LOPEZ ISLAND TEST/OBSERVATION WELL COMPLETION REPORT

by

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This Open File Technical Report presents the results of a hydrologic investigation by the Water Resources Program, Department of Ecology. It is intended as a working document and has received internal review. This report may be circulated to other Agencies and the Public, but it is not a formal Ecology Publication.

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Note: The authors were not present during the drilling and completion of these test holes. This report was written based on field notes by, and verbal communication with, Alan Wald, Marilyn Blair, and Linton Wildrick.

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I. INTRODUCTION

The residents of Lopez Island depend almost entirely on ground water for domestic needs (Whiteman et al, 1983). As a result, there is considerable concern about the quality and continued availability of ground water supplies on the island and in San Juan County in general. Of special concern is seawater intrusion, the movement of saltwater into freshwater aquifers. Seawater intrusion is often caused by pumping of the aquifers for human use and the resultant reduction in ground-water discharge to the sea. Natural disruptions to the hydrologic system such as droughts or a rise in sea level, may have similar effects. Some wells on northern Lopez Island, which previously yielded fresh water, have been abandoned due to high sodium chloride content. It is very likely that these well abandonments were necessary as a result of seawater intrusion.

To assess the magnitude of suspected seawater intrusion, The Department. of Ecology and local planning agencies need additional information about the hydrogeology and groundwater resources of areas prone to seawater intrusion. To aid in this hydrogeologic assessment, the Dept. of Ecology's Water Resources Program drilled three six-inch test holes on the north end of Lopez Island during the winter of 1987. Drilling was contracted to Edmonds Community College's Water Well Technology Program under the direction of Al Butler. An appropriation from the Washington Legislature provided funds. The three test wells provide information on the stratigraphy of glacial deposits, depth to bedrock, and chloride concentrations of the aquifers encountered.

II. WELL LOCATIONS

The three test wells are in a northwest/southeast trending line on the north end of Lopez Island (Figure 1). Test Hole #1 (TH-1) is located north of Ferry Road in the upper reach of the drainage above Shoal Bay and near several, shallower wells for which driller's logs were available. Test Hole #2 (TH-2) is located northwest of the intersection of Center Road and Cross Road, and southeast of the drainage divide between Shoal Bay and Port Stanley. Test Hole #3 (TH-3) is located at the old school house northwest of the third bend of the Port Stanley Road, past Hummel Lake. Locations were selected to provide information about aquifer characteristics in the Port Stanley and Spencer Spit areas.

FIGURE 1
LOPEZ ISLAND TEST/OBSERVATION WELL LOCATION MAP

1 MILE
7000 FEET
1 KILOMETRE

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 5 FEET

T35N–R2W

Test Hole #1 (TH-1)

Location:
Less than 100 feet north of the county road right-of-way,
Parcel #251113002, near the center of section 11, T35N, R2W.

Elevation: 115 feet above mean sea level*

Owners: Charles and Catherine Cochran
Easement Term: 1/8/87 to 1/8/97

Test Hole #2 (TH-2)

Location:
Within 100 feet of the SE corner of parcel #251144005
SE-SE-SE section 11, T35N, R2W.

Elevation: 130 feet above mean sea level*

Owners: Sidney and Jeanne Storer
Easement Term: 1/23/87 to 1/23/97

Test Hole #3 (TH-3)

Location:
Within 100 feet NW of the SE corner of parcel #251331001
E1/2 NE-SW Section 13 T35N, R2W.

Elevation: 90 feet above mean sea level*

Owner: Jack S. Akamine
Easement Term: 1/25/87 to 1/25/97

* Test-hole elevations were picked from the U.S. Geological Survey 1:24,000 scale topographic map and are assumed to be accurate to within ±10 feet (one-half the map contour interval).

III LOPEZ ISLAND GEOLOGY AND WATER RESOURCES

Bedrock Geology

The bedrock of Lopez Island consists of two very different rock types mashed together into a deformed, metamorphosed mixture known as a melange. These two rock types are: 1) Volcanic oceanic crust consisting of pillow basalts, greenstones, and spilite; and 2) Sedimentary rock ranging from deep ocean flysch-type sediments such as turbidites, clays, and shales, to coastal shallow water sediments such as sandstones and conglomerates which contain plant fragments, mudstones, and coal (Brandon, 1989; Cowan and Whetten, 1977; and Whetten 1975).

The igneous oceanic crust was extruded from the Pacific mid-ocean ridge as basalt, probably in Late Jurassic time. The sedimentary rocks were derived from sediments deposited on top of the oceanic crust from continental sources during the Late Jurassic and Early Cretaceous periods. During the processes of plate tectonics, the oceanic crust and overlying sedimentary rocks were carried into the subduction zone trench, at the boundary between the Farallon and North American Plates, and compressed, deformed, and metamorphosed into the jumbled, complex melange found in the San Juan Islands today (Alt and Hyndman, 1984; Burchfiel, 1983; Francheteau, 1983; and Whetten, 1975). The two promontories at the north end of Lopez Island, known as Upright Head and Humphrey Head, are bedrock exposures of sandstones and conglomerates with interbedded small coals, plant fragments, and chert (Whetten, 1975). The three test/observation wells all penetrated through the overlying glacial deposits and into the bedrock melange.

Bedrock Ground-Water Resources

The bedrock of Lopez Island is relatively impermeable, but contains fracture systems which usually yield water at rates of a few gallons per minute, enough for single domestic use (Whetten, 1975). Nevertheless, most water users on Upright and Humphrey Heads rely on public water-supply systems which have wells in higher-yielding, unconsolidated, glacial deposits. The majority of bedrock wells have heads within 20-30 feet of the land surface, even though the water yielding fracture zones may be much deeper (Whetten, 1975).

Glacial Geology

Well logs are the primary source of data about the thickness and extent of the unconsolidated, Pleistocene, glacial deposits which cover most of northern Lopez Island. Glacial deposits outcrop in the sea cliffs near Spencer Spit, Flat Point, and Odlin Park, and at the gravel pit on Port Stanley Road. In general, northern Lopez Island is covered by clay-rich Vashon till, ranging in thickness from zero to 53 feet or more (Whetten, 1975). Beneath the till is a thick sequence of glacial-drift sand and gravel. Sand and gravel deposits are generally thickest on ridges, where wells have penetrated up to 160 feet of these materials. Sea cliff exposures of the upper 50 to 60 feet of these deposits are interpreted as advance outwash, deposited by melt-water streams from an advancing glacier (Whetten, 1975). The sands are cross-bedded and well sorted; gravels may exhibit horizontal or cross-bedded structure with some imbrication.

Clay deposits occupy the valley bottoms at Port Stanley and Shoal Bay, and extend as much as 50 feet below sea level. In places, interstratified silt, sand and gravel layers occur within the clay. Most wells in these areas are completed in water-bearing sand or gravel below the clay. The clay deposits probably consist of lake and alluvial sediments, as well as fine-grained till. These valleys were not protected from advancing glaciers by bedrock to the north, so any advance-outwash deposits which were present could have been scoured out by the advancing glacier. The resulting depressions were then filled by fine-grained till deposits (Perkins, 1986).

Glacial Geology Ground-Water Resources

The majority of wells on northern Lopez Island draw water from the unconfined aquifer located in the advance-outwash sands and gravels. Wells are typically completed zero to 20 feet below sea level. In wells near the shore line, the top of the saturated zone, or "water table", is usually one foot or less above sea level. Water levels are generally less than 10 feet above sea level in wells further inland.

Artesian conditions exist in a few wells in the stream valleys where the water-bearing units are tens of feet below sea level. These units are confined by clay and silt deposits. Water levels in Port Stanley wells are approximately at sea level, and approximately 10 feet above sea level in Shoal Bay wells (Perkins, 1986).

IV. TEST/OBSERVATION WELL CONSTRUCTION

The Lopez Island test/observation wells were drilled by the Water Well Technology Program of Edmonds Community College, under agreement C0087155 with the Washington Department of Ecology. Drilling equipment included a model 2400-R, Bucyrus Erie, air-rotary drill with top-head drive; two Leroy, 250 psi compressors; a Mission, down-hole hammer for hard rock; and a model 2500 Tigre Tierra, casing hammer for sediments. Surface seals were placed with a hydraulically operated grout pump. Locking well caps were placed on all three wells (see Appendix A for design).

Test Hole #1

The drilling of test hole #1 began on February 6, 1987. A six-inch hole was air-rotary drilled, using a tricone bit. Six-inch, steel casing was installed through 128 feet of unconsolidated sediments. Bedrock was encountered at 128 feet [13 feet below mean sea level (bmsl)] and open-hole drilling commenced at that depth. The well was drilled to a total depth of 150 feet (35 feet bmsl). The well casing was perforated with six rows of 1/4 inch openings between the depths of 115 and 125 feet (mean sea level to 10 feet bmsl). The well is open-hole from 128 to 150 feet, ending at 35 feet below mean sea level (Figure 2).

Test Hole #2

The drilling of test hole #2 began on February 19, 1987. A six-inch hole was air-rotary drilled and a six-inch, steel casing was installed through 357 feet of mostly unconsolidated sediments. Bedrock was encountered at about 345 feet [215 feet below mean sea level (bmsl)]. Open-hole drilling began in competent rock at 357 feet and continued to 382.5 feet (252.5 feet bmsl). At this point, the casing was advanced 10 feet in order to blow out about 17 feet of sediment which had collected in the open hole. Open-hole drilling continued to a total depth of 400 feet (270 feet bmsl). The well casing was not perforated and the well is open to water entry only through fractured bedrock from 357 to 400 feet (227 to 270 feet bmsl) and the open end of the casing. It was thought that, due to the fragmented nature of the bedrock, it was not necessary to pull the casing back to expose unconsolidated material (Figure 3).

Test Hole #3

The drilling of test hole #3 began on March 11, 1987. A six-inch hole was drilled by air-rotary methods and six-inch, steel casing was installed through 271.5 feet of unconsolidated sediments. Bedrock was encountered at about 271.5 to 274 feet [181.5 to 184 feet below mean sea level (bmsl)] . The tricone bit was then removed, a pneumatic hammer installed, and open-hole drilling commenced to a total depth of 325 feet (235 feet bmsl). As with test hole #2, the steel casing was not perforated and the well is open to water entry only through fractured bedrock from 271.5 to 325 feet (181.5 to 235 feet bmsl) and the open end of the casing (Figure 4).

V. WATER BEARING ZONES AND WATER LEVELS

Groundwater levels were measured in test holes #1 and #2 periodically during drilling to give a general index of changes in hydraulic head with depth. The measurements where usually taken in the morning before start-up of the equipment. This allowed the water level to stabilize, somewhat, and drill cuttings to settle overnight. Water levels were measured with an Actat electric water-level probe (e-tape).

Test Hole #1

Water-bearing intervals were first encountered at a depth of 112 to 116 feet [3 feet above to 1 foot below mean sea level (bmsl)]. At about 118 feet (3 feet bmsl) the water level was 103 feet below land surface [12 feet above mean sea level (amsl)]. The water level was again measured when drilling reached the depth of 135.5 feet and was 108.5 feet below land surface (6.5 feet amsl). The primary water-bearing unit appears to be a 16-foot-thick unit of sand lying between 112 and 128 feet below land surface (3 feet amsl to 13 feet bmsl).

Test Hole #2

The first water-bearing interval was encountered at a depth of 132-138 feet [2 to 8 feet below mean sea level (bmsl)]. The primary water bearing zone is a 63-foot-thick unit of sand and gravel between 132 and 195 feet (2 and 65 feet bmsl). At a drilling depth of 138 feet (8 feet bmsl) the measured water level was 126.6 feet below land surface (3 feet amsl). The water level was 127.4 feet when drilling had reached the depth of 158 feet (28 feet bmsl). Attempts to obtain water-level measurements as drilling continued were unsuccessful.

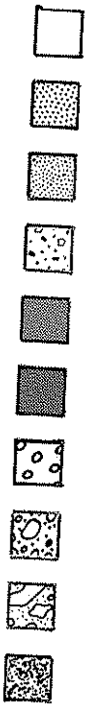
A second major, water-bearing zone exists between 264 and 310 feet below land surface (134 and 180 feet bmsl). This 46-foot-thick unit consists of sand and gravel. Water-producing zones were also encountered at 314-335 feet and 345-357 feet (184-205 and 215-357 feet bmsl, respectively). Water production below bedrock level (~345 feet) might derive from the fractured bedrock material, but may be derived from water flowing down the well annulus from overlying, unconsolidated material.

Test Hole #3

The first water-bearing zone encountered in this well was a 6-foot-thick unit of clay with a trace of sand and gravel between the depths of 94 and 100 feet [4 & 10 feet below mean sea level (bmsl)]. Water production in this zone was only about 2 gallons per minute (gpm). Water was also found in a narrow band of sediments occurring between 126 and 128 feet deep (36 & 38 feet bmsl); water production was about 5 gpm. An 8-foot-thick zone of water-bearing sediments was found between 138 and 144 feet deep (48 & 54 feet bmsl); water production was about 6 gpm. A fourth water-bearing zone was found between 196 and 199 feet deep (106 & 109 feet bmsl); water production was 3 to 4 gpm. A fifth lens of water-bearing sediments occurred between 215 and 219 feet deep (125 & 129 feet bmsl); water production was only 1 gpm. Apparently, there was also water being produced from the bedrock since a water sample was collected at a depth of 274 feet (184 feet bmsl) and analyzed for chlorides. No water levels were measured during the drilling of test hole #3.

FIGURE 5
LEGEND FOR FIGURES 2–4

LITHOLOGIC LOG



TOP SOIL

CLEAN SAND

SILTY SAND

MEDIUM TO COARSE SAND WITH SOME GRAVEL

FINE SANDS, SILTS WITH CLAY, TIGHT

CLAY, CLAY WITH SILT, VERY TIGHT

FINE TO MEDIUM GRAVEL WITH SAND

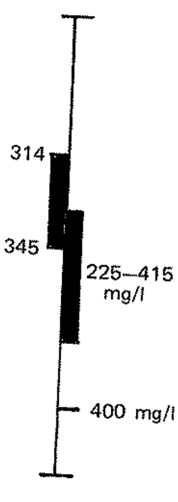
MEDIUM TO COARSE GRAVEL, WITH SAND

MEDIUM TO COARSE GRAVEL WITH FINE GRAINED SILT & CLAY MATRIX (TILL)

BEDROCK–UNDIFFERENTIATED

WATER AND WATER QUALITY

INDICATES A WATER BEARING ZONE WAS ENCOUNTERED FROM 314 FEET TO 345 FEET BELOW LAND SURFACE.



INDICATES A SERIES OF WATER SAMPLES WERE TAKEN AND ANALYZED FOR CHLORIDE CONCENTRATION ACROSS THE MARKED INTERVAL. THE RANGE OF CHLORIDE CONCENTRATIONS ARE SHOWN IN MILLIGRAMS PER LITER. (SEE TABLES 1, 2 OR 3 FOR DETAILED LISTING OF CHLORIDE CONCENTRATIONS)

INDICATES WATER SAMPLE WAS COLLECTED AT THIS DEPTH, ANALIZED, AND FOUND TO HAVE THE INDICATED CHORIDE CONCENTRATION, IN MILLIGRAMS PER LITER.

VI. WATER QUALITY - CHLORIDE CONCENTRATIONS

Ground water encountered during drilling was sampled and analyzed for chloride and sodium-chloride concentrations. Water samples were collected using the following method:

1. When a significant water-production zone was encountered, drilling was stopped;
2. the casing was advanced to the approximate top of the water-producing zone;
3. the water in the drill hole was air lifted from the well in order to clear drilling fluids from the well;
4. the well was allowed to recover for an appropriate (but unspecified) amount of time, and;
5. the well was air lifted a second time and a water-quality sample was taken from the water evacuated during this second air lift.

Water samples were analyzed for chloride concentrations at the well site using a Hach, Model 7-P, test kit, a silver nitrate titration (Mohr) method. Water samples were collected at various depths in each well (see Tables 1 thru 3). Samples were left undisturbed overnight to allow sediments to settle. A small portion of the water sample was then decanted for analysis. Results are presented in Tables 1, 2, and 3.

The United States Environmental Protection Agency has a recommended drinking water threshold, for chloride concentrations, of 250 milligrams per liter (mg/l). Test hole #1 had chloride concentrations of 75 mg/l or less at all depths. Test holes #2 and #3 both showed steadily increasing chloride concentrations with depth. In test hole #2 only water produced from the first aquifer at 132 to 195 feet deep [2 to 65 feet below mean sea level (bmsl)] had chloride concentrations of less than 250 mg/l. Test hole #3 had only one sample indicating a chloride concentration above 250 mg/l. This sample was collected at 269 feet from the surface (179 feet bmsl).

TABLE 1

Chloride Concentrations in Test Hole #1

Water Sample Number	Depth of Sample (feet)	Elevation (feet)*	Chloride Concentration (mg/l)
1	120	-5	60
2	122	-7	60
3	124	-9	75
4	125	-10	60
5	126	-11	75
6	127	-12	60
7	127	-12	40
8	128	-13	60
9	129	-14	45
10	129	-14	50
11	129	-14	50
12	136	-21	45
13	140	-25	50
14	140	-25	50
15	140	-25	57
16	150	-35	53
17	150	-35	45

* Negative elevations indicate number of feet below mean sea level.

TABLE 2

Chloride Concentrations in Test Hole #2

Water Sample Number	Depth of Sample (feet)	Elevation (feet)*	Chloride Concentration (mg/l)
1	132	-2	121
2	134	-4	114
3	135	-5	121
4	136	-6	76
5	137	-7	64
6	138	-8	64
7	138	-8	57
8	140	-10	60
9	141	-11	60
10	142	-12	60
11	143	-13	57
12	144	-14	64
13	145	-15	72
14	147	-17	76
15	150	-20	76
16	152	-22	76
17	155	-25	83
18	157	-27	83
20	164	-34	87
21	166	-36	83
22	170	-40	87
23	172	-42	83

TABLE 2

Chloride Concentrations in Test Hole #2

Water Sample Number	Depth of Sample (feet)	Elevation (feet)*	Chloride Concentration (mg/l)
24	175	-45	80
25	177	-47	83
26	178	-48	83
27	180	-50	83
28	183	-53	87
29	186	-56	72
30	191	-61	83
31	195	-65	98
32	207	-77	159
33	265	-135	394
34	265	-135	394
35	273	-143	409
36	273	-143	439
37	278	-148	409
38	296	-166	425
39	301	-171	425
40	307	-177	470
41	315	-185	485
42	320	-190	485
43	324	-194	485
44	329	-199	530
45	335	-205	425

TABLE 2

Chloride Concentrations in Test Hole #2

Water Sample Number	Depth of Sample (feet)	Elevation (feet)*	Chloride Concentration (mg/l)
46	338	-208	379
47	345	-215	379
48	345	-215	379
49	350	-220	425
50	355	-225	379
51	368	-238	379
52	370	-240	575
53	375	-245	700
54	377	-247	606
55	382.5	-253	700
56	400	-270	700
57	400	-270	830

* Negative elevations indicate number of feet below mean sea level.

TABLE 3

Chloride Concentrations in Test Hole #3

Water Sample Number	Depth of Sample (feet)	Elevation (feet)*	Chloride Concentration (mg/l)
1	96	-6	53
2	127	-37	53
3	140	-50	53
4	199	-109	76
5	219	-129	102
6	269	-179	364
7	274	-184	166

* Negative elevations indicate number of feet below mean sea level.

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APPENDIX A
WELL CAP DESIGN

(NOT TO SCALE)