



PITEAU ASSOCIATES
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March 18, 2005

Earth Tech Canada Inc.
1901 Rosser Street, 6th Floor
Burnaby, B.C.
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Attention: Mr. Scott Neuman

Dear Sirs:

Re: Hydrogeologic Assessment for Groundwater Supply, Lions Bay, B.C.

Piteau Associates Engineering Ltd. (Piteau) was retained by Earth Tech Canada Inc. (Earth Tech) to perform a hydrogeological assessment to define areas near the Village of Lions Bay which are most prospective for a potential development of a groundwater source. The work involved the review of available topographic and geological maps and reports, stereo-paired aerial photographs, information on existing water wells drilled in the area, and reports pertaining to groundwater resources.

BACKGROUND

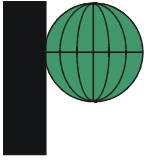
The Village of Lions Bay (the Village) is a community of about 1400 residents located on the east shore of Howe Sound, 25 km north of Vancouver (Fig. 1). Access is by Hwy. 99, which intersects the town.

The Village operates a water distribution system that supplies potable water to residences and businesses. According to Earth Tech, water is drawn into the system at intakes on Harvey Creek (79% of production), Magnesia Creek (21% of production) and Alberta Creek (used only during droughts). Earth Tech has indicated that the average daily water demand in 2004 was 28 L/s. However, after allowing for leakage, the actual consumption is about 10 L/s. Having regard to possible future expansion of the community, they have indicated that the feasibility of developing a 10 to 15 L/s groundwater supply source should be assessed.

SITE DESCRIPTION

The Village of Lions Bay is located along Hwy. 99, 11 km north of Horseshoe Bay on NTS mapsheet 92G/6.

The original settlement at Lions Bay was built on the alluvial fan of Harvey Creek, which juts into Howe Sound. Topography of the fan is subdued, with an average grade from tidewater to fan apex of about 20%. The fan consists of rapidly changing sand and gravel layers with occasional accumulations of unsorted sand, silt and gravel that were deposited by mass wasting events.



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Beyond the top of the fan, slope grade increases to 25%, and the built-up portion of town extends to an elevation of about 220 metres above sea level (m-asl). At this elevation, the slope breaks uphill to 50%, except in the Harvey Creek Valley, where the slope maintains a grade of about 25%.

Creeks draining Mount Harvey and The Lions are incised through overburden and into bedrock. The horizontal depth of the Magnesia Creek valley is about 16m, while that of the Harvey Creek valley is about 18m. The topographic divides along the eastern sides of these two creek catchment basins rise up to about 1700 and 1600 m-asl, respectively.

HYDROGEOLOGY

The dominant geologic profile in the Village area is about 1m of unconsolidated colluvium overlying metamorphosed sedimentary and volcanic bedrock belonging to the Gambier Group. According to Roddick (1965), this bedrock consists of bedded and foliated deposits of clastic sediments and a range of intermediate to felsic, subaerially deposited, flow and fragmental volcanics. The general morphology of Gambier Group rocks resembles a hanging pendant, or remnant, of older Gambier Group suspended in the main mass of Coast Plutonic rocks. The colluvium is likely quite a bit thicker than 1m in the area around the creek mouths, where it merges into fan deposits.

The eastern extent of Gambier Group rocks is at an intrusive contact about 1200m east of the Howe Sound shore, where a large mass of quartz diorite is exposed. Given the expected shape of the Gambier pendant, its contact with the quartz diorite likely dips to the west.

Groundwater in the Lions Bay area is likely controlled by bedrock openings called fractures. While bedrock is relatively impermeable to water, it can act as an aquifer when it has been fractured. Brittle plutonic and volcanic rocks are most susceptible to fracturing, and these have commonly been subjected to tectonic activity in this setting. While the porosity of the resulting rock is relatively low, the fractures can be extensive and intersecting fracture sets can result in moderately productive aquifer zones. The morphology of such zones is often erratic compared to sedimentary layering, and locations of suspected fracture zones should be confirmed in the field. The Gambier rocks have been tilted as they were thrust into place by regional faulting, and now exhibit bedding of various attitudes. Some sections dip nearly vertically. Their susceptibility to tectonic fracturing is variable, with the fine-grained clastic sediments forming foliated rocks, and the brittle volcanics tending to shatter.

Faults are fractures along which relative movement of rock has taken place. Rather than a single discrete plane, faults are commonly zones several metres or tens of metres wide, along which rocks have been crushed or torn. Fault zones can subsequently become conduits for groundwater movement, and are a good place to prospect for water in a bedrock environment. In particular, locations where intersecting fault sets are suspected warrant further investigation, as they may host a volume of rock that has been fractured in three dimensions.



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Through-going faults have not been identified on the regional bedrock geology maps (Roddick, 1965) and the Armstrong map (1990), but localized faulting and fracturing is common along Howe Sound.

As part of this hydrogeological assessment, Piteau has examined stereoscopic aerial photographs of the region surrounding Lions Bay, to delineate potential regional faulting and/or fractures. Linear geographic features that are interpreted as potential fault or fracture planes are indicated in Fig. 2. Areas where potential fault intersections exist are circled, and suggested locations for a test well are also indicated.

Water migrating along a fault plane projecting at an angle other than vertical would be intercepted by a vertical well from the top surface of the fault. The orientation of the fault or fracture must be ascertained prior to the selection of a drill site, so that the zone can be intersected at a depth of at least 30m below ground.

EXISTING WATER WELLS

There are no government records of water wells in the area covered by Fig. 1. Wells operating at Fury Creek north of Lions Bay are in a different hydrogeological regime. They draw water from a gravel aquifer that is not comparable to Lions Bay lithology.

Information obtained from a representative of the Seascapes development project, which is located just north of Horseshoe Bay, confirms that they drilled eight test wells on the property and that they now have three production wells. Typical well depths are 100 to 140m and yields are in the 0.8 to 1 L/s range. Many of the successful wells could not be used due to unacceptably high arsenic concentrations in the groundwater. Elevated arsenic concentrations have been a problem in geologically similar areas on Bowen Islands and some regions along the Sunshine Coast. However, this issue tends to be less of a problem in areas located near large creeks.

CLIMATE

Environment Canada climate data indicate that the average annual precipitation for Lions Bay Station for the 17-year period between 1984 to 2001 was 1662mm (Table I). This compares to reported 30-year annual average precipitation values of 2367mm and 2044mm for Squamish Upper Station and North Vancouver Capilano Station, respectively. As precipitation increases with increasing elevation, a value of 1850mm was used for estimating groundwater recharge for this assessment.

RECHARGE

If the presence of an aquifer is confirmed, an additional consideration is recharge. Recharge is the volume of water flowing through the ground into an aquifer. Recharge must exceed the sum of all discharge for the aquifer's water level to remain stable.



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The area available for recharge in each of the three basins of Harvey, Alberta and Magnesia creeks multiplied by the annual average precipitation provides an estimate of total annual hydrologic flow. Of this, most flows as surface runoff, while only a portion is available for groundwater recharge. Assuming that about 8% of the average annual precipitation can seep into the ground, the potential maximum available recharge in each of the three basins is summarized as follows:

Basin	L/s	USgpm
Harvey Creek	28.6	454
Magnesia Creek	17.3	275
Alberta Creek	4.3	68

This calculation suggests that, while a single well located in either the Harvey or Magnesia Creek basins could theoretically sustain the design flow, it is likely that a number of production wells will be needed to provide the 10 to 15 L/s required flow.

Based on available information, it is judged that individual well yields ranging up to about 4 L/s are possible for wells located close to Harvey and Magnesia Creeks. If it is confirmed that the local area fault/fracture zones dip towards the north, the best location for a test well is about 50m north of the creek channel. Other potential areas are along what appears to be cross faults, such as site 4, indicated on Fig.2.

A number of potential sites are represented as red dots on Fig. 2. These are presented as potential sites that appear worthy of additional assessment and consideration, especially in regards to land ownership and site access. The additional assessments, will involve examining bedrock exposures, looking for evidence of faults or large fracture zones in bedrock exposures, delineating the structural strikes, assessing the feasibility of bringing a truck-mounted drill rig to the site and proximity to existing water mains. Many of these sites may prove to be very expensive to access, and yet others may be relatively inexpensive, such as a site located near the fire hall.

WATER QUALITY

Experience from hydrogeologically similar areas suggest that the groundwater in the area should meet Canadian Drinking Water Quality guidelines. However, there are some metals that could potentially pose a water quality concern in water drawn from Gambier sediments. These include arsenic, mercury, lead, iron and manganese. However, high metals concentrations are normally expected where water has a long residence time in contact with its host formation. The fractured bedrock and high hydraulic gradients anticipated in the Lions Bay area suggest a high flux rate, and hence, a low residence time.

Elevated concentrations of iron and manganese only have an aesthetic impact on water quality and can normally be relatively easily removed, while some metals, such as arsenic, pose a health problem and are difficult to treat.



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In some areas, oxidation of sulphides in the bedrock can lead to water with low pH and/or a pungent “rotten egg” smell. If present, this is relatively easily removed.

COSTS

The cost of drilling and testing bedrock wells in the Lions Bay area could range from about \$109,614 to about \$181,342, as indicated on Table II. In developing these costs, the following assumptions were made:

1. It is estimated that it may be feasible to drill between four and six test holes and have three of these holes completed as production wells, which have the potential for yielding a combined flow of at least 10 L/s.
2. The pumps required to pump from the successful wells will fit into either a 150mm diameter bedrock hole or a 106mm diameter PVC casing that has been installed to stabilize the rock walls in the well.
3. The depth of the wells and test holes will range from 91.4 to 152.4m (300 to 500 ft) below ground surface.
4. Each successfully completed well will be aquifer pump tested for a period of 72 hours.
5. Groundwater quality will not be a significant issue.

The lowest cost estimate assumes that four 91m deep, unlined wells are constructed and that three have sufficient yield capacity to sustain a flow of at least 3.3 L/s.

CONCLUSIONS

- 1) Groundwater recharge estimates for the creek basins surrounding Lions Bay indicate that there is a potential for the required minimum 10 L/s flow being produced from wells drilled into fractured bedrock in either in the Harvey or Magnesia Creek basins.
- 2) It is estimated that between three and four wells will be required to sustain the minimum 10 L/s flow, and up to six 152m test deep holes may be required to prove up the desired yield and water quality.
- 3) Groundwater in the Lions Bay area will most likely be drawn from fractured bedrock aquifers, and experience suggests there is about a 70% chance that the required yield and water quality can be obtained from three wells drilled in this type of bedrock.
- 4) While there is a possibility that a well could be developed in the Harvey and Magnesia Creek fans, these potential water bearing zones (aquifers) are not well protected from surface contamination. Given that the potentially most productive zones are located below the



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highway, where contaminants could enter the aquifers and near the ocean where there is a potential for salt water intrusion, this option has been ruled out.

- 5) The estimated cost of a drilling and testing program, leading up to the construction of testing of three tested production wells is likely to be in the \$109,000 to \$182,000 range. This does not include the cost of preparing access to the selected drill sites, but does include the cost of engineering supervision of the program and GST.

RECOMMENDATIONS

- 1) Potential sites should be selected according to their potential ease of access to water mains and accessibility for a drill rig. Follow-up geological mapping should then be conducted at prioritized sites. The objective of this mapping should be to confirm the potential presence of fractured bedrock and determining the orientations of exposed geological structures such as faults and fractures.
- 2) A 150mm (6") diameter test hole should be drilled at the most promising sites, to a depth of about 100m and possibly as deep as 150m.
- 3) If an aquifer is encountered, the stability of the bedrock in the hole should be assessed to determine if liner pipe is required to protect a submersible pump installed in the hole.
- 4) Soon after a well is completed, an aquifer pumping test should be performed.
- 5) One or more water samples should be collected during the test and a sample sent to a laboratory for potability analysis.

We trust this is sufficient for your current needs.

Yours truly,

PITEAU ASSOCIATES ENGINEERING LTD.

Arnd Burgert, G.I.T.

R. Allan Dakin, P.Eng.

AB/RAD/dls
Att.

REFERENCES

Armstrong J.E., 1990. Vancouver Geology. Geological Association of Canada. 128 p.

Roddick, J.A., 1965. Vancouver North, Coquitlam and Pitt Lake Map Areas, British Columbia, Geological Survey of Canada, Memoir 335. 275 pp.

TABLES

TABLE I
CLIMATE DATA FOR HOWE SOUND
Canadian Climate Normals 1971-2000

Station	Latitude		Longitude		Elevation		Climate ID						
Squamish Upper	49° 54' N		123° 16' W		46.00 m		1047672						
Temperature													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	0.2	2.3	5.7	9.0	12.5	15.2	17.7	17.8	14.6	9.1	3.5	-0.1	9.0
Standard Deviation	2.5	2.0	1.8	1.3	1.3	1.3	1.2	1.0	1.3	1.1	2.0	2.2	1.8
Daily Maximum (°C)	2.9	6.0	10.6	14.6	18.3	20.9	24.0	24.5	21.0	13.8	6.2	2.2	13.7
Daily Minimum (°C)	-2.5	-1.5	0.7	3.4	6.7	9.4	11.3	11.2	8.2	4.4	0.8	-2.4	4.1
Precipitation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	265.7	235.3	188.9	159.2	105.8	85.8	61.1	59.6	88.2	279	357.5	245.2	2131.3
Snowfall (cm)	71.7	47.6	22.5	2.5	0.0	0.0	0.0	0.0	0.0	0.6	21.4	69.1	235.5
Precipitation (mm)	337.4	283	211.4	161.7	105.8	85.8	61.1	59.6	88.2	279.6	378.9	314.3	2366.8

Station	Latitude		Longitude		Elevation		Climate ID						
N Vancouver Capilano	49° 21' N		123° 7' W		93.00 m		1105655						
Precipitation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	219.2	224.7	188	142.4	112.1	89.2	69.4	62.4	94.4	205.9	294.5	284.6	1986.8
Snowfall (cm)	17.8	14.5	3.3	0.4	0.0	0.0	0.0	0.0	0.0	0.1	4.4	16.4	56.9
Precipitation (mm)	237	239.2	191.3	142.8	112.1	89.2	69.4	62.4	94.4	206	298.9	301	2043.7

Climate Averages 1984-2001

Station	Latitude		Longitude		Elevation		Climate ID						
Lions Bay	49° 27' N		123° 14' W		52.00 m		1104634						
Precipitation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation (mm)	217.5	161.4	152.5	139.2	102.6	80.0	48.8	60.3	67.1	195.4	241.7	195.9	1662.3

Source: Environment Canada

TABLE II

WELL DRILLING AND TESTING COST

Lined Bedrock Well = 500 feet deep

Item	Units	Qty	Field Drilling	
			Rate	Cost
Mobe & Demobe	LS	1	300	300
Drill and Case 200mm diam.	ft	15	50	750
Drill - 200mm diam in rock	ft	5	40	200
Set 150mm casing	ft	20	15.0	300
Drill - 150mm diam in rock	ft	480	30.0	14,400
Supply 110mm diam blank liner	ft	460	8	3,680
Supply 110mm diam screen	ft	40	11	440
Hourly work	Hour	6	250	1,500
200mm diam casing shoe	Unit	1	360	360
Bentonite seal and cap	Unit	1	300	300
Contingency	Unit	1	200	200
Per diem	day	3	300	900
TOTAL				23,330
GST				1,633
TOTAL				24,963

72 Hour Pumping Test on Well

Item	Units	Qty	Precision Pumps	
			Rate	Cost
Mobe & Demobe	LS	1	400	400
Set and with draw pump	hr	6	125	750
Pump testing	hr	72	95	6,840
Recovery	hr	4	80.0	320
Supply lay flat hose	ft	150	1.0	150
Per diem	day	4	200	800
TOTAL				9,260
GST				648
TOTAL				9,908

Unlined Hole 300 feet deep

Item	Units	Qty	Field Drilling	
			Rate	Cost
Site move	LS	1	600	600
Drill and Case 200mm diam.	ft	15	50	750
Drill - 200mm diam in rock	ft	5	40	200
Set 150mm casing	ft	20	15.0	300
Drill - 150mm diam in rock	ft	280	30.0	8,400
Supply 110mm diam blank liner	ft		8	
Supply 110mm diam screen	ft		11	
Hourly work	Hour	6	250	1,500
200mm diam casing shoe	Unit	1	360	360
Bentonite seal and cap	Unit	1	300	300
Contingency	Unit	1	200	200
Per diem	day	2	300	600
TOTAL				13,210
GST				925
TOTAL				14,135

Abandoned Test Hole

Item	Units	Qty	Field Drilling	
			Rate	Cost
Site move	LS	1	600	600
Drill and Case 200mm diam.	ft	15	50	750
Drill - 200mm diam in rock	ft	5	40	200
Set 150mm casing	ft	20	15.0	300
Drill - 150mm diam in rock	ft	280	30.0	8,400
Supply 110mm diam blank liner	ft		8	
Supply 110mm diam screen	ft		11	
Hourly work	Hour	6	250	1,500
200mm diam casing shoe	Unit	1	360	360
Bentonite seal and cap	Unit	1	300	300
Contingency	Unit	1	200	200
Per diem	day	2	300	600
TOTAL				13,210
GST				925
TOTAL				14,135

Scenario 1

Unlined well	Well	3	\$14,135	42,404
Abandoned test hole	Hole	1	\$14,135	14,135
Pumping test	Test	3	\$9,260	27,780
Sub total				84,319
Contingency	10%			8,432
Engineering	20%			16,864
Total				109,614

Scenario 2

Lined well	Well	3	\$24,963	74,889
Abandoned test hole	Hole	3	\$14,135	42,404
Pumping test	Test	3	\$9,260	27,780
Sub total				145,073
Contingency	10%			14,507
Engineering	15%			21,761
Total				181,342

Notes

- 1) Drilling costs based on Field Dilling quotation
- 2) Cost of gaining site access is not included

FIGURES



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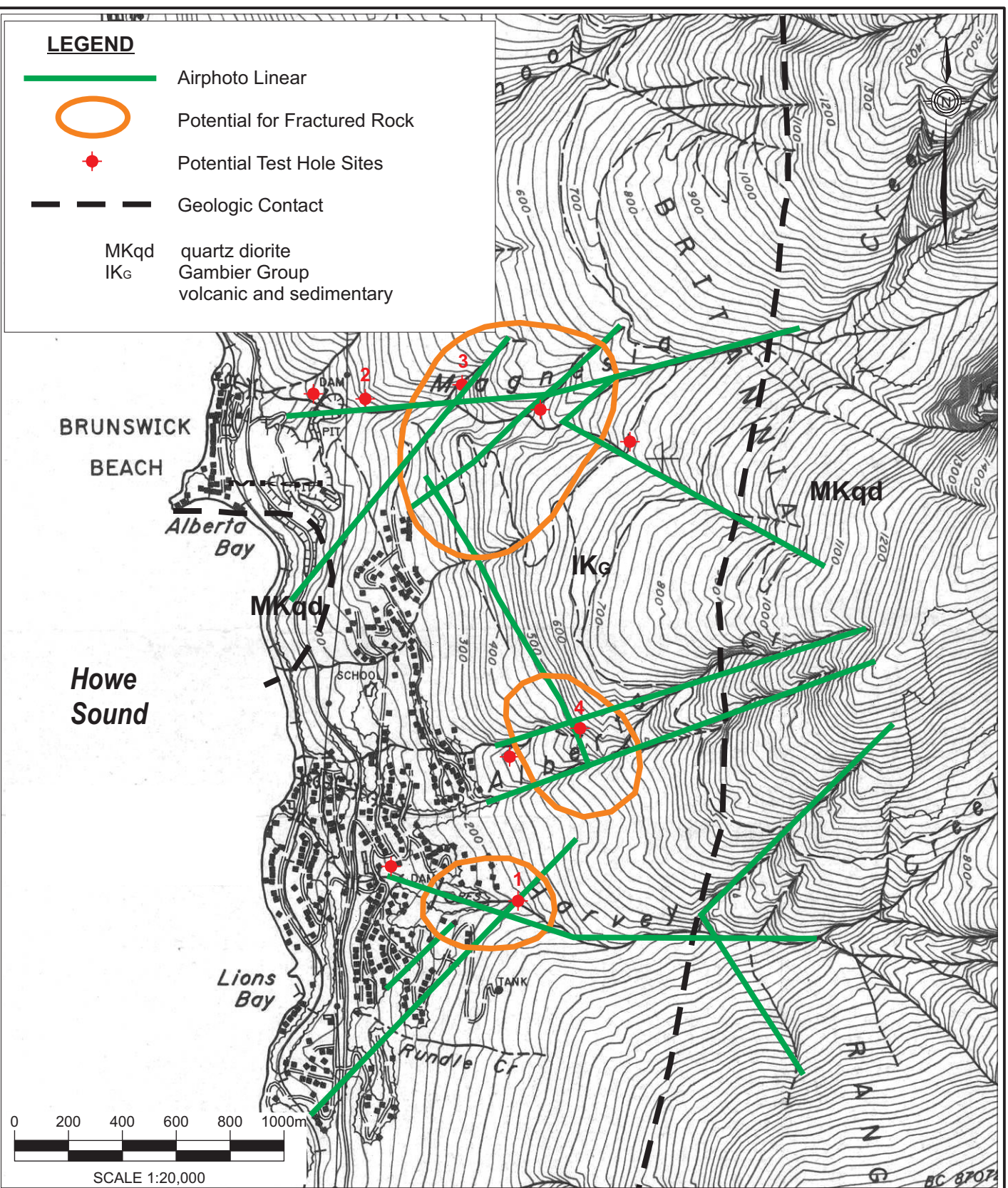
REVIEW OF GROUNDWATER
 SUPPLY POTENTIAL
 LIONS BAY, B.C.

LOCATION MAP

BY:	DATE:
AB/ss	MAR. 05
APPROVED:	FIG:
	1

LEGEND

-  Airphoto Linear
-  Potential for Fractured Rock
-  Potential Test Hole Sites
-  Geologic Contact
- MKqd quartz diorite
- IK_G Gambier Group volcanic and sedimentary



GEOLOGY FROM RODDICK et al 1974.

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REVIEW OF GROUNDWATER
 SUPPLY POTENTIAL
 LIONS BAY, B.C.

**LINEAR FEATURES INTERPRETED
 FROM AERIAL PHOTOGRAPHS**

BY:	DATE:
AB/ss	MAR. 05
APPROVED:	FIG:
	2