PRELIMINARY EVALUATION OF THE GROUNDWATER REGIME IN THE AREA OF A PROPOSED RESIDENTIAL/RECREATIONAL DEVELOPMENT AT COWAN POINT ON BOWEN ISLAND

Prepared for

L.G.L. ENVIRONMENTAL RESEARCH ASSOCIATES LTD.
9768 Second Street
SIDNEY, B.C. V8L 3Y8

Prepared by

PACIFIC HYDROLOGY CONSULTANTS LTD.
204 - 1929 West Broadway
VANCOUVER, B.C. V6J 1Z3

JULY 10, 1991

E. LIVINGSTON, P. Eng.
A. BADRY

PACIFIC HYDROLOGY CONSULTANTS LTD.

CONSULTING GROUNDWATER GEOLOGISTS

204 - 1929 WEST BROADWAY
VANCOUVER, B.C. V6J 1Z3
TELEPHONE: (604) 738-9232

July 10, 1991

L.G.L. Environmental Research Associates Ltd.
9768 Second Street
SIDNEY, B.C. V8L 3Y8

Attention: Mr. Gary F. Searing, M.S.,
Senior Wildlife Biologist

Subject: **Preliminary Evaluation of the Groundwater Regime in the Area of a Proposed Residential/Recreational Development at Cowan Point on Bowen Island**

Dear Sirs:

Enclosed herewith is our report concerning our preliminary evaluation of the groundwater situation in the Cowan Point area of Bowen Island.

We trust that the report meets with your approval. Please do not hesitate to contact us regarding any aspect of the contents of the report.

Yours truly,

PACIFIC HYDROLOGY CONSULTANTS LTD.

E. Livingston

E. Livingston, P. Eng.

c.c. Praxis Group Ltd. (6)

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1.0 SUMMARY AND CONCLUSIONS

1. The Cowan Point area of Bowen Island is underlain by volcanic rocks of the Bowen Island Group with a cover of glacial and post-glacial sediments of variable thickness. The overburden sediments are generally thin in the south-sloping part of the area and quite thick on the north-facing side of the Grafton Lake - Tunstall Bay Valley.

2. Groundwater in the subject area occurs in fractured rock and in the glacial sediments, moving in groundwater flow systems that flow both southward and northward away from the groundwater divide, which is located approximately at the surface water divide. Most of the proposed Development is located to the south of the surface water/ groundwater divide.

3. Most of the residents in the Cowan Point Road - Willies Way - Adams Road area depend on groundwater for water supply. Several types of wells are used to exploit the resource:

   a. drilled wells completed in fractured rock;

   b. drilled wells completed in glacial and interglacial sediments;

   c. dug wells completed in glacial sediments.

4. Most residents report that their wells are adequate for present demands and water quality is generally satisfactory.

5. There is a deep gravel aquifer present in the vicinity of the intersection of Adams Road and Cowan Point Road. This aquifer probably has sufficient capacity to supply a community water system. Incomplete data on water quality indicates that water in this aquifer contains sufficient iron and manganese to require treatment.

6. There is concern that the proposed Development may negatively affect well capacities and groundwater quality.

7. Under the prevailing conditions, it seems very unlikely that the proposed Development will have any significant effects on groundwater. Monitoring of groundwater levels and groundwater quality can be carried out to detect possible effects.

2.0 RECOMMENDATIONS

From our understanding of the proposed residential/recreational Development by Praxis Group at Cowan Point on Bowen Island, and based on our evaluation of the groundwater regime, as the next step in the proposed Development, we recommend the following:

1. Establish a water level observation well in the center of the "community" in the Cowan Road - Willies Way - Adams Road area, by equipping an unused water well, which is located near Willies Way and which is owned by the Sawmill Lane Strata Corporation, with a continuous water level recorder.

2. As soon as project approval is assured, drill two observation wells, one in an undisturbed area near the groundwater divide and one on the south slope within the proposed golf course.

3. After the project is approved and before substantial construction takes place, carry out pump tests and collect water samples from wells whose owners are concerned about the effect of the Development on their wells.

4. At such time as project approval is obtained, and based on the final proposed golf course design, install several shallow monitoring wells in the golf course area.

3.0 INTRODUCTION

3.1 Purpose and Scope

The purpose of this report is to present the results of Pacific Hydrology's preliminary groundwater investigation concerning a proposed residential/recreational Development by Praxis Group at Cowan Point on Bowen Island.

The investigation covered by this report has consisted of:

- assembling and reviewing published and unpublished documents concerning the geology and groundwater resources of the subject area;
- carrying out an inventory of water wells and spring discharges in the Cowan Road - Willies Way - Adams Road area;
- examining general hydrogeologic conditions to identify potential monitoring well sites and drafting agreements concerning the establishment of monitoring well sites and of background performance testing of existing wells;
- evaluating the groundwater flow regime and potential impacts from the proposed Development.

The investigation was carried out in general accordance with Pacific Hydrology's letter of proposal to L.G.L. Environmental Research Associates Ltd. dated February 13, 1991 which defined the main study objectives to be as follows:

- prepare for a program of pump testing of existing domestic wells;
- identify optimum locations for establishment of water quality and water level observation wells;
- define an ongoing program for the monitoring of groundwater quality and water levels.

3.2 Authority

Approval to proceed with the investigation covered by this report was given in a letter dated February 27, 1991 from L.G.L. Environmental Research Associates Ltd. to Pacific Hydrology:

> "As per our telephone conversation, this letter is to confirm acceptance of your proposal to Praxis Group to conduct a Stage I Groundwater Investigation for the Resort at Cowan Point on Bowen Island."

3.3 Acknowledgements

The cooperation, assistance and courtesy of local residents and well owners in the project area is gratefully acknowledged.

4.0 GROUNDWATER GEOLOGY

The area of the proposed Development is underlain by the Bowen Island Group of rocks which are intruded by diorite and granodiorite as shown on Figure 2 in Appendix A; this figure is a portion of Geological Survey of Canada Open File Map 611.

On Bowen Island, the Bowen Island Group is comprised predominantly of volcanic rocks with lesser amounts of sediments. In the paper by Friedman et al, the Bowen Island Group on Bowen Island is described as dark green fine-grained volcanics and "...locally interbedded with thinly laminated to massive white, pale grey, green and rarely pink fine-grained siliceous tuff, which is the most distinctive lithology of the sequence". These rocks, which are folded and altered, are of Lower to Middle Jurassic age.

The bedrock is overlain by an intermittent cover of glacial and glaciomarine sediments with minor amounts of recent sediments. The glacial cover is mostly a compact sandy gravelly silty till, locally as thick as 40 metres. The till was deposited by ice moving southward in the most recent glacial episode which ended about 12,000 years ago. The till is present on all but the steepest slopes but its distribution is quite uneven. For example, it is quite thick on the south side of the Tunstall Bay-Grafton Lake Valley but is thin or missing on much of the south-facing slope of Bowen Island. During and after the melting of glacial ice in the area, sea level was at least 100 metres above present sea level and large volumes of sediment-laden meltwater was flowing into the sea. Under these conditions, glaciomarine silty sediments were deposited in areas covered by the sea where slopes were not so steep as to prevent deposition. These sediments may contain scattered stones which were deposited from floating ice. A large part of the subject Property is above 100 metres elevation so the glaciomarine sediments are present only on the lower parts of the Property.

There are also minor amounts of younger sediments. On steep slopes, weathering processes and slow creep have produced a layer of slopewash. When the land emerged from the sea in post-glacial time, wave action produced thin beach deposits in some places on gentle slopes. There may also be raised deltas and marine terraces at elevations below about 100 metres. Present day streams are eroding their valleys with local deposition of fans and other modern stream deposits.

In addition to the glacial and post-glacial sediments described above, records of wells in the northeast-southwest valley between Grafton Lake and Tunstall Bay show that there is sand and gravel below till in that area. These sediments contain wood indicating that they were probably deposited during an interglacial interval.

5.0 GROUNDWATER HYDROLOGY

5.1 General Principles

All of the fresh water on Bowen Island originates as precipitation on the Island. Part of the precipitation runs off directly to the sea by way of streams. Part of the runoff is less direct, as it is delayed in moving through swamps and lakes and as underflow in streams. Part of the precipitation returns to the atmosphere by way of evaporation and, during the growing season, by transpiration. The remainder percolates into the ground to become groundwater which may reappear at surface as springs or seepages or base flow of streams; some deep-flowing water in fractured rock discharges into the sea below sea level.

Under the prevailing conditions, groundwater moves slowly in "groundwater flow systems", driven by gravity from recharge zones to zones of groundwater discharge. The major flow systems on Bowen Island extend from recharge areas in the high interior of the Island to the discharge ends in the sea below sea level where the discharge cannot be observed. Shorter flow systems, superimposed on the major systems, discharge into stream valleys, swamps, springs and bodies of water. This groundwater discharge maintains the flow of perennial streams during drought periods in late summer and fall.

The amount and timing of groundwater recharge is dependent on:

1. the amount and timing of precipitation;
2. the climatic conditions - temperature, wind, etc.;
3. the vegetative cover;
4. the permeability of the soil and of the underlying sediments and bedrock.

In areas where there is a cover of vigorous vegetation, groundwater recharge takes place almost entirely in winter and early spring. Once the growing season starts, evapotranspiration returns most of the precipitation to the atmosphere. In most years, a soil moisture deficiency develops in the summer and early fall. The late fall precipitation is largely held in the soil to relieve the soil moisture deficiency; thus, groundwater recharge only starts when the soil moisture reaches field capacity, probably in mid-winter.

It must be emphasized that the processes of recharge and discharge in detail are quite complex; however, with the possible exception of smooth unfractured rock outcrop, groundwater recharge takes place everywhere in the recharge zones. As discussed earlier, the process is generally intermittent; exceptions are recharge from beds of perennial streams and from ponds and lakes. In a similar manner, groundwater discharge is very widespread in discharge zones. However, in contrast to recharge, discharge is much more constant because the fluctuations of recharge tend to be reduced or "smoothed out" in long slow movement through the groundwater flow system. Although the proposed Development is based on a community wastewater collection system, and not on individual onsite facilities, such facilities are utilized in the study area; therefore, a general discussion of groundwater hydrology would be incomplete with addressing this issue.

With the foregoing discussion about groundwater recharge and groundwater discharge in mind, it is evident that conventional onsite wastewater disposal facilities must be located in groundwater recharge zones, and not in groundwater discharge zones, since it is not possible to put water into the ground where the flow is toward surface. The effluent, which undergoes some treatment in the septic tank, is further treated in the soil in which the distribution trenches are excavated. Research has shown that pathogens and viruses are eliminated by movement through 0.6 to 1.2 m (2 to 4 ft) of unsaturated soil and sediments beneath the field; materials of higher permeability logically require a greater unsaturated depth for proper treatment of the wastewater than materials which have lower permeability. The only mobile ion in wastewater which may be a contaminant is nitrate; however, for nitrate to become a contaminant, it must reach the water table in sufficient quantity to become a significant constituent of groundwater. Nitrate is not an health hazard except for small babies and, even then, only if it reaches high concentrations - greater than 10 mg/L as N (45 mg/L NO_3). Troubles from wastewater disposal fields are quite unusual. Most problems are due to poor design and construction and/or to lack of maintenance.

5.2 Cowan Point Area

With specific reference to the proposed residential/recreational development at Cowan Point, the groundwater flow regime is straightforward:

1. The proposed Development is largely in the recharge area for a southeast-moving groundwater flow system.

2. Josephine Ridge separates the south-moving groundwater flow system from the north-moving system.

The groundwater flow regime in the Cowan Point area is illustrated on Figure 4 in Appendix A.

Groundwater recharge takes place by downward movement through all of the subsurface sediments. For all practical purposes, the bedrock has no primary permeability; however, in most places, it is fractured sufficiently so that water from saturated soil can move down into the fractures in the rock. The till, which underlies part of the area, is, in most places, weathered to a depth of about one metre (3 ft). This weathered zone, on which vegetation grows, is quite permeable. The unweathered sandy gravelly till of Bowen Island is also permeable, with an estimated hydraulic conductivity in the range 10^{-4} to 10^{-6} cm/sec. To put this in perspective, a sediment with an hydraulic conductivity of 10^{-5} cm/sec can accept 8.6 mm of water per day.

Irrigation of the proposed golf course would tend to increase groundwater recharge from irrigation. Plans call for the application of about 450 million litres (100 million imperial gallons) of water per year. Since about one quarter of the golf course is in the recharge area for north-flowing groundwater, if 10% of the irrigation water reaches the water table, about 11¼ million litres (2½ million gallons) of water per year would be added to the north-flowing groundwater. This is equivalent to about 1.1 L/sec (14.5 igpm) during a 120 day irrigation season.

6.0 GROUNDWATER RESOURCE USE

For practical purposes, the groundwater resource of an area is the groundwater which can be recovered for long-term use by wells and springs. Most domestic water on Bowen Island comes from individual wells. In several places - for example, Tunstall Bay, Bowen Bay and Bluewater Park - water from several drilled wells supplies small community water systems; there are, of course, also community intakes on creeks and lakes. Most of the domestic and community drilled wells on Bowen Island are completed in fractured rock. The locations of all known water wells in the area of the proposed Development are shown on Figure 3 in Appendix A. These locations are not surveyed but, rather, are approximate locations determined by a field inventory and/or as shown on the water well records on file with B.C. Ministry of Environment. As shown in Table 1 in Appendix B, drilled well depths in the project area vary from less than 20 m (65 ft) to more than 200 m (656 ft) and well capacities range from dry holes to about 3 L/sec (40 igpm), with average capacities probably less than 0.3 L/sec (4 igpm). In general, the quality of the groundwater in the project area is acceptable for domestic uses. Seawater intrusion is not known to be a problem on Bowen Island.

There are several wells located north of the project area, along the valley between Grafton Lake and Tunstall Bay that are completed in one (or more?) deep sand and gravel aquifer(s), which may have the potential to supply a moderate amount of water - perhaps as much as 10 L/sec (133 igpm). Very little is known about this aquifer, as it has only been used by wells supplying from one to four domestic connections. There are also a number of dug wells supplying domestic water. These vary in depth from two to ten metres (6½ to 33 ft). Most of the dug wells are excavated in glacial till and they tend to have lower capacities in late summer and fall than in winter and spring. Water quality from dug wells is usually very good.

7.0 POTENTIAL GROUNDWATER IMPACTS AND MITIGATION

7.1 General Issues

There is concern about the effect of the proposed Development on groundwater - specifically, about the possible effects on the capacity of existing wells and springs located north of the development area and also to the quality of water yielded by the wells and springs. Most of the proposed Development and activities associated with the Development would take place on the south slope of Bowen Island, where there is reported to be only one well located near the south shore. The concern is whether development activities on the northern part of the area would affect the groundwater flow systems which supply the wells in the Cowan Road - Willies Way - Adams Road area.

The capacity of any particular rock well depends on the number and character of fractures intersected by the bore hole and on the position of the water table which determines the number of fractures that contain water. A well which has intersected many clean open fractures has an higher capacity than one in which there are few fractures or where the fractures are filled with rock flour (gouge) or secondary minerals. The position of the water table is also important in determining well capacity, in that a well with a low water level has a lower capacity than the same well with an high water level. Fluctuations in the water table change the capacities of wells; in fact, some shallow dug wells become dry at times of minimum groundwater conditions during the summer drought when the water table is at its lowest. Drilled wells that obtain water from fractured rock are also prone to seasonal fluctuations, particularly if they are being pumped at a rate greater than the fracture system can sustain by normal groundwater flow. Removal of groundwater stored in the fractures eventually results in dewatering of the rock mass.

As far as the capacity of wells located near the proposed Development is concerned, the question is whether activities during construction and/or operation of the proposed residential/ recreational Development - in particular, the operation of a golf course - will reduce

recharge to the groundwater flow system supplying any particular well. In general, activities which increase surface water runoff reduce groundwater recharge and those which reduce evapotranspiration tend to increase groundwater recharge. Residents along Adams Road report that the flows of small streams draining the recently logged area on the north-facing slope west of Cowan Road are now much higher following rainfall events than they were previously.

It is worth noting that a single action such as the aforementioned logging may cause multiple effects, some of which are contradictory. For example, clearing of large dense forest will reduce transpiration during the growing season, thus increasing the amount of water available for recharge. However, lack of shade in late winter may cause rapid snow melt and runoff of meltwater which would otherwise have recharged groundwater.

Plans for the proposed Development call for very little more clearing of forest and, if anything, planting of trees and shrubs is likely to result in a net increase in forest-type cover. The construction of the golf course will involve the placing of a large amount of sand, particularly in parts of the area where there is much rock outcrop. The resulting areas of grass, underlain by permeable sand, would certainly be favourable for natural groundwater recharge with some additional recharge from summer irrigation. The proposed Development includes a comprehensive stormwater system, in which all stormwater from the roads and housing areas will be subject to oil separation and sediment removal before being stored in open reservoir ponds for use in golf course irrigation. Depending on weather conditions and other factors, it is likely that there will be very little runoff from the golf course and residential areas. Thus, from this discussion, it appears that total groundwater recharge in the development area may actually be greater post-development than it is now and/or was before the area was logged.

The concern about groundwater quality is whether fertilizers, herbicides and pesticides which may be used on and around the proposed golf course will get into the groundwater and eventually reach domestic wells. This possibility depends on a number of factors:

1. The type of fertilizers, if any, that are used on the golf course and how, when and where they are applied.

2. The type of herbicides and pesticides that are used and how and where they are applied.

3. The location of the groundwater divide between the north-flowing groundwater flow systems and the south-flowing systems.

Golf course use of fertilizers is generally not more than 10% of fertilizer use on farms and pesticide use is also much less than on farms. Fertilizer and chemical use on golf courses tends to be concentrated largely on greens and tees where the effects can be easily monitored.

Of the three main constituents of chemical fertilizers, the only one which is sufficiently mobile to enter the groundwater regime is nitrate. Obviously, if fertilizer application is completely effective, all of the constituents, including nitrate, will be taken up by the plants (in this case grasses) and none will get into the groundwater. Nitrate in water is not an health hazard unless its concentration is fairly high - about 45 milligrams per litre - and even then only for small babies. To develop a nitrate concentration high enough for concern requires an excessive long-term use of fertilizer. This has occcured in several places in the Lower Fraser Valley where very large amounts of fertilizer have been used in intensive agriculture over many years.

The problem of possible contamination by herbicides and pesticides is somewhat different because the concentrations of these chemicals which are considered to be contaminants is extremely low - about 0.025% as much as the 45 millgrams per litre for nitrate mentioned above. Thus, it is clear that these chemicals should be selected with care, their use should be timed for maximum effectiveness and minimum groundwater recharge and use should be kept to a minimum. It may also be possible to restrict the use of these chemicals to the south side of the groundwater divide to isolate them from the existing wells on the north slope.

7.2 Mitigation

Experience shows that there is often a perception that some activity has a negative impact on either the quantity or quality of groundwater yielded by a particular well; this is particularly true in situations where the aquifer is fractured rock and where individual well water supplies may already be marginal. While it is possible, based on an understanding of groundwater flow mechanisms, to put forward various arguments that negative impacts are impossible or quite unlikely in a given situation, ultimately, there is only one procedure which will satisfy concerned well owners that the quality and quantity of groundwater from their well has not been affected: this procedure is to carry out well performance and water quality analyses prior to any development activity so as to have background data with which to compare post-development well performance and water quality data.

As mentioned previously, the direction of groundwater flow under the proposed Cowan Point residential/recreational development and the adjacent properties is controlled primarily by topography and the groundwater divide. The groundwater divide usually corresponds quite closely with the surface water divide but, because of the random nature of rock fracturing, recharge conditions, and other factors, the two divides may not correspond exactly. Also, because of the seasonal nature of groundwater recharge and complex flow paths, the groundwater divide may shift slightly on a seasonal basis. The question of whether the proposed raising of the level of Josephine Lake will affect wells in the Willies Way area has arisen. Since both surface water and groundwater in the Josephine Lake area are far removed from groundwater on the north side of the groundwater divide, there will be no effect on the groundwater regime in the Willies Way area.

8.0 GROUNDWATER MONITORING

The purpose of a monitoring program in connection with the Cowan Point Development is to detect changes in quantity and quality of groundwater in the area being developed and particularly in the adjoining area on the north where residents are dependent almost entirely on groundwater. As discussed previously in this report in Section **5.0 GROUNDWATER HYDROLOGY**, the groundwater regime is in dynamic equilibrium with climate and other factors which affect recharge and discharge. The main factors influencing groundwater are weather, land use and groundwater use. One of the main functions of monitoring is to separate the various effects as much as possible. For example, several years of below average precipitation, particularly if this occurs in the winter and early spring, may cause a decline in the water table which may be felt by certain residents in reduced well capacities. If water level observations in an observation well located in an area undisturbed by activities which may affect the groundwater level, show this same decline, the cause of the change is made clear. On the other hand, a declining water table in an area close to active development when the observation well in the undisturbed area shows no similar decline, indicates that a factor other than weather is responsible for the change.

In monitoring groundwater quality, the reasoning is similar but, in this case, the monitoring well should be located in the area of maximum disturbance. Changes in the area of maximum disturbance are greater and also occur sooner than in more distant areas. Thus, if changes of groundwater quality in such a well remain within acceptable limits, wells outside the area of maximum disturbance would almost certainly not show unacceptable changes in water quality.

The pump testing and water chemistry testing of individual wells that is recommended is a type of monitoring whose main function is to separate perception from reality. Experience shows that the evaluation of wells by well owners is often quite subjective, probably largely because of a lack of understanding about groundwater flow mechanisms.

Under the prevailing conditions in the Cowan Point area, groundwater flow systems operate on a yearly cycle because the main factors affecting flow are weather controlled. Except in rather extreme cases, trends cannot be observed on a single year's records; therefore, it is important to start monitoring existing conditions as soon as possible, and before any extensive activity, in order to show cause and effect. It is usually possible to select one or more long-term observation wells from the Provincial Observation Well Network, at which conditions are somewhat similar, in order to indicate trends which may be in effect. A few Provincial Observation well records go back as far as 1954 but most were established since 1963.

In the Cowan Point situation, conditions in three environments can be monitored:

1. an area of minimum disturbance in or close to the crown land along the eastern side of the proposed Development, preferably near the groundwater divide;

2. an area of considerable disturbance - for example, the area on the south slope of the golf course;

3. an area where residents are using groundwater from domestic wells - for example, near Willies Way.

As outlined previously, an unused drilled well located near Willies Way and owned by a Strata Corporation has been identified as a possible monitoring well. The well owners have agreed to allow this well to be used by the Cowan Point Developer as an observation well. The well is completed in the fractured rock aquifer which supplies most of the domestic wells in that area so it would be effective in showing how the water table varies in an area of maximum groundwater use.

9.0 SELECTED REFERENCES

The following published and unpublished documents were used in the preparation of this report:

1. Roddick, J.A. and G.J. Woodsworth (1979): **Geology of Vancouver Island West Half and Mainland Part of Alberni**; Geological Survey of Canada Map Open File 611, of scale 1:50,000.

2. Friedman, R.M., J.W.H. Monger and H.W. Tipper (1990): "Age of the Bowen Island Group, Southwestern Coast Mountains, British Columbia"; in **Canadian Journal of Earth Sciences,** Vol. 27, No. 11, pp 1456-1461.

3. British Columbia Ministry of Environment (1978): Resource Analysis Branch Publication, **Bowen Island: a resource analysis for land use planning**; Volume I, co-ordinated by John Block, 97 pp.

4. Hirvonen, H.E. (1976): **Bowen Island A Landscape Analysis**; Environment Canada, Forestry Service Report BC-X-122, 29 pp.

5. Petrie J.M. (1976): "Bowen Island Groundwater Potential - Preliminary Report", Internal Report of Water Investigations Branch, B.C. Ministry of Environment.

6. N.T.S. Map 92G/6, **North Vancouver**, of scale 1:50,000.

7. Water Well Location Map, W.W. 92G.034 of scale 1:20,000, along with records of 32 wells compiled by Groundwater Section of B.C. Ministry of Environment.

8. Sheet 1, Cowan Point Bowen Island Map of scale 1:2,000, prepared by Triathlon Mapping Corporation from aerial photographs flown on March 15, 1986.

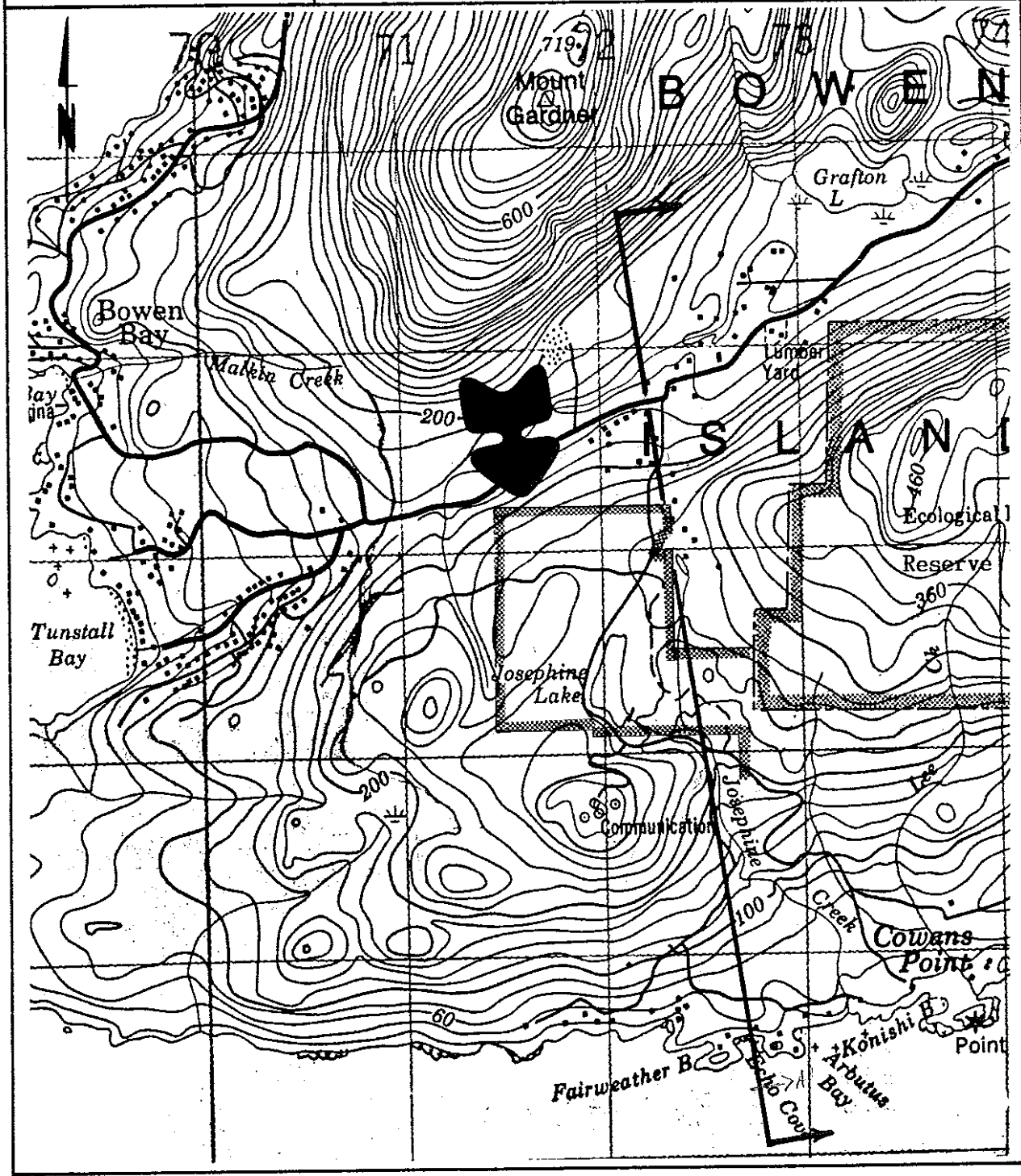
9. United States Environmental Protection Agency (1980): **Design Manual Onsite Wastewater Treatment and Disposal Systems**; October 1980, 392 pp.

10. B.C. Ministry of Health (1986): **Sewage Disposal Regulation**; B.C. Reg. 411/85, O.C. 2398/85, Sept. 30/86, 17 pp.

APPENDIX A

ILLUSTRATIONS

FIGURE 1	COWAN POINT AREA LOCATION MAP



Notes:

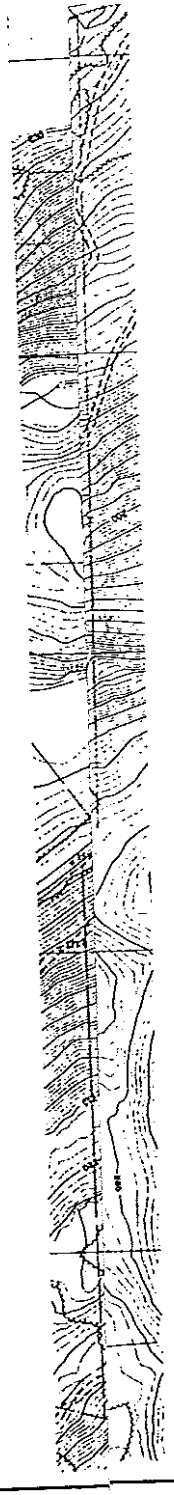
1. The base map is 1:50,000 scale topographic map N.T.S. 92G/6, **Vancouver,** enlarged to a scale of approximately 1:30,000; contour interval is 20 metres.
2. ▒▒▒ Outline of northern part of proposed Cowan Point Residential/Recreational Development.
3. ⌐¬ Line of schematic hydrogeologic section (see Figure 4, Page A - 4).

FIGURE 2	COWAN POINT GEOLOGY MAP

Notes:

1. The base map is Geological Survey of Canada Open File Map 611, of scale 1:125,000, enlarged to an approximate scale of 1:76,000.
2. ▒▒▒▒▒▒ outline of northern part of proposed Praxis' Residential/Recreational Cowan Point Development.
3. Legend: J_B = Bowen Island Group of Middle Jurassic age; **d** = diorite, minor gabbro and quartz diorite; **gdu** = granodiorite.

FIGURE 3

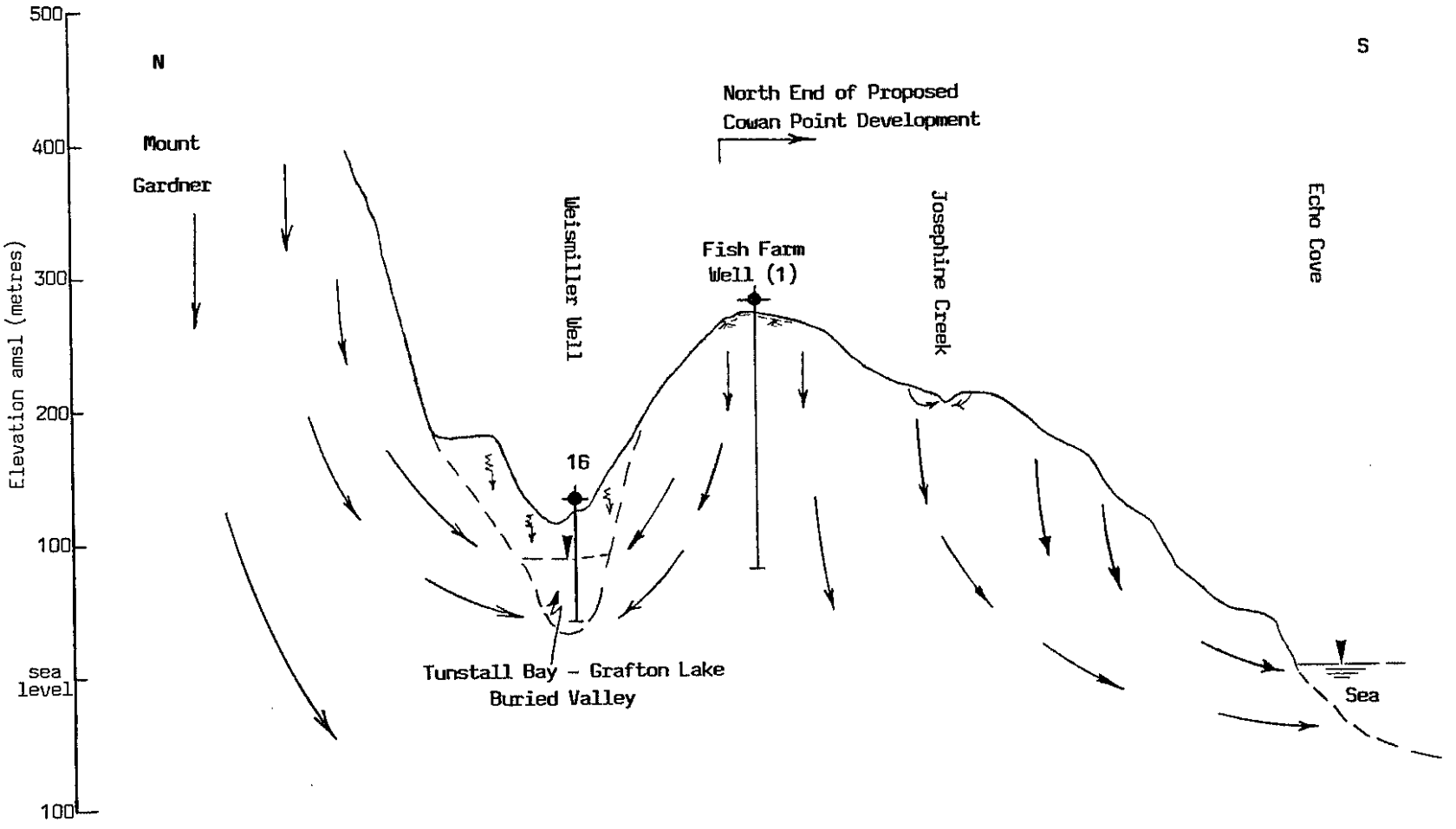


Notes: 1. The arch 15, 1986, reduced to a scale of appr

2.

3.

FIGURE 4	SCHEMATIC HYDROGEOLOGIC CROSS-SECTION OF COWAN POINT AREA



Notes:

1. Horizontal scale 1:30,000; vertical scale = 1:5,000; vertical exaggeration 6 times.
2. Water Well, as identified (for well details, see Table 1 in Appendix B).
3. Probable direction of groundwater flow. 4. unsaturated flow. 5. water table.

APPENDIX B

WATER WELL INVENTORY

APPENDIX B

COWAN POINT WATER WELL INVENTORY

The water well inventory contained in Table 1 of this Appendix is based on the following:

1. Water well records on file with Groundwater Section of B.C. Ministry of Environment.

2. Driller's records obtained directly from contractors for wells which they have drilled in the subject area.

3. Miscellaneous records and other information contained in Pacific Hydrology's files from previous project experience on the southwestern part of Bowen Island.

4. Discussions with local well owners during a well inventory and field reconnaissance.

It is obvious that Table 1 may contain errors or omissions; the information in the Table can be updated as new information becomes available.

The approximate locations of the wells in Table 1 are shown on Figure 3 in Appendix A.

Table 1. Inventory of Water Wells in the Cowan Point – Willies Way – Adams Road Area of Bowen Island

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
1	51.8	(170)	6.1	(20)	**House Well** 0 – 0.9 m (0– 3 ft) brown till 0.9–35.1 m (3–115 ft) soft rock with fractures 35.1–51.8 m (115–170 ft) hard rock. 3.0 m (10 ft) of 150 mm (6") diameter casing.	Joff Groehne (Twin Lakes Trout Farm); Lot 6849, Cowan Road.	Fish ponds (3) are supplied by surface water from the east and from the "Deeper Well". The "House Well" supplies the main house and cottage. The House Well was constructed by Jay Dee in 1977 and has an estimated capacity by the driller of 0.09 L/sec (1.5 gpm); the Deep Well was by Rural Well Drillers in 1982, and the Cottage Well was also by Rural Well Drillers in 1982.
B-2	189.9	(623)	1.5	(5)	**Deep Well** 0 – 1.8 m (0– 6 ft) organic sand, gravel 1.8– 2.4 m (6– 8 ft) till 2.4–137.2 m (8–450 ft) Bowen Island Volcanics 137.2–146.3 m (450–480 ft) granite, medium grain 146.3–189.9 m (480–623 ft) Bowen Island Volcanics. 3.35 m (11 ft) of 150 mm (6") diameter casing.		
2	38.1	(125)	?		0 – 0.3 m (0– 1 ft) overburden 0.3– 1.2 m (1– 4 ft) broken rock 1.2–38.1 m (4–125 ft) granite. Well is cased to 2.7 m (9 ft).	J. Roueche; on Lot 1828; Well is located northwest of pond, east of access road.	Well was drilled by Tri-K in 1989; its capacity was rated by driller at 0.25 L/sec (4 USgpm).

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
3	64.0	(210)	flows in winter and spring		All in rock.	Lorne Carmichael; Lot 46, Plan 13841, on east side of Cowan Road.	Drilled by Tri-K in September 1989 and rated at 0.05 L/sec (3/4 gpm). Well is barely adequate in late summer. The water quality is excellent while flowing but contains iron and tastes unpleasant in late summer. Water conductivity in April 1991 was 200 ms.
4	140.2	(460)	28.0	(92)	0 - 0.9 m (0- 3 ft) loose broken rock and silty sand 0.9- 2.7 m (3- 9 ft) compact clay and gravel 2.7-129.6 m (9-425 ft) bedrock (granite) 129.6-138.7 m (425-455 ft) Bowen Island Volcanics 138.7-140.2 m (455-460 ft) granite. 150 mm (6") diameter casing to 4.9 m (16 ft).	Owner unknown; Lot A, Plan 18864.	Well was drilled by Rural Well Drillers in March 1981. Driller's estimated capacity was <0.06 L/sec (<1 gpm).
5	?		?		Probably all till.	A. Neimers; Lot 3, Plan 20478.	Former owner Cerenko. Two dug wells on Property; well at east end of Lot is in use; well near centre of Lot is not used. Quantity is adequate.
6	3?	(10?)	0	(0)	Probably all till.	Ray Woodrow; Lot A, Plan 496. Well is near northeast corner of Lot.	Well dug by excavator probably in 1989. Well overflows in spring and has sufficient good quality water.

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
7	3?	(10?)	0	(0)	Probably all till.	Peggy and George Proudlock; Lots 1 and 2, Plan 21511; Well is near southeast corner of Lot 2.	Uncased well dug by excavator.
8	79.3	(260)		?	0 - 0.9 m (0- 3 ft) sandy stony soil 0.9- 1.5 m (3- 5 ft) brown silty clay 1.5- 5.5 m (5- 18 ft) very stony grey hardpan 5.5-16.2 m (18- 53 ft) compact bouldery till 16.2-20.4 m (53- 67 ft) wet, silty gravelly till with boulders 20.4-35.1 m (67-115 ft) bouldery till with seams of sand near bottom 35.1-79.3 m (115-260 ft) bedrock. Fractures with water between 35.1 and 36.6 m (115 and 120 ft). 150 mm (6") diameter casing extends to 35.7 m (117 ft).	B. Thomson; Lot 52, Plan 18459, Willies Way; Well is on an easement across Willies Way, probably "Ex 18124" on S.L. 3.	Well was drilled by Nor-West Water Well Drilling Ltd. in June 1983 and rated at 0.06+ L/sec (1+ gpm). Nor-West also drilled a poor well to 79.3 m (260 ft) on Lot 52; it was rated at about 0.3 L/min (5 gal/hr).
9	68.6	(225)	7.6	(25)	0 -11.6 m (0 - 38 ft) gravel and boulders 11.6-12.5 m (38 - 41 ft) gravel with water 12.5-21.3 m (41 - 70 ft) till 21.3-25.9 m (70 - 85 ft) silty clay and till 25.9-68.6 m (85 -225 ft) bedrock. 150 mm (6") diameter casing to 26.5 m (87 ft).	H. Timms; Lot 37, Plan 13841, on south side of Willies Way.	Well drilled by Nor-West Water Well Drilling Ltd. in October 1982. Estimated capacity by driller of 0.06 L/sec (1 gpm).

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
10	17.4	(57)	7.9	(26)	0 - 7.0 m (0- 23 ft) brown stony till 7.0-17.4 m (23- 57 ft) coarse gravel; water-bearing 17.4-18.9 m (57- 62 ft) grey till Completed with 1.2 m (4 ft) well of screen with 0.5 mm (0.020") slots set between 16.2 and 17.4 m (53 and 57 ft).	J. Harder; Lot 39 on Willies Way.	125 mm (5") diameter casing; drilled by J. Switzer in May 1976; rated at 0.16 L/sec (2.5 US(?)gpm). This well also supplies the Aun House on Lot 38.
11	25.9	(85)	7.6	(25)	0 - 6.4 m (0- 21 ft) overburden 6.4-18.0 m (21- 59 ft grey granite 18.0-18.6 m (59- 61 ft) pink rock; water 18.6-20.4 m (61- 67 ft) grey granite 20.4-20.7 m (67- 68 ft) grey and pink soft granite 20.7-25.9 m (68- 85 ft) grey granite, hard Cased with 150 mm (6") diameter casing to 6.4 m (21 ft).	Ralph Gotzek; Lot 43, Plan 13841, on west side of Cowan Road.	Until about two years ago, the Gotzeks used a dug well on their lot (43) but it was not quite adequate. The well which they now use was drilled by Field Drilling in 1988. The drilled well is on Lot 44 which has been sold to the Reilly's who will use the dug well on Lot 43. The drilled well was rated by the driller at 0.19 L/sec (3 USgpm).

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
12	32.9	(108)	15.2	(50)	0 - 0.9 m (0 - 3 ft) brown till 0.9- 2.1 m (3 - 7 ft) dense brown till 2.1- 3.4 m (7 - 11 ft) dirty gravel 3.4-18.3 m (11 - 60 ft) very dense grey till with boulders 18.3-32.9 m (60 -108 ft) bedrock with water-bearing fractures between 31.1 and 32.3 m (102 and 106 ft). 150 mm (6") diameter casing to 18.3 m (60 ft).	N. Brunanski; Lot 41, Plan 13841.	Well was drilled by Jay Dee in October 1977; well record shows drillers estimated capacity of 0.16 L/sec (2½ gpm) but Brunanski says that it is a minimal supply. A dug well is also used, along with a creek until early summer (June) when it goes
13	49.2	(161.5)	39.6	(130)	0 -42.7 m (0-140 ft) gravelly till with boulders 42.7-49.4 m (140-162 ft) cemented gravel; water-bearing. Well is completed with 1.2 m (4 ft) of screen of slot size 1.27 mm (0.050") with the assembly set from 47.8 to 49.2 m (156.7 to 161.5 ft).	Sawmill Lane Strata Corporation; access to 4 lots of VR1821 is from Willies Way.	Well was drilled by Field Drilling in February 1983. It supplies all four Strata Lots. Well is rated by driller at 1.26 L/sec (20 USgpm).

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
14	93.0	(305)	?		0 -34.8 m (0-114 ft) sandy gravelly till with boulders 34.8-93.0 m (114-305 ft) granite volcanic rock with seams of water. 150 mm (6") diameter casing extends to 35.1 m (115 ft).	Sawmill Lane Strata Corporation; Well is located on an easement near the east end of S.L. 4.	This well is unused. It is assumed to be a well drilled by Field Drilling in February 1984 which was rated at 0.03 L/sec (½ gpm).
15	91.5	(300)	25.6	(84)	0 - 0.9 m (0- 3 ft) loamy sand with some gravel 0.9-11.3 m (3- 37 ft) compact sandy silt with gravel and a few boulders 11.3-18.0 m (37- 59 ft) compact silty gravel 18.0-25.9 m (59- 85 ft) soft decomposed granite 25.9-91.5 m (85-300 ft) granite bedrock. 150 mm (6") casing to 19.5 m (64 ft).	Joe Merrin; Lot 49, Plan 18459; access from Willies Way. Way.	Well drilled by Rural Well Drillers in 1981 for former owner Keith Ewart. Capacity rated by driller at 0.1 L/sec (3 gpm). According to Joe Merrin, the supply is adequate and of good quality.

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
16	71.9	(235.75)	32.0	(105)	0 - 2.1 m (0 - 7 ft) sandy clay 2.1-24.4 m (7 - 80 ft) till(?) 24.4-41.2 m (80 - 135 ft) fine silty sand 41.2-44.2 m (135 - 145 ft) silty sandy clay 44.2-54.9 m (145 - 180 ft) gravelly till with silty layers 54.9-65.9 m (180 - 216 ft) fine silty sand with some water 65.9-67.4 m (216 - 221 ft) gravel and fine silty sand; water-bearing 67.4-68.6 m (221 - 225 ft) gravel; dirty; some water 68.6-70.1 m (225 - 230 ft) gravel and sand, silty and dirty 70.1-71.9 m (230-235.75 ft) silty gravel and sand; water-bearing 71.9-73.5 m (235.75-241 ft) gravel; no water. Well is completed as an open-end 150 mm (6") diameter casing.	W. Weismiller; Lot 14, Plan 18459.	Well drilled by Field Drilling Contractors in September 1988 supplies a four lot subdivision; it was rated by the driller to have a capacity of 3.15 L/sec (50 gpm).
17	-		-		-	A. (C.) Buchannan; Lot 48, Plan 15946.	Three wells were drilled by Western Water Wells in 1970, the deepest to 46.0 m (151 ft); all were poor. Water supply is from a licence on Lister Creek.

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
18	80.5	(264)	35.1	(115)	0 -12.8 m (0- 42 ft) till 12.8-14.9 m (42- 49 ft) compact silty sand 14.9-19.2 m (49- 63 ft) compact silty gravel 19.2-23.8 m (63- 78 ft) bouldery till 23.8-31.4 m (78-103 ft) compact silty sand and gravel 31.4-33.5 m (103-110 ft) compact fine silty sand 33.5-57.9 m (110-190 ft) compact clayed silt 57.9-61.9 m (190-203 ft) compact silty sand with some gravel; water-bearing 61.9-66.5 m (203-218 ft) compact clayey silt 66.5-73.2 m (218-240 ft) silty sand and gravel; wood; water-bearing 73.2-76.8 m (240-252 ft) compact silty sand and fine gravel; water-bearing 76.8-79.6 m (252-261 ft) interbedded silty sand, gravel, silt 79.6-80.5 m (261-264 ft) sandy silty gravel; good water-bearing Well completed as open-end casing at 80.5 m (264 ft).	I. Townsend-Gault; Lot A, Blk. C, D.L. 1426.	Well was drilled in April 1974 by Rural Well Drillers. It is completed in a sand and gravel aquifer which contains wood. Water contains some iron and manganese. Well has no screen but Rural estimated aquifer capacity at 3.2 L/sec (50 gpm). An analysis by M.O.E. Lab' in 1975 shows: total dissolved solids of 75.4 mg/L, iron of 1.1 mg/L and hardness of 47.3 mg/L.

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	(ft)	Static Water Level m	(ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
19	32.3	(106)	25.6	(84)	0 - 3.0 m (0 - 10 ft) brown till and boulders 3.0-10.7 m (10 - 35 ft) grey till 10.7-28.4 m (35 - 93 ft) dense grey till 28.4-32.3 m (93 -106 ft) dense gravel, water-bearing. Open-end 150 mm (6") diameter casing at 32.3 m (106 ft).	Owner - ?; Lot 27, Plan 13841.	Well was drilled by Jay Dee in June 1976. Capacity rated by driller at 0.32 L/sec (5 USgpm).
20	28.0	(92)	16.8	(55)	0 - 1.2 m (0- 4 ft) brown till 1.2-16.8 m (4- 55 ft) fine grey silty sand 16.8-28.4 m (55- 93 ft) light grey fine sand, silt 28.4-30.5 m (93-100 ft) dark grey silt. Well is completed with 1.2 m (4 ft) of 0.5 mm (0.020") slot screen set from 26.8 to 28.0 m (88 to 92 ft).	D.B. Mills and M.B. Standell; Lot 25, Plan 13841, Adams Road; home is for sale.	Well was constructed in 1980 by Jay Dee Drilling Ltd. for former owner, Charles Haynes. Driller's estimated capacity was 0.19 L/sec (3 USgpm) but new well owner reports that the well is not quite adequate in summer.
21	83.5?	(274?)				John Coates; Lot 22, Plan 13841, Adams Road.	Drilled about 1978 by unknown driller for former owner Murray Nozak. Owner reports plenty of good quality water.

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
22	29.6	(97)	18.6	(61)	0 - 7.6 m (0 - 25 ft) sandy till with a few boulders 7.6-19.8 m (25 - 65 ft) compact silty sand with occasional boulder 19.8-22.9 m (65 - 75 ft) silty gravel; some water 22.9-29.9 m (75 - 98 ft) coarse compact gravel; water-bearing. Well is completed as 150 mm (6") open-end casing at 29.6 m (97 ft).	Owner - ?; Lot 19, Plan 13841.	Well was drilled by Rural Well Drillers in September 1980. Driller estimated capacity at 0.3 L/sec (5 gpm).
23	44.2	(145)	?		0 - 3.0 m (0- 10 ft) dirt 3.0-17.7 m (10- 58 ft) silty clay 17.7-18.0 m (58- 59 ft) silty gravel and clay 18.0-33.5 m (59-110 ft) grey silty clay 33.5-41.2 m (110-135 ft) brown silty clay with wood at 120-125 ft 41.2-42.1 m (135-138 ft) blue clay 42.1-44.2 m (138-145 ft) broken rock 44.2-44.4 m (145-145½ ft) rock. Well is completed as open-end 150 mm (6") diameter casing.	W. Riddell; Lot 16, Plan 13841; Well supplies private utility.	Well presently supplies Lot 12 (Joy Davies), Lot 14 (Jack Ciesielski), Lot 16 and Lot 21, all facing on Adams Road. Well was drilled by Field Drilling in 1988 and rated at 0.19 L/sec (3 gpm).

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m	Completed Well Depth (ft)	Static Water Level m	Static Water Level (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
24	-		-		-	B. Lonnguist; Lot 6, Plan 13841.	Supply is from an intake on a small creek, about 40 metres from the house; the creek flows northeastward to Grafton Lake.
25	6.1	(20)	?		Dug well, about 7.6 m (25 ft) in diameter with wood cover; no casing.	Dave and Sharon Dennis; Lot 11, Plan 13841, Adams Road.	The dug well has been used by owners for seven years. It also supplies Ian Watson on Lot 10. Supply has always been adequate; quality is good.
26	≃ 3.7	(≃12)	?		Dug well.	G. Carr; Lot 4, Plan 13841, Adams Road.	The dug well is inadequate from July to November; water quality is good.

Table 1. Inventory of Water Wells in the Cowan Point - Willies Way - Adams Road Area of Bowen Island (cont'd)

Map Ident No.	Completed Well Depth m (ft)	Static Water Level m (ft)	Driller's Litholog and Well Construction Details	Property Owner and Location	Remarks
27	214.9 (705)	?	0 - 10.6 m (0- 35 ft) brown soil, fill 10.6- 21.6 m (35- 71 ft) dark soil sandy clay mixture; loose from 18.3 to 21.6 m (60 to 71 ft) with water 21.6- 24.4 m (71- 80 ft) gravel seam, hardpan 24.4-114.3 m (80-375 ft) soft green granite 114.3-214.9 m (375-705 ft) darker rock, some feldspar; fracture with water at 199.1 m (653 ft). 24.7 m (81 ft) of well casing.	Patrice Dufour; Lot 2, Plan 13841, Adams Road.	Well drilled by Tri-K Drilling for builder, Peter Black, in 1990; estimated capacity of 0.3 L/sec ($\frac{1}{2}$ USgpm).
28				Johni De Groot; Lots 1 and 2, Plan 21034, D.L. 492; Adams Road and also a lot adjoining lots 1, 2, 3 and 4?	Ms. De Groot owns three wells, on north ends of Lots 1 and 2 and on the east end of the south lot. These are three of four wells drilled in 1990(?) by the developers, Sunset Estates (Murray Cyprus).