ROBINSON, ROBERTS & BROWN LTD.

GROUND WATER GEOLOGISTS
1409 BEWICKE AVENUE
NORTH VANCOUVER, BRITISH COLUMBIA
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AFFILIATED OFFICE
TACOMA, WASHINGTON

HABITAT OF GROUNDWATER
GABRIOLA ISLAND
BRITISH COLUMBIA

for

Department of Lands, Forests and Water Resources
Water Resources Service
Groundwater Division

W. L. Brown, P.Eng.
R. B. Erdman

Draft - January 1973
Completed - January 1975

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DRAWINGS

(At Back of Report)

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CONCLUSIONS

Available information, data and experience as of January 1975 leads the writer to conclude;

1. A groundwater-bearing fault and fracture pattern has been proven to be present on Gabriola Island. Please see Geologic map in pocket.
2. This fault and fracture pattern forms a large Island-wide water distribution system. Thus surface drainage basins on the Island will have no bearing on the groundwater potential of any part of the Island.
3. Promising groundwater-bearing zones of fractured sandstones and shales exist beneath Gabriola Island to a known depth of 300 feet. Such zones probably exist to a depth of at least 1,000 feet.
4. Wells capable of producing economically significant amounts of water to community wells must be located in fractured zones.

5. The quality of the water obtained from wells 300 feet deep will be excellent except where these wells are located close to the shoreline where they encounter shallow fractures subject to salt water contamination. Wells located in the central areas of the Island will most probably produce potable water from depths of at least 1000 feet.
6. Properly located, designed, constructed and stabilized wells 300 feet deep should be capable of producing at rates of from 20 to 50 gpm. Wells drilled to deeper depths should have safe production capacities up to 100 gpm.
7. The recharge available to enter the subsurface groundwater-bearing system is estimated to be 3000 gpm.
8. A geological concept concludes that an additional 2200 gpm of water may be flowing through the system as underflow from Vancouver Island. Of this amount, 1100 gpm is estimated to be interceptable.
9. Using the Water Utilities Division water requirements of 0.41 US gpm per housing unit, 7500 units could be serviced from local recharge. An additional 2600 could be serviced if underflow from Vancouver Island takes place.
10. Using an average of 3.5 persons per home, the local recharge can satisfy the water requirements of 26,000 people and the underflow can satisfy the water requirements of 9,000 people for a total population on Gabriola Island of 35,000 people serviced by groundwater producing wells.

11. The water stored within the rock fractures to a depth of 300 feet will more than satisfy the needs of 35,000 people during the usual 100 day of drought.

INTRODUCTION

Robinson Roberts and Brown Ltd., a firm of Consulting Groundwater Geologists with offices in North Vancouver, was authorized by the Groundwater Division, Water Investigations Branch, Victoria, British Columbia to study the Groundwater Geology and Hydrology of Gabriola Island.

The Geologic and hydrologic features controlling the habitat of Groundwater beneath the Island were established. This allowed a reasonable estimate to be made of the safe productive capacity of the groundwater-bearing reservoirs. To arrive at this estimate the following were studied and evaluated.

1. Stratigraphy of the sedimentary rocks that compose the Island.
2. Structure of the Island with special reference to the fault and fracture zones.
3. Recharge and Storage
4. Water quality
5. Protection of the subsurface reservoirs from sea water intrusion and pollution by near surface waters.

The field work and test drilling program was completed during the summer of 1972. Compilation of data, calculation of aquifer parameters, air photo studies, and preparation of a geologic map and cross-sections took place in the fall and winter of 1972-73. A draft report was sent to the Groundwater Division for informal comments in February, 1973, and a reply was received in May, 1973. The report was edited, rewritten, and presented in final form in February 1975. The writers have accumulated considerable experience on wells and well systems that obtain water from fractured bedrock during the period between the writing of the initial draft and the writing of the final report. This experience allowed a re-assessment to be made on the results of the 1972 program. A more reliable set of conclusions are herein presented than would have been possible in January 1973.

Previous studies of the groundwater geology of Gabriola Island have been made by Robinson Roberts & Brown Ltd., for private individuals, companies and the Regional District of

Nanaimo. A report on the groundwater geology of Gabriola Island was presented to the Regional District in January, 1972. In summary, this study concluded that groundwater-bearing zones with promising productive capacities are present beneath Gabriola Island. Sets of interconnected fracture and fault zones which form a natural water distribution system exist beneath the Island. This report also concluded that properly located, designed and constructed wells up to 300 feet deep should be capable of producing at rates of from 30 to 100 gpm.

The efficient and friendly co-operation of members of the Groundwater Division under the direction of Dr. J. W. Foweraker, P.Eng., is gratefully acknowledged.

FIELD INVESTIGATIONS

Five test wells were drilled to depths of between 250 and 325 feet. These wells are shown as Wells 72-1 to 5 inclusive on the Geologic map (at back of report). Drilling was closely supervised by a Geologist to obtain maximum information on rock types, location of fracture zones and groundwater flows. All wells were logged with portable caliper, gamma ray, self potential and resistivity devices. Four of the five wells were test pumped. The logs of the test wells and the drawdown water level graphs drawn from the pump test measurements are included in this report.

A total of 1450 feet of hole was drilled by an air rotary drilling machine using a 6-1/4-inch diameter bit. Surface casing (6-1/4-inch I.D.) was set into an 8-inch diameter hole drilled 10 feet into the rock. Artesian flows were expected during the drilling of Well 72-2 so that the casing was cement grouted into the rock. At all other locations drill cuttings were allowed to plug the annular space between the 8-inch diameter hole and the 6-1/4-inch diameter casing. All wells except test well 72-2 were fitted with locked caps. Test well 72-2 was fitted with a flanged cap and a 1/2-inch diameter capped plug so that artesian pressure readings could be easily made if and when desired.

The total drilling, development and moving time for the five wells was 7-1/2 working days. The total cost of this work was $9,211.50 or an average price of $6.35 per foot. The test pumping was conducted by a sub-contractor specialist for a total cost of $2,666.00 or for an average cost of $29.63 per hour.

All roads and trails, as well as parts of the coastline, were examined to obtain as much geologic information as possible.

Complete chemical analyses were run on water samples from the four pump tested wells and partial analyses were run on water samples collected from those domestic wells where water had been previously analysed by the Groundwater Division in December, 1971.

It will be noted from the Geologic map that three of the test wells were located in areas of easy access close to major fracture zones and one was located in the fractured part of the anticline's crest. Well 72-4 was located in unfractured ground where a low water yield was expected.

GENERAL GEOLOGY

INTRODUCTION

Several generations of geologists have studied the geology of Gabriola Island and the Nanaimo area since the late 1850's. These studies were spurred by the discovery of coal at Nanaimo in 1849 and continued throughout the coal mining period that lasted until 1960. Those readers who wish a more complete description of the geology of Gabriola Island and adjoining areas should refer to the two following papers. These two excellent papers not only describe the geology of the area but also include a short history of geological investigation and lengthy bibliographies.

Muller, J.E. and Jeletzky, J.A. 1970, Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia; Geol. Surv. Can. Paper 69-25, 77 pp.

Muller, J.E. and Atchison, M.E. 1971, Geology, History and Potential of Vancouver Island Coal Deposits; Geol. Surv. Can. Paper 70-53, 50 pp.

UNCONSOLIDATED GEOLOGY

No large or widespread deposits of unconsolidated sediments are present on the Island. A small deposit of sands and gravels are present along the road that runs sub-parallel with the southern coast of the island. Clays are present in places in the central valley and overlie some of the shale beds on the southern side of the Island. A thin, less than three-foot, soil covers large sections of the island into which effluent from domestic sewer systems is allowed to percolate.

The potential for the development of groundwater from the unconsolidated sediments is virtually nil. Therefore only cursory attention was paid to the geology or hydrology of these deposits.

BEDROCK GEOLOGY

Please refer to the attached Geologic map and cross-sections. These show the basic characteristics of the bedrock geology of Gabriola Island.

Stratigraphy

The standard stratigraphic rock units have been used in this report. These units have been accepted by the modern geologists who have worked with the geology of the Nanaimo area and Gulf Islands. For additional stratigraphic discussions please refer to the two Geological Survey of Canada papers referenced in the introduction to this section of the report. Five rock units outcrop on the island. Three of these consist predominantly of interbedded sandstones and two consist predominantly of interbedded shales. These units are:

Name	Predominant Lithology	Thickness in Feet: Gabriola Island	Thickness in Feet: Nanaimo Basin (G.S.C.Paper 69-25)
Gabriola	sandstone	970 plus	3,000
Spray	shale	250	1,770
Geoffrey	sandstone	450	1,500
Northumberland	shale	600 plus	1,000
Total Thickness		2,270	7,270

A hole was drilled (July 1907 - May 1909) on the southern shore of Gabriola Island to explore for coal. This hole drilled through 587 feet of Northumberland shales, 362 feet of Decourcy sandstones (outcrops on Mudge Island immediately south of Gabriola Island) and then 1060 feet of Cedar shale

Thus the Upper Cretaceous aged sedimentary rock sequence is known to be at least 2009 feet thick beneath the southern side of the Island.

For the purposes of the present study a simple stratigraphic decision was made. The thickness of the various rock units have been kept constant across the island. No attempt has been made to study or postulate facies changes (gradational changes of rock types) or thickness changes of the various rock units.

Depositional History

The sedimentary sandstones and shales were deposited near the shore of a marine basin (brackish lagoonal to shallow neritic environment) whose water depths and shorelines shifted with time. The depositional environment changed gradually so that no sharp contacts exist between the predominantly shale sequences and the predominantly sandstone sequences. A gradational zone of interbedded sandstones and shales are present as one proceeds from a sandstone to a shale sequence.

Subsequent to the deposition of the sedimentary rocks they were folded into a syncline and plunging anticline.

After folding, the island became broken into several fault blocks. The fault zones shown on the geologic map are those that are obvious on the airphotos, readily observable along the sea coast and indicated by surface observations and drilling. The near-vertical fracturing associated with some of these zones is extremely important to the recharging of the groundwater system from local precipitation. It is also of paramount importance to any program designed to protect the groundwater from near surface water contamination or pollution.

Structure

The main structural features are shown on the Geologic map and cross-sections. Reference to these drawings will show that the Island is broken into a series of fault blocks and folded into one syncline and one anticline.

The syncline generally conforms with the geographical axis of the Island. The northern limb of the syncline has gentle 3 to 10 degree southwesterly dips. The southern limb generally dips 15 degrees to the northeast. As mapped by others (see Geol. Surv. Can. Paper 69-25) shales of the Spray formation were shown to outcrop at ground surface in the axial areas of the syncline. Field examination and well drilling information showed that only small areas of shale are at ground surface, along the axis of the syncline. (Please see the attached Geologic Map).

The southern limb and plunging nose of an anticline is present in the northwestern part of the Island. The southern limb of the anticline dips 12 degrees to the southwest. The westward plunging nose of the anticline is readily observable on air photos where the sandstone-shale-sandstone contacts can be observed to curve around the axis.

Two types of faults cut through the Island. Those that trend sub-parallel to the folds and those that cut across the folds. The faults that trend sub-parallel to the folds are believed to be predominantly strike-slip in nature. These faults are not associated with as wide or as well developed fracture zones as those faults that cut across the geologic grain of the Island. The cross faults where observed along the coastal cliffs exhibit very prominant fracture zones. The fractures in these zones are open and have a near vertical dip. The traces of these faults as observed on airphotos as shown on the map indicate that the faults are steeply dipping to vertical.

RESULTS OF TEST DRILLING

INTRODUCTION

The Geologic results obtained from each test well are outlined below. Please refer to the complete log of each test well at the back of this report and to the Geologic map and cross-sections.

TEST WELL 72-1

This well was located close to McCallum Road to determine the groundwater potential of an east-west trending fault zone that is very prominantly displayed on the air photos. We interpret (please see cross-section E-E) that this well started in the Spray shale, entered the Geoffrey sandstone at a depth of 115 feet, intersected the fault zone at a depth of 215 feet and drilled into the Northumberland shales to a total depth of 325 feet (mean sea level).

A road cut a few hundred feet south of the well shows a shale (Northumberland) in normal contact with an overlying sandstone (Geoffrey) as shown in section E-E.

The fault zone intersected by Well 72-1 has an apparent dip of 50^{o} (derived from the location of the surface trace of the fault and its position in the well). It has an apparent vertical component of displacement of 800 feet (based upon the Geoffrey-Northumberland contact on each side of the fault). The shales probably formed an impervious gouge which closed any open fractures. Several minor water-bearing fractures associated with the fault were intersected. The accumulative flow rate obtained during drilling as shown on the log was 10 gpm.

TEST WELL 72-2

This test well is located in the eastern part of the island along Peterson Road. It was drilled to a total depth of 275 feet (155 feet below sea level). The well log shows that a sandstone sequence with a few minor shale interbeds was encountered. We interpret that the well was drilled in the Geoffrey sandstone formation.

The main water-bearing zone was encountered at a depth of 190 feet where an air-blowing flow of 16 US gpm was obtained during drilling. After drilling was terminated at a depth of 275 feet the water-bearing zone was developed by airsurging and swabbing. This work increased the blowing flow rate to 70 US gpm.

The first attempt to drill this test well at a location 500 feet to the south of the location shown on the map failed because over 70 feet of unconsolidated clays and sands were encountered. The type of drilling rig used was unable to set casing through the running water-bearing sands. Sandstone is exposed at the ground surface to both the north and the south of the location of the aborted test well. We therefore conclude that the first well was located directly on top of the major northeast-southwest trending fault zone which is readily observable on the air photos. The straight surface expression of this fault as it crosses hilly topography indicates that it must have a near vertical dip. The major water-bearing zone in the well at a depth of 190 feet must be caused by feather type fracturing associated with the main fault zone.

TEST WELL 72-3

This well is located in the western part of the island at an elevation of 305 feet above sea level. It was drilled in the Department of Highways works yard, to a depth of 250 feet (55 feet above sea level) through a sandstone section that contained a few shale interbeds. This predominantly sandstone section is believed to be the Gabriola formation. A major water-bearing fracture zone was penetrated between depths of 165 and 200 feet. The surface trace of a fault is present approximately 400 feet south of the well. If the fracture zone encountered at a depth of 165 feet in the well, is the same zone, then the fault dips northward at a low angle of approximately 20°. A private well is located on the surface trace of the fault. The water in this private well became "muddied" when the test well was drilling through the fracture zone. The water level in the private well was also affected by the pumping test that was performed on Test Well 72-3. The fracture zone in the test well could be subsidary feather fracturing associated with the main fault instead of the main fault itself.

TEST WELL 72-4

Test Well 72-4 was drilled to a depth of 275 feet (65 feet below sea level). The well was located almost 1/2 mile to the east of a major fracture zone. As such, its water-bearing capabilities are considered to be representative of wells located in generally unfractured rock without benefit of geologic advice. This well, which is capable of delivering 3 US gpm, would satisfy the domestic requirements of one home.

No pump test was conducted in this well because the air blowing water flow during drilling was too low. Attempts to improve the flow by surging were not successful.

TEST WELL 72-5

This test hole was located in the northern part of the island to test the productivity of the nose of the plunging anticline. It was drilled to a depth of 325 feet (205 feet below sea level). Spray shales were drilled to a depth of 78 feet where Geoffrey sandstones were encountered. It is interpreted that the well remained in the Geoffrey sandstones throughout the rest of the well. It will be noted however, that a shaley sequence was encountered in the bottom 40 feet of the well. This suggests that the Northumberland shales might have been reached if the well had been continued to a total depth of 400 feet.

It will be noted on the well log that most of the water was encountered at the shale-sandstone contact at a depth of 78 feet. Several small fault zones were encountered but these appeared to be filled with gouge and were therefore non-productive.

RESULTS OF TEST PUMPING

INTRODUCTION

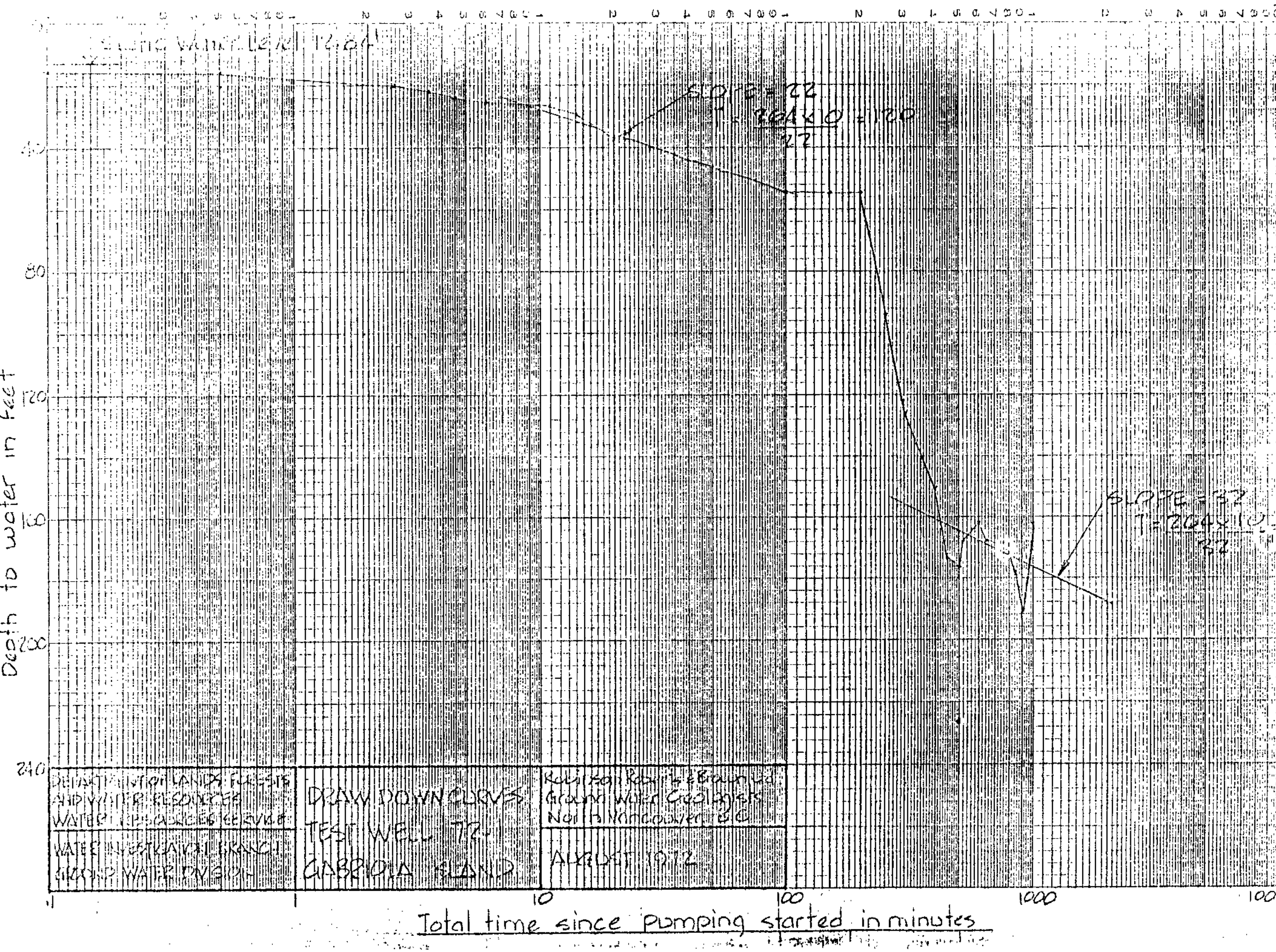
Four of the five wells were test pumped. A pumping test was not carried out on Well 72-4 because an air blowing rate of only 3 gpm of water was obtained. Drawdown and recovery water level readings and pump discharge flow measurements were taken and recorded during the pump tests. Water level measurements were taken on a privately owned well during the pump test on well 72-3. The duration of the tests ranged from 1000 minutes on 72-1 to 1500 minutes on wells 72-3 and 72-5. Pumping rates ranged from 7.5 gpm to 75 gpm. The measurements made and recorded during the pump tests are reproduced on pages following the description of each test.

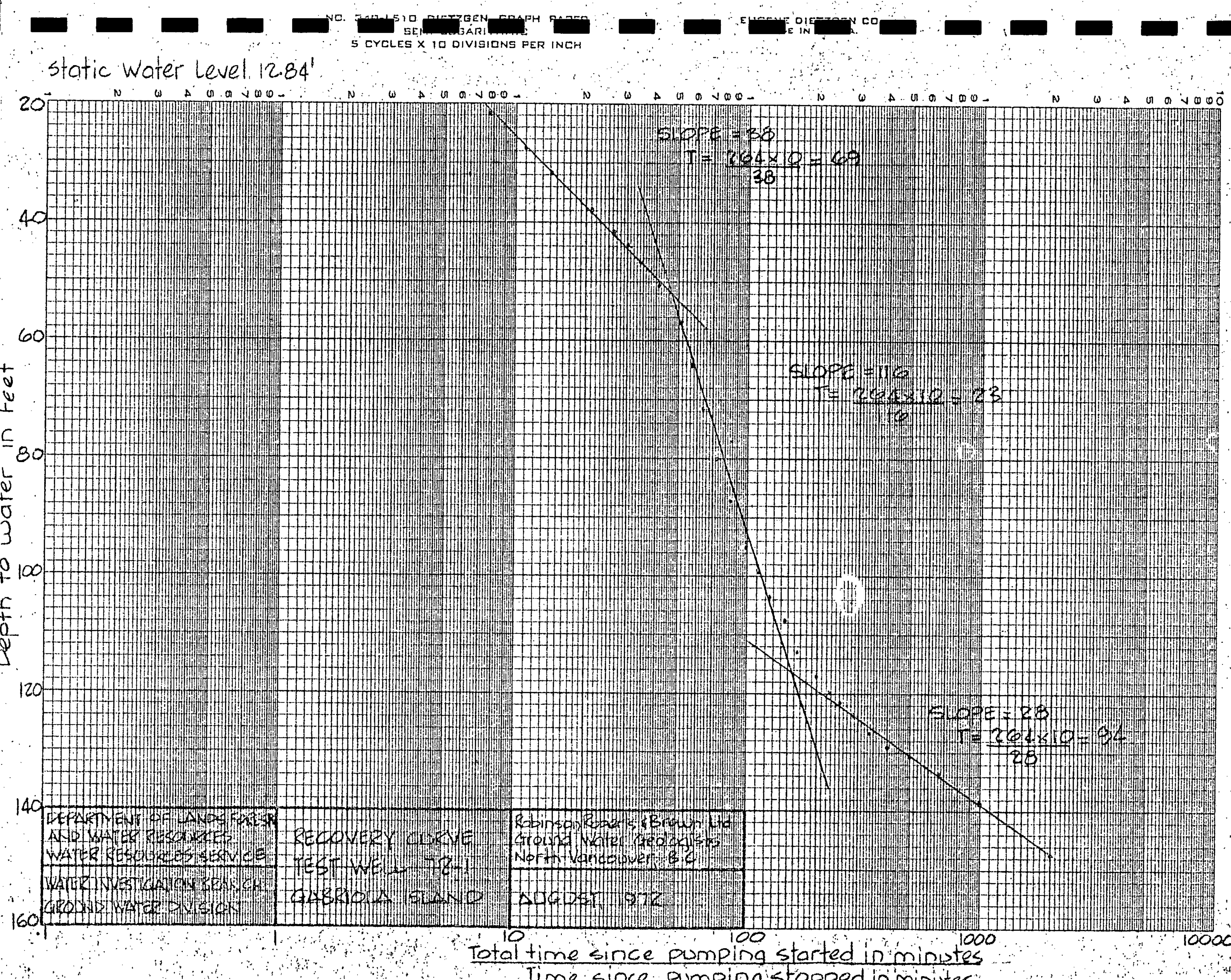
TEST WELL 72-1

A plot of the drawdown data shows that near stabilization occured at a depth of 54 feet after 100 minutes of pumping. The transmissibility of this leg of the drawdown curve is calculated to be 120 US gpd/ft. At 200 minutes into the test a negative boundary was encountered and the pumping level dropped sharply. At 400 minutes into the test it became necessary to reduce the pumping rate because the water level was close to pump suction. After the reduction in pumping rate the water level recovered 10 feet but after 100 minutes started to decline again. At 930 minutes it was necessary to reduce the pumping rate to 7.5 gpm. The water level was still recovering when the test was terminated. After 400 minutes the "average" transmissibility was calculated to be 83 gpd/ft.

The recovery curve shows the typical backward "s" curve of fractured rock aquifers. The transmissibility for the lower leg of the curve was 94 US gpd/ft, the middle part of the curve was 23 US gpd/ft, and the upper part was 69 US gpd/ft. The recovery curve also indicates that recharge is taking place into the aquifer. The specific capacity of the well is 0.05 gpm per foot of drawdown.

Based upon the results of this test we rate the safe productive potential of Well 72-1 at 5 US gpm. At this rate the pumping level should remain above a depth of 220 feet after a severe drought for 100 days.


Depth to water in feet
40
80
120
160
200
240
.1
1
10
100
1000
10000
Total time since pumping started in minutes
SLOPE = 22
T = 264 x 10 / 22 = 120
SLOPE = 32
T = 264 x 10 / 32 = 83
DRAW DOWN CURVES
TEST WELL 72
GABRIOLA ISLAND
AUGUST 1972


NO. 340-L510 DIETZGEN GRAPH PAPER
5 CYCLES X 10 DIVISIONS PER INCH
Static Water Level 12.84'
SLOPE = 38
T = 264 x 10 / 38 = 69
SLOPE = 116
T = 264 x 10 = 23
SLOPE = 28
T = 264 x 10 / 28 = 94
Depth to water in feet
20
40
60
80
100
120
140
160
1
10
100
1000
10000
DEPARTMENT OF LANDS FOR AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
GROUND WATER DIVISION
RECOVERY CURVE
TEST WELL 78-1
GABRIOLA ISLAND
Robinson Roberts & Brown Ltd
Ground Water Geologists
North Vancouver, B.C.
AUGUST 1972
Total time since pumping started in minutes
Time since pumping stopped in minutes

GABRIOLA WELL #72-1

DRAWDOWN

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
				Aug 22, 1972
0	16:30:00	13.50		Static Water Level
	16:30:30	15.35	10	
1	16:31:00	16.70		
	16:31:30	18.23		
2	16:32:00	19.38		
	16:32:30	20.35		
3	16:33:00	21.28		
	16:33:30	22.00		
4	16:34:00	23.22		
	16:34:30	23.95		
5	16:35:00	24.46		
6	16:36:00	25.00		
7	16:37:00	25.56		
8	16:38:00	25.87		
9	16:39:00	26.13		
10	16:40:00	27.09		
12	16:42:00	28.98		
14	16:44:00	32.50		
16	16:46:00	34.62		
18	16:48:00	35.67		
20	16:50:00	36.29		
25	16:55:00	38.34		
30	17:00:00	39.74	10	
35	17:05:00	41.53	10	

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
40	17:10:00	43.10	10	
50	17:20:00	45.25	10	Very cloudy
75	17:45:00	51.00	10	52°F
100	18:10:00	53.17	10	
150	19:00:00	53.64	10	
200	19:50:00	53.72	10	
250	20:40:00	93.10	10	
300	21:30:00	125.18	10	
350	22:20:00	150.03	10	
400	23:10:00	174.05	10	
450	24:00:00	177.37	9	
520	1:10:00	168.54	9	Aug 23, 1972
580	2:10:00	165.57	9	
630	3:00.00	172.45	9	
680	3:50:00	167.86	9	
730	4:40:00	168.60	9	
780	5:30:00	170.00	9	
830	6:20:00	171.45	9	
880	7:10:00	179.45	9	
930	8:00:00	191.51	9	
980	8:50:00	160.50	7.5	
	RECOVERY			
1000/0	9:10:00	151.46		Pump Off
	9:10:30	146.80		
1	9:11:00	138.30		
	9:11:30	133.78		
2	9:12:00	130.45		
	9:12:30	128.79		

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
3	9:13:00	126.35		
	9:13:30	123.32		
4	9:14:00	121.48		
	9:14:30	119.55		
5	9:15:00	117.10		
6	9:16:00	112.60		
7	9:17:00	107.65		
8	9:18:00	103.54		
9	9:19:00	99.21		
10	9:20:00	94.58		
12	9:22:00	86.82		
14	9:24:00	79.85		
16	9:26:00	71.57		
18	9:28:00	63.98		
20	9:30:00	56.69		Stopped hearing water running in
25	9:35:00	50.36		
30	9:40:00	46.62		
35	9:45:00	43.75		
40	9:50:00	41.66		
50	10:00:00	37.93		
75	10:25:00	31.57		
100	10:50:00	27.26		
150	11:40:00	21.88		
200	12:30:00			

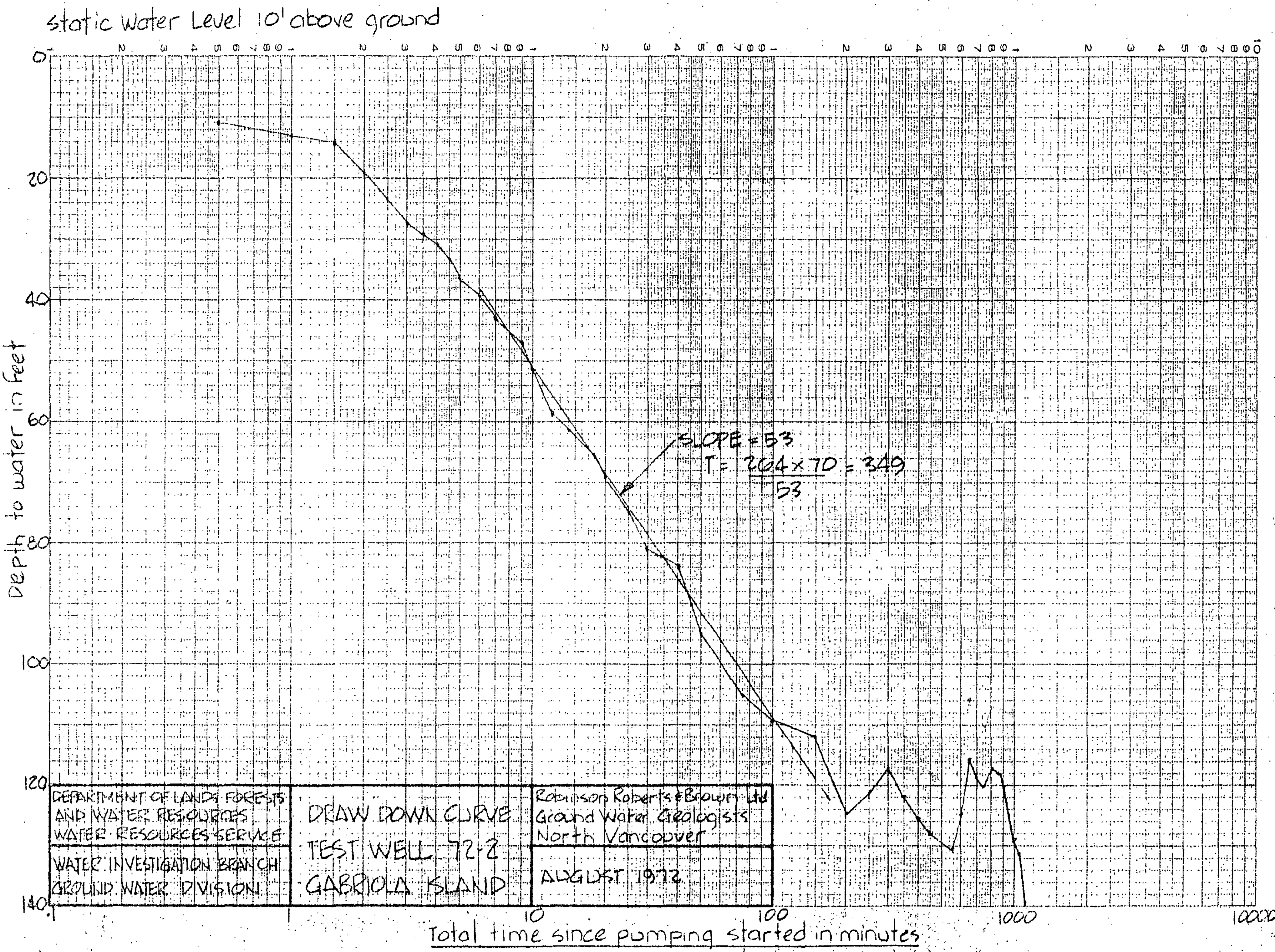
TEST WELL 72-2

Test Well 72-2 was pumped at a rate of 70 US gpm for 1000 minutes, and 75 US gpm for the last 400 minutes of the test. At the start of the test the well was flowing at ground surface at a rate of 3 gpm from a calculated static water level of approximately 10 feet above ground surface. Near stabilization was reached after 550 minutes with the pumping water level at a depth of 132 feet. The plot of the drawdown curve indicated a transmissibility of 349 US gpd/ft.

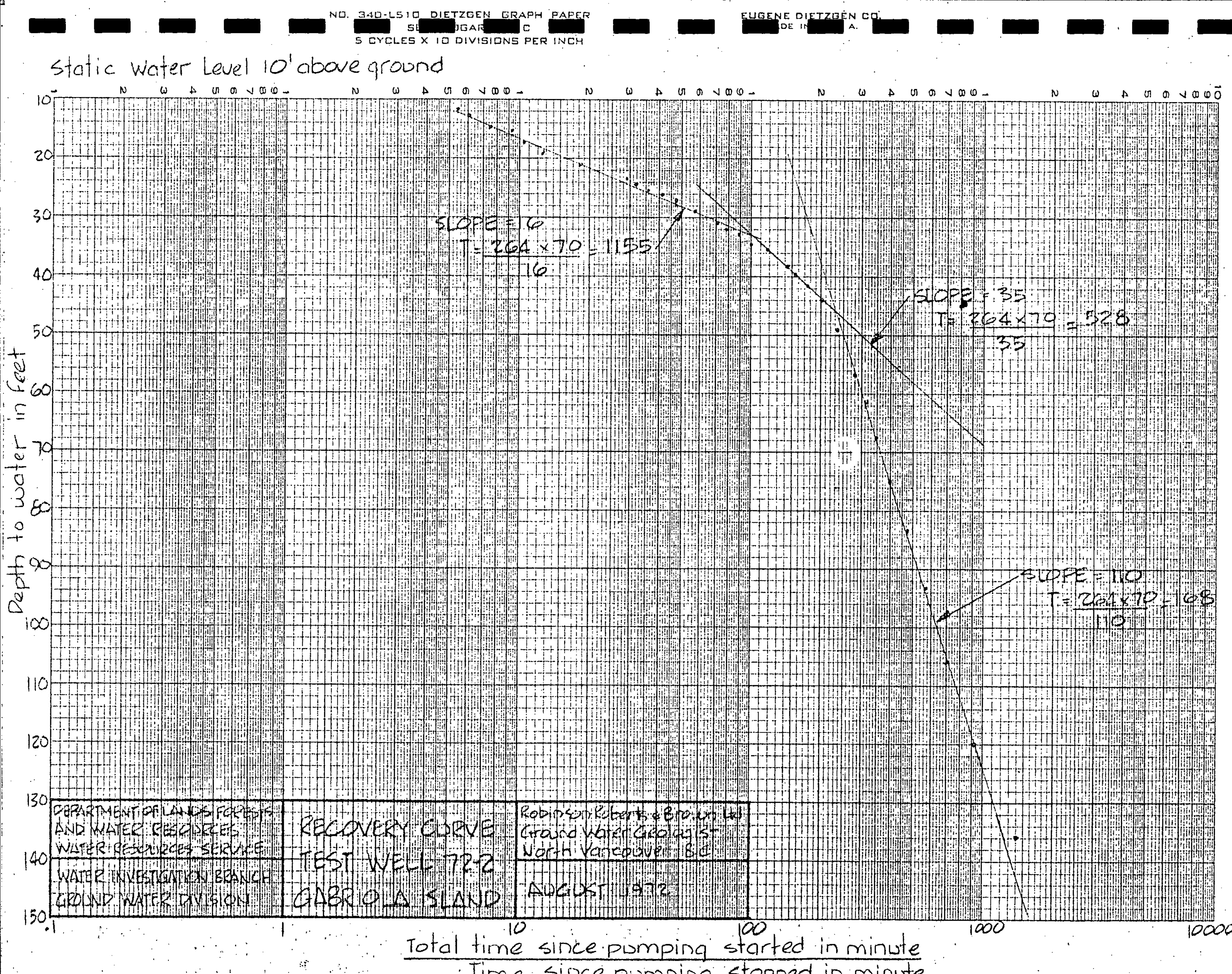
The recovery curve shows a typical sand and gravel aquifer configuration and not the bedrock curve that would be anticipated. This indicates a high degree of fracturing. The first leg of the recovery has a transmissibility of 148 US gpd/ft., the middle leg 528 US gpd/ft. and the final leg 1155 US gpd/ft. Since the specific capacity of the well can be no greater than 0.3 gpm per foot of drawdown the most logical "design" transmissibility is judged to be 500 US gpd/ft.

Based upon available data the safe productive potential is rated at 50 US gpm. At this rate the pumping level in the well should not drop below a depth of 200 feet after a 100 day drought.

NO. 340-L510 DIETZGEN GRAPH PAPER SE GAR C EUGENE DIETZGEN CO. E IN A.
5 CYCLES X 10 DIVISIONS PER INCH



28.



NO. 340-L510 DIETZGEN GRAPH PAPER
EUGENE DIETZGEN CO.
5 CYCLES X 10 DIVISIONS PER INCH
Static Water Level 10' above ground
SLOPE = 16
T = 264 × 70 / 16 = 1155
SLOPE = 35
T = 264 × 70 / 35 = 528
SLOPE = 110
T = 264 × 70 / 110 = 168
Depth to water in Feet
DEPARTMENT OF LANDS FORESTS AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
GROUND WATER DIVISION
RECOVERY CURVE
TEST WELL 72-2
GABRIOLA ISLAND
Robinson Roberts & Brown Ltd
Ground Water Geologists
North Vancouver B.C.
AUGUST 1972
Total time since pumping started in minute
Time since pumping stopped in minute

GABRIOLA WELL #72-2

DRAWDOWN

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
				Aug 23, 1972
0	13:50:00			Pump on flowing
	13:50:30	12.49	70	at 3gpm
1	13:51:00	12.90		
	13:51:30	14.06		
2	13:52:00	14.85		
	13:52:30	23.80		
3	13:53:00	26.96		
	13:53:30	28.05		
4	13:54:00	30.99		
	13:54:30	33.67		
5	13:55:00	36.45		
6	13:56:00	39.75		
7	13:57:00	43.34		
8	13:58:00	46.37		
9	13:59:00	49.03		
10	13:60:00	51.36		
12	14:02:00	56.22		
14	14:04:00	60.63		
16	14:06:00	63.48		
18	14:08:00	65.54		
20	14:10:00	68.75		
25	14:15:00	75.10		
30	14:20:00	80.32		
40	14:30:00	84.00		
50	14:40:00	94.53		

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
75	15:05:00	105.17		
100	15:30:00	109.83		
150	16:20:00	111.88		
200	17:10:00	124.63		
250	18:00:00	120.65		
300	18:50:00	117.40		
350	19:40:00	121.65		
400	20:30:00	125.80		
450	21:20:00	128.50		
500	22:10:00			
550	23:00:00	130.83		
600	23:50:00	124.51		
650	00:40:00	115.30		Aug 24, 1972
700	1:30:00	118.70		
750	2:20:00	120.00		
800	3:10:00	117.60		
850	4:00:00	118.30		
900	4:50:00	121.46		Control valve trouble, discharge fluctuating at 6:30:00. Opened valve, discharge to 75 gpm and water level at suction at a depth of 200 feet for remainder of test of 400 minutes to 13:10:00.
950	5:40:00	125.83		
1000	6:30:00	129.87		
	RECOVERY			
0	13:10:00	200.	75	Pump off
	13:10:30	154.9		
1	13:11:00	136.		
	13:11:30	120		
2	13:12:00	105.85		
	13.12:30	93.3		
3	13:13:00	83.35		
	13.13.30	75.0		

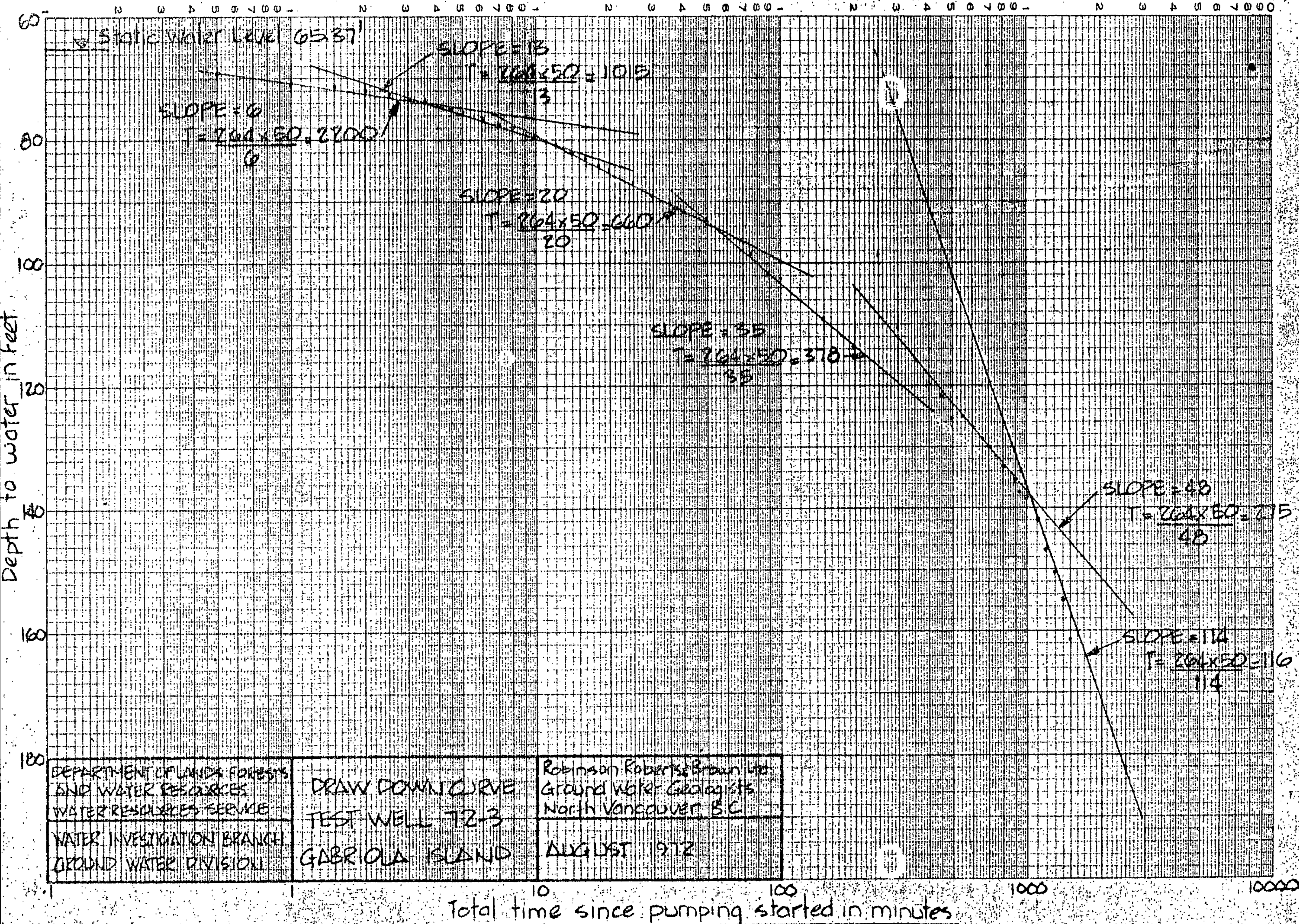
Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
4	13:14:00	67.7		
	13:14:30	61.93		
5	13:15.00	56.66		
6	13:16:00	49.05		
7	13:17:00	44.20		
8	13:18:00	41.43		
9	13:19:00	39.69		
10	13:20:00	38.16		
12	13:22:00	35.53		
14	13:24:00	34.45		
16	13:26:00	32.86		
18	13:28:00	31.97		
20	13:30:00	30.98		
25	13:35:00	29.10		
30	13:40:00	27.2		
35	13:45:00	26.25		
40	13:50:00	25.25		
45	13:55:00	24.5		
50	14:00:00	23.75		Pulled pump
80	14:30:00	20.64		
120	14:50:00	19.10		
145	15:15:00	17.40		
170	15:40:00	15.18		
220	16:30:00	14.30		
285	17:35:00	12:55		
320	18:10:00	11.77		
2540	8:10:00	5.7		Aug 25, 1972
2740	11:30:00	5.2		
7270	15:00:00	.6		Aug 28, 1972

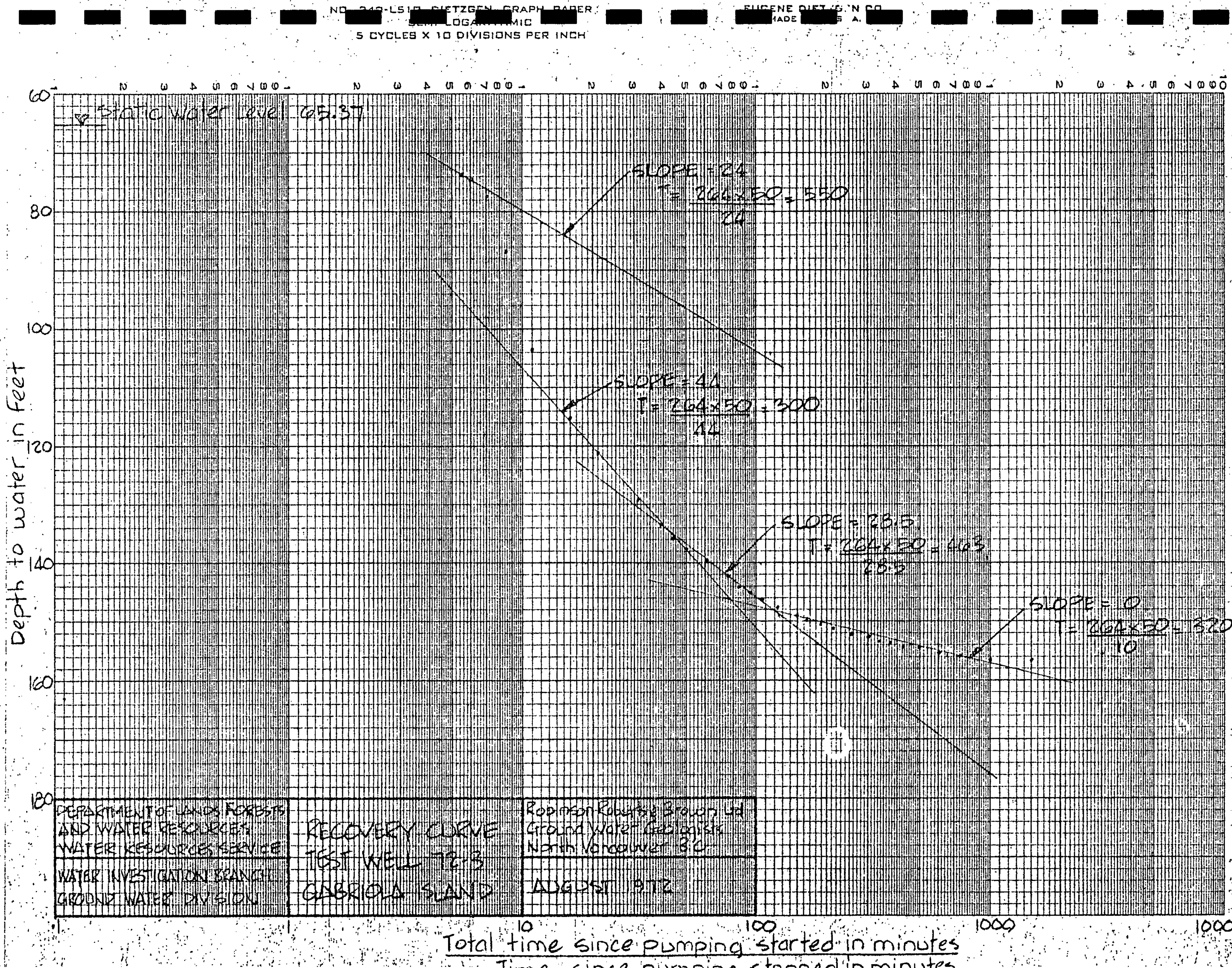
TEST WELL 72-3

This well was test pumped at a rate of 50 US gpm for 1500 minutes. Four negative boundaries were encountered during the pump test. These boundaries reduced the transmissibility of the well from 2200 US gpd/ft. at the start of the test to 116 US gpd/ft. on the last limb of the drawdown curve. The private well that was used as an observation well had a 7 foot decline in water level. The transmissibility as calculated between the pumping hole and the observation well is 1040 US gpd/ft. This figure agrees closely with the 1015 US gpd/ft. obtained on the second leg of the drawdown curve. From the relative depths of the two wells it is felt that this transmissibility is measured along a fracture zone.

The specific capacity of the well after the 1500 minutes of pumping can be no greater than 0.5 gpm per foot of drawdown. The recovery curve is again typical of that of bedrock aquifers with a backward "s" configuration. The lower limb has a transmissibility of 1320, the middle 300 to 460 and the top limb 550 US gpd/ft.

The safe productive potential of the well using a transmissibility of 500 US gpd/ft is judged to be 35 US gpm. At this rate the pumping level should not drop below a depth of 215 feet below ground surface after a 100 day drought.


Static Water Level 65.87
SLOPE = 13
T = 264 x 50 / 13 = 1015
SLOPE = 6
T = 264 x 50 / 6 = 2200
SLOPE = 20
T = 264 x 50 / 20 = 660
SLOPE = 35
T = 264 x 50 / 35 = 378
SLOPE = 48
T = 264 x 50 / 48 = 275
SLOPE = 114
T = 264 x 50 / 114 = 116
Depth to water in feet
60
80
100
120
140
160
180
.1
1
10
100
1000
10000
Total time since pumping started in minutes
DEPARTMENT OF LANDS FORESTS AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
GROUND WATER DIVISION
DRAW DOWN CURVE
TEST WELL 72-3
GABRIOLA ISLAND
Robinson Roberts & Brown Ltd
Ground Water Geologists
North Vancouver, B.C.
AUGUST 1972


SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
Static water Level 65.37
SLOPE = 24
T = 264 x 50 / 24 = 550
SLOPE = 44
T = 264 x 50 / 44 = 300
SLOPE = 28.5
T = 264 x 50 / 28.5 = 463
SLOPE = 0
T = 264 x 50 / 10 = 320
Depth to water in Feet
60
80
100
120
140
160
180
1
10
100
1000
10000
Total time since pumping started in minutes
DEPARTMENT OF LANDS FORESTS AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
GROUND WATER DIVISION
RECOVERY CURVE
TEST WELL 72-3
GABRIOLA ISLAND
Robinson Roberts & Brown Ltd
Ground Water Geologists
North Vancouver B.C.
AUGUST 1972

35

PUMP TEST -WELL #72-3

GABRIOLA ISLAND

Well at house across road is 500 feet away. Its SWL is 37.43 feet @ 8:10

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
				Aug 17, 1972 Cloudy-Cool
	8:25:00	64.61		Static Water Level
0	9:00:00			Pump on
	9:00.30	69.17	50	
1	9:01:00	70.42		
	9:01:30	71.20		
2	9:02:00	71.96		
	9:02:30	72.55		
3	9:03:00	73.25		
	9:03:30	73.78		
4	9:04:00	74.35		
	9:04:30	74.88		
5	9:05:00	75.32	50	
6	9:06:00	76.21		
7	9:07:00	77.14		
8	9:08:00	78.00	50	
9	9:09:00	78.65		
10	9:10:00	79.36		
12	9:12:00	80.54		
14	9:14:00	81.94		
16	9:16:00	82.95		
18	9:18:00	83.93		

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
20	9:20:00	84.81	50	
25	9:25:00	86.70		
30	9:30:00	88.85	50	
35	9:35:00	90.12		
40	9:40:00	91.23		
50	9:50:00	93.69		Obs. Hole 37.38
75	10:15:00	98.63		51^{O}F
100	10:40:00	102.27		
150	11:30:00	108.98		
200	12:20:00	113.45		*
250	13:10:00	98.13		
300	14:00:00	110.79	50	
350	14:50:00	115.78	50	
400	15:40:00	119.20	50	
450	16:30:00	121.62	50	Obs. Hole 42.80
500	17:20:00	125.13	50	
550	18:10:00	125.02		
600	19:00:00	126.77	50	
650	19:50:00	128.49		
700	20:40:00	129.88		
750	21:30:00	131.54		
800	22:20:00	133.22		
850	23:10:00			
900	24:00:00	135.51		
950	00:50:00	137.45		Aug 18, 1972
1000	1:40:00	138.11		
1050	2:30:00	139.00		
1200	5:00:00	146.42		

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
1250	5:50:00	148.45		
1300	6:40:00	150.44		
1350	7:30:00	152.61		
1400	8:20:00	155.04	50	Obs. Well 44.25
1450	9:10:00	158.03	50	
1500	10:00:00	161.66	50	

*Water is still milky like that from a glacier

RECOVERY

0	10:00:00			Pump off
	10:00:30	155.36		
1	10:01:00	156.72		
	10:01:30	156.22		
2	10:02:00	155.70		
	10:02:30	155.20		
3	10:03:00	154.67		
	10:03.30	154.15		
4	10:04:00	153.63		
	10:04:30	153.17		
5	10:05:00	152.75		
6	10:06:00	151.93		
7	10:07:00	151.12		
8	10:08.00	150.40		
9	10:09.00	149.66		
10	10:10:00	148.90		
12	10:12:00	147.46		
14	10:14:00	146.17		
16	10:16:00	144.97		

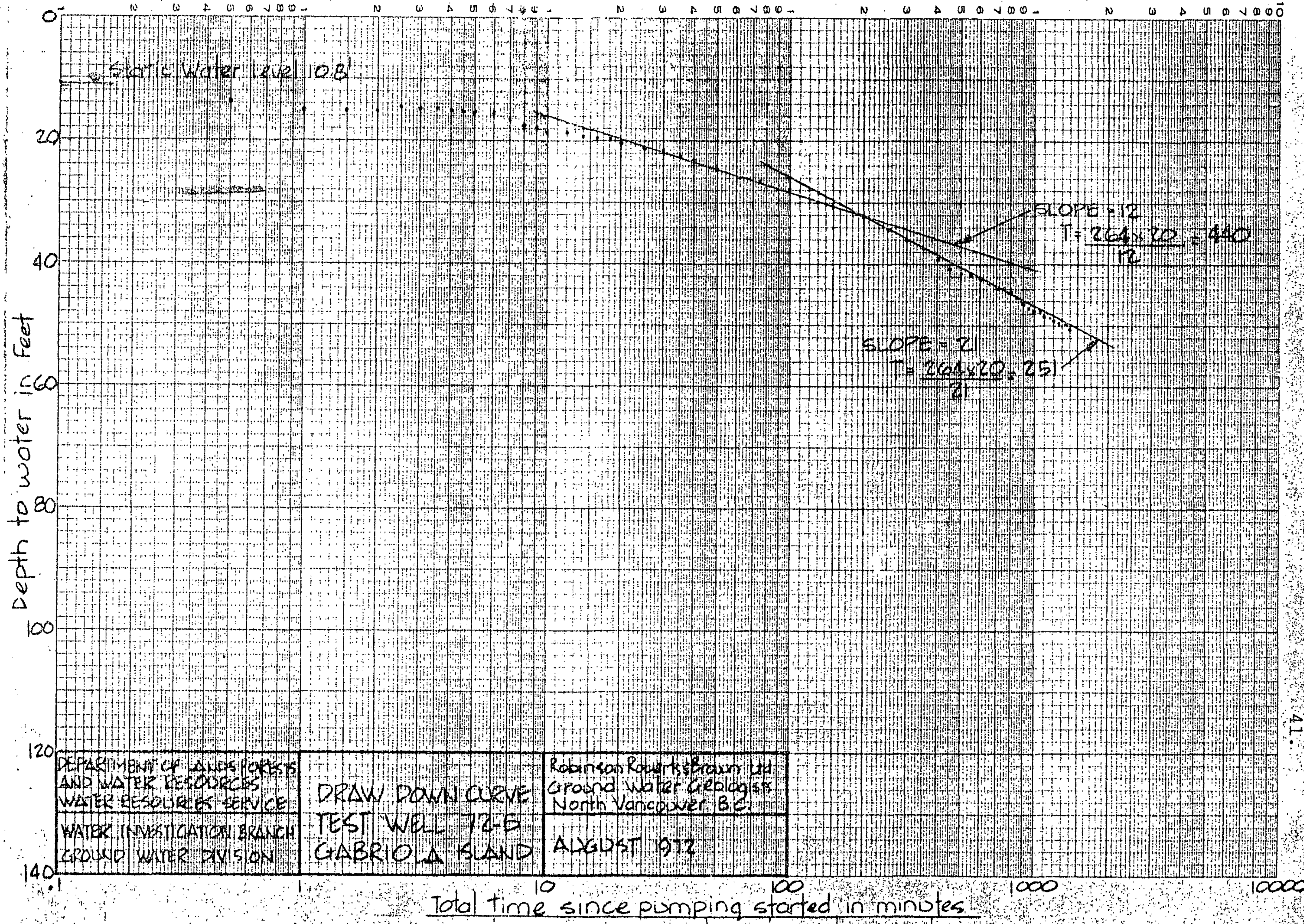
Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
18	10:18:00	143.79		
20	10:20:00	142.63		
25	10:25:00	139.78		
30	10:30:00	137.23		
35	10:35:00	135.38		
40	10:40:00	133.31		
50	10:50:00	129.34		
75	11:15:00	121.42		
100	11:40:00	115.03		
150	12:30:00	103.24		
200	13:20:00	86.77		
250	14:10:00	77.66		
300	15:00:00	74.71		
330	15:30:00	73.65		

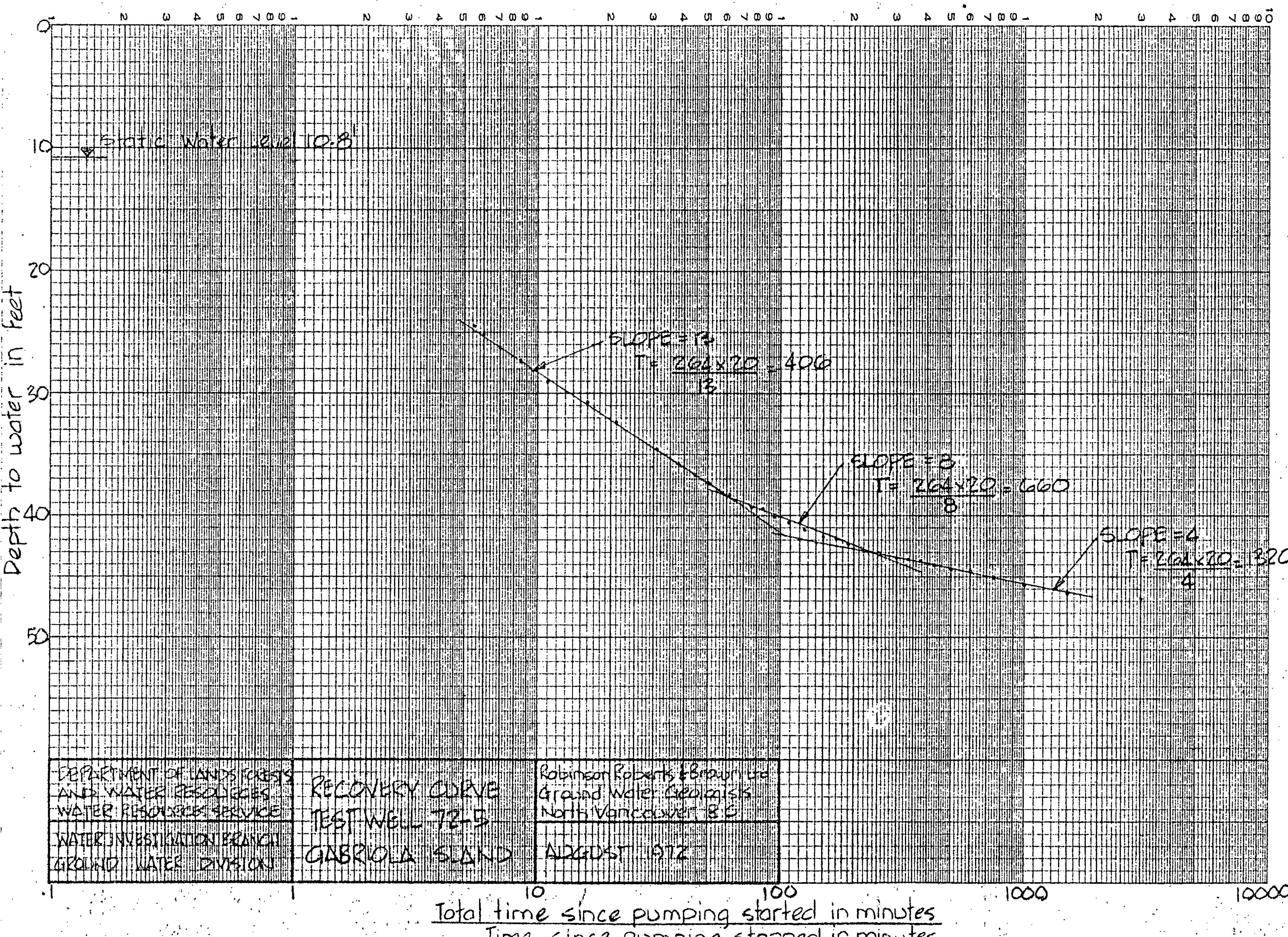
TEST WELL 72-5

This well was pumped at a rate of 20 gpm for 1500 minutes. At the end of the test the pumping level in the well had reached a depth of 50.83 feet below the top of the casing and was nearly stabilized. A plot of the drawdown measurements shows only two limbs with transmissibilities calculated at 440 and 250 US gpd/ft. The plot of the recovery data gives transmissibilities of 1320 on the first leg, 406 on the middle leg, and 660 on the top leg. The specific capacity of the well is no greater than 0.5 gpm per foot of drawdown. The safe production capacity of the well is judged to be 20 gpm.

As can be seen from the above, wells penetrating faults on Gabriola Island have transmissibilities ranging between 20 at 1000 US gpd/ft. A transmissibility of 500 US gpd/ft is judged to be a reasonable design figure. The rock flour present in some fault zones indicates that the transmissibilities will be low (less than 100 US gpd/ft.).

Specific capacities of the wells that were test pumped ranged between 0.05 gpm per foot of drawdown to 0.5 gpm per foot of drawdown.


Static Water Level 10.8'
SLOPE = 12
T = 264x20 / 12 = 440
SLOPE = 21
T = 264x20 / 21 = 251
Depth to water in Feet
Total time since pumping started in minutes
DEPARTMENT OF LANDS FORESTS AND WATER RESOURCES WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH GROUND WATER DIVISION
DRAW DOWN CURVE TEST WELL 72-6 GABRIOLA ISLAND
Robinson Roberts & Brown Ltd Ground Water Geologists North Vancouver, B.C.
AUGUST 1972


Static Water level 10.8'
SLOPE = 13
T= 264x20 / 13 = 406
SLOPE = 8
T= 264x20 / 8 = 660
SLOPE = 4
T= 264x20 / 4 = 320
Depth to water in feet
Total time since pumping started in minutes
DEPARTMENT OF LANDS FORESTS AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
GROUND WATER DIVISION
RECOVERY CURVE
TEST WELL 72-5
GABRIOLA ISLAND
Robinson Roberts & Brown Ltd
Ground Water Geologists
North Vancouver B.C.
AUGUST 1972

42.

GABRIOLA WELL #72-5

DRAWDOWN

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
				Aug 21, 1972
	10:15:00	10.61		Static Water Level
0	10:40:00			Pump on
	10:40:30	13.83	20	
1	10:41:00	14.60		
	10:41:30	14.88		
2	10:42:00	15.02		
	10:42:30	14.69		
3	10:43:00	14.70		
	10:43:30	14.74		
4	10:44:00	14.84		
	10:44:30	15.00		
5	10:45:00	15.31		
6	10:46:00	15.63		
7	10:47:00	16.16	20	
8	10:48:00	17.04		
9	10:49:00	17.93		
10	10:50:00	18.38		
12	10:52:00	18.70		
14	10:54:00	19.13		
16	10:56:00	19.54		
18	10:58:00	19.92		
20	11:00:00	20.28		
25	11:05:00	21.10	20	
30	11:10:00	21.68		
35	11:15:00	22.25		
40	11:20:00	23.07		

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
50	11:30:00	24.27		Milky
75	11:55:00	26.27		52°F
100	12:20:00	27.92		
150	13:10:00	30.37		
200	14:00:00	32.09		
250	14:50:00	34.13		
300	15:40:00	35.98		
350	16:30:00	37.52		
400	17:20:00	39.00		
450	18:10:00	40.50	20	
500	19:00:00	41.21		
550	19:50:00	41.53		
600	20:40:00	42.26		
650	21.30:00	42.91		
700	22:20:00	43.65		
750	23:10:00	44.07		
800	24:00:00	44.42		
850	00:50:00	45.25		Aug 22, 1972
900	1:40:00	46.20	20	
950	2:30:00	46.78	20	
1000	3:20:00	47.11		
1050	4:10:00	47.70		
1100	5:00:00	48.20		
1150	5:50:00	48.62		
1200	6:40:00	48.92		
1250	7:30:00	49.46		
1300	8:20:00	49.10		
1350	9:10:00	49.96	20	
1400	10:00:00	50.40		
1450	10:50:00	50.23		52°F
1500	11:40:00	50.83		

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
		RECOVERY		
0	11:40:00	50.83		Pump off
	11:40:30	46.56		
1	11:41:00	46.17		
	11:41:30	45.60		
2	11:42:00	45.07		
	11:42:30	44.67		
3	11:43:00	44:36		
	11:43:30	44.08		
4	11:44:00	43.82		
	11:44:30	43.62		
5	11:45:00	43.39		
6	11:46:00	42.98		
7	11:47:00	42.66		
8	11:48:00	42:30		
9	11:49:00	41.97		
10	11:50:00	41.67		
12	11:52:00	41.05		
14	11:54:00	40.50		
16	11:56:00	40.00		
18	11:58:00	39.55		
20	12:00:00	39.18		
25	12:05:00	38.22		
30	12:10:00	37.31		
35	12:15:00	36.55		
40	12:20:00	35.89		
50	12:30:00	34.63		
75	12:55:00	32.26		
100	13:20:00	30.60		

Elapsed Time (Minute)	Time (Minute)	Depth to Water (feet)	Discharge U.S. G.P.M.	Remarks
150	14:10:00	29.00		
200	15:00:00	27.25		
250	15:50:00	26.09		
300	16:40:00	25.05		
350	17:30:00	24.42		
400	18:20:00			

RESULTS OF GEOPHYSICAL LOGGING

The traces of logs obtained from resistivity, self potential and gamma ray logging tools are shown on the well logs attached to this report.

The resistivity logs show the difference between the shales and sandstones. However, where the sandstones are fractured and contain slightly saline water, the resistivity curves look like those opposite the shales.

The self potential curves appear to be meaningless. This could be caused by stray electrical currents from electric power lines or other sources.

The Gamma Ray curves are also meaningless. This is probably because of the lack of contrast between the radioactivity of the sandstone and shale.

The Caliper logging device shows where a hole overbreaks and therefore presumably when soft or fractured rock is present. However, the overbreak areas did not correlate with water flows.

From the above, it appears that a fully trained and experienced well site geologist is the most useful and only tool for this type of exploratory drilling program.

GROUNDWATER

INTRODUCTION

Our present (February 1975) interpretation of the Groundwater Geology and Hydrology of Gabriola Island is based upon information and data from the following sources.

1. Numerous studies for private individuals and companies.
2. A study conducted for the Nanaimo Regional District.
3. Inventory of domestic water wells by the Groundwater Division.
4. The drilling and testing program conducted during the summer of 1972 for the Groundwater Division.
5. Experience in evaluating wells and well fields that obtain their water from fractured rock.

EVALUATION OF INFORMATION FROM DOMESTIC WELLS

To date, the great majority of wells drilled on Gabriola Island supply water to individual homes. Few of these wells have been constructed to develop the full productive potential of the groundwater-bearing zones that exist beneath the Island. A home owner, with limited funds, will order drilling stopped when he and the driller consider that the well will supply sufficient water for his needs. Since, the needs of a home can be satisfied with a continuous productive capacity of only 0.41 US gpm, most wells have been stopped when it was judged from the results of primative tests that the productive capacity of the well exceeds 3 gpm. Wells drilled for developers needing water to supply several homes have been stopped when it is judged that their productive potential exceeds 20 gpm. Thus the full productive potential of the water-bearing zones were not tested until the summer of 1972.

The depths of most domestic wells range from 50 to 150 feet. A few wells fall into the 150 to 300 foot depth range while only one is 500 feet in depth. The deeper wells were drilled into the less promising groundwater-bearing areas. If sufficient water had been obtained at shallower depths, drilling would have been stopped. Since 300 feet appeared to be in the spring of 1972, the economic limits for most domestic wells, the 1972 drilling and testing program used wells that approximated this depth.

EVALUATION OF 1972 PROGRAM

The results of test well 72-4 coupled with the results of the domestic wells drilled to date suggest that fractures capable of yielding water to satisfy the requirements of a domestic water supply are present in sandstones remote from major fracture zones. Domestic water wells can be located almost anywhere on Gabriola Island with a reasonable expectation of success.

Test Well 72-1 (cross-section E-E) encountered a major transverse fault at a depth of 217 feet. The thin section of Geoffrey sandstone encountered coupled with the prominence of the surface trace of the zone indicates that the fault is of major proportions. Only 1 gpm of water was encountered in the zone associated with this fault. The fault movement was probably of such a magnitude that rock flour was produced and the fractures were sealed. Also the fault separates a sandstone and a shale section. The shales could have absorbed most of the movements and the fractures became self-sealing. The fault is a longitudinal fault that separates the anticline from the syncline. Longitudinal faults are formed by compression so that they are less apt to develop good fracture permeability and porosity than the cross-faults which have tension fractures associated with them.

Test Well 72-2 was drilled to test the productive potential of a major cross fault that is readily observable on air photos, on ground and at sea coast. As noted earlier, the surface trace of this fault has been deeply eroded probably by glacial plucking and filled with over 70 feet of clays, silts, and sands. It would be interesting to drill a cable tool well into these unconsolidated sediments to test their potential. The clay cap to this zone, very fortunately, will prevent contamination or pollution from near surface waters.

The second location for Test Well 72-2 (as shown on the map) was some distance from the surface trace of the fracture zone. It encountered an excellent water-bearing zone at a depth of 190 feet. This is the contact between a shale and sandstone sequence. Surging increased the initial flow of 16 gpm to 70 gpm. This flow increase was probably caused by the removal of mud made in the hole as the drill cut through the overlying nine feet of shale. The fracture encountered at a depth of 190 feet must be associated with the fault zone observed at ground surface. It cannot be the main fracture zone because the main zone must have a near vertical dip.

Test Well 72-3 is located in a small fault block which has been subjected to shattering. The essentially sandstone section has been fractured in such a manner that the drilling and testing of this well seriously affected a neighboring well.

The anticline crest tested by Test Well 72-5 does not show the degree of fracturing that is usually associated with anticlines. The main water-bearing zone was encountered at a depth of 78 feet which is again at the contact between a shale and sandstone sequence. Surface dips suggest that the axial plane of the anticline dips to the north. If this is true, wells located to the north of the axis an appropriate distance to intersect the axial zone at a depth of, for example, 250 feet might be more productive than well 72-5 because greater available drawdown would exist than was present in Test Well 72-5.

From the above, it would appear that:

1. Longitudinal fault zones are not productive.
2. Fracture zones associated with cross faulting are highly productive.
3. The productivity of a cross fault zone itself was not tested but is believed to be high (experience elsewhere).
4. Shale-sandstone contacts are productive.
5. A 10-foot thick fracture zone encountered from depths of 230 to 240 feet in Test Well 72-4 had a very low productivity. No obvious surface trace of this fault exists so that the fracturing is believed to be caused by bedding plane adjustments which in this case caused self sealing fractures.

AQUIFIC COEFFICIENTS

Pumping tests conducted on wells obtaining groundwater from the shales of the Northumberland formation where they have been affected by fracturing adjacent to a major cross-fault shows that the transmissibility ranges from 1100 to 2200 US gpd/ft. The coefficient of storage for the same area ranges from .0014 to .0072. Preliminary tests on wells located in the Spray shales indicate that the transmissibilities are in the 200 to 350 US gpd/ft range and that the storage is .00005. These figures are for wells that are not related to a fracture zone and may be taken as representative for shales that have only been fractured by folding and not by secondary faulting.

The transmissibility of 72-1 that obtained most of its water near the Spray shale-Geoffrey sandstone contact removed from the fault zone is very low with a full range of 120 to 23 US gpd/ft.

The transmissibility of the fracture zone at 72-2 is believed to be 500 US gpd/ft. The transmissibility of the fractured sandstone in the small fault block tested by 72-3 is also considered to be 500 US gpd/ft and that of the Spray formations near the crest of the anticline to be 500 US gpd/ft. Please see the following summary chart.

Well No.	Depth (feet)	Transmissibility (US gpd/ft)		Safe Productive Yield (US gpm)
		range	design value	
72-1	325	120-23	50	5
72-2	275	1155-148	500	50
72-3	250	2200-116	500	35
72-4		NO PUMP TEST		
72-5	325	1320-250	500	20

STORAGE

Experience with dewatering systems and with wells obtaining water from fractured bedrock aquifers has shown that long pumping tests are required before reliable transmissibility and storage factor values can be calculated.

Storage factor values calculated from the results of short (2 to 5 day) pump tests can be extremely misleading. Before useful design figures for this factor can be calculated the pump test must be run long enough to actually dewater a reasonably large cone around each well. Storage factors obtained from short pump tests before this amount of dewatering is achieved will represent the artesian conditions that exist in the bedrock fracture system. These values will range from 1×10^{-4} to 1×10^{-6}. If these values are used to design a dewatering system the required amount of water level lowering will not be achieved. If they are used to establish safe productive potentials of well fields or of hydrologic regions excessively conservative conclusions will be made. These conclusions could adversely affect the development of an area or be used as a basis to import water into a region with an attendant crushing tax burden on the local inhabitants and the general tax payer.

Our experience indicates that useful design values of storage factors for fractured and fissured bedrock aquifers range from 1×10^{-2} to 1×10^{-3}. This is equivalent to an effective porosity of from 1 to 1/10 of one percent.

Using these values the upper 300 foot zone beneath Gabriola Island will contain an amount of water in storage that is equivalent to an annual discharge of 20,000 gpm to 2,000 gpm. If a storage factor of 1.5×10^{-3} is used the water in storage will equal the estimated annual recharge equivalent of 3,000 gpm (discussed later in this section). An effective porosity of 0.15% for the fractured rock beneath Gabriola Island appears to the writers to be a rationally conservative value. The conclusions given above are based on:

Area of Gabriola Island	- 12,500 acres
Saturated thickness to 300 feet	- 250 feet
Storage factor	- 0.0015
Gallons per acre foot	- 325,850 US gallons
Minutes in a year	- 525,600

$$\frac{12{,}500 \times 250 \times 0.0015 \times 325{,}850}{525{,}600} = 3{,}000 \text{ gpm}$$ (US) 2906

It therefore appears that at full development of the groundwater potential that any water removed can be replenished during the remainder of the year when recharge take place.

Unlike other Gulf Islands, the sandstones and shales forming Gabriola Island were deposited in a near shore to lagoonal environment. Thus a saline water problem other than that caused by sea water encroachment into near shore wells does not exist to a tested depth of 300 feet. Most probably it would not exist within a rock zone over 1000 feet thick.

SAFE PERENNIAL WELL YIELDS

Useful generalizations covering average conditions are very difficult to make for fractured bedrock water-bearing zones because conditions can vary greatly. For example, if a well is located on a fault the rock may be so badly fractured and ground into rock flour that only a limited amount of water can be obtained. Faults have been observed to act as "dams" to regional groundwater flows. The optimum zone for the best productivity per well is outside the highly faulted zone but inside the edge of fracturing.

Properly designed, constructed, cleaned and stabilized wells less than 300 feet deep intersecting shales near fractures should have safe perennial per well yields in the 30 to 50 gpm range. Similar wells in shales not near a fracture zone will have expected safe perennial yields in the 5 to 15 gpm range. Wells intersecting fractured sandstone should have safe yields ranging from 20 to 50 gpm, while those located away from fracture zones will be capable of yielding only enough water to service one household.

POTENTIAL LOCAL RECHARGE

The average annual precipitation recorded at Departure Bay, 5 miles from Gabriola Island is 34 inches. We assume that the average annual precipitation that falls on Gabriola Island will be the same. — Less - rains in Nanaimo "more fog" than on Gab.

Approximately 200 wells were known to exist on Gabriola Island in the fall of 1972. The rated (by drillers and owners) safe productive capacities of these wells totalled approximately 900 gpm. This gives a reasonable average per well yield for wells located without benefit of geologic knowledge of 4.5 gpm.

To analyse recharge, we divided the Island into hydrologic regions. These regions are defined by their topography, lithology of bedrock at or close to ground surface, and presence or absence of fault and fracture zones. The percentage of the average annual precipitation of 34 inches that seeps into the ground for each region was then estimated.

Based upon the percentage of precipitation that is judged to enter the fault and fracture system of the Island, we conclude that a total water equivalent of 3000 gpm is available to recharge the system each year. This is equivalent to an average annual recharge of 4.6 inches or 13.6% of the average annual precipitation of 34 inches. This means that water can be safely withdrawn from the groundwater system at this rate. In years of drought there will be a decline in the general water table and the pumping levels. These will be restored during years of high precipitation. The pumps in all wells must be set so that the bowls are submerged under low water drought conditions. The wells must be located within any particular fracture zone to drain water evenly along the whole zone. Aquifers with fracture permeability having more or less distinct boundaries can be easily overpumped at any one place. The appearance of a constantly lowering water level can suggest erroneously that the productive potential has been exceeded. The well spacing for any given zone must be calculated from coefficients derived from properly supervised and analysed pump tests. The coefficients will also allow the positioning of wells so that salt water intrusion and contamination can be kept minimal.

POTENTIAL REGIONAL RECHARGE

The groundwater-bearing fault and fracture system of Gabriola Island is geologically, and we presume hydrologically, connected to the fracture system that is present along the eastern slope of Vancouver Island. We believe that the sea floors of the intervening channels have their fractures sealed with muds, silts, and in places glacial tills or hardpan. Thus salt water should not enter the system between Vancouver Island and Gabriola Island.

The longitudinal axis of Gabriola Island is 9 miles long. Of this distance approximately 2 miles of fractured rocks are available to transmit groundwater from Vancouver Island. If this water enters the fracture system above an elevation of 1000 feet, the areas of recharge are approximately 6 miles west of Gabriola Island. The calculated transmissibility for 100 feet of fractured rock on Gabriola Island ranges from 1000 to 2200 US gpd/ft. For conservative estimates the lower figure will be used. This means that for a 1000 foot deep fracture zone the transmissibility will rise to 10,000 US gpd/ft. Based on the above, the estimated groundwater flow towards

Gabriola Island from the eastern slope of Vancouver Island is as follows:

$$\frac{\text{2 miles x 10,000 US gpd/ft x 1000 feet}}{\text{6 miles}} = \text{3.3 million US gallons per day}$$

This is equivalent to approximately 2200 gpm. If only half of this water can be economically intercepted then the useable water is equivalent to 1100 gpm. We believe that the quality of the deep flowing water will be acceptable for human consumption because it will be flowing through fractured metamorphosed volcanics and quartzites.

SUMMARY

Based on available information and present experience we judge that the total productive potential of properly located well fields on Gabriola Island will be 3000 US gpm from local recharge and 1100 US gpm from regional recharge. The total 4100 US gpm can serve the water requirements of 10,000 housing units (based on the water consumption rate established by the Water Utilities Division of 0.41 US gpm/unit). If we assume that the average house will contain 3.5 persons, the probable groundwater potential of Gabriola Island will satisfy the requirements of 35,000 people.

WATER QUALITY

Water samples were collected shortly before the end of the pump tests run on four of the wells that were drilled for this study. Water samples were also collected from 14 existing drilled wells that were being pumped for domestic use. Table I summarises the chemical analyses of these groundwaters. It also includes nine analyses of waters taken during other studies from pump tests of wells in the Descanso Bay and False Narrows areas.

A) Test Wells 72-1, 2, 3, 5

Examination of results indicates that the water from four wells:

1. are slightly alkaline
2. are turbid
3. have a high level of suspended matter

4. report high iron readings
5. are essentially sodium bicarbonate or sodium cloride groundwaters
6. contain very low concentrations of calcium, magnesium, and potassium.

The turbidity (see Can Test Report attached), high level of suspended matter and high iron readings should be ignored. Experience with wells producing water from bedrock fractures show that it takes a considerable time to produce clear water. This is particularly true when the wells are drilled with an air rotary type machine. In one instance it took almost six months of constant pumping before the water became crystal clear. In all instances the test wells were pumped for approximately one day.

The following table was drawn to discover whether or not depth was a factor affecting water quality in these four wells.

Test Well	Elevation (ft) water bearing zones	Chlorides ppm	Sulphates ppm	Total of Calcium & Magnessium	Sodium ppm
72-1	225, 102,61,23	15.0	8.6	4.7	110
72-2	-7-, -95	36.5	13.8	2.3	101
72-3	135 to 105	80.0	9.3	6.3	103
72-5	43, -70	120.5	3.7	3.4	158

B) Other Wells

An examination of the water analyses (Table I) shows no obvious relationship between water quality and bedrock geology. Wells with low pH and HCO_3^- concentrations are generally shallow and are located in the recharge zones. These wells generally have relatively high Ca^{+2} and Mg^{+2} concentrations (up to 82.8 and 21.2 ppm respectively). As the water moves through the flow system the Na^+ concentration increases as the Ca^{+2} and Mg^{+2} concentrations decrease. This change would be caused by a cation exchange, Ca^{+2} and Mg^{+2} for Na^+ on the clay minerals in the shales.

Wells located in the low lying areas (groundwater discharge zones) generally have higher Cl^- and SO_4^- concentrations than those wells drilled in higher areas (recharge zones). Sodium ion is the dominant cation in these discharge zones.

There are no obvious cases of salt water intrusion in the wells sampled. Well 37 has high Na^+ and Cl^+ concentrations but SO_4^{-2} is proportionately low. Wells A and F are both located near the coastline, are drilled into artesian aquifers and have low chloride concentrations. The only well that may possibly be contaminated by sea water is well H. Unfortunately there is no detailed log of this well available and it was not possible to determine the depth at which the saline water enters this well.

In general we believe that the salts in the groundwaters on Gabriola Island are derived from salts in the bedrock sediments. The distribution of the bedrock salts do not follow any well defined pattern. Based on observations in Well 72-5 it is possible that the salty zones occur where massive shale beds (probably marine origin) are in contact with more permeable sandstone beds. More field data will be needed to prove the validity of this observation. The water quality does not appear to be simply related to depth of the well. The depth relationship in Well 72-1 to 72-5 was discussed earlier. Other examples such as Well B compared to Well E which shows a decrease of Cl^- concentration with depth illustrates this lack of correlation.

The nature of the groundwater chemistry encountered in a well on Gabriola Island will depend on a number of factors such as:

1. The location of the well with respect to the groundwater flow systems feeding the well.
2. The location and salinity of saline bedrock zones relative to this flow system supplying the well.
3. Cation exchange capacity of the shale.
4. Presence of soluble minerals such as calcite and gypsum.
5. Local Eh - Ph conditions
6. Permeability of the bedrock.

Groundwater Used for Drinking Water: The inorganic water analyses shown in Table I indicates that, with one exception, groundwaters are potable and that most waters meet the criteria set out in the Canadian Drinking Water Standards (1968).

Some results are outlined below:

1. The pH ranged from 6.10 to 8.50. This is within the acceptable limits.
2. The chloride content in all but six wells ranged from 10.5 ppm to 80.0. Three wells had chloride contents that exceeded the preferred level of 250 ppm. (395, 425 and 407 ppm Cl^-). One of these (No. 26) supplies water to the Gabriola Sands Provincial Park. The water quality should therefore be rechecked in early summer.
3. The sulphate concentrations in all waters was very low and were all acceptable.
4. A nitrate concentration of 165 ppm which is above the public health standard (44.3 ppm NO_3) was noted in one well. This concentration was reported to the well owner as soon as the chemical results became known.

TABLE I

Summary of Chemical Analyses of Groundwater Gabriola Island

Sample Code (3)(4)	Section (2)	Approx Depth (ft)	Ions (ppm) (5) HCO_3^-	Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+	pH (1)	TDS ppm
2	12		176	25.0	14.8	2.2	0.3	84.0	1.1	7.7	
3	25		82	28.5	13.0	14.2	4.6	35.0	1.2	6.2	
5	18		284	14.0	14.2	2.7	0.3	120.0	0.7	8.3	
7	2		144	15.5	13.8	28.9	3.8	30.0	1.2	7.2	
8	28		84	65.5	6.8	64.1	21.3	43.0	2.8	6.1	
10	18		172	12.5	3.7	9.8	4.6	52.0	1.2	6.9	
13	20		208	10.5	1.6	7.6	2.4	72.0	2.5	7.6	
25	31		176	13.0	2.5	20.9	5.9	42.0	1.0	7.3	
26	21		222	395.0	16.3	82.8	15.7	220.0	3.5	7.4	
30	5		222	55.5	8.2	4.4	1.4	110.0	1.1	8.2	
32	22		46	19.5	9.3	9.8	7.0	13.0	1.0	6.1	
34	31		194	13.0	13.4	6.7	3.0	81.0	0.7	8.5	
37	21		118	425.0	3.9	41.8	4.3	265.0	1.7	6.9	
47	21		82	44.5	29.4	35.2	5.1	26.0	0.5	6.1	
A	20	60	38	11.0	11.7	6.1	3.9	22.0	0.7	6.3	107
B	12	115	193	40.5	15.8	0.5	1.6	96.0	0.8	8.3	365
C	12	90	208	30.0	19.1	10.5	4.0	74.0	1.9	7.8	362
D	12	90	235	157.5	21.4	22.0	7.3	168.0	1.2	7.7	628
E	12	90	226	166.0	18.7	31.3	14.2	128.0	1.3	7.5	600
F	28	100	200	46.0	12.1	10.4	5.6	89.0	2.2	7.4	385
G	28	100	217	29.0	11.9	1.7	1.7	108.0	1.2	8.5	395
H	28	171	248	407.0	39.4	17.0	12.8	429.0	2.5	8.6	1,200
I	28	100	211	18.0	6.2	1.7	1.3	94.0	1.3	8.2	346
72-1	14	325	258	15.0	8.6	3.1	1.6	110.0	1.0	8.3	410
72-2	6	275	194	36.5	13.8	1.8	0.5	101.0	0.7	8.35	364
72-3	19	250	152	80.0	9.3	5.8	0.5	103.0	1.3	8.10	365
72-5	22	325	238	120.5	3.7	3.1	0.3	158.0	1.5	8.45	540

NOTES:

1. All pH readings were made using the electrometric method in the laboratory a few days after sampling.

2. See sampling locations on Figure

3. Sample A to I are also known by the following identifications in Robinson, Roberts and Brown reports:

A	Gabriola Wildwood Estates Ltd., Descano Bay Subdivision	- Well No. 2
B	" " " " " " "	- Well No. 4
C	" " " " " " "	- Well No. 9
D	" " " " " " "	- Well No. 7
E	" " " " " " "	- Well No. 8
F	" " " " Jenkins Subdivision	- Well No. 1
G	" " " " " "	- Well No. 2
H	" " " " " "	- House Opposite
I	" " " " " "	- Well No. 3

4. These wells are numbered in the same manner as used on the Groundwater Division Figure 4 entitled Gabriola Island Hydrochemical Data Work Sheet. The sampled wells are the same or in close proximity to the wells sampled by the Groundwater Division.

5. All samples analysed in the laboratory by Can Test Ltd. using standard APHA methods.

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Report On Water Samples for Chemical Analysis

File No. 3703 A

Report No.

Reported to Robinson, Roberts & Brown
1632 McGuire
North Vancouver

Date September 11, 1972

We have tested 4 samples of water submitted by you on August 28, 1972 and report as follows:

Sample Identification

The samples were submitted in plastic bottles labelled -

Sample 1	Well #1 - August 23, 1972	9:00 a.m.	Gabriola Island
Sample 2	Well #2 - August 24, 1972		Gabriola Island
Sample 3	Well #3 - August 18, 1972	9:48 a.m.	Gabriola Island
Sample 4	Well #5 - August 22, 1972	11:30 a.m.	Gabriola Island

Method of Testing

The samples were tested in accordance with the procedures set down in "Standard Methods for the Examination of Water and Waste Water" - 13th Edition, published by the American Public Health Association, 1971.

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File No. 3703 A
Page 2

Chemical Analysis of Water Samples

SECTION 6 #5

Test		72-1	72-2	72-3	~~72-4~~ 72-5	
pH (electrometric)		8.30	8.35	8.10	8.45	
Color (Pt-Co scale)		0.5	L 0.5	1.5	L 0.5	ppm
Turbidity (SiO_2 scale)		340.	129.	315.	28.	ppm
Suspended Matter		962.	162.	495.	60.8	ppm
Fixed		902.	136.	458.	50.4	ppm
Volatile		60.	26.	37.	10.4	ppm
Hardness (Calculated)		14.3	6.6	16.6	9.0	ppm
Dissolved Anions						
Alkalinity						
Bicarbonates	HCO_3	258.	194.	152.	238.	ppm
Carbonates	CO_3	2.	1.5	trace	2.5	ppm
Hydroxyl Ion	OH	nil	nil	nil	nil	ppm
Chlorides	Cl	15.0	36.5	80.0	120.5	ppm
Sulfates	SO_4	8.6	13.8	9.3	3.7	ppm
Phosphates	PO_4	L 0.1	L 0.1	L 0.1	L 0.1	ppm
Nitrates	NO_3	L 0.1	L 0.1	L 0.1	L 0.1	ppm
Dissolved Cations						
Silica	SiO_2	12.7	12.4	11.8	11.8	ppm
Iron	Fe	0.07	0.06	0.07	0.05	ppm
Aluminum	Al	L 0.05	L 0.05	L 0.05	L 0.05	ppm
Calcium	Ca	3.1	1.8	5.8	3.1	ppm
Magnesium	Mg	1.6	0.5	0.5	0.3	ppm
Sodium	Na	110.	101.	103.	158.	ppm
Potassium	K	1.0	0.7	1.3	1.5	ppm
Manganese	Mn	L 0.05	L 0.05	L 0.05	L 0.05	ppm
Copper	Cu	0.018	0.009	0.017	0.015	ppm
Lead	Pb	L 0.01	L 0.01	L 0.01	L 0.01	ppm
Zinc	Zn	0.010	0.007	0.007	0.007	ppm
Total Iron	Fe	32.0	30.0	36.0	11.0	ppm
Total Dissolved Solids		410.	364.	365.	540.	ppm
Fixed		281.	266.	289.	420.	ppm
Volatile		129.	98.	76.	120.	ppm

L = less than

Remarks

Examination of the above results indicated that all four water samples were quite similar in composition. All samples were slightly alkaline, high in suspended matter, very low in hardness and moderate to high in dissolved mineralization.

The suspended matter appeared to be a very finely divided silt material which was difficult to remove by filtration because the particles clogged the silter paper. The high total iron contents were associated with this suspended matter.

File No. 3703 A
Page 2

Chemical Analysis of Water Samples

Test		1	2	3	4	
pH (electrometric)		8.30	8.35	8.10	8.45	
Color (Pt-Co scale)		0.5	L 0.5	1.5	L 0.5	ppm
Turbidity (SiO_2 scale)		340.	129.	315.	28.	ppm
Suspended Matter		962.	162.	495.	60.8	ppm
Fixed		902.	136.	458.	50.4	ppm
Volatile		60.	26.	37.	10.4	ppm
Hardness (Calculated)		14.3	6.6	16.6	9.0	ppm
Dissolved Anions						
Alkalinity						
Bicarbonates	HCO_3	258.	194.	152.	238.	ppm
Carbonates	CO_3	2.	1.5	trace	2.5	ppm
Hydroxyl Ion	OH	nil	nil	nil	nil	ppm
Chlorides	Cl	15.0	36.5	80.0	120.5	ppm
Sulfates	SO_4	8.6	13.8	9.3	3.7	ppm
Phosphates	PO_4	L 0.1	L 0.1	L 0.1	L 0.1	ppm
Nitrates	NO_3	L 0.1	L 0.1	L 0.1	L 0.1	ppm
Dissolved Cations						
Silica	SiO_2	12.7	12.4	11.8	11.8	ppm
Iron	Fe	0.07	0.06	0.07	0.05	ppm
Aluminum	Al	L 0.05	L 0.05	L 0.05	L 0.05	ppm
Calcium	Ca	3.1	1.8	5.8	3.1	ppm
Magnesium	Mg	1.6	0.5	0.5	0.3	ppm
Sodium	Na	110.	101.	103.	158.	ppm
Potassium	K	1.0	0.7	1.3	1.5	ppm
Manganese	Mn	L 0.05	L 0.05	L 0.05	L 0.05	ppm
Copper	Cu	0.018	0.009	0.017	0.015	ppm
Lead	Pb	L 0.01	L 0.01	L 0.01	L 0.01	ppm
Zinc	Zn	0.010	0.007	0.007	0.007	ppm
Total Iron	Fe	32.0	30.0	36.0	11.0	ppm
Total Dissolved Solids		410.	364.	365.	540.	ppm
Fixed		281.	266.	289.	420.	ppm
Volatile		129.	98.	76.	120.	ppm

L = less than

Remarks

Examination of the above results indicated that all four water samples were quite similar in composition. All samples were slightly alkaline, high in suspended matter, very low in hardness and moderate to high in dissolved mineralization.

The suspended matter appeared to be a very finely divided silt material which was difficult to remove by filtration because the particles clogged the silter paper. The high total iron contents were associated with this suspended matter.

The dissolved mineralization was primarily sodium bicarbonate and in some instances sodium chloride. The samples contained very little calcium and magnesium.

All samples met the American Public Health Association standards for domestic water supplies on all tests conducted.

Prior to its use for drinking purposes we would recommend that the water be tested for its bacteriological purity.

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Report On Water Samples for Chemical Analysis

File No. 3705 A

Report No.

Reported to Robinson, Roberts & Brown
1632 McGuire
North Vancouver, B.C.

Date September 12, 1972

We have tested 14 samples of water submitted by you on August 28 and 29, 1972 and report as follows:

Sample Identification

The samples were a series of well waters that had been taken on Gabriola Island on August 24 and August 28, 1972. Each sample was submitted to the laboratory in a plastic bottle labelled as to well number and date of sampling.

Method of Testing

The samples were tested in accordance with the procedures set down in "Standard Methods for the Examination of Water and Waste Water" - 13th Edition, published by the American Public Health Association, 1971.

RESULTS OF TESTING

		2	3	5	7	8	10	13	
pH		7.65	6.15	8.30	7.15	6.10	6.90	7.55	
Suspended Matter*		0.9	2.6	6.4	3.6	6.4	0.3	3.2	ppm
Fixed		0.1	0.7	6.2	2.4	3.6	0.3	1.5	ppm
Volatile		0.8	1.9	0.2	1.2	2.8	0	1.7	ppm
Hardness (Calculated)		5.5	55.2	6.8	87.8	247.6	43.4	28.8	ppm
Dissolved Anions									
Alkalinity									
Bicarbonates	HCO_3	176.	82.	284.	144.	84.	172.	208.	ppm
Carbonates	CO_3	nil	nil	1.0	nil	nil	nil	nil	ppm
Hydroxyl Ion	OH	nil	nil	nil	nil	nil	nil	nil	ppm
Chlorides	Cl	25.0	28.5	14.0	15.5	65.5	12.5	10.5	ppm
Sulfates	SO_4	14.8	13.0	14.2	13.8	6.8	3.7	1.6	ppm
Dissolved Cations									
Calcium	Ca	2.2	14.2	2.7	28.9	64.1	9.8	7.6	ppm
Magnesium	Mg	L 0.3	4.6	L 0.3	3.8	21.3	4.6	2.4	ppm
Sodium	Na	84.	35.	120.	30.0	43.	52.	72.	ppm
Potassium	K	1.1	1.2	0.7	1.2	2.8	1.2	2.5	ppm

		25	26	30	32	34	37	47	
pH		7.30	7.35	8.20	6.10	8.50	6.85	6.10	
Suspended Matter*		0.5	2.1	0.8	10.2	1.0	1.4	7.9	ppm
Fixed		0.1	1.5	0.6	9.1	0.6	1.3	6.9	ppm
Volatile		0.4	0.6	0.2	1.1	0.4	0.1	1.0	ppm
Hardness (Calculated)		76.4	271.4	16.7	53.2	29.1	122.1	108.9	ppm
Dissolved Anions									
Alkalinity									
Bicarbonates	HCO_3	176.	222.	222.	46.	194.	118.	82.	ppm
Carbonates	CO_3	nil	nil	trace	nil	1.5	nil	nil	ppm
Hydroxyl Ion	OH	nil	nil	nil	nil	nil	nil	nil	ppm
Chlorides	Cl	13.0	395.	55.5	19.5	13.0	425.	44.5	ppm
Sulfates	SO4	2.5	16.3	8.2	9.3	13.4	3.9	29.4	ppm
Dissolved Cations									
Calcium	Ca	20.9	82.8	4.4	9.8	6.7	41.8	35.2	ppm
Magnesium	Mg	5.9	15.7	1.4	7.0	3.0	4.3	5.1	ppm
Sodium	Na	42.	220.	110.	12.5	81.	265.	26.	ppm
Potassium	K	1.0	3.5	1.1	1.0	0.7	1.7	0.5	ppm

L = less than

* = Samples filtered on 0.45 ± 0.02 micron membrane.

Sampling Dates

Samples taken August 24, 1972 = Well Nos. 5, 25, 26, 30, 34

Samples taken August 28, 1972 = Well Nos. 2, 3, 7, 8, 10, 13, 32, 37, 47

Remarks

The sample from Well No. 8 was also analyzed for nitrates in order to obtain a cation - anion balance. The nitrate (NO_3) content was 165. ppm which was above the public health standard (44.3 ppm NO_3).

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[signature]

D. K. Dixon

FUTURE PROGRAMS

INTRODUCTION

Groundwater is the most economic source of water to satisfy the water needs of the present inhabitants of Gabriola Island. Analyses indicate that the subsurface water-bearing reservoirs presently known to exist beneath the Island can satisfy the water needs of 26,000 inhabitants. Theoretical consideration indicates that another 9,000 inhabitants can possibly be serviced.

If modern geologic and construction techniques are used to locate, design, test and construct the wells the groundwater source will be as reliable as any surface source of imported water.

Groundwater can be used to great economic, environmental and aesthetic advantage during three stages of an areas-population increase:

1. Where the population is small, scattered and with only a few clusters of low density communities.
2. Where the water demand of the population exceeds the productive potential of the subsurface water-bearing reservoirs.
3. Where the water demand of the population equals or exceeds the productive potential of surface sources of imported water.

During Stage 1 development (the state that presently exists on Gabriola Island) groundwater from individual domestic wells or wells serving small community water systems is the only viable source of water. Growth patterns should be planned so that as individual wells become less attractive for economic and health protection reasons the community water systems and wells can be interconnected into an Island wide system.

During Stage 2 when a tax base exists to economically finance imported water the community wells can be used to assist peak loads and to serve isolated or "tag end" areas.

When Stage 3 arrives, all water sources must be developed to their fullest potential.

The following programs should be completed during the next five years to allow the making of more sophisticated estimates of the Island's groundwater potential.

MONITORING PROGRAM

This program should consist of the placing of automatic water level recorders on Test Wells 72-3 and 72-5. Both of these wells are located where the recorders can be protected against vandals.

The shut-in pressure head at Test Well 72-2 should be measured every week. Mr. Bolton who owns the ranch across the road from this well would most probably be prepared to take these readings.

A series of up-to-date charts should be kept which will show the fluctuations of the water level in the wells and the cumulative sum curves of precipitation.

If the wells can be pumped to ensure reliable results it would be extremely interesting to check the water quality every month for one year.

The water samples should be analysed for nitrates, phosphates, chlorides, sulphates, calcium, magnesium and sodium.

DRILLING PROGRAM

At the present time, we believe that the basic structural features of the Island are sufficiently well known. Unfortunately, the stratigraphy of the sedimentary rocks beneath the western-most and eastern-most fault blocks are uncertain. The presence and thickness of Gabriola sandstones in these fault blocks is questionable. Also the groundwater productivity of the fault and fracture zones are uncertain.

We therefore believe that two 500 foot deep wells should be drilled at suitable locations at either end of the Island.

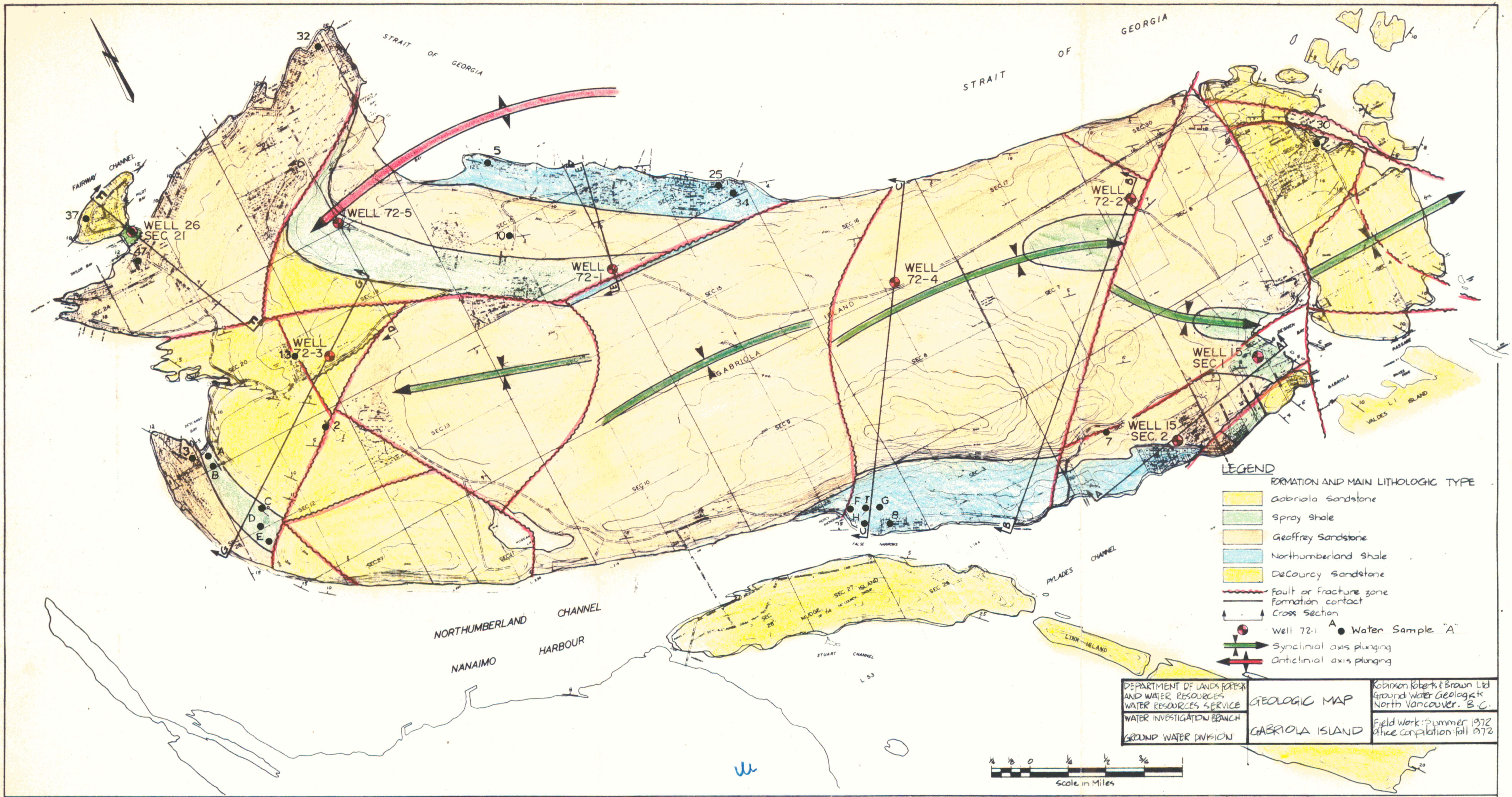
Eventually, one or two deep, 5,000 foot test wells will have to be drilled. These, however, do not appear warranted until the local water demand increases markedly so that the 500 foot deep and shallower water-bearing zones become over taxed. At such a time the economics of obtaining water from deep wells or from the Nanaimo Water District should be studied. If surface water was preferable, the deep tests would not be warranted until the surface source itself became over-taxed.

PROTECTION PROGRAM

The effects of the disposal of effluent from domestic sewerage systems (septic tank or aerated sludge) on the groundwater system should be studied. We would propose to take a small area where both a domestic water system supplied from wells and domestic sewage systems exist. Such areas could be at Silva Bay or Tinson Point.

There has been considerable discussion by numerous people concerning the magnitude of the problems concerning the protection of public health in areas underlain by surface or near surface bedrock. However, no factual studies have been conducted in British Columbia.

Such a study could only be meaningful if most of the local inhabitants co-operated. A relatively detailed map would have to be made of the area in which wells, drain fields, fractures, etc. would be located. Water samples would be collected and analysed for pollution indicators.



the regional district of nanaimo

GEOLOGIC MAP

• Based on surface mapping and test hole data with reference to Muller J.E. and Jeletzky 'Geology of the Upper Cretaceous, Nanaimo Group, Vancouver Island, and Gulf Islands, British Columbia' Geological Survey of Canada Paper 69-25

DATE OF ISSUE: 17-12-1969.
CONTOUR INTERVAL: 25 FEET.

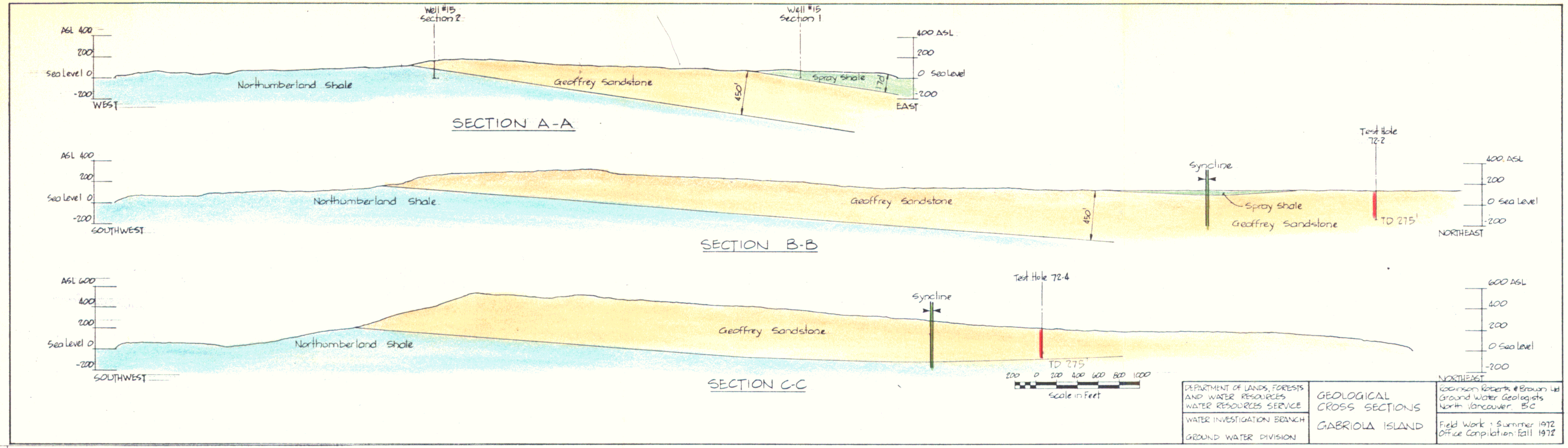
REVISIONS

GABRIOLA ISLAND

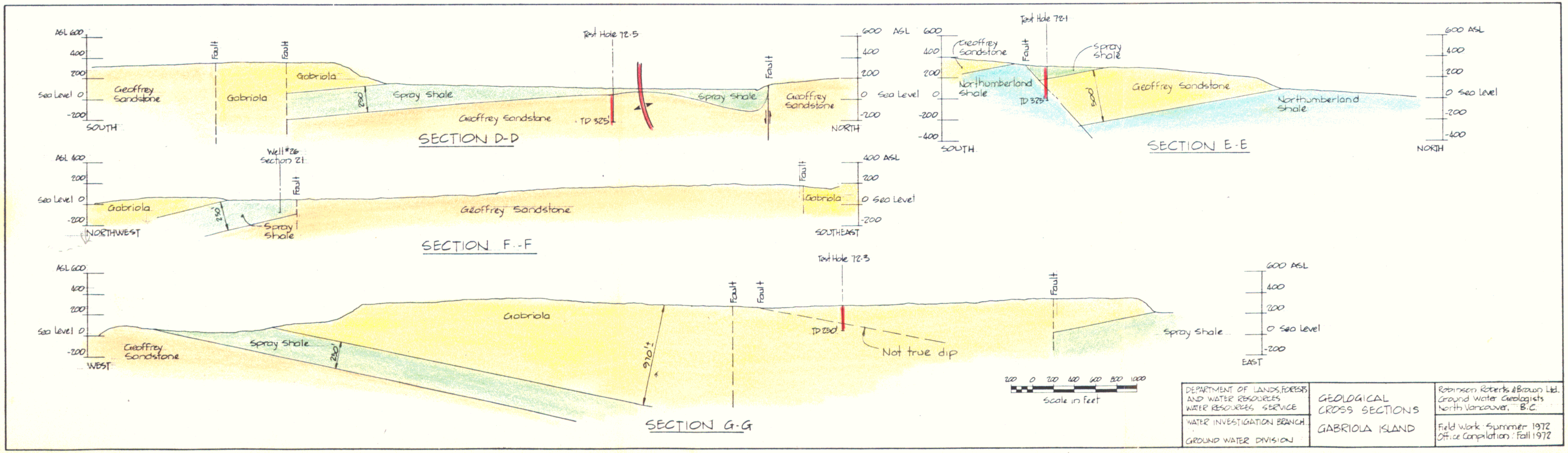
REVISIONS.

• Fall, 1972 · Geology revised to conform with Summer 1972 drilling program. Test Holes located on map. W.L. Brown

PREPARED BY THE PLANNING DEPARTMENT, BASED ON MAPS COMPILED BY THE SURVEYS AND MAPPING BRANCH, DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES, VICTORIA, BRITISH COLUMBIA.



Well #15 Section 2
Well #15 Section 1
ASL 400
200
Sea Level 0
-200
WEST
Northumberland Shale
Geoffrey Sandstone
Spray Shale
450'
70'
400 ASL
200
0 Sea Level
-200
EAST
SECTION A-A
Test Hole 72-2
Syncline
ASL 400
Sea Level 0
SOUTHWEST
Northumberland Shale
Geoffrey Sandstone
Spray Shale
Geoffrey Sandstone
TD 275'
450'
400 ASL
0 Sea Level
NORTHEAST
SECTION B-B
Test Hole 72-4
Syncline
ASL 600
400
200
Sea Level 0
-200
SOUTHWEST
Northumberland Shale
Geoffrey Sandstone
TD 275'
600 ASL
0 Sea Level
NORTHEAST
SECTION C-C
200 0 200 400 600 800 1000
Scale in Feet
DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
GROUND WATER DIVISION
GEOLOGICAL CROSS SECTIONS
GABRIOLA ISLAND
Robinson Roberts & Brown Ltd.
Ground Water Geologists
North Vancouver, B.C.
Field Work : Summer 1972
Office Compilation: Fall 1972



ASL 600
400
200
Sea Level 0
-200
SOUTH
Fault
Fault
Test Hole 72-5
Geoffrey Sandstone
Gabriola
Gabriola
Spray Shale
250'
Geoffrey Sandstone
TD 325'
Spray Shale
Fault
Geoffrey Sandstone
600 ASL
0 Sea Level
NORTH
SECTION D-D
Test Hole 72-1
Geoffrey Sandstone
Fault
Spray Shale
Northumberland Shale
TD 325'
500'
Geoffrey Sandstone
Northumberland Shale
SOUTH
600 ASL
0 Sea Level
-400
NORTH
SECTION E-E
Well #26 Section 21
ASL 400
Sea Level 0
NORTHWEST
Gabriola
250'
Spray Shale
Fault
Geoffrey Sandstone
Fault
Gabriola
400 ASL
0 Sea Level
SOUTHEAST
SECTION F-F
Test Hole 72-3
ASL 600
Sea Level 0
WEST
Geoffrey Sandstone
Spray Shale
250'
Gabriola
970'±
Fault
Fault
TD 250'
Not true dip
Fault
Spray Shale
600 ASL
0 Sea Level
EAST
SECTION G-G
200 0 200 400 600 800 1000
Scale in Feet
DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
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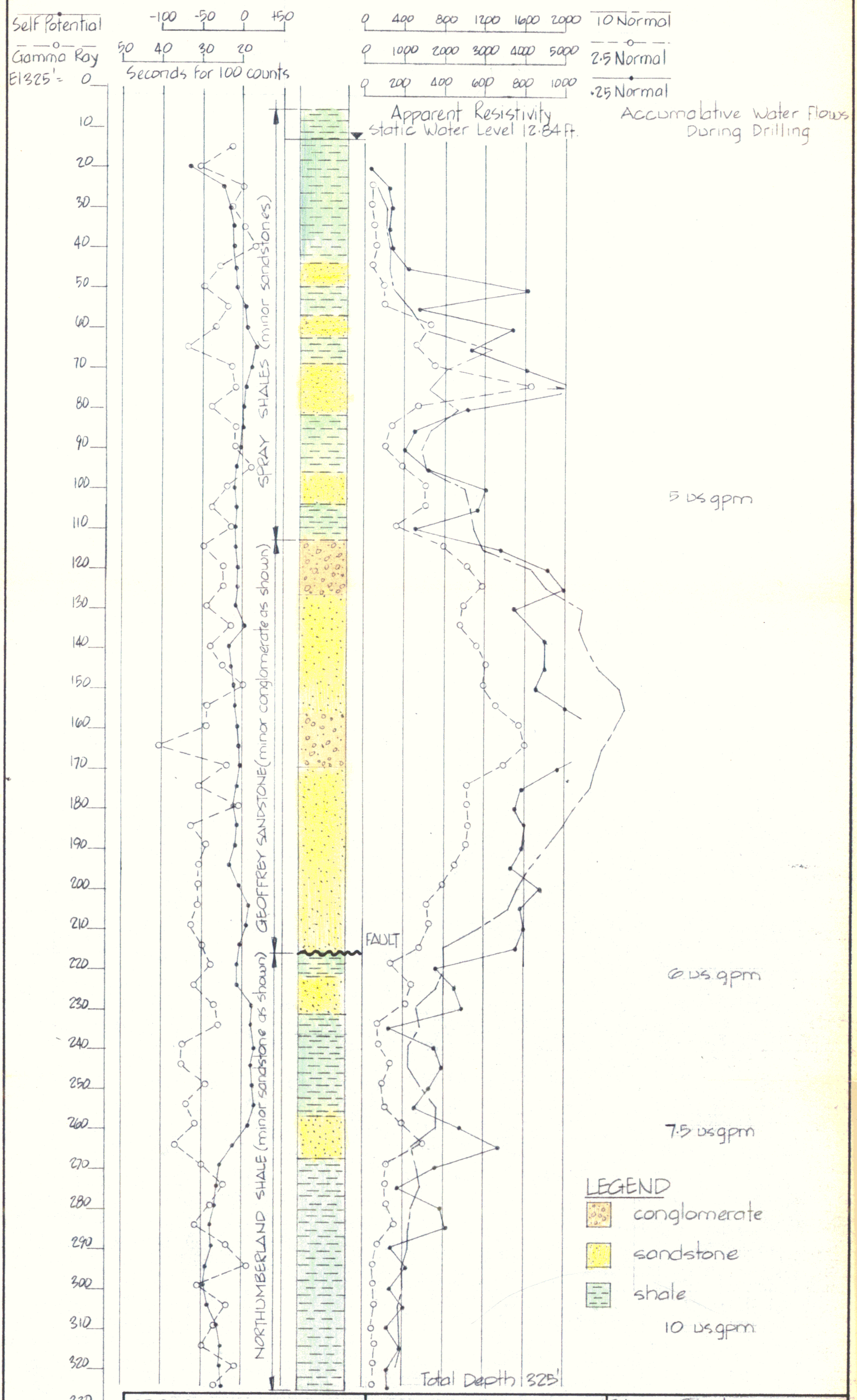
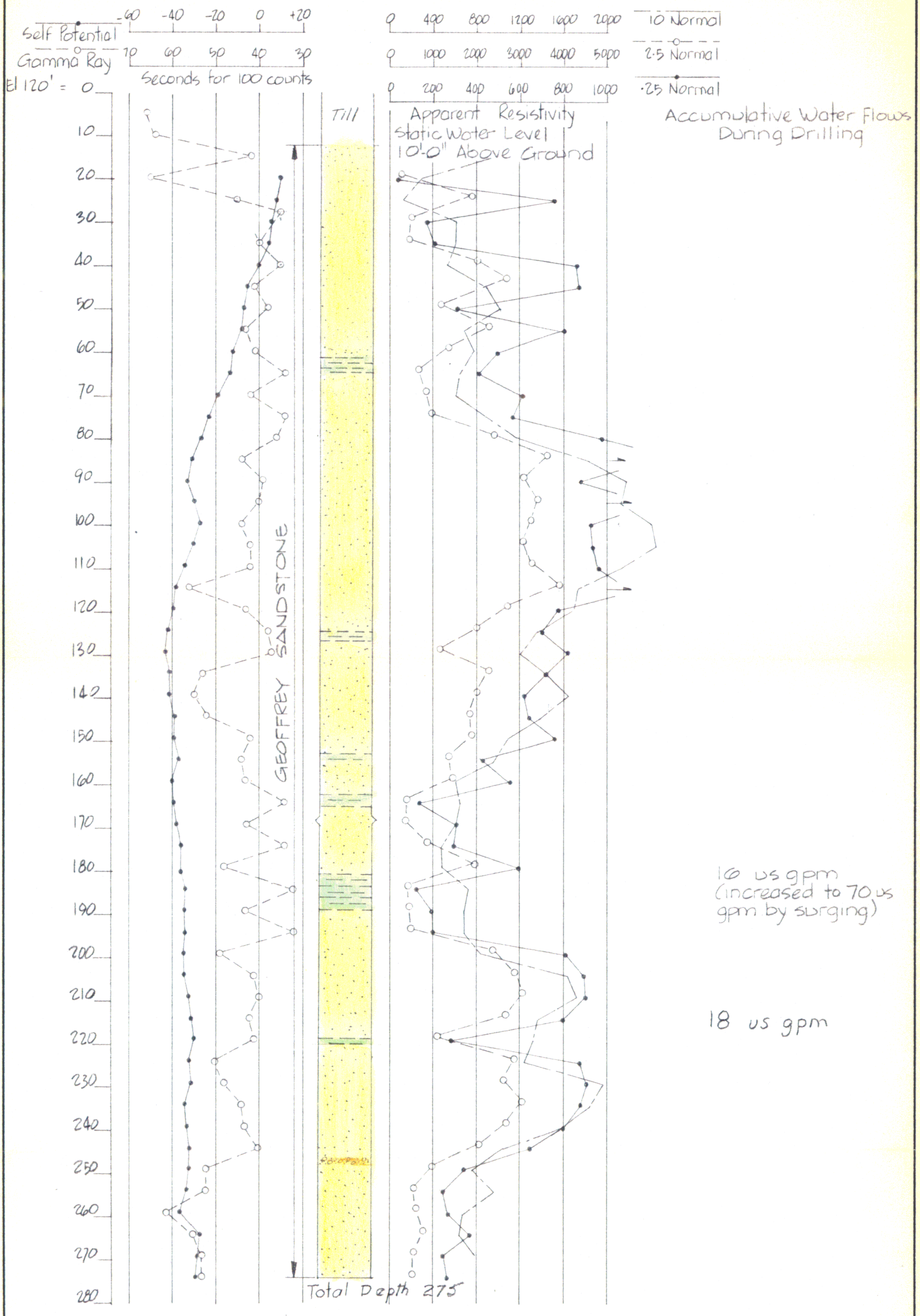


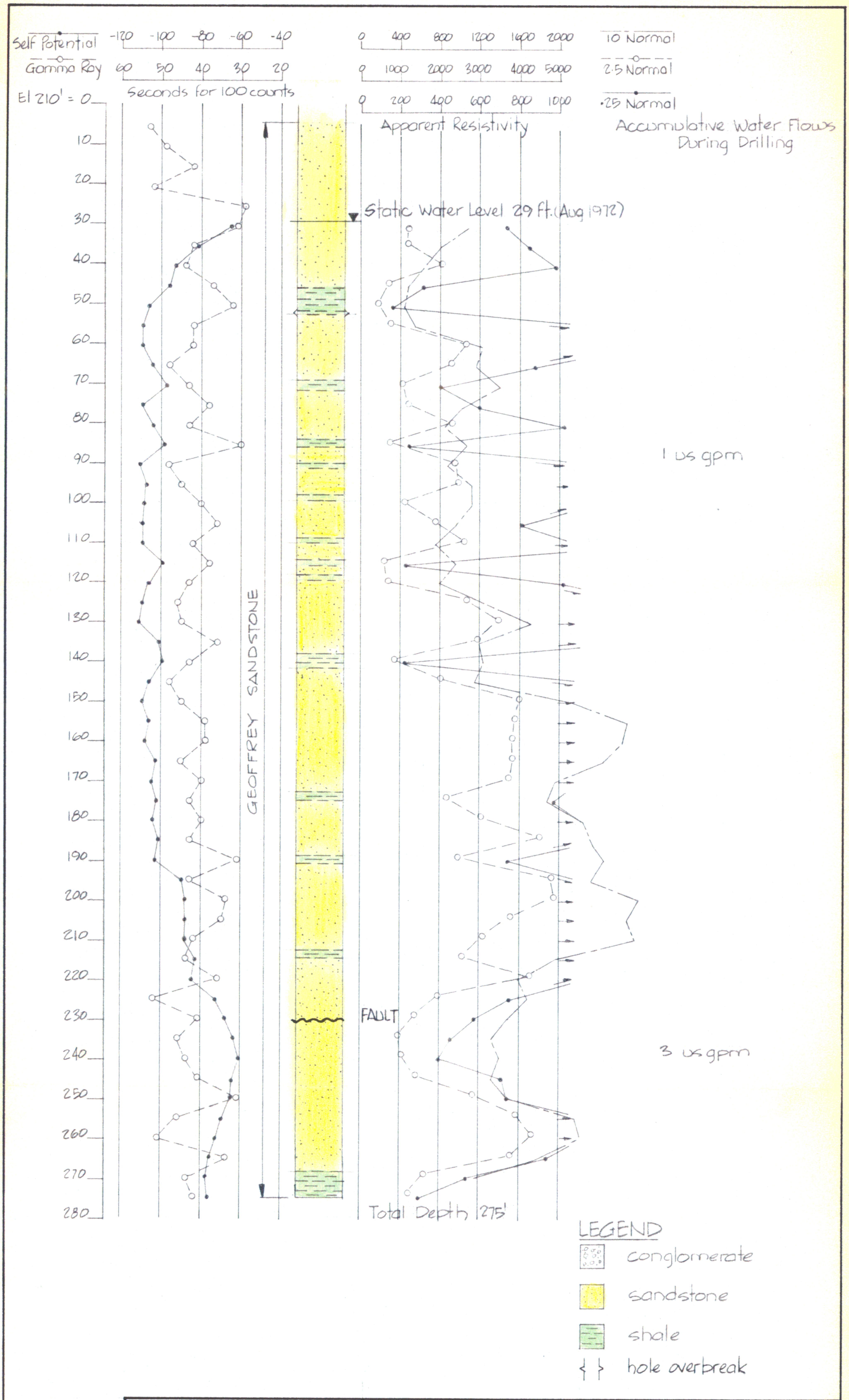
DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES WATER RESOURCES SERVICE	LOG TEST WELL 72-1	Robinson Roberts & Brown Ltd Ground Water Geologists North Vancouver, B.C.
WATER INVESTIGATION BRANCH GROUND WATER DIVISION	GABRIOLA ISLAND	Field Work: Summer 1972 Office Compilation: Fall 1972



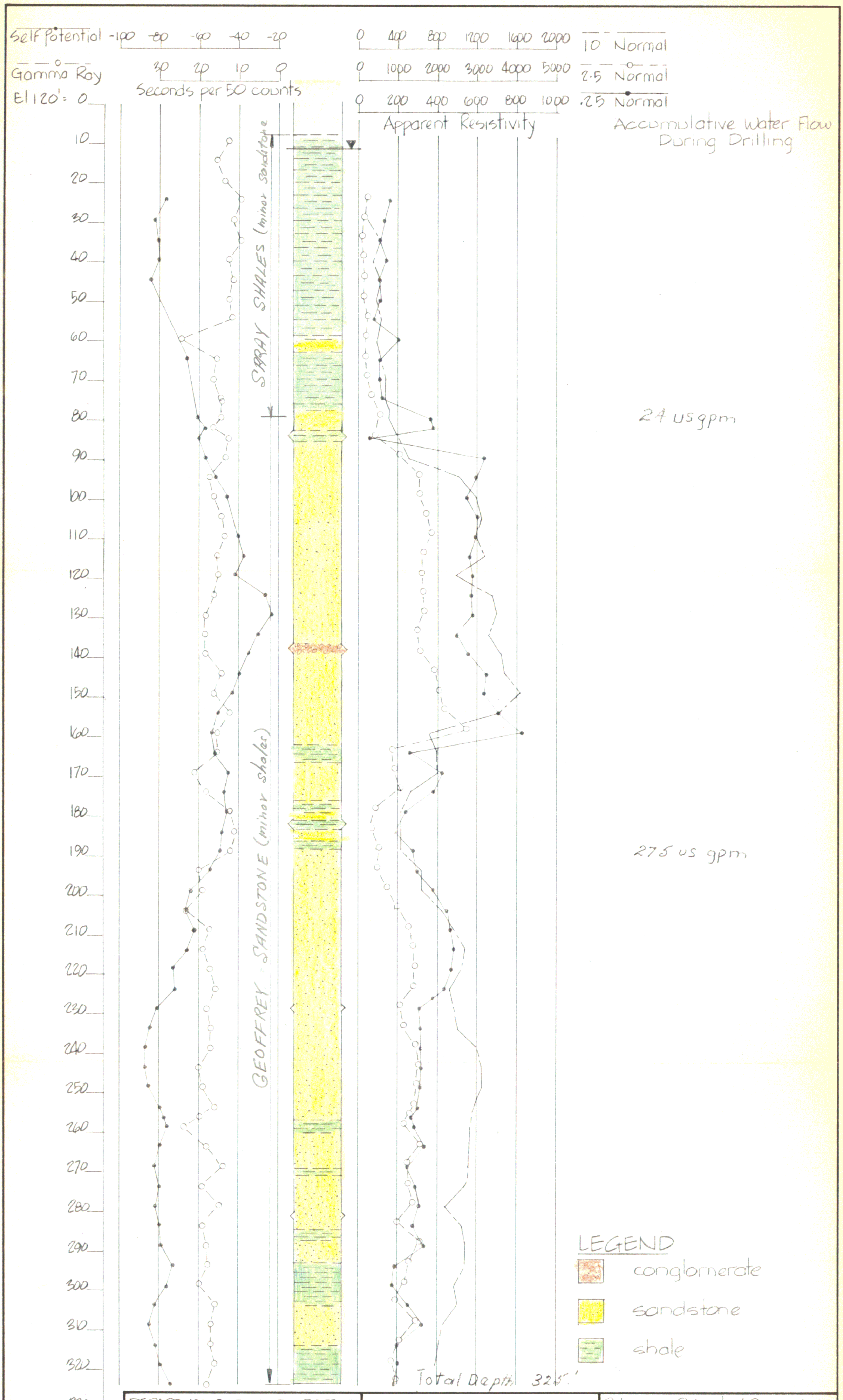
LEGEND

- conglomerate
- sandstone
- shale
- { } hole overbreak

DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES WATER RESOURCES SERVICE	LOG TEST WELL 72-2 GABRIOLA ISLAND	Robinson Roberts & Brown Ltd. Ground Water Geologists North Vancouver, B.C.
WATER INVESTIGATION BRANCH GROUND WATER DIVISION		Field Work: Summer 1972 Office Compilation: Fall 1972



DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES WATER RESOURCES SERVICE	LOG TEST WELL 72-4	Robinson Roberts & Brown Ltd Ground Water Geologists North Vancouver, B.C.
WATER INVESTIGATION BRANCH GROUND WATER DIVISION	GABRIOLA ISLAND	Field Work: Summer 1972 Office Compilation: Fall 1972



DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATION BRANCH
GROUND WATER DIVISION

LOG TEST WELL 72-5
GABRIOLA ISLAND

Robinson Roberts & Brown Ltd
Ground Water Geologists
North Vancouver B.C.

Field Work: Summer 1972
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