ug/L	0.1ug/L	0.2 ug/g	(a)	<0.02	0.05
Chrysene	ug/L	NR	NR	NR	(a)	<0.02	0.08
Benzo(b&j)fluoranthene	ug/L					<0.02	0.07
Benzo(k)fluoranthene	ug/L					<0.02	0.06
Benzo(a)pyrene	ug/L	0.01 ug/L	NR	0.06 ug/L	(a)	<0.02	0.08
Indeno(1,2,3-cd)pyrene	ug/L					<0.04	0.06
Dibenz(a,h)anthracene	ug/L					<0.04	0.02
Benzo(g,h,i)perylene	ug/L					<0.04	0.09

Notes:
NR = not recommended due to insufficient data
(a) From Table 25 of "British Columbia Approved Water Quality Guidelines"; 2006 Edition; Updated August 2006
(b) Reportable detection limit raised due to limited initial sample amount

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Section 5

Management Plan for Still Creek

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5. MANAGEMENT PLAN FOR STILL CREEK

5.1 GUIDING VISION

The 2002 Enhancement Plan and the ISMP outline a number of concepts for both Renfrew Ravine Park and Renfrew Community Park. Some of these concepts require that further engineering analyses be conducted to determine their feasibility. The following section summarizes most of the major recommendations from both documents.

2002 ENHANCEMENT PLAN

- a deep well infiltration pilot project is recommended for the watershed upstream of Renfrew Ravine to test the feasibility of collecting and infiltrating the initial rainfall in a rain event and avoid piping it directly to Still Creek;
- a pilot project of downspout disconnections is recommended in the upper watershed to increase the effective pervious area and reduce the runoff response to rainfall;
- implementation of a suite of best management practices for collecting, storing and infiltrating rainfall to support baseflow and reduce the runoff response to rainfall;
- the City of Vancouver source control program to eliminate cross-connections between commercial or industrial properties and the stormsewer should be maintained and supported;
- constructed wetlands could be located in neighbourhood parks as a means to store and treat stormwater, including Renfrew Community Park, to provide some detention for small events, improve water quality and potentially provide habitat;
- temporary flood storage in Renfrew Ravine was identified by the GVRD in a 1999 Preliminary Flood Reduction Alternatives for Still Creek report, and was dismissed due to landowner and geotechnical concerns; and
- habitat and stream rehabilitation in Renfrew Ravine and stream bank and bed rehabilitation in Renfrew Community Park – to include a detailed assessment of habitat potential, and construction of additional habitat or aesthetic features such as pools, riffles, and side channels.

2007 INTEGRATED STORMWATER MANAGEMENT PLAN

The ISMP supported many of the initiatives and best management practices that were developed in the 2002 Enhancement Study, and reviewed and offered further background on potential flood protection and water quality treatment facilities. A list of decision criteria was also developed to assess the potential enhancement projects in a structured way.

The goals stated in the ISMP were less prescriptive that the previous Enhancement Study and focused on the following criteria:

- Stream Corridor: connectivity of open channel, riparian areas, fish accessibility, channel complexity, macroinvertebrate community, and reduction of impervious areas;

- Upland Habitat: increase in urban forest and street tree inventory, and increase the percentage of linked green space;

- Water Quality: improved total suspended solids (TSS), fecal coliform, dissolved oxygen, and temperature;

- Flooding: improve flood protection for 25-year return period storm, decrease length of flooded roads, decrease number of buildings flooded in a 200-year return period event;

- Erosion: limit extent of sediment transport and number of erosion sites, and lower average flow velocity;

- Recreation: increase recreational access and activities, increase length of trail, increase number of access points to creek, increase length of navigable channel;

- Education: increase stewardship activities, decrease illegal dumping; and

- Cost Effectiveness: address high benefit to cost projects where possible.

5.2 HYDROLOGICAL AND GEOTECHNICAL OBSERVATIONS

In order to provide more context to the hydrological and geotechnical study, a preliminary review of available previous planning documents has been made and summarized above. The following section will comment on the some of the above initiatives as they relate to the two parks. Given that the authors of this report do not have the long history with the previous planning processes, this review should be considered preliminary and subject to discussion.

HYDROLOGICAL AND GEOTECHNICAL

The above plans discussed two main categories of hydrological best management practices:

- catchment-wide infiltration best management practices and small scale detention; and
- community scale initiatives (sub-catchment sized detention structures).

In general, catchment-wide best management practices to slow the runoff response to rainfall are supported. While expensive, there may be some opportunities to employ some of these ideas west of the Renfrew Ravine in the event that the City of Vancouver undertakes a sewer separation project in the near future. However, careful consideration of implementation of infiltration works in the area of the Renfrew Ravine should be undertaken as additional groundwater could lead to exacerbation of slope instability.

The one large detention structure that has previously been proposed for Renfrew Ravine was reconsidered in the 2002 Enhancement Study. Impounding of water in Renfrew Ravine is not recommended based on the very clear examples of previous landsliding, earthflows and generally steep slope geometry. In order to make such a proposal feasible, substantial engineering works would be likely required and would very much change the character of Renfrew Ravine.

It is also important to note that Renfrew Ravine presently acts to detain and attenuate peak flows given the flow restriction at the 27th and 22nd Avenue culverts. Additional detention or flood reduction measures might better be implemented in the upper catchment where the gradient and discharges are lower.

WATER QUALITY AND HABITAT

Initial water quality parameters during low flow in Renfrew Community Park indicated low levels of metals, hydrocarbons, fecal coliforms, and TSS. Other parameters of interest raised in the ISMP include temperature and dissolved oxygen.

A series of ponds and wetlands was proposed for Renfrew Community Park to try to help address water quality issues and provide some flood relief and physical habitat. There are two large areas on either side of Still Creek midway through the park that could provide good opportunity for some linked wetland and habitat/aesthetic pools. There is also a low depression on the east side of the creek near the community centre that could be developed into a wetland amenity.

Given the site constraints, it is likely that effective water quality treatment in a wetland would not be possible during larger rain events (e.g. 500 L/s), as there wouldn't be sufficient time and space to remove the fine sediment (TSS) bound with dissolved metals and PAH. At lower discharges (baseflow) the levels of contaminants are not sufficiently high to warrant treatment. Therefore, our recommendation would be to try to address the two existing outfalls (26th Avenue and 20th Avenue), and the 29th Avenue sewer, if feasible, with end-of-pipe treatment options such as centrifugal settling systems that would remove fines at higher discharges. This would allow Renfrew Community Park to be used for purely aesthetic and habitat enhancements. The end-of-pipe treatments would likely benefit habitat enhancement works due to improved water quality and less concentration of fine sediments and contaminants in constructed ponds and wetlands.

There may be other opportunities for ponds and wetlands in the upper watershed where gradients are lower. These opportunities may only be realized in the future with land use change and densification of single family lots.

EROSION AND GEOTECHNICAL STABILITY

The bed of Still Creek through Renfrew Ravine is very stable, aside from scour at culverts and outfalls, and the bed elevation is controlled by the two culvert crossings and some deposits of cobble – boulder material that may have been derived from landsliding. Some fine sediment is transported through the system, as can be seen from deposits upstream of the 27th Avenue culvert and on some gravel bar edges.

With an absence of bedload (sediment transport through the creek) from upstream sources and a very armoured bed, Still Creek is prone to lateral erosion in order to dissipate the energy of the water during a flood. There are some locations in Renfrew Ravine where lateral erosion has reached the ravine walls (as shown on the terrain maps). Some consideration should be given to bank protection in these areas to limit landsliding. If possible, aquatic habitat friendly bank protection should be implemented, and if possible, the other bank should remain natural to allow for natural adjustment of the creek channel.

In Renfrew Community Park, the entire channel is protected with either rock or concrete retaining walls. Some of the rock retaining walls may soon reach the limit of service based on vegetation growth, scour at the toe, and general wear. Replacement of the existing walls with more natural boulder and vegetated banks is an alternative to the rock walls. Protection of the banks in Renfrew Community Park should be maintained at some level due to the steep slopes in the area and proximity to structures. Further incision of the bed is unlikely as most of the channel bed has exposed bedrock surfaces. Therefore, any enhancement of the channel should consider this constraint, with channel enhancements modelled on the morphology of bedrock streams rather than that of meandering rivers.

5.3 MANAGEMENT PLAN OPPORTUNITIES

In discussions with the Still Creek Stewardship Society and the Vancouver Board of Parks and Recreation, a number of goals for the parks were discussed. For Renfrew Community Park the goals include making the park: attractive, inviting, amenable, and interpretive, with an overall goal of improving the natural environment. For Renfrew Ravine Park, the goals include: good access, improvements to the vegetation community, and future potential habitat works.

The following sections outline the management plan opportunities available for both Renfrew Ravine Park and Renfrew Community Park. These opportunities are developed below in sections that include:

- recreation development;
- vegetation enhancement;
- aquatic habitat enhancement; and
- wildlife habitat enhancement.

RENFREW COMMUNITY PARK

Recreation Development

In Renfrew Community Park there is a well developed trail system that has been recently improved with the addition of fencing around the creek and near steeper slopes and narrow areas. There could be some additional improvement to the trail system to improve access, especially in areas where grades are steep. The trail system also lacks "destinations" such as viewing areas, or seating areas. A park management plan could investigate these opportunities and the potential for the integration of environmental interpretive areas in the trail network.

Vegetation Enhancements

Renfrew Community Park is also relatively well maintained; however, there are a number of ornamental bushes and trees that have grown quite large. With the development of the fence around Still Creek, one opportunity could be to incorporate more native riparian plants near the creek, and removal of larger ornamental clumps. The riparian areas could be developed in patches that could be fenced off to allow natural regeneration, and could include both shrub and tree species.

Aquatic Habitat Enhancement

There is very little aquatic habitat in Still Creek in Renfrew Community Park. The only habitat exists in the small bedrock pools, and there is no refuge during high flow events. Aquatic habitat could be developed in the community park; however, it is a fairly involved commitment of providing area and capital cost for development. Therefore, development of aquatic habitat is likely not as high of a priority as recreational development and vegetation enhancement but should still be considered an important part of the management plan.

The two main options for the development of aquatic habitat in the park system are off-channel construction and in-channel upgrades. The off-channel pool concept links three ponds for minor water quality treatment and habitat development. The upstream-most pond could be a water treatment wetland allowing fine sediment to filter through denser wetland vegetation before reaching the mid habitat pool. The mid and lower pools would be purely habitat pools and would be connected by small channels that ideally would enter Still Creek in a pool area upstream of a rock riffle. The incorporation of off-channel pools has the potential to:

- improve aquatic habitat by providing an area with lower velocities during high flow events, therefore minimizing the "flushing" effect of aquatic species;
- provide an introductory level of water treatment through the settling of particles;
- provide a small amount of storage during large rainfall events; and
- provide aesthetically pleasing features and opportunities for education and interpretation.

There are three locations which have been identified as possible locations for off-stream aquatic habitat development; all of the opportunities are located in the Renfrew Community Park (see Figure 5-3). It should be noted that these off-channel developments would require a system to minimize the volume of water entering the pools during high flow events.

In-stream channel improvements include the development of a stream channel restoration plan that would systematically replace the mortared stone walls with more natural vegetated banks, with more complex boulder elements and pools (possibly).

One approach would be to systematically replace the stone walls with engineered banks using a combination of boulder elements (or riprap), planting elements (soil bioengineering), and riparian planting. This could be done in lieu of the current maintenance on the Still Creek walls by Metro Vancouver. This plan would potentially replace all bank works throughout the community park upstream of the concrete flume section near Renfrew Street.

Wildlife Habitat Enhancement

Improvements to the existing wildlife habitat can be created in both parks by retaining or planting habitat trees for migratory or upland birds through select removal of vegetation. Also wildlife habitat could be improved through the development of more continuous green corridors and linked green spaces through the region.

A concept of vegetated islands forming boulevards in the adjacent wide roads has been proposed to aid in the linking of the Still Creek corridor, as shown on Figure 5-2 and 5-3. This concept would need more development with appropriate professionals to ensure that is feasible; however, it is considered worthy of more investigation and discussion as a possible opportunity to facilitate and encourage wildlife to travel between the Renfrew Ravine Park and the Renfrew Community Park, as well as with other green spaces in the area. These aesthetic features would provide areas of refuge for wildlife to aid in the transition between the different green spaces established in the parks

RENFREW RAVINE PARK

Recreation Development

One of more feasible options for Renfrew Ravine Park would be to develop a trail system likely comprising gravel trail on grade or elevated boardwalk areas to provide access to the ravine bottom for stewardship and education. The ravine bottom trail could extend from the culvert at the Boyd Diversion to 27th Avenue to meet to the existing trail at that location. It is foreseen that one footbridge crossing would be required for this trail.

The use of a boardwalk pathway rather than a dirt or gravel pathway encourages users to remain on the pathway in a more aesthetically pleasing method than using a fence to achieve the same goal. This minimizes impacts on the environment by protecting existing and new vegetation, minimizing erosion, and encourages protection of the stream banks. A boardwalk is also considered ‘all-weather’ and can therefore be used year-round and during elevated water levels. A proposed layout of the trail is shown in Figures 5-1 and 5-2. Major considerations for the trail layout included:

- Avoiding steeper slopes and utilizing the terrace floodplain in the ravine bottom, which resulted in the incorporation of one stream crossing in Renfrew Ravine Park due to the narrow floodway region available between the channel and the steep valley walls.
- The addition of lights along the pathway system will allow users safer access during the evenings, increasing the use of the pathway.
- Maintaining access for roadway river crossings for Metro Vancouver.
- Cost effectiveness of the project by addressing the high benefit of the pathway system to the costs associated with the project.

A trail further upstream from 27th Avenue to 29th Avenue is considered a future option as the ravine is much narrower in this location there is less ability to develop a trail. Also, the presence of the Skytrain Station at 29th Avenue has likely led to some access and dumping of refuse in the ravine near 29th Aveune. For the time being it may be better to limit access to the ravine at 29th Avenue with fencing and focus on efforts further north.

Presently there is a section of perimeter trail on the east side of the Renfrew Ravine from about 29th to 27th Avenue. In lieu of a ravine bottom trail, this trail could be continued north along the edge of ravine. A trail and low fence along this length of the ravine could assist in controlling invasive vegetation and providing good access and some education. Any planning of trails and larger structures (platforms, etc.) should be done in consultation with a geotechnical engineer.

Vegetation Enhancement

Like recreational development, vegetation enhancement through the parks is another feasible goal for the management plan for Renfrew Ravine Park. This element of the management plan would include increasing the diversification and protection of the vegetation. In Renfrew Ravine Park, vegetation could be used to promote bank stability and efforts can be made on a small manageable scale to plant riparian trees such as western red cedar, which would provide trees that could provide a long term mature canopy.

Any vegetation enhancement would need to include an invasive vegetation control component to provide good opportunities for growth.

Aquatic and Wildlife Habitat Development

There are fewer needs for aquatic or wildlife habitat enhancement in Renfrew Ravine. Off-channel works could be constructed in the ravine where there is available space but careful consideration of slope stability would be required. Habitat works in the ravine could be considered once the success of any works in Renfrew Community Park have been implemented and can be evaluated.

OTHER CONSIDERATIONS

Other considerations discussed by the Still Creek Stewardship Society include:

- The trash rack / inlet conditions at downstream end of Renfew Community Park at Renfrew Street could be improved to limit possible flooding.

- The City of Vancouver Engineering department should review the BGC report and consider the longer term requirements for houses situated near Renfrew Ravine.

- Opportunities for stormwater treatment at the end of pipe could be undertaken for the existing stormwater outfalls at 20th Avenue and 26th Avenue and at the outlet of 29th Avenue, if feasible. These initiatives would likely be implemented by the City of Vancouver Engineering and Metro Vancouver and may not form part of the Park Management Plan.

5.4 REPORT SUBMISSION

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

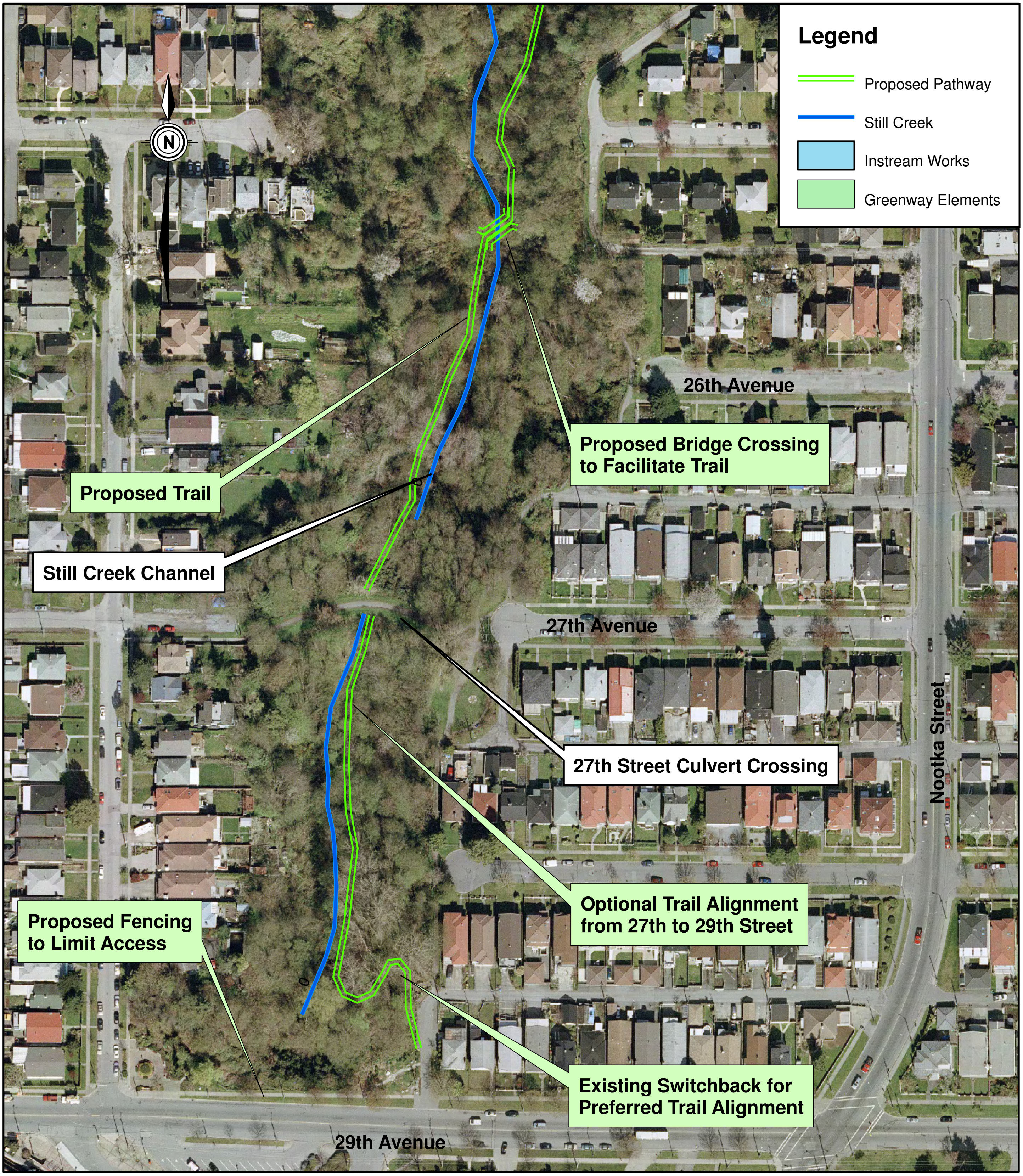
Original signed by:

____
Erica Ellis, M.Sc., G.I.T.
Fluvial Geomorphologist

Reviewed by:

Original signed by:

____
David Matsubara, M.Eng., P.Eng.
Project Manager



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KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

Still Creek Stewardship Society
Renfrew Ravine Hydrology and Geotechnical Society

Project No.	Date
2511.001	September 2008

Management Plan Opportunities
Renfrew Ravine Park (South)
Figure 5-1

KERR WOOD LEIDAL associates limited CONSULTING ENGINEERS

Still Creek Stewardship Society
Renfrew Ravine Hydrology and Geotechnical Study

Project No.	Date
2511.001	September 2008

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Scale 1:2,000

Management Plan Opportunities
Renfrew Ravine Park (North)

Figure 5-2

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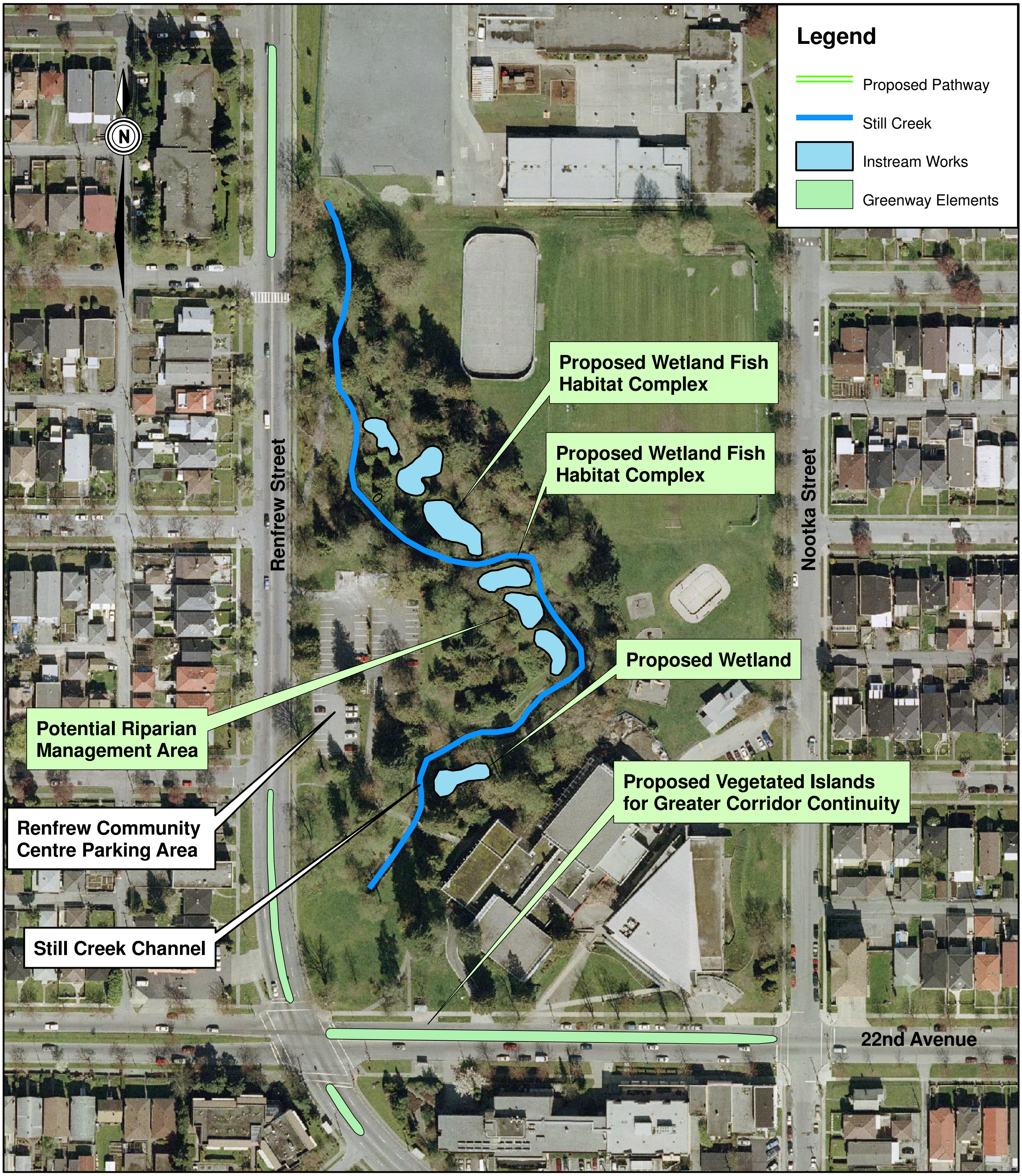

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KERR WOOD LEIDAL associates limited CONSULTING ENGINEERS

Still Creek Stewardship Society
Renfrew Ravine Hydrology and Geotechnical Society

Project No.	Date
2511.001	September 2008

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Scale 1:2,000

Management Plan Opportunities
Renfrew Community Park

Figure 5-3

Appendix A

Photos

KERR WOOD LEIDAL
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CONSULTING ENGINEERS

Photo 1
Looking upstream at 29th Avenue stormsewer outlet

Photo 2
Looking at west bank from stream channel – Class IV to V terrain stability class

Photo 3
Looking downstream at 27th Avenue culvert crossing

Photo 4
Looking at large failure surface on east slope of Renfrew Ravine downstream of 27th Ave

Photo 5
Looking at stormwater outfall at 26th Avenue – note the channel incision since construction

Photo 6
Some iron coloured sediment and seepage on small bar downstream of 26th Avenue

Photo 7
Exposure of glaciolacustrine or glaciofluvial sediment on west slope near Boyd Diversion

Photo 8
Looking downstream at Boyd Diversion/22nd Avenue Culvert Crossing

Photo 9
Looking upstream in Renfrew Community Park (22nd Avenue in background)

Photo 10
Outlet of 22nd Avenue culvert under higher flows

Photo 11
Looking upstream in Still Creek at foot bridge in Renfew Community Park – low flow condition

Photo 12
Looking upstream from footbridge under higher flow condition – note blue flagging indicates previous high water mark

Photo 13
Looking downstream near Renfrew Street in concrete channel section

Photo 14
Looking downstream in concrete channel section under higher flow condition

Photo 15
Renfrew Street culvert inlet – note rafted debris indicated in the field near the top of debris rack

Photo 16/17
Looking downstream at debris rack under low flow on the left and higher flow on the right. Note the debris on the rack.

Appendix B

BGC Geotechnical Study

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

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May 23, 2008

Project No. 0371-022

David Matsubara
Kerr Wood Leidal Associates Ltd.
200 – 4185A Still Creek Drive
Burnaby, BC V5C 6G9

Dear Mr. Matsubara:

Re: RENFREW COMMUNITY AND RAVINE PARKS – GEOTECHNICAL STUDY

INTRODUCTION

This letter summarizes the observations and conclusions made by BGC Engineering Inc. (BGC) addressing a geotechnical study for the Renfrew Community and Renfrew Ravine Parks.

This assessment was authorized by you by email on December 11, 2007, in reference to our proposal dated November 14, 2007. That proposal was based on terms of reference provided to Kerr Wood Leidal Associates Ltd. (KWL) by the Still Creek Stewardship Society (SCSS), and forwarded to BGC on November 8, 2007. We understand that this report will form part of a geotechnical and hydrologic report prepared by KWL for SCSS and the City of Vancouver Parks Board.

On December 14, 2007, Martin Zaleski, PG (California), met with you and with Erica Ellis of KWL at the site to perform a brief reconnaissance and to discuss the project. Field work was carried out in January and February of 2008 by Martin Zaleski and Tara Coultish, GIT, both of BGC.

SCOPE OF WORK

The purpose of BGC's study was to provide a preliminary assessment of terrain stability within the parks. This preliminary assessment is intended to support the planning process for rehabilitation of the parks.

The scope of this study was intended to satisfy the terms of reference provided Nov. 8, 2007 by KWL, and included:

- Description of Renfrew Ravine/Community park in terms of location, aspect, maximum and minimum elevations, and major landforms;
- Identification of landforms and other features that indicate past or ongoing slope instability, such as landslide scars and landslide or debris flow deposits;
- Qualitative rating of slope stability;
- Preparation of a terrain map showing terrain characteristics and geohazards; and
- Draft and Final reports.

Terrain mapping was based on airphoto interpretation and fieldwork, and was modified after the British Columbia terrain mapping system (Howes and Kenk, 1997).

The scope did not include:

- A hydrologic assessment;
- Assessment of terrain stability related to construction;
- Assessment of terrain stability related to seismic activity;
- Geohazard risk assessment;
- Detailed mapping of bedrock lithology at bedrock outcrops;
- Quantitative stability assessment based on deterministic or probabilistic approaches; or
- Recommendations for geohazard mitigation

The level of detail and certainty of BGC's conclusions are limited by the site conditions, method of investigation and BGC's limitations, as described below.

WORK PROGRAM

The work program for this study was outlined in our proposal. It included: a review of airphotos, reports and maps; field work; and preparation of maps and reports.

BGC collected and reviewed select published geologic and geotechnical reports and maps relevant to the study, as cited in the references section, below.

BGC was provided with the following reports, maps and data sets by KWL:

- A geotechnical report by DMJM/Thomson Simons (1982), addressing the Vanness section of the Vancouver Skytrain;
- A site topographic survey by the Vancouver Parks Board (2007); and
- Geospatial data sourced from the City of Vancouver (2007).

No other geologic or geotechnical reports addressing other facilities near the study area, such as residences, infrastructure improvements or the Renfrew Community Centre, were made available for this study by the City of Vancouver.

BGC acquired and reviewed six sets of historic stereo pair aerial photographs covering the project site and environs. Airphoto interpretation was used to map ground features, modified after the terrain classification system for British Columbia (Howes and Kenk, 1997), and to document historic changes around the site from slope instability or grading. Table 1 contains a list of aerial photographs reviewed for the site.

Table 1. List Of Aerial Photographs Used In Study.

Date	Flight Line	Photo Numbers	Nominal Scale
6 April 1949	BC 737	77, 78	1:10,000
28 April 1963	BC 5062	30, 31	1:12,000
15 July 1976	BC 5720	115, 116	1:12,000
1982	A25941	140, 141	1:24,000
1989	A27396	115, 116	1:25,000
22 May 1999	SRS 6064	125, 126	1:30,000

Topographic information from the Vancouver Parks Board (2007) survey is shown on Drawings 1 through 3. Topographic information for Renfrew Community Park was based on a ground survey, and was found to be sufficiently accurate for terrain mapping purposes. Topographic contours within Renfrew Ravine Park were based on aerial photogrammetry, and were not sufficiently accurate for terrain mapping; however, these contours do allow a general characterization of the ravine morphology.

BGC personnel were onsite for four field days in January and February of 2008. Two days were spent on mapping and ground truthing across the study area in order to:

- confirm aerial photograph interpretations;
- locate and map smaller terrain features;
- locate and classify natural soil and rock exposures;
- and locate features related to slope stability, including past slope failures, cuts, fills, springs and tributary channels.

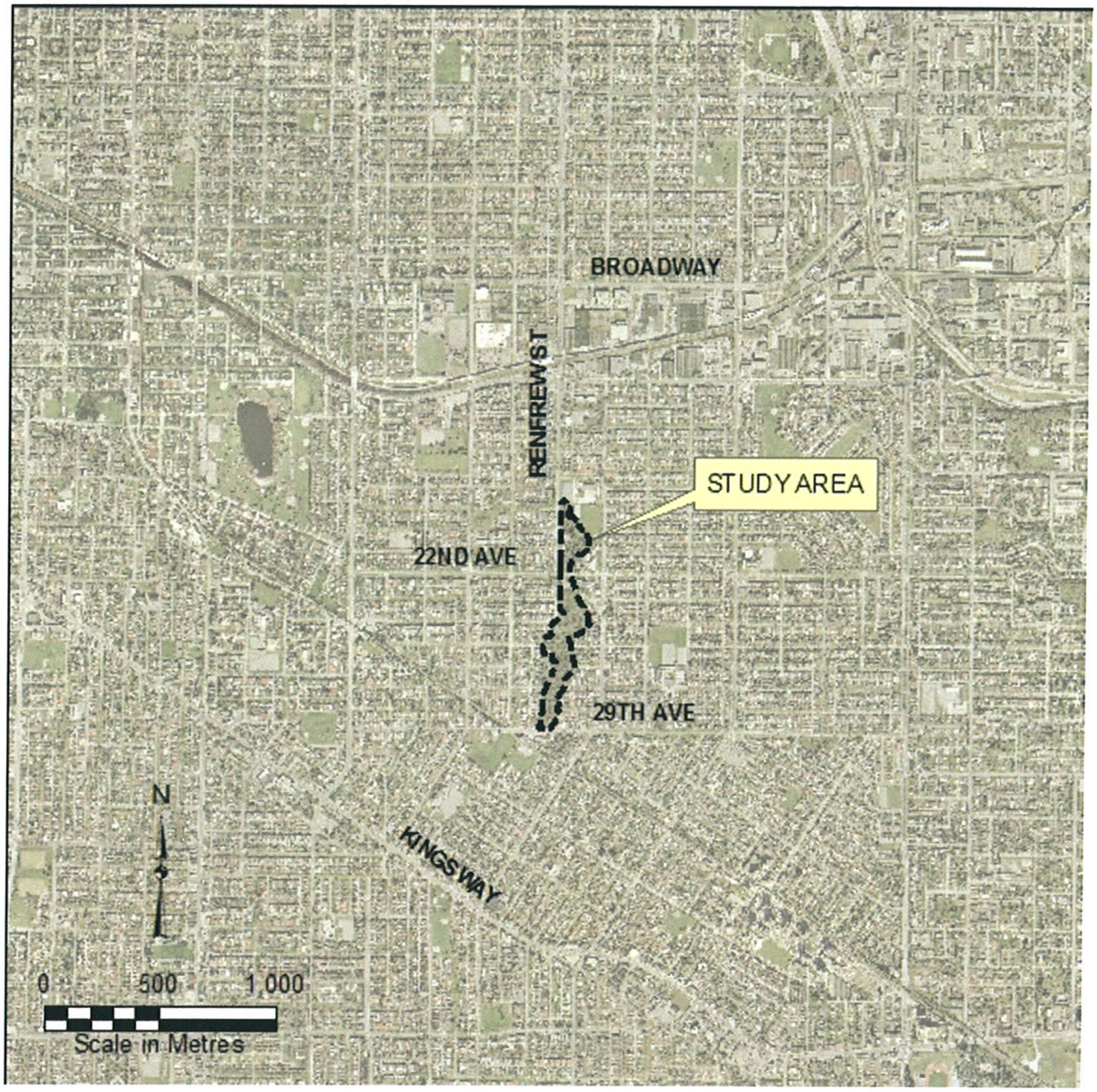
Two days were spent working with KWL to obtain supplemental topographic information within Renfrew Ravine Park. BGC worked with KWL personnel to survey select topographic sections from the ravine crest to the stream channel at 30 to 50 m intervals using total station equipment, while KWL performed a channel survey. Additional slope gradient measurements were made using a hand clinometer.

BGC's aerial photographic and field data were compiled to produce a map showing interpreted terrain polygons and engineering geologic information. Each terrain polygon was attributed with a terrain symbol, a range of slope gradients, and a slope stability classification, as defined below and provided in Drawings 1 through 3.

STUDY SITE DESCRIPTION

Location

Figure 1. Project Location Map



The study site includes Renfrew Community Park and Renfrew Ravine Park, which are both located within the City of Vancouver. Renfrew Community Park occupies 3.96 hectares bounded by 22nd Avenue, Renfrew Street, 17th Avenue and Nootka Street, and is developed with a community centre, library, paved parking lots and outdoor sports fields. Renfrew Ravine Park is mostly undeveloped, and occupies 5 hectares immediately south of Renfrew

Community Park bounded by 22nd Avenue, Renfrew Street, 29th Avenue and Nootka Street. Figure 1 depicts the project location.

Physiographic Setting

The site lies astride Still Creek, which flows northward along the bottom of a ravine incised into northward facing, rolling, gently to moderately sloping terrain. The ravine reaches a maximum depth of about 20 m between the thalweg and the urbanized uplands, near 25th Avenue. Ravine depth decreases both northward (downstream) and southward (upstream), to about 5 m near the culvert inlet at 19th Avenue, and about 14 m near the culvert outfall near 29th Avenue. The average channel gradient is about 3% (2°).

Still Creek enters the site immediately north of 29th Avenue, daylighting in a culvert and flowing north along the bottom of the ravine for about 100 m. It enters an 80 m long culvert beneath a foot path that crosses the ravine at 27th Avenue, and then continues above ground until reaching another culvert beneath 22nd Avenue and Boyd Diversion. It daylights again in Renfrew Community Park after passing through the 150 m long culvert, where it is largely within a concrete channel until entering another culvert near the intersection of Renfrew Street and 19th Avenue.

Ground elevations within Renfrew Ravine Park are between 46 and 90 m above sea level. The highest point within Renfrew Ravine Park is located atop the ravine at the south end of the site, near 29th Avenue. The lowest point is located along the ravine thalweg, at the inlet of the culvert passing beneath Boyd Diversion. Elevations within Renfrew Community Park are between 46 and 67 m, with the highest point outside the ravine near the intersection of 22nd Avenue and Nootka Street, and the lowest point in the ravine thalweg at the culvert inlet near the intersection of Renfrew Street and 19th Avenue.

Ravine slope gradients range from nearly flat (on flood plains and terraces) to more than 100% (in cuts and slide scars). Most slopes fall between 30% (17°) and 70% (35°). Significant grading has occurred around Renfrew Community Park to construct artificial channel banks, road and trail embankment fills, playing fields and the Community Centre. The original ravine has been filled in to support roads and trails at 22nd, 27th and 29th Avenues. Fills are also present beneath homes and yards on both sides of Renfrew Ravine.

Climate and Vegetation

The Köppen-Geiger classification of the local climate is *Cfb*, or temperate without a dry season and with warm summers (Peel et al, 2007). The study area is within the Coastal Western Hemlock biogeoclimatic ecosystem (Meidinger and Pojar, 1991). Average annual precipitation is approximately 1300 mm, of which 96% occurs as rainfall, and 71% occurs between the months of October and March (Environment Canada, 2007).

Renfrew Community Park has been landscaped and is vegetated with deciduous and coniferous trees, ferns and exotic plants. Renfrew Ravine Park is vegetated with a second-growth mixture of deciduous trees, brush, ferns and thick blackberry bushes with few conifers. Old-growth stumps are present throughout the study area.

Hydrology and Groundwater

Most precipitation falling on the site infiltrates into the soil and either flows as seepage through the soil and colluvium, or enters the local groundwater flow network by infiltrating the proglacial and glacial sediments.

Many small seeps and springs were observed across the study area. Springs are more common toward the ravine bottom. Some flatter terrain around the ravine bottom contains saturated, soft colluvial soils where springs are concentrated. Many small aquifers may be present within more permeable glaciofluvial sediments, perched upon or constrained by less permeable glaciolacustrine sediments or tills. The incised ravine may capture groundwater from some of these aquifers, which may be hydraulically connected to source areas located some distance from the ravine.

Geologic Setting

The Burrard Peninsula is underlain mostly by Eocene Kitsilano Formation sandstone bedrock, deposited unconformably atop Jurassic to Cretaceous aged intrusive and clastic sedimentary rocks. Oligocene basaltic volcanic rocks are exposed on certain topographic highs within the Peninsula, including Queen Elizabeth Park and the south side of the False Creek flats (BCGS, 2005). Kitsilano Formation sandstone bedrock is exposed along the Still Creek channel within the study area, dipping 19 to 23 degrees (34 to 42%) toward the southwest.

During the Late Pleistocene, the Burrard Peninsula was covered by glaciers. Repeated glacial advances and retreats between 18,000 and 12,000 years before present (bp) left relatively compact, complex interlayered proglacial and glacial deposits, lying unconformably atop the bedrock. Known collectively as Vashon Drift (Armstrong, 1984), these deposits include tills, glaciofluvial sands and gravels, and glaciolacustrine silts and clays.

As the last of the ice sheets melted and retreated, the Burrard Peninsula experienced isostatic rebound. The relative sea level around the Lower Mainland was up to 200 m higher during deglaciation than at present (Clague, 1989), as evidenced by the presence of elevated shorelines and discontinuous veneers of glaciomarine and marine sediments. These deposits are known as Capilano Formation sediments, and are around 13,000 to 10,500 years old (Armstrong, 1984).

After the uplands emerged, streams eroded rapidly downward and headward through the relatively unconsolidated glacial sediments, and more slowly through the more-consolidated bedrock. The rapid erosion, which continued through the Holocene epoch to the present day, left many ravines with steep side and head slopes. These steep slopes have experienced mass movement, ranging from slow creep through to rapid earth slides and flows. As a result of mass movement and soil development processes, ravine side slopes are mostly covered with a veneer of colluvium, with some areas mantled with thicker colluvium as landslide debris (Polygons 15, 41 and 43 on Drawings 2 and 3). Limited outcrops of the underlying Vashon Drift and Kitsilano Formation are exposed in these ravines where bank erosion or recent slides have occurred.

Human settlement and development in the last 150 years has produced significant changes in Metro Vancouver urban ravine environments. Many ravines have been filled with a mix of excavation material and undifferentiated fill and channelled through culverts to allow for denser development. Aerial photographs suggest that Still Creek extended headward (south) beyond 29th Avenue, before it was filled for development and channelled through storm drains. Where ravines remain unfilled, they are often modified by grading along their side slopes. Common scenarios include dumping construction debris or yard waste into ravines behind properties, placing fill on steep ravine slopes to enlarge usable yard space, or directing drainage toward the crests of ravine slopes. Often, such practices increase the likelihood of slope failures.

Still Creek has been altered in many places as part of urban development near the study area. Large fills that cross the ravine support roadways at 22nd Avenue and the Boyd Diversion (Polygons 36 and 46), and a foot path at 27th Avenue (Polygons 21 and 56). Still Creek passes through culverts beneath these fills. The head of Still Creek has been buried by fills that extend south from 29th Avenue (Polygon 45). Water enters the Still Creek channel at the south end of the study area from storm drains, and flows out into another long culvert beneath fills at the north end of the study area.

Artificial fills are also present along certain ravine slopes, particularly where they have been modified to support roadways (Polygons 50 and 51), homes (Polygons 26, 27, 44 and 58), or yards (Polygons 1, 22 and 23). Slopes with fill are, in many cases, steeper than adjacent natural ravine slopes.

Soils

The location and extent of soils underlying the study area were inferred from limited natural exposures, the observable ground surface morphology, and reviews of previous geologic and geotechnical work completed nearby. Few natural exposures were found, as most of the site is mantled with thick deposits of colluvium and fill, and further obscured by dense vegetation. The dense vegetation also obscured the morphology of the ground surface.

Hummocky terrain was observed on the uplands above the study area on aerial photographs, which suggests that till caps much of the ground around the ravines. The vegetation cover and scale of the photographs did not permit detailed mapping of terrain polygons at a scale that would be useful for the study. By comparing the terrain between time-sequential aerial photographs, it was apparent that fills have been placed in many locations around the ravine crests.

The DMJM/Thomson-Simons report (1982) indicates that the area near the 29th Avenue Station, located immediately south of the study area, is underlain by an interlayered sequence of "sand with silt seams" and "till and till-like soil", capped with a veneer of fill. Subsuface profiles in this report suggest that these units are largely subhorizontal, but pinch out and interfinger in a complex manner, with occasional backfilled stream channels occurring nearby. The "sand with silt seams" may represent either glaciomarine or interlayered glaciofluvial and glaciolacustrine soils.

Table 2 describes soil exposures found during BGC's ground traverses. Locations refer to polygon numbers on Drawings 1 through 3. Soils are classified in accordance with the Unified Soil Classification System, modified to CGS (2006).

Table 2. Soil exposures within the study area.

Location (Polygon)	Exposure Description	Soil Description	Interpretation
10	Scarp along the uppermost metre of the ravine slope, formed by shallow failures and erosion	Gravel, GW, fine to coarse, and sand, trace silt, well to gap graded, dense, maximum diameter 200 mm, rounded to subangular, light reddish brown, moist, homogeneous, moderate cementation, clasts mostly granitic and volcanic	basal till
9	Bottom of stream channel	Sandstone, medium, trace silt, poorly graded, very weak, reddish brown, stratified	Kitsilano Fm.
13	Stream bank, eroded into adjacent floodplain	Sand, SW, fine to coarse, and gravel, cobble to boulder sized, trace silt, well graded, loose, maximum diameter 200 mm, rounded to subrounded, brown, moist, stratified	fluvial deposits
37	Eroded bank on outside stream bend, incised into a steep slope. Clay exposed in channel and lowermost 1 m of bank, overlain by 2 to 3 m of sand.	Clay, CH, high plastic, stiff, olive gray with some orange banding, wet, laminated, weak cementation, no dilatancy, stratified with 10 cm sand beds. Overlain by 3 sand, SP, trace silt, medium, uniformly graded, compact, maximum diameter 1 mm, mottled gray and orange, wet, stratified, no cementation.	glaciolacustrine clay and glaciofluvial sand

Table 2 (continued). Soil exposures within the study area.

Location (Polygon)	Exposure Description	Soil Description	Interpretation
55	Eroded bank on outside stream bend exposes an angular unconformity with south-dipping sandstone overlain by horizontally stratified glaciofluvial sand	Sandstone, medium, trace silt, poorly graded, weak, brown, stratified; overlain by sand, SM, fine to medium, silty, compact, maximum diameter 1 mm, reddish brown to grayish brown; moist, stratified, no cementation	Kitsilano Fm overlain by glaciofluvial sand
17	Top of landslide head scarp, above horizontal contact with glaciofluvial deposits exposed in Polygon 16	Sand, SW, fine, silty and gravelly, rounded to subangular, well graded, dense, maximum diameter 300 mm, yellowish brown to olive brown, moist, homogeneous, weak cementation, clasts are intrusive and volcanic	basal till
16	Landslide head scarp, below horizontal contact with till described in Polygon 17	Sand, SP, medium, gravelly, trace silt, poorly graded, rounded, maximum diameter 80 mm, compact, yellowish to grayish brown, moist, cross bedded, weakly cemented	glaciofluvial
15	Hummocky, saturated landslide terrain below scarp	Sand, SW, medium, silty, gravelly, well graded, maximum diameter 300 mm, subangular to rounded, yellowish brown, wet, homogeneous, uncemented, dilatant	Colluvium (landslide deposit)
41	Eroded bank on outside stream bend, hummocky terrain below large, muted scarp	Sand, SC, clayey, some gravel, some organics, well graded, subangular to subrounded, maximum size 200 mm, loose, mixed gray and orange, moist, homogeneous	Colluvium (landslide deposit)
40	Exposure in small scarp on hillslope	Sand, SM, fine, silty, some gravel, some organics, gap graded, subrounded to subangular, maximum size 200 mm, loose, grayish to reddish brown, moist, homogeneous, uncemented	Colluvium
42	Toe of spur ridge, eroded by stream exposes an angular unconformity	See Polygon 55	glaciofluvial over Kitsilano Fm sandstone
33	Exposure in cut below old access road	Sand, SP, fine to medium, gravelly, trace silt, gap graded, rounded, maximum size 100 mm, dense, gray, moist, stratified, weak cementation	glaciofluvial
29	Eroded stream bank	See polygon 33	glaciofluvial
53	Root wad of fallen tree, 5 m below slope crest	See polygon 33	glaciofluvial

Exposures of dense, homogeneous mixtures of gravel, sand, silts and clays were interpreted to represent basal till, probably as part of the Vashon Drift. In general, till was found near the crest of the ravines, often associated with steeper natural slopes.

Compact to dense, stratified sands and gravels were interpreted as glaciofluvial deposits. Stiff, laminated silts and clays were interpreted as glaciolacustrine deposits. The relatively high density and consistency of these units is interpreted to be a result of compaction by the overriding glacial readvances which left the till deposited above them.

The stratified and laminated soils may represent glaciomarine deposits. However, because glaciomarine deposits were expected to cap the local stratigraphy, and because these soils were found compacted beneath till, BGC considers it more likely that these soils represent glaciofluvial and glaciolacustrine members of the Vashon Drift which were buried by one or more glacial readvances.

Landsliding

Landslides present the most significant geohazards at the site. Several historic and young earth slides, flows and complexes have been observed across the site (Drawings 1 through 3). Contributing factors to landslide occurrence include site geologic and hydrologic conditions, precipitation and anthropogenic alteration, as discussed below.

BGC found several small earth slides and earth flows within Renfrew Ravine Park that displayed sharp, unvegetated scarps and lateral flanks exposing the underlying soil. Their activity level is interpreted as suspended to dormant-historic (Wieczorek, 1984; Cruden and Varnes, 1996). Most are 10 to 20 m^3 in volume; one dormant-historic slide, located on the east side of the ravine near 26th Avenue, is about 100 to 200 m^3 in volume (Polygons 15, 16 and 17).

Several dormant-historic to dormant-young (Wieczorek, 1984; Cruden and Varnes, 1996), complex earth slides and flows have been inferred within large, bowl-shaped depressions that have steep, arcuate flanks (i.e. Polygons 14 and 52). These larger landslides are differentiated from channel meander slopes in that they have hummocky deposits within the bowls, sloping gradually down toward the channel (Polygons 41 and 43), as opposed to a flatter, smoother stream terrace. These complex slides are several hundred cubic metres in volume. They are inferred to be Late Holocene aged. In many cases, smaller and younger slides have occurred within terrain identified as larger landslide complexes, and the potential for renewed activity remains present. In general, these large, complex slides are overgrown with thick brush, which obscures the ground surface morphology. Additional work, including subsurface investigations, may help clarify whether these sites are correctly classified as landslides.

There were no landslides identified in Renfrew Community Park, north of 22nd Avenue. This may be a legacy of lower slopes in this section of the ravine, or because the original ground has been modified by grading.

The uppermost 0.5 to 2 m of soil on steeper slopes is undergoing gradual downslope creep in many places, resulting in a downslope-thickening mantle of loose colluvium, composed of a mixture of organics and glacial soils. In general, creep is common in slopes underlain by frequently wetted unconsolidated soils.

Movement within the historic and young slide areas is most likely to recur in response to high antecedent precipitation and rainfall intensity, consistent with other studies in the Lower Mainland (Jakob and Weatherly, 2003; BGC, 2006). These conditions result in locally elevated groundwater conditions, which may reduce effective stresses and lower shear strengths, particularly where permeability contrasts exist. Morphology that concentrates surface water runoff, such as bowls, gullies, hollows or concave slopes, increases the likelihood of slide occurrence by locally raising pore pressures and reducing soil shear strengths.

Landslides are more likely to occur in slopes underlain by fill. In the study area, fill slopes often have slope gradients that are steeper than natural slopes, which tends to increase driving forces for slope failure. Some fills are supported with retaining walls, although in many cases these walls are not engineered and in various stages of deterioration. In most cases, fills have been sidecast, without stripping existing loose colluvium; consequently, they may be deriving support from unstable materials. Fills may also interrupt natural drainage patterns, causing local increases in pore pressures and corresponding slope stability reductions.

TERRAIN MAPPING AND STABILITY CLASSIFICATION

The study area was divided into polygons based on the underlying soils, surface expressions and geomorphological processes. Each polygon was assigned a terrain symbol, modified after Howes and Kenk (1997). Appendix A contains a legend to the terrain and stability symbols depicted on Drawings 1 through 3.

BGC attempted to map the glacial stratigraphy across the site. However, much of the complex glacial stratigraphy was obscured by dense vegetation and deposits of younger soils or fills. Where it was possible to infer the extent of individual constituents of the glacial stratigraphy from nearby exposures or the ground surface morphology, they were mapped as basal till (M), glaciofluvial sands and gravels (FG), and glaciolacustrine silts and clays (LG). Otherwise, glacial soils were mapped as undifferentiated glacial sediments (U).

Most of the site is mantled with younger soils which obscure the underlying stratigraphy. These soils have been mapped as fluvial deposits (F or FA), fill (A) or colluvium (C). The extent of these deposits at the site is more easily and reliably inferred from observations of ground surface morphology supported by a few soil exposures.

Bedrock (R) was mapped where it was observed in stream channels. It was assumed to underlie the remainder of the site at the approximate level of the Still Creek channel. It probably forms a gently northward-descending, irregular surface, into which Still Creek is slightly incised in places.

A qualitative terrain stability classification system was employed for the project, as described in Table 3. Five terrain stability classes were used, with higher stability classes being associated with higher potential terrain instability. These classes were based on the type of soil underlying a given terrain polygon, the slope gradients associated with that polygon, the presence or absence of seepage or saturated soils, and any evidence for past slope instability. A qualitative approach is suitable to give a general idea of terrain stability (RIC, 1996). For site-specific development, a quantitative analysis of slope stability, supported by more detailed surface mapping and subsurface investigations, is recommended.

Table 3. Terrain stability classification system for Renfrew Community and Renfrew Ravine Parks.

Stability Class	Description
I	Stable. Includes gently sloping (<15%) areas underlain by active floodplains, rock, glaciofluvial deposits, till and mixed glacial drift. Rock inclined at up to 50% is also considered stable.
II	Probably stable. Includes flat-lying (<15%) glaciolacustrine deposits, fills, and saturated active fluvial deposits. Glaciofluvial deposits, till and mixed glacial drift inclined at up to 30%, and rock at up to 70%, is also included.
III	Potentially Unstable. Glaciolacustrine deposits, fill, and other glacial deposits that are saturated or gullied, that are inclined at up to 30%, are included. Other glacial deposits that are not saturated or gullied can be inclined up to 50%, and rock may exceed 70%.
IV	Probably unstable. Glaciolacustrine deposits, other saturated glacial deposits, and fills inclined up to 50% are included. Other glacial deposits may be inclined up to 70% if they are not saturated or gullied. Any slopes showing evidence of creep fall into this category.
V	Unstable. Fill and glaciolacustrine deposits exceeding 50% gradient, and all other glacial deposits exceeding 70% gradient, are included. All rapid mass movement source and deposition areas are included, including thick deposits of colluvium. Any saturated ground in excess of 50% gradient is included.

In general, fill and glaciolacustrine sediments are less stable than till, fluvial and glaciofluvial deposits, or bedrock. Most fill that is found around Greater Vancouver urban ravines is non-engineered, and is often placed loosely on potentially unstable ground. Glaciolacustrine deposits usually comprise fine grained soils, which have inherently lower shear strengths than coarse grained soils. Saturated ground conditions and perched water tables are often associated with the relatively impermeable fine grained soils that comprise the glaciolacustrine deposits.

Past instability is often the most reliable indicator of potentially unstable terrain. Areas where landslide or creep features were observed are considered to be less stable than comparable areas where past mass movement was not observed. Consequently, terrain polygons that include mass movement (-R, -F) or gully erosion (-V) geomorphological process symbols are assigned to higher stability classes.

Ground moisture is associated with reduced stability, due to reductions in effective stresses from increased pore water pressures and seepage forces in soils. Terrain polygons that include the saturated ground (-L) process symbol are assigned to higher stability classes.

Steeper ground is assigned progressively higher stability classes (representing lower terrain stability) for otherwise similar soils or processes.

CONCLUSIONS

The project site is probably underlain by interlayered glacial sediments. Still Creek has eroded a steep-sided ravine into these sediments and, in places, has eroded into the underlying Kitsilano Formation sandstone. Younger soils, including fluvial deposits and colluvium, mantle the older soils and bedrock across most of the study area. Natural conditions have been modified by human development in historic time, including the placement of fill.

Landsliding is associated with oversteepened terrain, saturated soils, high groundwater tables and low-strength soils. Repeated ancestral landsliding has produced broad, steep-walled bowls in places along the ravine side slopes. Ravine slopes are oversteepened as a result of the rapid erosion rate of Still Creek, which has exceeded the capacity of the ravine walls to adjust and flatten back to stable angles; and by artificial grading, including road cuts and fill placement. Groundwater probably perches atop lenses of relatively impermeable glaciolacustrine sediments, as evidenced by springs and saturated ground within the ravine, and the presence of these sediments observed in natural exposures around the site. Low-strength soils include loose or fine grained soils, such as fill, colluvium and glaciolacustrine deposits.

A qualitative terrain stability assessment was undertaken for the project site, based on BGC's observations of soils, surface expressions, geomorphological processes and slope gradients across the site. Most of the side slopes in Renfrew Ravine Park were assigned to terrain stability classes IV and V, representing "probably unstable" and "unstable" terrain, respectively. This classification was based on the steeper and higher slopes, saturated ground and evidence for past landsliding observed in this section of the study area. The side slopes of Renfrew Community Park mostly fell within stability classes III (potentially unstable) and IV (probably unstable), owing to lower slope heights, gentler slope gradients and a relative absence of saturated ground and evidence for past landsliding. Drawings 1 through 3 depict terrain mapping and terrain stability for the site, and Appendix A describes terrain stability criteria.

RECOMMENDATIONS

Designs for buildings, retaining walls, roads, trails underground utilities, pipelines or any other facilities planned on or near the ravine should reference site-specific geotechnical investigations that include quantitative slope stability and/or foundation analyses. Such investigations should be scoped by a qualified geoscientist or geotechnical engineer to specifically address the proposed improvement(s), and should include subsurface investigations where appropriate.

LIMITATIONS

The qualitative terrain stability assessment is considered suitable for planning purposes, and for an overall sense of slope stability within the study area. The terrain mapping which forms the basis for the stability assessment is based on BGC's interpretations, derived from the methods outlined in this report. Uncertainty in BGC's interpretations exists as a result of: dense vegetation that obscured the ground surface across most of the study area; colluvium and fill cover across most of the sloping terrain; limited exposures of soils and rock; few available geologic and geotechnical reports containing subsurface information near the study area; and limitations imposed by the project's purpose and scope. Consequently, BGC's interpretations of the site geology and terrain stability, and the conclusions and recommendations based upon them, should be considered preliminary. Site-specific designs should be based on more detailed investigations tailored to the needs of each specific project.

Additional geologic or geotechnical studies may reveal ground conditions that differ from those inferred to exist as part of this report. BGC reserves the right to modify or update our conclusions and recommendations where necessitated by additional information.

The findings of this report are valid as of the present date. However, changes in the conditions of the site and its environs can occur with the passage of time, whether they be due to natural or artificial processes. In addition, changes in applicable or appropriate standards occur whether they result from legislation or the broadening of knowledge. Accordingly, the findings of this report may be invalidated, wholly or partially, by changes outside of BGC's control.

Our drawings and maps are meant to be sufficiently accurate at the scales portrayed. Reproducing these maps, particularly at different scales, may imply a level of accuracy not warranted by the scope and methods used in this project.

BGC prepared this letter report for the account of Kerr Wood Leidal Associates Ltd. The material in it reflects the judgement of BGC staff in light of the information available to BGC at the time of report preparation. Any use a third party makes of this report or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

As a mutual protection to our client, the public, and ourselves, all reports and drawings are submitted for the confidential information of our client for a specific project. Authorization for any use and/or publication of this report or any data, statements, conclusions or abstracts from or regarding our reports and drawings, through any form of print or electronic media, including without limitation, posting or reproduction of same on any website, is reserved pending BGC's written approval.

CLOSURE

It is hoped that the foregoing satisfies the requirements of the assessment you requested. Please do not hesitate to contact the undersigned if you have any questions or require additional information.

Thank you for the opportunity to undertake this assessment.

Yours sincerely
BGC ENGINEERING INC.
per:

Martin P. Zaleski, B.Sc., P.G.
Engineering Geologist

Reviewed by:

PROFESSIONAL
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M. JAKOB
BRITISH COLUMBIA
GEOSCIENTIST
Aug. 28'08

Matthias Jakob, Ph.D., P.Geo.
Senior Geoscientist

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MPZ/ljb

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APPENDIX A

Terrain Map Legend

POLYGON LABELS

Terrain symbol	Cv|U–Fc
Slope gradient range	40-90%
Terrain Stability Class	IV

Refer to Table 3 in the report text for a description of Terrain Stability Classes.

TERRAIN SYMBOLS

Simple Terrain Symbols: Used when one surficial material is present within a polygon

Example: Cv – Rc

Surficial Material — Geomorphological process sub-type
Surface expression — Geomorphological process (up to 3 may be assigned)

Composite Terrain Symbols: Used when 2 or 3 terrain types are present within a polygon

Cv.Mh	indicates that 'C' and 'M' are roughly equal in extent
Cv/Mh	indicates that 'C' is greater in extent than 'M' (about 60:40)
Cv//Mh	indicates that 'C' is much greater in extent than 'M' (about 80:20)

Stratigraphic Terrain Symbols

Cv|Mh	indicates that 'Cv' overlies 'Mh'
/Cv|Mh	indicates that 'Cv' partially overlies 'Mh'

Surficial Material Types

A	Fill	Homogeneous mixtures of sand, silt, clay, gravel, organic materials and assorted human debris (concrete, tires, small appliances, automobile parts). Loose, no cementation.
C	Colluvium	Homogeneous mixture of sand, silt, clay, gravel and humic soil. Clasts are subrounded to subangular, up to cobble size. Loose, no cementation, moist to wet.
F,FA	Fluvial	Stratified, well graded sand and gravel with trace silt. Rounded clasts up to boulder size. Loose, no cementation. FA Indicates active floodplain (subject to channel changes)
LG	Glaciolacustrine	Stratified to varved, medium to high plastic clays and silts with trace gravels (dropstones). Stiff, wet, weak cementation, no dilatancy. Probably compacted by overriding glacial advances. Associated with springs and high ground moisture. Possibly glaciomarine.
FG	Glaciofluvial	Stratified to cross bedded, well graded sand with some gravel and trace silt. Contains rounded clasts ranging from fine gravel to coarse cobble sizes. Compact to dense, no to weak cementation. Has probably been compacted by overriding glacial advances. Possibly glaciomarine.
M	Glacial Till	Homogeneous, well graded to gap graded sand, gravel and silt. Contains rounded to subangular granitic and volcanic clasts up to large cobble sizes. Dense and weakly to moderately cemented.

U	Undivided	Interlayered till, glaciolacustrine, glaciofluvial and possibly glaciomarine sediments. Obscured by younger overlying sediments and vegetation.
R	Bedrock	Fine to medium grained, stratified Kitsilano Formation sandstone.

Surface Expressions

p	Plain	v	Veneer (0-2 m thick deposit)
h	Hummocky	t	Terrace
c	Cone (>15°)	f	Fan (<15°)
r	Ridge	u	Undulating

Geomorphologic Processes

R	Rapid landslide (runout zone)	F	Slow landslide (runout zone)
R"	Rapid landslide (initiation zone)	F"	Slow landslide (initiation zone)
V	Gully erosion	L	Saturated ground
I	Irregularly meandering channel		

Mass Movement Process Subtypes (with F, F", R, R")

e	Earth flow	u	Slump
x	Combined slump and earth flow	c	Soil creep

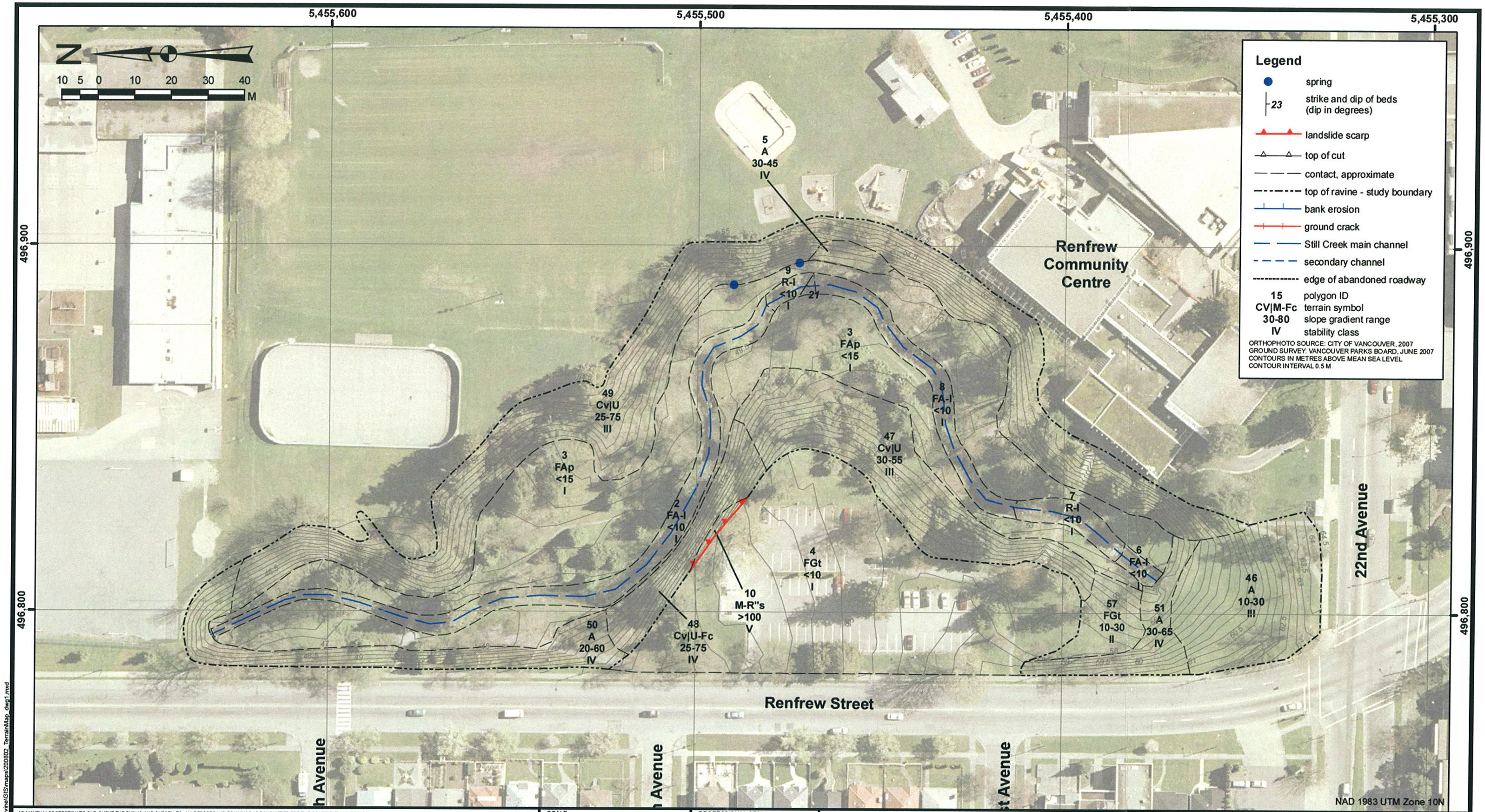
Fluvial Process Subtypes (with I)

u	Progressive bank erosion

Examples

Cv|U – Fc	Colluvial veneer overlying undifferentiated Vashon Drift; subject to creep
FAp – L	Active floodplain with saturated ground
Ch – LRx	Hummocky colluvium in a saturated, rapid combined slump and earthflow runout zone (landslide deposit)
Cv|U – R"x	Colluvial veneer atop undifferentiated Vashon Drift, in an initiation zone for rapid earth flows (landslide scarp)

DRAWINGS



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DATE:	MAR 2008
DRAWN:	MPZ, TNR
DESIGNED:	MPZ, TNR
CHECKED:	MJ
APPROVED:	

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: KERR WOOD LEIDAL ASSOCIATES LTD.

PROJECT: RENFREW COMMUNITY AND RAVINE PARKS

TITLE: TERRAIN MAP

PROJECT No.:	DWG No.:	REV.:
0037-022	1	1

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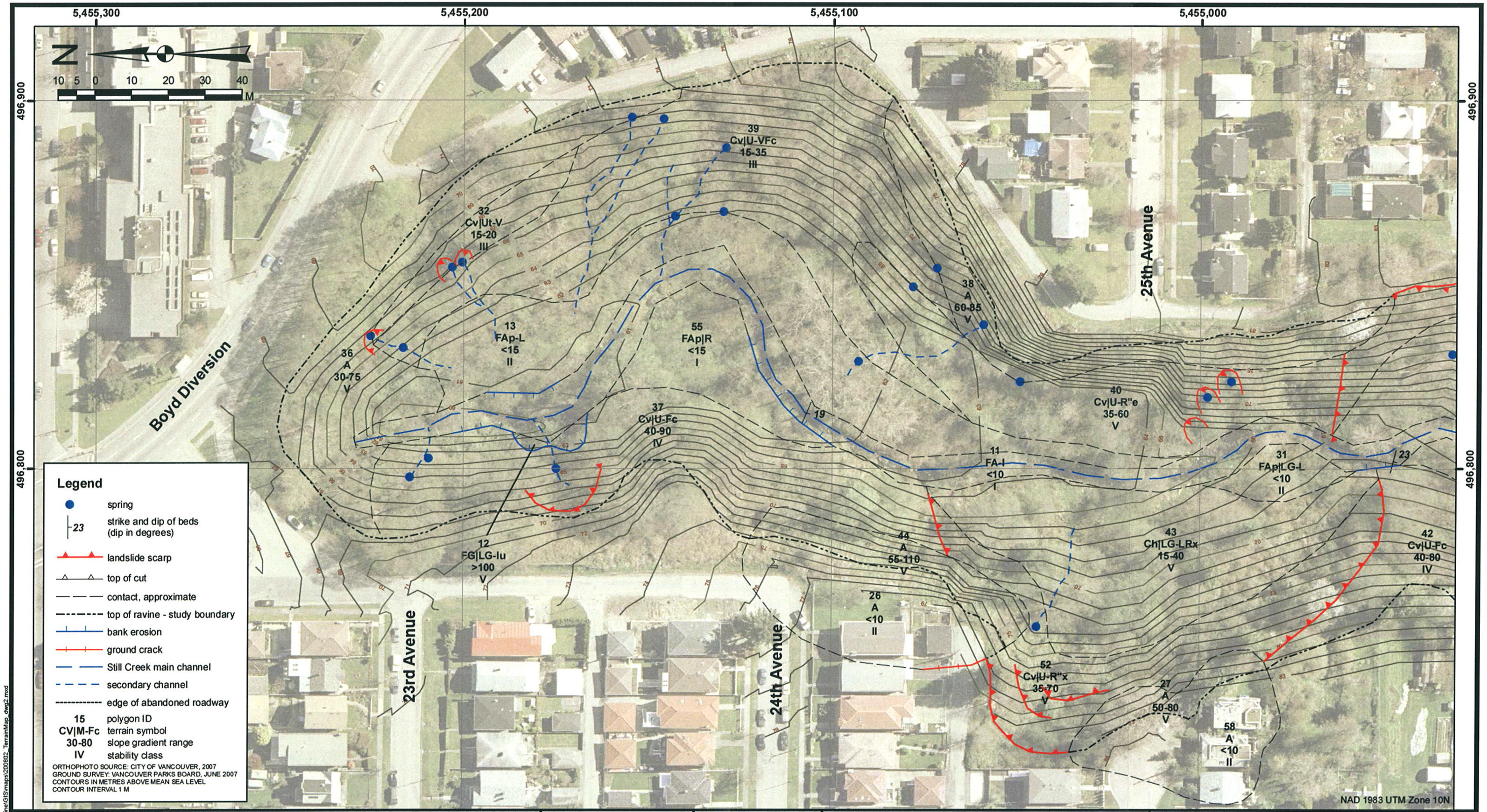

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DATE:	MAY 2008
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DESIGNED:	MPZ, TNR
CHECKED:	MJ
APPROVED:	

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
KERR WOOD LEIDAL ASSOCIATES LTD.

PROJECT:
RENFREW COMMUNITY AND RAVINE PARKS

TITLE:
TERRAIN MAP

PROJECT No.:	DWG No.:	REV.:
0037-022	2	1

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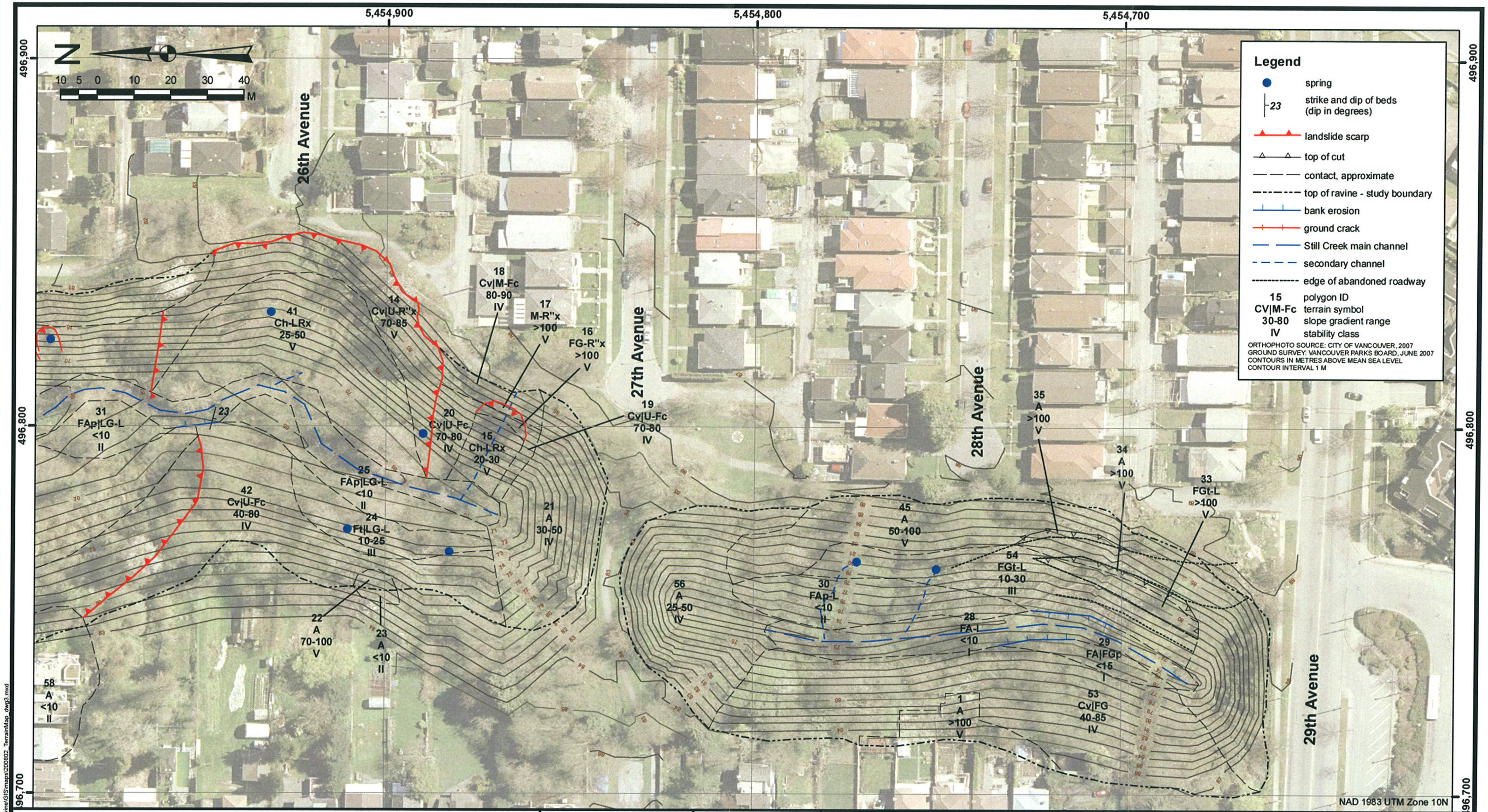

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DESIGNED:	MPZ, TNR
CHECKED:	MJ
APPROVED:	

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: KERR WOOD LEIDAL ASSOCIATES LTD.

PROJECT: RENFREW COMMUNITY AND RAVINE PARKS

TITLE: TERRAIN MAP

PROJECT No.:	DWG No.:	REV.:
0037-022	3	1

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DWG TO BE READ WITH BGC LETTER TITLED "GEOTECHNICAL STUDY" DATED MAY 23, 2008

Appendix C

Water and Soil Quality Test Results

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

Your Project #: 2511.001
Your C.O.C. #: F77636

Attention: David Matsubara
KERR WOOD LEIDAL
BURNABY
Suite 200
4185A Still Creek Drive
Burnaby, BC
CANADA V5C 6G9

Report Date: 2008/02/27

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: A807269
Received: 2008/02/20, 16:20

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Elements by ICPMS (total)	2	2008/02/21	2008/02/21	BRN SOP-00203	Based on EPA 200.8
Moisture	2	N/A	2008/02/22	BRN SOP-00321 R3.0	Ont MOE -E 3139
pH (2:1 DI Water Extract) (1)	2	2008/02/21	2008/02/22	BRN SOP-00266 R1.0	Carter, SSMA 16.2
BC Hydrocarbons in Soil by GC/FID (1)	2	2008/02/21	2008/02/21	BRN SOP-00341 R5.0	BCMOE Soil Method 3

Sample Matrix: Water
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Biochemical Oxygen Demand	1	N/A	2008/02/27	BRN SOP-00261 R2.0	SM 5210
Coliforms (MPN)	1	N/A	2008/02/20	BIO101 Rev 2.5	Based on SM-9223B
Fecal Coliform as E. Coli (MPN)	1	N/A	2008/02/20	BIO101 Rev 2.5	Based on SM-9223B
Hardness Total (calculated as CaCO3)	1	N/A	2008/02/24		
Na, K, Ca, Mg, S by CRC ICPMS (total)	1	2008/02/21	2008/02/23	BRN SOP-00204	Based on EPA 200.8
Elements by CRC ICPMS (total) (1)	1	2008/02/21	2008/02/23	BRN SOP-00204	Based on EPA 200.8
PAH in Water by GC/MS (SIM)	1	2008/02/21	2008/02/22	BRN SOP-00331 R6.0	Based on EPA 8270C
Total LMW, HMW, Total PAH Calc	1	N/A	2008/02/25		
Total Suspended Solids	1	N/A	2008/02/25	BRN SOP-00277 R2.0	Based on SM - 2540 D

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) SCC/CAEAL

../2

Your Project #: 2511.001
Your C.O.C. #: F77636

Attention: David Matsubara
KERR WOOD LEIDAL
BURNABY
Suite 200
4185A Still Creek Drive
Burnaby, BC
CANADA V5C 6G9

Report Date: 2008/02/27

CERTIFICATE OF ANALYSIS

-2-

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

ROB MACARTHUR, BBY Customer Service
Email: rob.macarthur@maxxamanalytics.com
Phone# (604) 444-4808 Ext:253

==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. SCC and CAEAL have approved this reporting process and electronic report format.

Total cover pages: 2

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		I89915	I89916		
Sampling Date		2008/02/20 10:30	2008/02/20 10:45		
COC Number		F77636	F77636		
	Units	**ZEN RAVINE 1**	**ZEN RAVINE 2**	**RDL**	**QC Batch**
Physical Properties					
Moisture	%	22.6	20.3	0.3	2131757

RDL = Reportable Detection Limit

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

TOTAL PETROLEUM HYDROCARBONS (SOIL)

Maxxam ID		I89915	I89916		
Sampling Date		2008/02/20 10:30	2008/02/20 10:45		
COC Number		F77636	F77636		
	Units	**ZEN RAVINE 1**	**ZEN RAVINE 2**	**RDL**	**QC Batch**
Hydrocarbons					
EPH (C10-C19)	mg/kg	<100	<100	100	2134308
EPH (C19-C32)	mg/kg	348	219	100	2134308
Surrogate Recovery (%)					
O-TERPHENYL (sur.)	%	96	98		2134308
RDL = Reportable Detection Limit					

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		I89914		
Sampling Date		2008/02/20 9:40		
COC Number		F77636		
	Units	**22ND D/S**	**RDL**	**QC Batch**
Calculated Parameters				
Total Hardness (CaCO3)	mg/L	80.7	0.5	2131211
Demand Parameters				
Biochemical Oxygen Demand	mg/L	<10	10	2138623
Physical Properties				
Total Suspended Solids	mg/L	8	4	2133493

RDL = Reportable Detection Limit

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		I89914		
Sampling Date		2008/02/20 9:40		
COC Number		F77636		
	Units	**22ND D/S**	**RDL**	**QC Batch**
Total Metals by ICPMS				
Total Aluminum (Al)	mg/L	0.292	0.001	2131763
Total Antimony (Sb)	mg/L	<0.0005	0.0005	2131763
Total Arsenic (As)	mg/L	0.0006	0.0001	2131763
Total Barium (Ba)	mg/L	0.025	0.001	2131763
Total Beryllium (Be)	mg/L	<0.0001	0.0001	2131763
Total Bismuth (Bi)	mg/L	<0.001	0.001	2131763
Total Boron (B)	mg/L	0.019	0.005	2131763
Total Cadmium (Cd)	mg/L	0.00003	0.00001	2131763
Total Chromium (Cr)	mg/L	<0.001	0.001	2131763
Total Cobalt (Co)	mg/L	<0.0005	0.0005	2131763
Total Copper (Cu)	mg/L	0.0070	0.0002	2131763
Total Iron (Fe)	mg/L	0.773	0.005	2131763
Total Lead (Pb)	mg/L	0.0017	0.0002	2131763
Total Manganese (Mn)	mg/L	0.058	0.001	2131763
Total Mercury (Hg)	mg/L	<0.00002	0.00002	2131763
Total Molybdenum (Mo)	mg/L	0.001	0.001	2131763
Total Nickel (Ni)	mg/L	<0.001	0.001	2131763
Total Selenium (Se)	mg/L	<0.0001	0.0001	2131763
Total Silicon (Si)	mg/L	7.8	0.1	2131763
Total Silver (Ag)	mg/L	<0.00002	0.00002	2131763
Total Strontium (Sr)	mg/L	0.148	0.001	2131763
Total Thallium (Tl)	mg/L	<0.00005	0.00005	2131763
Total Tin (Sn)	mg/L	<0.005	0.005	2131763
Total Titanium (Ti)	mg/L	0.012	0.005	2131763
Total Uranium (U)	mg/L	0.0001	0.0001	2131763
Total Vanadium (V)	mg/L	<0.005	0.005	2131763
Total Zinc (Zn)	mg/L	0.016	0.005	2131763
Total Zirconium (Zr)	mg/L	<0.0005	0.0005	2131763
Total Calcium (Ca)	mg/L	23.9	0.05	2138717
Total Magnesium (Mg)	mg/L	5.14	0.05	2138717
Total Potassium (K)	mg/L	2.41	0.05	2138717
Total Sodium (Na)	mg/L	17.1	0.05	2138717

RDL = Reportable Detection Limit

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		I89914		
Sampling Date		2008/02/20 9:40		
COC Number		F77636		
	Units	**22ND D/S**	**RDL**	**QC Batch**
Total Sulphur (S)	mg/L	5	3	2138717

RDL = Reportable Detection Limit

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

MICROBIOLOGY (WATER)

Maxxam ID		I89914		
Sampling Date		2008/02/20 9:40		
COC Number		F77636		
	Units	**22ND D/S**	**RDL**	**QC Batch**
Microbiological Param.				
Fecal Coliform as E. Coli	MPN/100mL	<1	1	2130768
Parameter				
Total Coliforms	MPN/100mL	<1	1	2130755

RDL = Reportable Detection Limit

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

CSR/CCME METALS - SOIL (SOIL)

Maxxam ID		I89915		I89916		
Sampling Date		2008/02/20 10:30		2008/02/20 10:45		
COC Number		F77636		F77636		
	Units	**ZEN RAVINE 1**	**RDL**	**ZEN RAVINE 2**	**RDL**	**QC Batch**
Misc. Inorganics						
Soluble (2:1) pH	pH Units	6.71	0.01	7.38	0.01	2131582
Total Metals by ICPMS						
Total Aluminum (Al)	mg/kg	8910	100	7190	100	2134453
Total Antimony (Sb)	mg/kg	1.8	0.1	1.2	0.1	2134453
Total Arsenic (As)	mg/kg	6.7	0.2	4.1	0.2	2134453
Total Barium (Ba)	mg/kg	102	0.1	25.6	0.1	2134453
Total Beryllium (Be)	mg/kg	0.1	0.1	0.2	0.1	2134453
Total Bismuth (Bi)	mg/kg	0.1	0.1	<0.1	0.1	2134453
Total Cadmium (Cd)	mg/kg	0.41	0.05	<0.2 (1)	0.2	2134453
Total Chromium (Cr)	mg/kg	25	1	55	1	2134453
Total Cobalt (Co)	mg/kg	5.7	0.3	5.3	0.3	2134453
Total Copper (Cu)	mg/kg	61.7	0.5	31.6	0.5	2134453
Total Iron (Fe)	mg/kg	18300	100	15000	100	2134453
Total Lead (Pb)	mg/kg	54.6	0.1	60.6	0.1	2134453
Total Magnesium (Mg)	mg/kg	4130	100	4030	100	2134453
Total Manganese (Mn)	mg/kg	217	0.2	191	0.2	2134453
Total Mercury (Hg)	mg/kg	<0.05	0.05	<0.05	0.05	2134453
Total Molybdenum (Mo)	mg/kg	1.2	0.1	4.3	0.1	2134453
Total Nickel (Ni)	mg/kg	14.3	0.8	34.5	0.8	2134453
Total Phosphorus (P)	mg/kg	593	10	316	10	2134453
Total Potassium (K)	mg/kg	422	100	374	100	2134453
Total Selenium (Se)	mg/kg	<0.5	0.5	<0.5	0.5	2134453
Total Silver (Ag)	mg/kg	0.13	0.05	0.05	0.05	2134453
Total Sodium (Na)	mg/kg	231	100	183	100	2134453
Total Strontium (Sr)	mg/kg	23.1	0.1	17.6	0.1	2134453
Total Thallium (Tl)	mg/kg	<0.05	0.05	<0.05	0.05	2134453
Total Tin (Sn)	mg/kg	3.1	0.1	153	0.1	2134453
Total Titanium (Ti)	mg/kg	407	1	389	1	2134453
Total Vanadium (V)	mg/kg	34	2	34	2	2134453
Total Zinc (Zn)	mg/kg	189	1	88	1	2134453
Total Zirconium (Zr)	mg/kg	<0.5	0.5	0.6	0.5	2134453

RDL = Reportable Detection Limit
(1) RDL raised for Cd due to sample matrix interference.

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

TOTAL PAH - WATER (WATER)

Maxxam ID		I89914		
Sampling Date		2008/02/20 9:40		
COC Number		F77636		
	Units	**22ND D/S**	**RDL**	**QC Batch**
Polycyclic Aromatics				
Low Molecular Weight PAH`s	ug/L	0.2	0.1	2127626
High Molecular Weight PAH`s	ug/L	0.06	0.04	2127626
Total PAH	ug/L	0.2	0.1	2127626
Naphthalene	ug/L	0.05 (1)	0.02	2131938
2-Methylnaphthalene	ug/L	0.06 (1)	0.02	2131938
Quinoline	ug/L	<0.1 (1)	0.1	2131938
Acenaphthylene	ug/L	<0.02 (1)	0.02	2131938
Acenaphthene	ug/L	<0.02 (1)	0.02	2131938
Fluorene	ug/L	0.03 (1)	0.02	2131938
Phenanthrene	ug/L	0.05 (1)	0.02	2131938
Anthracene	ug/L	<0.02 (1)	0.02	2131938
Acridine	ug/L	<0.1 (1)	0.1	2131938
Fluoranthene	ug/L	0.02 (1)	0.02	2131938
Pyrene	ug/L	0.04 (1)	0.02	2131938
Benzo(a)anthracene	ug/L	<0.02 (1)	0.02	2131938
Chrysene	ug/L	<0.02 (1)	0.02	2131938
Benzo(b&j)fluoranthene	ug/L	<0.02 (1)	0.02	2131938
Benzo(k)fluoranthene	ug/L	<0.02 (1)	0.02	2131938
Benzo(a)pyrene	ug/L	<0.02 (1)	0.02	2131938
Indeno(1,2,3-cd)pyrene	ug/L	<0.04 (1)	0.04	2131938
Dibenz(a,h)anthracene	ug/L	<0.04 (1)	0.04	2131938
Benzo(g,h,i)perylene	ug/L	<0.04 (1)	0.04	2131938
Surrogate Recovery (%)				
D10-ANTHRACENE (sur.)	%	95		2131938
D12-BENZO(A)PYRENE (sur.)	%	98		2131938
D8-ACENAPHTHYLENE (sur.)	%	90		2131938
TERPHENYL-D14 (sur.)	%	89		2131938

RDL = Reportable Detection Limit
(1) RDL raised due to limited initial sample amount.

Maxxam Job #: A807269
Report Date: 2008/02/27

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

General Comments

Results relate only to the items tested.

KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
P.O. #:
Site Reference:

Quality Assurance Report

Maxxam Job Number: VA807269

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2130755 SL7	BLANK	Total Coliforms	2008/02/20	<1		MPN/100mL	
2130768 SL7	BLANK	Fecal Coliform as E. Coli	2008/02/20	<1		MPN/100mL	
2131582 AL8	SPIKE	Soluble (2:1) pH	2008/02/22		100	%	96 - 104
	RPD	Soluble (2:1) pH	2008/02/22	0.1		%	20
2131757 RL2	BLANK	Moisture	2008/02/22	<0.3		%	
	RPD	Moisture	2008/02/22	1		%	20
2131763 AA1	MATRIX SPIKE	Total Arsenic (As)	2008/02/23		105	%	75 - 125
		Total Beryllium (Be)	2008/02/23		100	%	75 - 125
		Total Cadmium (Cd)	2008/02/23		101	%	75 - 125
		Total Chromium (Cr)	2008/02/23		116	%	75 - 125
		Total Cobalt (Co)	2008/02/23		109	%	75 - 125
		Total Copper (Cu)	2008/02/23		103	%	75 - 125
		Total Lead (Pb)	2008/02/23		103	%	75 - 125
		Total Nickel (Ni)	2008/02/23		82	%	75 - 125
		Total Selenium (Se)	2008/02/23		106	%	75 - 125
		Total Uranium (U)	2008/02/23		108	%	75 - 125
		Total Vanadium (V)	2008/02/23		116	%	75 - 125
		Total Zinc (Zn)	2008/02/23		NC	%	75 - 125
	SPIKE	Total Arsenic (As)	2008/02/23		97	%	75 - 125
		Total Beryllium (Be)	2008/02/23		97	%	75 - 125
		Total Cadmium (Cd)	2008/02/23		90	%	75 - 125
		Total Chromium (Cr)	2008/02/23		115	%	75 - 125
		Total Cobalt (Co)	2008/02/23		112	%	75 - 125
		Total Copper (Cu)	2008/02/23		111	%	75 - 125
		Total Lead (Pb)	2008/02/23		114	%	75 - 125
		Total Nickel (Ni)	2008/02/23		112	%	75 - 125
		Total Selenium (Se)	2008/02/23		94	%	75 - 125
		Total Uranium (U)	2008/02/23		115	%	75 - 125
		Total Vanadium (V)	2008/02/23		115	%	75 - 125
		Total Zinc (Zn)	2008/02/23		100 (1)	%	75 - 125
	BLANK	Total Aluminum (Al)	2008/02/23	<1		ug/L	
		Total Antimony (Sb)	2008/02/23	<0.5		ug/L	
		Total Arsenic (As)	2008/02/23	<0.1		ug/L	
		Total Barium (Ba)	2008/02/23	<1		ug/L	
		Total Beryllium (Be)	2008/02/23	<0.1		ug/L	
		Total Bismuth (Bi)	2008/02/23	<1		ug/L	
		Total Boron (B)	2008/02/23	<5		ug/L	
		Total Cadmium (Cd)	2008/02/23	<0.01		ug/L	
		Total Chromium (Cr)	2008/02/23	<1		ug/L	
		Total Cobalt (Co)	2008/02/23	<0.5		ug/L	
		Total Copper (Cu)	2008/02/23	<0.2		ug/L	
		Total Iron (Fe)	2008/02/23	<5		ug/L	
		Total Lead (Pb)	2008/02/23	<0.2		ug/L	
		Total Manganese (Mn)	2008/02/23	<1		ug/L	
		Total Mercury (Hg)	2008/02/23	<0.02		ug/L	
		Total Molybdenum (Mo)	2008/02/23	<1		ug/L	
		Total Nickel (Ni)	2008/02/23	<1		ug/L	
		Total Selenium (Se)	2008/02/23	<0.1		ug/L	
		Total Silicon (Si)	2008/02/23	<100		ug/L	
		Total Silver (Ag)	2008/02/23	<0.02		ug/L	
		Total Strontium (Sr)	2008/02/23	<1		ug/L	
		Total Thallium (Tl)	2008/02/23	<0.05		ug/L	
		Total Tin (Sn)	2008/02/23	<5		ug/L	
		Total Titanium (Ti)	2008/02/23	<5		ug/L	
		Total Uranium (U)	2008/02/23	<0.1		ug/L	

KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
P.O. #:
Site Reference:

Quality Assurance Report (Continued)

Maxxam Job Number: VA807269

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2131763 AA1	BLANK	Total Vanadium (V)	2008/02/23	<5		ug/L	
		Total Zinc (Zn)	2008/02/23	<5		ug/L	
		Total Zirconium (Zr)	2008/02/23	<0.5		ug/L	
	RPD	Total Aluminum (Al)	2008/02/23	14.9		%	25
		Total Copper (Cu)	2008/02/23	NC		%	25
		Total Iron (Fe)	2008/02/23	2.1		%	25
		Total Lead (Pb)	2008/02/23	NC		%	25
		Total Manganese (Mn)	2008/02/23	0.3		%	25
		Total Zinc (Zn)	2008/02/23	5.7		%	25
2131938 LS2	MATRIX SPIKE	D10-ANTHRACENE (sur.)	2008/02/22		79	%	30 - 130
		D12-BENZO(A)PYRENE (sur.)	2008/02/22		79	%	30 - 130
		D8-ACENAPHTHYLENE (sur.)	2008/02/22		75	%	30 - 130
		TERPHENYL-D14 (sur.)	2008/02/22		75	%	30 - 130
		Naphthalene	2008/02/22		74	%	40 - 130
		2-Methylnaphthalene	2008/02/22		68	%	40 - 130
		Quinoline	2008/02/22		104	%	40 - 130
		Acenaphthylene	2008/02/22		76	%	40 - 130
		Acenaphthene	2008/02/22		72	%	40 - 130
		Fluorene	2008/02/22		72	%	40 - 130
		Phenanthrene	2008/02/22		83	%	40 - 130
		Anthracene	2008/02/22		84	%	40 - 130
		Acridine	2008/02/22		95	%	40 - 130
		Fluoranthene	2008/02/22		83	%	40 - 130
		Pyrene	2008/02/22		81	%	40 - 130
		Benzo(a)anthracene	2008/02/22		77	%	40 - 130
		Chrysene	2008/02/22		81	%	40 - 130
		Benzo(b&j)fluoranthene	2008/02/22		89	%	40 - 130
		Benzo(k)fluoranthene	2008/02/22		85	%	40 - 130
		Benzo(a)pyrene	2008/02/22		89	%	40 - 130
		Indeno(1,2,3-cd)pyrene	2008/02/22		81	%	40 - 130
		Dibenz(a,h)anthracene	2008/02/22		85	%	40 - 130
		Benzo(g,h,i)perylene	2008/02/22		83	%	40 - 130
	SPIKE	D10-ANTHRACENE (sur.)	2008/02/22		94	%	30 - 130
		D12-BENZO(A)PYRENE (sur.)	2008/02/22		98	%	30 - 130
		D8-ACENAPHTHYLENE (sur.)	2008/02/22		84	%	30 - 130
		TERPHENYL-D14 (sur.)	2008/02/22		94	%	30 - 130
		Naphthalene	2008/02/22		85	%	40 - 130
		2-Methylnaphthalene	2008/02/22		78	%	40 - 130
		Quinoline	2008/02/22		104	%	40 - 130
		Acenaphthylene	2008/02/22		87	%	40 - 130
		Acenaphthene	2008/02/22		80	%	40 - 130
		Fluorene	2008/02/22		78	%	40 - 130
		Phenanthrene	2008/02/22		98	%	40 - 130
		Anthracene	2008/02/22		98	%	40 - 130
		Acridine	2008/02/22		113	%	40 - 130
		Fluoranthene	2008/02/22		97	%	40 - 130
		Pyrene	2008/02/22		93	%	40 - 130
		Benzo(a)anthracene	2008/02/22		94	%	40 - 130
		Chrysene	2008/02/22		97	%	40 - 130
		Benzo(b&j)fluoranthene	2008/02/22		103	%	40 - 130
		Benzo(k)fluoranthene	2008/02/22		100	%	40 - 130
		Benzo(a)pyrene	2008/02/22		108	%	40 - 130
		Indeno(1,2,3-cd)pyrene	2008/02/22		105	%	40 - 130
		Dibenz(a,h)anthracene	2008/02/22		105	%	40 - 130
		Benzo(g,h,i)perylene	2008/02/22		101	%	40 - 130

KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
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Quality Assurance Report (Continued)

Maxxam Job Number: VA807269

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2131938 LS2	BLANK	D10-ANTHRACENE (sur.)	2008/02/22		89	%	30 - 130
		D12-BENZO(A)PYRENE (sur.)	2008/02/22		100	%	30 - 130
		D8-ACENAPHTHYLENE (sur.)	2008/02/22		82	%	30 - 130
		TERPHENYL-D14 (sur.)	2008/02/22		89	%	30 - 130
		Naphthalene	2008/02/22	<0.01		ug/L	
		2-Methylnaphthalene	2008/02/22	<0.01		ug/L	
		Quinoline	2008/02/22	<0.05		ug/L	
		Acenaphthylene	2008/02/22	<0.01		ug/L	
		Acenaphthene	2008/02/22	<0.01		ug/L	
		Fluorene	2008/02/22	<0.01		ug/L	
		Phenanthrene	2008/02/22	<0.01		ug/L	
		Anthracene	2008/02/22	<0.01		ug/L	
		Acridine	2008/02/22	<0.05		ug/L	
		Fluoranthene	2008/02/22	<0.01		ug/L	
		Pyrene	2008/02/22	<0.01		ug/L	
		Benzo(a)anthracene	2008/02/22	<0.01		ug/L	
		Chrysene	2008/02/22	<0.01		ug/L	
		Benzo(b&j)fluoranthene	2008/02/22	<0.01		ug/L	
		Benzo(k)fluoranthene	2008/02/22	<0.01		ug/L	
		Benzo(a)pyrene	2008/02/22	<0.01		ug/L	
		Indeno(1,2,3-cd)pyrene	2008/02/22	<0.02		ug/L	
		Dibenz(a,h)anthracene	2008/02/22	<0.02		ug/L	
		Benzo(g,h,i)perylene	2008/02/22	<0.02		ug/L	
	RPD	Naphthalene	2008/02/22	NC		%	40
		2-Methylnaphthalene	2008/02/22	NC		%	40
		Quinoline	2008/02/22	NC		%	40
		Acenaphthylene	2008/02/22	NC		%	40
		Acenaphthene	2008/02/22	NC		%	40
		Fluorene	2008/02/22	NC		%	40
		Phenanthrene	2008/02/22	NC		%	40
		Anthracene	2008/02/22	NC		%	40
		Acridine	2008/02/22	NC		%	40
		Fluoranthene	2008/02/22	NC		%	40
		Pyrene	2008/02/22	NC		%	40
		Benzo(a)anthracene	2008/02/22	NC		%	40
		Chrysene	2008/02/22	NC		%	40
		Benzo(b&j)fluoranthene	2008/02/22	NC		%	40
		Benzo(k)fluoranthene	2008/02/22	NC		%	40
		Benzo(a)pyrene	2008/02/22	NC		%	40
		Indeno(1,2,3-cd)pyrene	2008/02/22	NC		%	40
		Dibenz(a,h)anthracene	2008/02/22	NC		%	40
		Benzo(g,h,i)perylene	2008/02/22	NC		%	40
2133493 LL4	MATRIX SPIKE	Total Suspended Solids	2008/02/25		100	%	N/A
	SPIKE	Total Suspended Solids	2008/02/25		102	%	N/A
	BLANK	Total Suspended Solids	2008/02/25	<4		mg/L	
	RPD	Total Suspended Solids	2008/02/25	NC		%	25
2134308 JP1	MATRIX SPIKE	O-TERPHENYL (sur.)	2008/02/21		99	%	70 - 130
		EPH (C10-C19)	2008/02/21		89	%	50 - 130
		EPH (C19-C32)	2008/02/21		82	%	50 - 130
	SPIKE	O-TERPHENYL (sur.)	2008/02/21		94	%	70 - 130
		EPH (C10-C19)	2008/02/21		72	%	50 - 130
		EPH (C19-C32)	2008/02/21		104	%	50 - 130
	BLANK	O-TERPHENYL (sur.)	2008/02/21		99	%	70 - 130
		EPH (C10-C19)	2008/02/21	<100		mg/kg	
		EPH (C19-C32)	2008/02/21	<100		mg/kg	

KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
P.O. #:
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Quality Assurance Report (Continued)

Maxxam Job Number: VA807269

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2134308 JP1	RPD	EPH (C10-C19)	2008/02/21	NC		%	50
		EPH (C19-C32)	2008/02/21	18.3		%	50
2134453 DJ	MATRIX SPIKE	Total Arsenic (As)	2008/02/21		117	%	75 - 125
		Total Beryllium (Be)	2008/02/21		119	%	75 - 125
		Total Cadmium (Cd)	2008/02/21		105	%	75 - 125
		Total Chromium (Cr)	2008/02/21		101	%	75 - 125
		Total Cobalt (Co)	2008/02/21		102	%	75 - 125
		Total Copper (Cu)	2008/02/21		107	%	75 - 125
		Total Lead (Pb)	2008/02/21		99	%	75 - 125
		Total Mercury (Hg)	2008/02/21		101	%	75 - 125
		Total Nickel (Ni)	2008/02/21		108	%	75 - 125
		Total Selenium (Se)	2008/02/21		105	%	75 - 125
		Total Vanadium (V)	2008/02/21		114	%	75 - 125
		Total Zinc (Zn)	2008/02/21		111	%	75 - 125
	QC STANDARD	Total Aluminum (Al)	2008/02/21		93	%	75 - 125
		Total Antimony (Sb)	2008/02/21		104	%	75 - 125
		Total Arsenic (As)	2008/02/21		101	%	75 - 125
		Total Barium (Ba)	2008/02/21		97	%	75 - 125
		Total Beryllium (Be)	2008/02/21		109	%	75 - 125
		Total Bismuth (Bi)	2008/02/21		94	%	75 - 125
		Total Cadmium (Cd)	2008/02/21		92	%	75 - 125
		Total Chromium (Cr)	2008/02/21		98	%	75 - 125
		Total Cobalt (Co)	2008/02/21		103	%	75 - 125
		Total Copper (Cu)	2008/02/21		98	%	75 - 125
		Total Iron (Fe)	2008/02/21		101	%	75 - 125
		Total Lead (Pb)	2008/02/21		97	%	75 - 125
		Total Magnesium (Mg)	2008/02/21		101	%	75 - 125
		Total Manganese (Mn)	2008/02/21		96	%	75 - 125
		Total Molybdenum (Mo)	2008/02/21		92	%	75 - 125
		Total Nickel (Ni)	2008/02/21		106	%	75 - 125
		Total Phosphorus (P)	2008/02/21		93	%	75 - 125
		Total Silver (Ag)	2008/02/21		101	%	75 - 125
		Total Strontium (Sr)	2008/02/21		100	%	75 - 125
		Total Thallium (Tl)	2008/02/21		91	%	75 - 125
		Total Tin (Sn)	2008/02/21		101	%	75 - 125
		Total Titanium (Ti)	2008/02/21		102	%	75 - 125
		Total Vanadium (V)	2008/02/21		104	%	75 - 125
		Total Zinc (Zn)	2008/02/21		100	%	75 - 125
	SPIKE	Total Arsenic (As)	2008/02/21		106	%	75 - 125
		Total Beryllium (Be)	2008/02/21		99	%	75 - 125
		Total Cadmium (Cd)	2008/02/21		98	%	75 - 125
		Total Chromium (Cr)	2008/02/21		103	%	75 - 125
		Total Cobalt (Co)	2008/02/21		101	%	75 - 125
		Total Copper (Cu)	2008/02/21		106	%	75 - 125
		Total Lead (Pb)	2008/02/21		100	%	75 - 125
		Total Mercury (Hg)	2008/02/21		103	%	75 - 125
		Total Nickel (Ni)	2008/02/21		105	%	75 - 125
		Total Selenium (Se)	2008/02/21		102	%	75 - 125
		Total Vanadium (V)	2008/02/21		107	%	75 - 125
		Total Zinc (Zn)	2008/02/21		108	%	75 - 125
	BLANK	Total Aluminum (Al)	2008/02/21	<100		mg/kg	
		Total Antimony (Sb)	2008/02/21	<0.1		mg/kg	
		Total Arsenic (As)	2008/02/21	<0.2		mg/kg	
		Total Barium (Ba)	2008/02/21	<0.1		mg/kg	
		Total Beryllium (Be)	2008/02/21	<0.1		mg/kg	

KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
P.O. #:
Site Reference:

Quality Assurance Report (Continued)

Maxxam Job Number: VA807269

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2134453 DJ	BLANK	Total Bismuth (Bi)	2008/02/21	<0.1		mg/kg	
		Total Cadmium (Cd)	2008/02/21	<0.05		mg/kg	
		Total Chromium (Cr)	2008/02/21	<1		mg/kg	
		Total Cobalt (Co)	2008/02/21	<0.3		mg/kg	
		Total Copper (Cu)	2008/02/21	<0.5		mg/kg	
		Total Iron (Fe)	2008/02/21	<100		mg/kg	
		Total Lead (Pb)	2008/02/21	<0.1		mg/kg	
		Total Magnesium (Mg)	2008/02/21	<100		mg/kg	
		Total Manganese (Mn)	2008/02/21	<0.2		mg/kg	
		Total Mercury (Hg)	2008/02/21	<0.05		mg/kg	
		Total Molybdenum (Mo)	2008/02/21	<0.1		mg/kg	
		Total Nickel (Ni)	2008/02/21	<0.8		mg/kg	
		Total Phosphorus (P)	2008/02/21	<10		mg/kg	
		Total Potassium (K)	2008/02/21	<100		mg/kg	
		Total Selenium (Se)	2008/02/21	<0.5		mg/kg	
		Total Silver (Ag)	2008/02/21	<0.05		mg/kg	
		Total Sodium (Na)	2008/02/21	<100		mg/kg	
		Total Strontium (Sr)	2008/02/21	<0.1		mg/kg	
		Total Thallium (Tl)	2008/02/21	<0.05		mg/kg	
		Total Tin (Sn)	2008/02/21	<0.1		mg/kg	
		Total Titanium (Ti)	2008/02/21	<1		mg/kg	
		Total Vanadium (V)	2008/02/21	<2		mg/kg	
		Total Zinc (Zn)	2008/02/21	<1		mg/kg	
		Total Zirconium (Zr)	2008/02/21	<0.5		mg/kg	
	RPD	Total Copper (Cu)	2008/02/21	2.4		%	35
		Total Zinc (Zn)	2008/02/21	2.6		%	35
2138623 VL	SPIKE	Biochemical Oxygen Demand	2008/02/27		98	%	80 - 120
	BLANK	Biochemical Oxygen Demand	2008/02/27	<10		mg/L	
	RPD	Biochemical Oxygen Demand	2008/02/27	0.9		%	25
2138717 AA1	BLANK	Total Calcium (Ca)	2008/02/23	<0.05		mg/L	
		Total Magnesium (Mg)	2008/02/23	<0.05		mg/L	
		Total Potassium (K)	2008/02/23	<0.05		mg/L	
		Total Sodium (Na)	2008/02/23	<0.05		mg/L	
		Total Sulphur (S)	2008/02/23	<3		mg/L	
	RPD	Total Calcium (Ca)	2008/02/23	0.2		%	25
		Total Magnesium (Mg)	2008/02/23	0.02		%	25

N/A = Not Applicable
NC = Non-calculable
RPD = Relative Percent Difference
(1) Spike invalid due to high sample concentration.

Burnaby: 8577 Commerce Court V5A 4N5 Telephone(604) 444-4808 Fax(604) 444-4511

A807267

Maxxam Analytics Inc
8577 Commerce Court
Burnaby, BC V5A 4N5
www.maxxamanalytics.com

Phone: (604) 444-4808
Fax: (604) 444-4511
Toll Free: 1-800-440-4808

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST PAGE ___ OF ___

A807269 **ANALYSIS REQUEST** F 77636

COMPANY NAME: Kerr Wood Leidal Associates Ltd
PH. #: 604-294-2088
E-mail: dmatsubara@kwl.ca
FAX #: 604-294-2090

COMPANY ADDRESS: 200-4185A Still Creek Drive Burnaby BC V5C 6G9

CLIENT PROJECT ID: (#) #2511.001

SAMPLER NAME (PRINT): David Matsubara

PROJECT MANAGER: David Matsubara

LAB USE ONLY

	FIELD SAMPLE ID	MAXXAM LAB # (Lab Use Only)	MATRIX: GROUND WATER	SURFACE WATER	SOIL	OTHER	# CONTAINERS	SAMPLING: DATE DD/MM/YY	TIME	HEADSPACE VAPOUR	ANALYSIS REQUEST
1	22nd D/S BOD	E89914		✓				Feb 20/08	9:40		BOD
2	22nd D/S TSS			✓				"	9:40		TSS
3	22nd D/S PAH			✓				"	9:46		PAH (2 BOTTLES)
4	22nd D/S FECAL			✓				"	9:40		FECAL COLIFORM
5	22nd D/S TOTAL METALS			✓				"	9:46		TOTAL METALS
6	2EN RAVINE 1	15		✓	✓			"	10:30		TOTAL METALS AND EPH
7	2EN RAVINE 2	16			✓			"	10:45		TOTAL METALS AND EPH
8											
9											
10											
11											
12											

TAT (Turnaround Time)

<5 DAY TAT MUST HAVE PRIOR APPROVAL

some exceptions apply please contact lab

STANDARD 5 BUSINESS DAYS ☐
RUSH 3 BUSINESS DAYS ☐
RUSH 2 BUSINESS DAYS ☐
URGENT 1 BUSINESS DAY ☐
OTHER BUSINESS DAYS ____

P.O. NUMBER / QUOTE NUMBER:

SPECIAL DETECTION LIMITS / CONTAMINANT TYPE:

☐ CCME
☐ CSR
☐ ALBERTA TIER 1
☐ OTHER

LAB USE ONLY
ARRIVAL TEMPERATURE °C: J.S
DUE DATE:
LOG IN CHECK:

ACCOUNTING CONTACT:

SPECIAL REPORTING OR BILLING INSTRUCTIONS:

JARS USED:

RELINQUISHED BY SAMPLER:	DATE: DD/MM/YY	TIME:	RECEIVED BY:
RELINQUISHED BY:	DATE: DD/MM/YY	TIME:	RECEIVED BY:
RELINQUISHED BY:	DATE: DD/MM/YY 20/02/08	TIME: 16:20	RECEIVED BY LABORATORY: A.M

CUSTODY RECORD

COCFORM - BC - 08/06

ORIGINAL - MAXXAM YELLOW - MAXXAM PINK - CLIENT

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Your Project #: 2511.001
Your C.O.C. #: F62484

Attention: David Matsubara
KERR WOOD LEIDAL
BURNABY
Suite 200
4185A Still Creek Drive
Burnaby, BC
CANADA V5C 6G9

Report Date: 2008/03/10

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: A809198
Received: 2008/03/03, 13:25

Sample Matrix: Water
Samples Received: 4

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Biochemical Oxygen Demand	1	N/A	2008/03/10	BRN SOP-00261 R2.0	SM 5210
Fecal Coliform as E. Coli (MPN)	1	N/A	2008/03/03	BIO101 Rev 2.5	Based on SM-9223B
Hardness Total (calculated as CaCO3)	1	N/A	2008/03/06		
Na, K, Ca, Mg, S by CRC ICPMS (total)	1	2008/03/04	2008/03/05	BRN SOP-00204	Based on EPA 200.8
Elements by CRC ICPMS (total) (1)	1	2008/03/04	2008/03/05	BRN SOP-00204	Based on EPA 200.8
PAH in Water by GC/MS (SIM)	1	2008/03/04	2008/03/05	BRN SOP-00331 R6.0	Based on EPA 8270C
Total LMW, HMW, Total PAH Calc	1	N/A	2008/03/06		
Total Suspended Solids	1	N/A	2008/03/07	BRN SOP-00277 R2.0	Based on SM - 2540 D

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) SCC/CAEAL

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

NAMITA SAHNI, BBY Customer Service
Email: namita.sahni@maxxamanalytics.com
Phone# (604) 444-4808 Ext:230

==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. SCC and CAEAL have approved this reporting process and electronic report format.

Total cover pages: 1

Maxxam Job #: A809198
Report Date: 2008/03/10

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		J03002	J03005		
Sampling Date		2008/03/03	2008/03/03		
COC Number		F62484	F62484		
	Units	**22ND & D/S 1L**	**22ND & D/S METALS**	**RDL**	**QC Batch**
Calculated Parameters					
Total Hardness (CaCO3)	mg/L		20.0	0.5	2156533
Demand Parameters					
Biochemical Oxygen Demand	mg/L	<10		10	2164704
Physical Properties					
Total Suspended Solids	mg/L	56		4	2167875

RDL = Reportable Detection Limit

Maxxam Job #: A809198
Report Date: 2008/03/10

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		J03005		
Sampling Date		2008/03/03		
COC Number		F62484		
	Units	**22ND & D/S METALS**	**RDL**	**QC Batch**
Total Metals by ICPMS				
Total Aluminum (Al)	mg/L	1.50	0.001	2158690
Total Antimony (Sb)	mg/L	0.0013	0.0005	2158690
Total Arsenic (As)	mg/L	0.0018	0.0001	2158690
Total Barium (Ba)	mg/L	0.023	0.001	2158690
Total Beryllium (Be)	mg/L	<0.0001	0.0001	2158690
Total Bismuth (Bi)	mg/L	<0.001	0.001	2158690
Total Boron (B)	mg/L	0.011	0.005	2158690
Total Cadmium (Cd)	mg/L	0.00013	0.00001	2158690
Total Chromium (Cr)	mg/L	0.004	0.001	2158690
Total Cobalt (Co)	mg/L	0.0007	0.0005	2158690
Total Copper (Cu)	mg/L	0.0221	0.0002	2158690
Total Iron (Fe)	mg/L	1.83	0.005	2158690
Total Lead (Pb)	mg/L	0.0111	0.0002	2158690
Total Manganese (Mn)	mg/L	0.056	0.001	2158690
Total Mercury (Hg)	mg/L	<0.00002	0.00002	2158690
Total Molybdenum (Mo)	mg/L	<0.001	0.001	2158690
Total Nickel (Ni)	mg/L	0.002	0.001	2158690
Total Selenium (Se)	mg/L	0.0001	0.0001	2158690
Total Silicon (Si)	mg/L	3.1	0.1	2158690
Total Silver (Ag)	mg/L	0.00003	0.00002	2158690
Total Strontium (Sr)	mg/L	0.030	0.001	2158690
Total Thallium (Tl)	mg/L	<0.00005	0.00005	2158690
Total Tin (Sn)	mg/L	<0.005	0.005	2158690
Total Titanium (Ti)	mg/L	0.061	0.005	2158690
Total Uranium (U)	mg/L	<0.0001	0.0001	2158690
Total Vanadium (V)	mg/L	<0.005	0.005	2158690
Total Zinc (Zn)	mg/L	0.055	0.005	2158690
Total Zirconium (Zr)	mg/L	<0.0005	0.0005	2158690
Total Calcium (Ca)	mg/L	6.31	0.05	2165216
Total Magnesium (Mg)	mg/L	1.02	0.05	2165216
Total Potassium (K)	mg/L	0.86	0.05	2165216
Total Sodium (Na)	mg/L	3.75	0.05	2165216

RDL = Reportable Detection Limit

Maxxam Job #: A809198
Report Date: 2008/03/10

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		J03005		
Sampling Date		2008/03/03		
COC Number		F62484		
	Units	**22ND & D/S METALS**	**RDL**	**QC Batch**
Total Sulphur (S)	mg/L	<3	3	2165216

RDL = Reportable Detection Limit

KERR WOOD LEIDAL
Maxxam Job #: A809198
Report Date: 2008/03/10

Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

MICROBIOLOGY (WATER)

Maxxam ID		J03004		
Sampling Date		2008/03/03		
COC Number		F62484		
	Units	**22ND & D/S FECAL**	**RDL**	**QC Batch**
Microbiological Param.				
Fecal Coliform as E. Coli	MPN/100mL	>2400	1	2158314

RDL = Reportable Detection Limit

Maxxam Job #: A809198
Report Date: 2008/03/10

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

TOTAL PAH - WATER (WATER)

Maxxam ID		J03003		
Sampling Date		2008/03/03		
COC Number		F62484		
	Units	**22ND & D/S PAH**	**RDL**	**QC Batch**
Polycyclic Aromatics				
Low Molecular Weight PAH`s	ug/L	0.38	0.05	2158119
High Molecular Weight PAH`s	ug/L	0.88	0.02	2158119
Total PAH	ug/L	1.3	0.05	2158119
Naphthalene	ug/L	0.03	0.01	2159462
2-Methylnaphthalene	ug/L	0.03	0.01	2159462
Quinoline	ug/L	0.06	0.05	2159462
Acenaphthylene	ug/L	0.01	0.01	2159462
Acenaphthene	ug/L	0.01	0.01	2159462
Fluorene	ug/L	0.03	0.01	2159462
Phenanthrene	ug/L	0.16	0.01	2159462
Anthracene	ug/L	0.05	0.01	2159462
Acridine	ug/L	<0.05	0.05	2159462
Fluoranthene	ug/L	0.19	0.01	2159462
Pyrene	ug/L	0.20	0.01	2159462
Benzo(a)anthracene	ug/L	0.05	0.01	2159462
Chrysene	ug/L	0.08	0.01	2159462
Benzo(b&j)fluoranthene	ug/L	0.07	0.01	2159462
Benzo(k)fluoranthene	ug/L	0.06	0.01	2159462
Benzo(a)pyrene	ug/L	0.08	0.01	2159462
Indeno(1,2,3-cd)pyrene	ug/L	0.06	0.02	2159462
Dibenz(a,h)anthracene	ug/L	<0.02	0.02	2159462
Benzo(g,h,i)perylene	ug/L	0.09	0.02	2159462
Surrogate Recovery (%)				
D10-ANTHRACENE (sur.)	%	75		2159462
D12-BENZO(A)PYRENE (sur.)	%	73		2159462
D8-ACENAPHTHYLENE (sur.)	%	68		2159462
TERPHENYL-D14 (sur.)	%	73		2159462

RDL = Reportable Detection Limit

Maxxam Job #: A809198
Report Date: 2008/03/10

KERR WOOD LEIDAL
Client Project #: 2511.001
Site Reference:
Sampler Initials: DM

General Comments

Results relate only to the items tested.

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Quality Assurance Report

Maxxam Job Number: VA809198

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2158314 SL7	BLANK	Fecal Coliform as E. Coli	2008/03/03	<1		MPN/100mL	
2158690 AA1	MATRIX SPIKE	Total Arsenic (As)	2008/03/05		103	%	75 - 125
		Total Beryllium (Be)	2008/03/05		101	%	75 - 125
		Total Cadmium (Cd)	2008/03/05		97	%	75 - 125
		Total Chromium (Cr)	2008/03/05		112	%	75 - 125
		Total Cobalt (Co)	2008/03/05		109	%	75 - 125
		Total Copper (Cu)	2008/03/05		111	%	75 - 125
		Total Lead (Pb)	2008/03/05		102	%	75 - 125
		Total Nickel (Ni)	2008/03/05		107	%	75 - 125
		Total Selenium (Se)	2008/03/05		101	%	75 - 125
		Total Uranium (U)	2008/03/05		115	%	75 - 125
		Total Vanadium (V)	2008/03/05		112	%	75 - 125
		Total Zinc (Zn)	2008/03/05		102	%	75 - 125
	SPIKE	Total Arsenic (As)	2008/03/05		98	%	75 - 125
		Total Beryllium (Be)	2008/03/05		104	%	75 - 125
		Total Cadmium (Cd)	2008/03/05		98	%	75 - 125
		Total Chromium (Cr)	2008/03/05		98	%	75 - 125
		Total Cobalt (Co)	2008/03/05		98	%	75 - 125
		Total Copper (Cu)	2008/03/05		102	%	75 - 125
		Total Lead (Pb)	2008/03/05		102	%	75 - 125
		Total Nickel (Ni)	2008/03/05		99	%	75 - 125
		Total Selenium (Se)	2008/03/05		102	%	75 - 125
		Total Uranium (U)	2008/03/05		104	%	75 - 125
		Total Vanadium (V)	2008/03/05		96	%	75 - 125
		Total Zinc (Zn)	2008/03/05		102	%	75 - 125
	BLANK	Total Aluminum (Al)	2008/03/05	<1		ug/L	
		Total Antimony (Sb)	2008/03/05	<0.5		ug/L	
		Total Arsenic (As)	2008/03/05	<0.1		ug/L	
		Total Barium (Ba)	2008/03/05	<1		ug/L	
		Total Beryllium (Be)	2008/03/05	<0.1		ug/L	
		Total Bismuth (Bi)	2008/03/05	<1		ug/L	
		Total Boron (B)	2008/03/05	<5		ug/L	
		Total Cadmium (Cd)	2008/03/05	<0.01		ug/L	
		Total Chromium (Cr)	2008/03/05	<1		ug/L	
		Total Cobalt (Co)	2008/03/05	<0.5		ug/L	
		Total Copper (Cu)	2008/03/05	<0.2		ug/L	
		Total Iron (Fe)	2008/03/05	<5		ug/L	
		Total Lead (Pb)	2008/03/05	<0.2		ug/L	
		Total Manganese (Mn)	2008/03/05	<1		ug/L	
		Total Mercury (Hg)	2008/03/05	<0.02		ug/L	
		Total Molybdenum (Mo)	2008/03/05	<1		ug/L	
		Total Nickel (Ni)	2008/03/05	<1		ug/L	
		Total Selenium (Se)	2008/03/05	<0.1		ug/L	
		Total Silicon (Si)	2008/03/05	<100		ug/L	
		Total Silver (Ag)	2008/03/05	<0.02		ug/L	
		Total Strontium (Sr)	2008/03/05	<1		ug/L	
		Total Thallium (Tl)	2008/03/05	<0.05		ug/L	
		Total Tin (Sn)	2008/03/05	<5		ug/L	
		Total Titanium (Ti)	2008/03/05	<5		ug/L	
		Total Uranium (U)	2008/03/05	<0.1		ug/L	
		Total Vanadium (V)	2008/03/05	<5		ug/L	
		Total Zinc (Zn)	2008/03/05	<5		ug/L	
		Total Zirconium (Zr)	2008/03/05	<0.5		ug/L	
	RPD	Total Aluminum (Al)	2008/03/05	7.1		%	25
		Total Antimony (Sb)	2008/03/05	NC		%	25

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KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
P.O. #:
Site Reference:

Quality Assurance Report (Continued)

Maxxam Job Number: VA809198

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2158690 AA1	RPD	Total Arsenic (As)	2008/03/05	NC		%	25
		Total Barium (Ba)	2008/03/05	0.3		%	25
		Total Beryllium (Be)	2008/03/05	NC		%	25
		Total Bismuth (Bi)	2008/03/05	NC		%	25
		Total Boron (B)	2008/03/05	NC		%	25
		Total Cadmium (Cd)	2008/03/05	NC		%	25
		Total Chromium (Cr)	2008/03/05	NC		%	25
		Total Cobalt (Co)	2008/03/05	NC		%	25
		Total Copper (Cu)	2008/03/05	2.5		%	25
		Total Iron (Fe)	2008/03/05	5.7		%	25
		Total Lead (Pb)	2008/03/05	6.3		%	25
		Total Manganese (Mn)	2008/03/05	NC		%	25
		Total Molybdenum (Mo)	2008/03/05	NC		%	25
		Total Nickel (Ni)	2008/03/05	NC		%	25
		Total Selenium (Se)	2008/03/05	NC		%	25
		Total Silicon (Si)	2008/03/05	2.5		%	25
		Total Silver (Ag)	2008/03/05	NC		%	25
		Total Strontium (Sr)	2008/03/05	1.1		%	25
		Total Thallium (Tl)	2008/03/05	NC		%	25
		Total Tin (Sn)	2008/03/05	NC		%	25
		Total Titanium (Ti)	2008/03/05	NC		%	25
		Total Uranium (U)	2008/03/05	NC		%	25
		Total Vanadium (V)	2008/03/05	NC		%	25
		Total Zinc (Zn)	2008/03/05	NC		%	25
		Total Zirconium (Zr)	2008/03/05	NC		%	25
2159462 SY	MATRIX SPIKE	D10-ANTHRACENE (sur.)	2008/03/05		77	%	30 - 130
		D12-BENZO(A)PYRENE (sur.)	2008/03/05		75	%	30 - 130
		D8-ACENAPHTHYLENE (sur.)	2008/03/05		73	%	30 - 130
		TERPHENYL-D14 (sur.)	2008/03/05		73	%	30 - 130
		Naphthalene	2008/03/05		82	%	40 - 130
		2-Methylnaphthalene	2008/03/05		74	%	40 - 130
		Quinoline	2008/03/05		109	%	40 - 130
		Acenaphthylene	2008/03/05		77	%	40 - 130
		Acenaphthene	2008/03/05		82	%	40 - 130
		Fluorene	2008/03/05		81	%	40 - 130
		Phenanthrene	2008/03/05		96	%	40 - 130
		Anthracene	2008/03/05		83	%	40 - 130
		Acridine	2008/03/05		93	%	40 - 130
		Fluoranthene	2008/03/05		83	%	40 - 130
		Pyrene	2008/03/05		83	%	40 - 130
		Benzo(a)anthracene	2008/03/05		76	%	40 - 130
		Chrysene	2008/03/05		78	%	40 - 130
		Benzo(b&j)fluoranthene	2008/03/05		82	%	40 - 130
		Benzo(k)fluoranthene	2008/03/05		87	%	40 - 130
		Benzo(a)pyrene	2008/03/05		89	%	40 - 130
		Indeno(1,2,3-cd)pyrene	2008/03/05		84	%	40 - 130
		Dibenz(a,h)anthracene	2008/03/05		84	%	40 - 130
		Benzo(g,h,i)perylene	2008/03/05		83	%	40 - 130
	SPIKE	D10-ANTHRACENE (sur.)	2008/03/05		79	%	30 - 130
		D12-BENZO(A)PYRENE (sur.)	2008/03/05		81	%	30 - 130
		D8-ACENAPHTHYLENE (sur.)	2008/03/05		74	%	30 - 130
		TERPHENYL-D14 (sur.)	2008/03/05		76	%	30 - 130
		Naphthalene	2008/03/05		65	%	40 - 130
		2-Methylnaphthalene	2008/03/05		64	%	40 - 130
		Quinoline	2008/03/05		98	%	40 - 130

KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
P.O. #:
Site Reference:

Quality Assurance Report (Continued)

Maxxam Job Number: VA809198

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2159462 SY	SPIKE	Acenaphthylene	2008/03/05		71	%	40 - 130
		Acenaphthene	2008/03/05		73	%	40 - 130
		Fluorene	2008/03/05		70	%	40 - 130
		Phenanthrene	2008/03/05		77	%	40 - 130
		Anthracene	2008/03/05		76	%	40 - 130
		Acridine	2008/03/05		83	%	40 - 130
		Fluoranthene	2008/03/05		75	%	40 - 130
		Pyrene	2008/03/05		77	%	40 - 130
		Benzo(a)anthracene	2008/03/05		72	%	40 - 130
		Chrysene	2008/03/05		74	%	40 - 130
		Benzo(b&j)fluoranthene	2008/03/05		79	%	40 - 130
		Benzo(k)fluoranthene	2008/03/05		83	%	40 - 130
		Benzo(a)pyrene	2008/03/05		86	%	40 - 130
		Indeno(1,2,3-cd)pyrene	2008/03/05		82	%	40 - 130
		Dibenz(a,h)anthracene	2008/03/05		81	%	40 - 130
		Benzo(g,h,i)perylene	2008/03/05		81	%	40 - 130
	BLANK	D10-ANTHRACENE (sur.)	2008/03/05		80	%	30 - 130
		D12-BENZO(A)PYRENE (sur.)	2008/03/05		80	%	30 - 130
		D8-ACENAPHTHYLENE (sur.)	2008/03/05		75	%	30 - 130
		TERPHENYL-D14 (sur.)	2008/03/05		78	%	30 - 130
		Naphthalene	2008/03/05	<0.01		ug/L	
		2-Methylnaphthalene	2008/03/05	<0.01		ug/L	
		Quinoline	2008/03/05	<0.05		ug/L	
		Acenaphthylene	2008/03/05	<0.01		ug/L	
		Acenaphthene	2008/03/05	<0.01		ug/L	
		Fluorene	2008/03/05	<0.01		ug/L	
		Phenanthrene	2008/03/05	<0.01		ug/L	
		Anthracene	2008/03/05	<0.01		ug/L	
		Acridine	2008/03/05	<0.05		ug/L	
		Fluoranthene	2008/03/05	<0.01		ug/L	
		Pyrene	2008/03/05	<0.01		ug/L	
		Benzo(a)anthracene	2008/03/05	<0.01		ug/L	
		Chrysene	2008/03/05	<0.01		ug/L	
		Benzo(b&j)fluoranthene	2008/03/05	<0.01		ug/L	
		Benzo(k)fluoranthene	2008/03/05	<0.01		ug/L	
		Benzo(a)pyrene	2008/03/05	<0.01		ug/L	
		Indeno(1,2,3-cd)pyrene	2008/03/05	<0.02		ug/L	
		Dibenz(a,h)anthracene	2008/03/05	<0.02		ug/L	
		Benzo(g,h,i)perylene	2008/03/05	<0.02		ug/L	
	RPD	Naphthalene	2008/03/05	NC		%	40
		2-Methylnaphthalene	2008/03/05	NC		%	40
		Quinoline	2008/03/05	NC		%	40
		Acenaphthylene	2008/03/05	NC		%	40
		Acenaphthene	2008/03/05	NC		%	40
		Fluorene	2008/03/05	NC		%	40
		Phenanthrene	2008/03/05	NC		%	40
		Anthracene	2008/03/05	2.3		%	40
		Acridine	2008/03/05	NC		%	40
		Fluoranthene	2008/03/05	4.1		%	40
		Pyrene	2008/03/05	5.5		%	40
		Benzo(a)anthracene	2008/03/05	NC		%	40
		Chrysene	2008/03/05	NC		%	40
		Benzo(b&j)fluoranthene	2008/03/05	6.9		%	40
		Benzo(k)fluoranthene	2008/03/05	4.6		%	40
		Benzo(a)pyrene	2008/03/05	3.6		%	40

KERR WOOD LEIDAL
Attention: David Matsubara
Client Project #: 2511.001
P.O. #:
Site Reference:

Quality Assurance Report (Continued)

Maxxam Job Number: VA809198

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2159462	SY	RPD	Indeno(1,2,3-cd)pyrene	2008/03/05	NC		%	40
			Dibenz(a,h)anthracene	2008/03/05	NC		%	40
			Benzo(g,h,i)perylene	2008/03/05	NC		%	40
2164704	VL	SPIKE	Biochemical Oxygen Demand	2008/03/10		103	%	80 - 120
		BLANK	Biochemical Oxygen Demand	2008/03/10	<10		mg/L	
		RPD	Biochemical Oxygen Demand	2008/03/10	10.6		%	25
2165216	AA1	BLANK	Total Calcium (Ca)	2008/03/05	<0.05		mg/L	
			Total Magnesium (Mg)	2008/03/05	<0.05		mg/L	
			Total Potassium (K)	2008/03/05	<0.05		mg/L	
			Total Sodium (Na)	2008/03/05	<0.05		mg/L	
			Total Sulphur (S)	2008/03/05	<3		mg/L	
		RPD	Total Calcium (Ca)	2008/03/05	4.8		%	25
			Total Magnesium (Mg)	2008/03/05	1.3		%	25
			Total Potassium (K)	2008/03/05	1.5		%	25
			Total Sodium (Na)	2008/03/05	2.0		%	25
			Total Sulphur (S)	2008/03/05	NC		%	25
2167875	LL4	MATRIX SPIKE	Total Suspended Solids	2008/03/07		100	%	N/A
		SPIKE	Total Suspended Solids	2008/03/07		107	%	N/A
		BLANK	Total Suspended Solids	2008/03/07	<4		mg/L	
		RPD	Total Suspended Solids	2008/03/07	NC		%	25

N/A = Not Applicable
NC = Non-calculable
RPD = Relative Percent Difference

Burnaby: 8577 Commerce Court V5A 4N5 Telephone(604) 444-4808 Fax(604) 444-4511

A804148

Maxxam Analytics Inc

8577 Commerce Court
Burnaby, BC V5A 4N5
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Phone: (604) 444-4808
Fax: (604) 444-4511
Toll Free: 1-800-440-4808

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

PAGE 1 OF 1

ANALYSIS REQUEST F 62484

COMPANY NAME: KERR WOOD LEIDAL

PH. #: 604 293 3259
E-mail: dmatsubara@kwl.ca
FAX #:

COMPANY ADDRESS: 200 - 4185 STILL CREEK DR BURNABY, BC

CLIENT PROJECT ID: (#) 2511.001

SAMPLER NAME (PRINT): DAVID MATSUBARA

PROJECT MANAGER: DAVID MATSUBARA

	FIELD SAMPLE ID	MATRIX: GROUND WATER	SURFACE WATER	SOIL	OTHER	# CONTAINERS	SAMPLING: DATE DD/MM/YY	TIME	HEADSPACE VAPOUR	BOD	TSS	PAH (TOTAL)	TOTAL METALS	FECAL COLIFORM
1	22nd D/S 1L		✓				03/03/08			✓	✓			
2	22nd D/S PAH		✓				03/03/08					✓		
3	22nd D/S Fecal		✓				03/03/08							✓
4	22nd D/S metals		✓				03/03/08						✓	
5														
6														
7														
8														
9														
10														
11														
12														

TAT (Turnaround Time)

<5 DAY TAT MUST HAVE PRIOR APPROVAL

*some exceptions apply please contact lab

- STANDARD 5 BUSINESS DAYS ☐
- RUSH 3 BUSINESS DAYS ☐
- RUSH 2 BUSINESS DAYS ☐
- URGENT 1 BUSINESS DAY ☐

OTHER BUSINESS DAYS ____

P.O. NUMBER / QUOTE NUMBER:

SPECIAL DETECTION LIMITS / CONTAMINANT TYPE:

☐ CCME ☐ CSR ☐ ALBERTA TIER 1 ☐ OTHER

ARRIVAL TEMPERATURE °C: 3 3

DUE DATE:

LOG IN CHECK:

ACCOUNTING CONTACT:

SPECIAL REPORTING OR BILLING INSTRUCTIONS:

JARS USED:

RELINQUISHED BY SAMPLER:	DATE: DD/MM/YY	TIME:	RECEIVED BY:
RELINQUISHED BY:	DATE: DD/MM/YY	TIME:	RECEIVED BY:
RELINQUISHED BY:	DATE: DD/MM/YY 03/03/08	TIME: 13:25	RECEIVED BY LABORATORY: AM

CUSTODY RECORD

COCFORM - BC - 06/06

ORIGINAL - MAXXAM YELLOW - MAXXAM PINK - CLIENT