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CONSULTING GROUNDWATER GEOLOGISTS

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March 16, 1993

Marine Drive Golf Club
7425 Yew Street
VANCOUVER, B.C. V6P 6H1

Attention: Mr. Barry L. Morgan, F.P.C.M.
General Manager

Subject: **Preliminary Evaluation of the Feasibility of Developing a Supply of Groundwater for Irrigation of the Marine Drive Golf Course**

Dear Sirs:

This letter is further to a discussion at the Marine Drive Golf Club on March 11, 1993, concerning the feasibility of developing a supply of irrigation water from a well(s) on the Golf Course; it is also further to a brief telephone discussion of March 10 between Mr. Blake Cook, Club President, and Mr. Ed Livingston, P. Eng., of Pacific Hydrology Consultants Ltd. Present at the onsite meeting of March 11 were: Mr. Barry Morgan, General Manager; Mr. Blake Cook, Club President; Mr. Peter Dotto, Superintendent; and Mr. Clyde Hall, Links Chairman, all of the Golf Club; and Ed Livingston of Pacific Hydrology.

1.0 INTRODUCTION

From the above mentioned discussions, we understand that the situation concerning irrigation water at the Marine Drive Golf Course is as follows:

1. The Golf Course is presently irrigated with water purchased from the GVRD.
2. In times of water shortage in the GVRD System, irrigation of the Golf Course is restricted.

3. Because present conditions indicate that there is likely to be a water shortage this year, the Golf Club wishes to investigate the possibility of developing a supply of groundwater sufficient for irrigation.

4. The desired capacity of a groundwater source(s) is as much as 15.1 L/sec (200 igpm), or more.

5. If considered feasible, the Golf Club would proceed quickly with a program of exploration drilling and testing to "prove up" a source.

In preparation of this letter, we have considered information in various published and unpublished documents concerning geology and groundwater resources of the Vancouver area, including the following:

1. Armstrong, J.E. and S.R. Hicock (1976): **Surficial Geology Vancouver British Columbia**; Geological Survey of Canada Map 1486A, scale of 1:50,000.

2. Armstrong, J.E. (1978): **Post-Vashon Wisconsin Glaciation, Fraser Lowland, British Columbia**; Geological Survey of Canada Bulletin 322, 34 pp.

3. Armstrong, J.E. (1984): **Environmental and Engineering Applications of the Surficial Geology of the Fraser Lowland, British Columbia**; Geological Survey of Canada Paper 83-23, 54 pp.

4. Clague, John J. (1983): **Late Quaternary Geology of Southwestern British Columbia**; Geological Association of Canada, Mineralogical Association of Canada, and Canadian Geophysical Union Joint Annual Meeting Guidebook for Field Trip 6, 112 pp.

5. Miscellaneous records for water wells located on the Burrard Upland, obtained from the files of B.C. Environment.

The purpose of this letter is to provide a preliminary evaluation of the feasibility of developing a groundwater source at the Golf Course and to outline a course of action for proceeding with the next phase of investigation.

2.0 GEOLOGIC SETTING

The Golf Course is located on the floodplain of the Fraser River at the north edge of the Fraser River delta. The northern border of the Golf Course is at the foot of the steep tree-covered slope which forms the edge of the Point Grey Upland. The south boundary of the Golf Course is the bank of the North Arm of the Fraser River. The geology of the Golf Course is well understood in a general way but the complex details at site specific locations, such as at the Golf Course, are unknown except where drilling has been carried out.

The Point Grey Upland area is underlain by unconsolidated deposits which may be 300 m or more thick at the Golf Course. These include very thick glacial and interglacial deposits covered with a layer of glaciomarine sediments that were deposited at the end of the last glacial event about 10,000 years ago when sea level was 100 m or more above present sea level. These sediments, which vary from sandy silt with a few stones to very stoney silty material that looks much like glacial till, were deposited from sediment-laden meltwater from nearby melting ice. Most of the stones were probably dropped from floating ice.

The glacial deposits under the glaciomarine sediments seem to be best classified as ice contact deposits. These are very heterogeneous mixtures of till, sand, gravel, silt and minor clay which were deposited on and around melting ice. Drilling in the South Vancouver - South Burnaby - New Westminster area shows that the ice contact deposits contain patches of sand and gravel which are sufficiently extensive to serve as aquifers with moderate capacity. Further west, under the University Lands, the glaciomarine deposits are underlain by sand; the ice contact deposits are missing.

The glaciomarine deposits slope southward under the sandy silty sediments of the modern delta of the Fraser River to a depth of more than 100 metres. These are typical fine deltaic sediments with rapid grain size changes in both horizontal and vertical directions. In some places, the deltaic sediments include plants debris such as peat and wood.

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3.0 GROUNDWATER HYDROLOGY

Most of the Burrard Upland is a groundwater recharge area where water from precipitation and other sources, such as leaking pipes, excessive lawn and garden watering, etc., moves down through the underlying glacial deposits to the water table below which the sediments are saturated. Groundwater moves mostly north and south to the sea. Groundwater moving southward discharges upward through the slowly permeable glaciomarine deposits into the deltaic sediments and then into the Fraser River. This groundwater movement results in artesian conditions, in which the groundwater is under enough pressure so that wells which reach aquifers have a static water level above sea level. When such wells are located close to sea level they may flow.

4.0 GROUNDWATER RESOURCE POTENTIAL AT MARINE DRIVE GOLF CLUB

There are two possible aquifers underlying most of the Golf Course:

1. The sandy silty sediments of the Fraser River Delta which underlie all but the north edge of the course.
2. Ice contact deposits below the glaciomarine deposits.

The deltaic sediments certainly contain water; the question is whether, at the Golf Course, they are permeable enough to serve as an aquifer with sufficient capacity to be an economical source(s) of irrigation water. With modern well construction using well screens, it is often possible to construct wells of moderate capacity, say 6.3 L/sec (100 USgpm) or more, in sandy sediments. Experience in other areas of the delta has shown that groundwater in the delta often contains enough dissolved iron to cause problems with staining of pavement, buildings, etc. The hazard of poor quality water may be less at the Golf Course than in other areas because it is close to the source of good quality water from the upland to the north.

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As pointed out previously, the ice contact deposits contain aquifers in the form of discontinuous masses of sand and gravel. However, long experience in searching for aquifers in the South Vancouver area shows that:

1. Aquifers of the required capacity are not present everywhere.
2. Water quality is generally quite good and certainly suitable for domestic use although, locally, iron removal treatment may be required.

A few existing old records of wells located on and at the base of the Burrard Upland give encouragement that, by careful drilling and careful well design, it may be possible to develop economic quantities of groundwater from one or more test wells at Marine Drive Golf Club. However, to construct efficient wells, it may be necessary to screen more than one aquifer zone by using blank pipe between screens.

5.0 GROUNDWATER EXPLORATION STRATEGY AT MARINE DRIVE GOLF COURSE

In a general way, there are two approaches which can be taken in a program of groundwater exploration at Marine Drive Golf Course:

1. Drill close to the north edge of the Golf Course, where the hole will start in glaciomarine deposits and exploration is confined to the underlying ice contact deposits.
2. Drill further south on the Golf Course, where the hole will pass through deltaic sediments before reaching the glaciomarine deposits and eventually the ice contact deposits. An hole at this location will explore both the deltaic and the deeper sediments. Obviously, if conditions appear favourable in the deltaic sediments, the hole would not be drilled deeper, at least until completion of the test well with a screen and until pump testing has been carried out. That is, under the prevailing conditions, it is important to keep in mind, that it may not be possible to assess the capacity of an aquifer from the drilling of a test hole; it may be necessary to install a well screen and carry out a pumping test to evaluate well and aquifer capacity and also water quality.

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With so little subsurface information on hand, it is difficult to predict drilling depths; however, from a general understanding of the geologic section, drilling depths of approximately 120 m (400 ft) and 150 m (500 ft) are considered to be realistic estimated depths for the purposes of estimating costs at the two areas outlined above. Based on present knowledge of hydrogeologic conditions, we estimate the likelihood of developing source capacity of 18.9 L/sec (250 igpm) in one or two wells at 60%.

6.0 COURSE OF ACTION AND COSTS

Under the prevailing conditions, we recommend that:

1. Test-production drilling be carried out using the cable tool method and starting with 30 to 40 m (100 to 120 ft) of 250 mm (10") diameter casing.

2. At the site close to the north edge of the Golf Course, carry the 250 mm (10") diameter casing to a depth as great as 30 m (100 ft) before changing to 200 mm (8") diameter casing, unless an aquifer with substantial potential is encountered within the upper 30 m, in which event it may be appropriate to continue the hole with 250 mm diameter casing to its final depth.

3. At the site further south on the Golf Course, continue the 250 mm (10") diameter to casing 40 m (120 ft), or greater, depending on how tight the casing has become, and in the event that the deltaic sediments do not contain an aquifer, continue the hole with 200 mm (8") diameter casing to a depth as great as 150 m (500 ft).

Under the prevailing conditions, where there is considerable uncertainty about drilling depths, etc., costs are difficult to estimate. However, on the basis outlined above, the estimate given in the table on the following page is considered to be realistic for a successful hole at the north edge of the Golf Course.

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Table 1. Estimated Costs of Test-Production Drilling and Testing at North Edge of Golf Course

Item	Description	Quantity	Unit Price($)	Total($)
1.	Mobilize-demobilize equipment to and from Golf Course.	1	500.	500.
2.	Supply casing shoes			
	a. 250 mm (10")	1	350.	350.
	b. 200 mm (8")	1	250.	250.
3.	Casing			
	a. Drilled and case 250 mm (10") diameter hole	30 m	165.	4,950.
	b. Supply and install 200 mm (8") overlap	30 m	85.	2,550.
	c. Drill and case 200 mm below 250 mm casing	91.5 m	130.	11,895.
4.	Supply 200 mm nominal diameter Johnson stainless steel well screen.	7.6 m	-	4,500.
5.	Hourly work pulling casing, installing well screen, developing well, etc.	60 hrs	100.	6,000.
6.	Conduct pumping test of successful well.			3,000.
7.	Engineering, supervision, sieve analyses, screen design, water analyses, evaluation and reporting.			5,000.
	Total Estimated Cost of a Successful Well			**38,995.**

In the event that three test wells were drilled to a similar depth with one completed as a successful well, the total cost of groundwater exploration could be as much as $80,000., including engineering. The "risk" cost of a completely unsuccessful program is estimated to be about $60,000. The costs of a similar program at a site further south would be more.

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We trust that this letter contains the information you require at this time; however, please do not hesitate to call for further discussion of the contents of this letter or groundwater exploration in general.

Yours truly,

PACIFIC HYDROLOGY CONSULTANTS LTD.

Ed Livingston

Ed Livingston, P. Eng.

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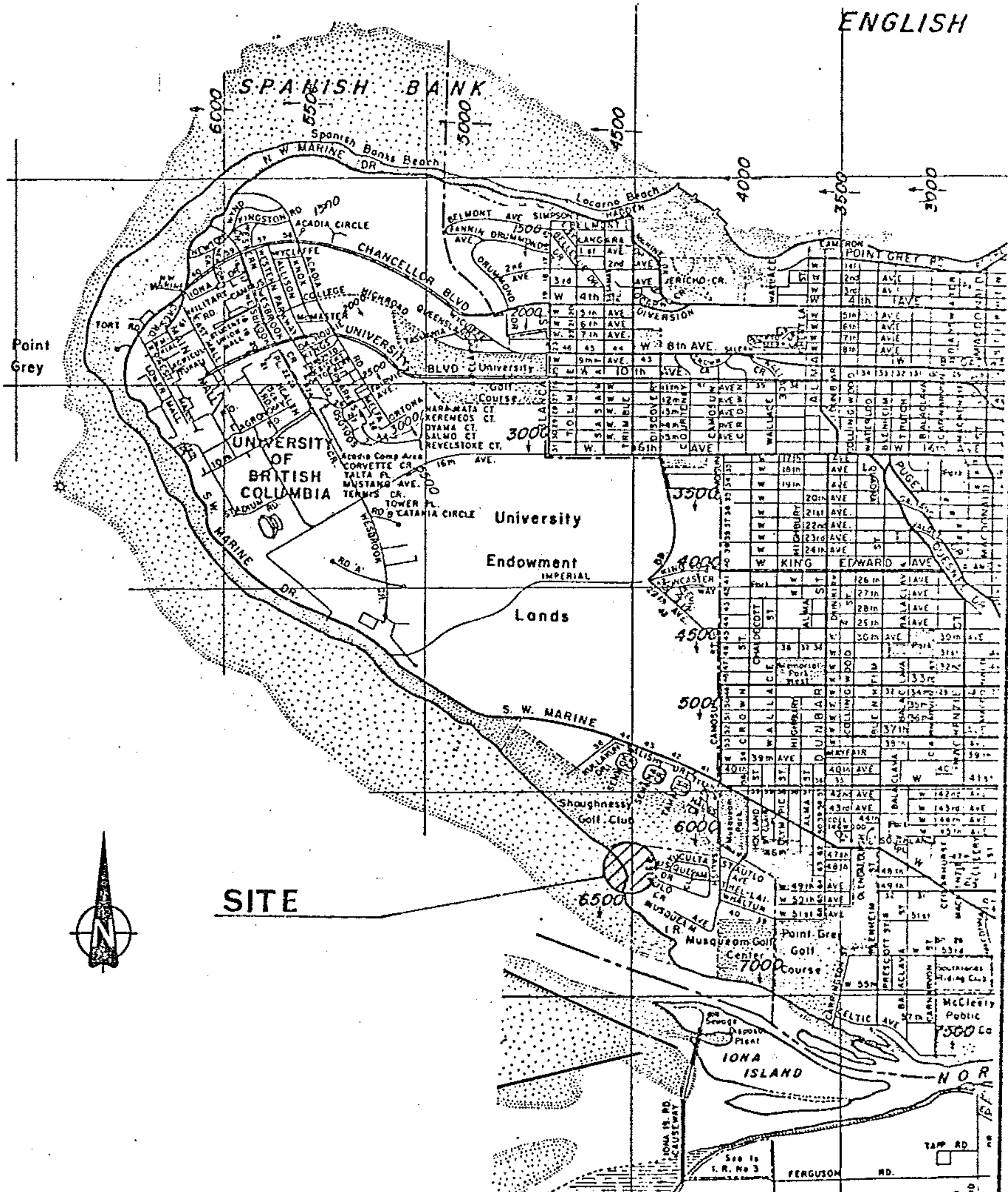
SITE PLAN

NTS-92G/3 #8

FIGURE 1

ENGLISH



Associated Geotechnical Consultants

GROUNDWATER SECTION

Rec. Jan. 24/78