Ground-Water Interactions Near the Highway Pond Gravel Pit, Pocatello, Idaho

John A. Welhan

Idaho Geological Survey
Morrill Hall, Third Floor
University of Idaho
Moscow, Idaho 83844-3014

Staff Report 01-3
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John A. Welhan[1]

SUMMARY AND PURPOSE

Relevant information which bears on the physical context and possible impact of the Highway Pond gravel pit and water exposed therein on local ground water and domestic wells is assembled and reviewed for the purpose of assisting authorities in making informed decisions concerning environmental impacts on the water resource, future public access and recreational uses, and reclamation plans for the gravel pit. It is not the intent of this report to identify and evaluate all possible contamination sources which have adversely impacted the water quality of nearby domestic wells, but rather to identify and evaluate those factors which could contribute to the Pond's possible impact on ground-water quality.

INTRODUCTION AND BACKGROUND

GEOLOGIC BACKGROUND

The study area (Figure 1) is located south of the City of Pocatello's incorporated area, on the floor of the lower Portneuf River valley (LPRV), adjacent to and northwest of land recently annexed by the city for School District 25's Century High School. It comprises the area immediately surrounding the Idaho Transportation Department (ITD) gravel pit, and overlies the eastern portion of the gravel aquifer on which more than half of Pocatello's municipal wells draw their water.

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[1] Idaho Geological Survey, Branch Office at Pocatello, Idaho State University, Pocatello

The geological setting of the Highway Pond has been described in detail by Welhan and Meehan (1994) and Welhan et al. (1996). Figure 2 shows the general configuration of coarse, relatively well-sorted, highly permeable gravel (Upper Gravels, of high permeability) overlying a deeper, poorly-sorted, silt- and clay-rich gravel (Tertiary Gravels) whose permeability is much lower. A layer of silt loam covers the valley floor to a depth of 5-40 feet. The upper gravel unit has been mined since the mid-1960s, and hosts the aquifer from which municipal and private wells draw water in the southern LPRV. The Highway Pond gravel pit is an area in which the protective, low-permeability silt loam unit has been removed to expose the underlying permeable gravels and the water table when it intersects the elevation of the gravel pit floor. The elevation of water in the pit mimics the elevation of water in nearby wells and is chemically very similar to local ground water. With one exception, all wells referenced in this study are completed in the shallow, upper aquifer gravel unit; only Hildreth Well 4 is completed in the deeper aquifer gravel unit.

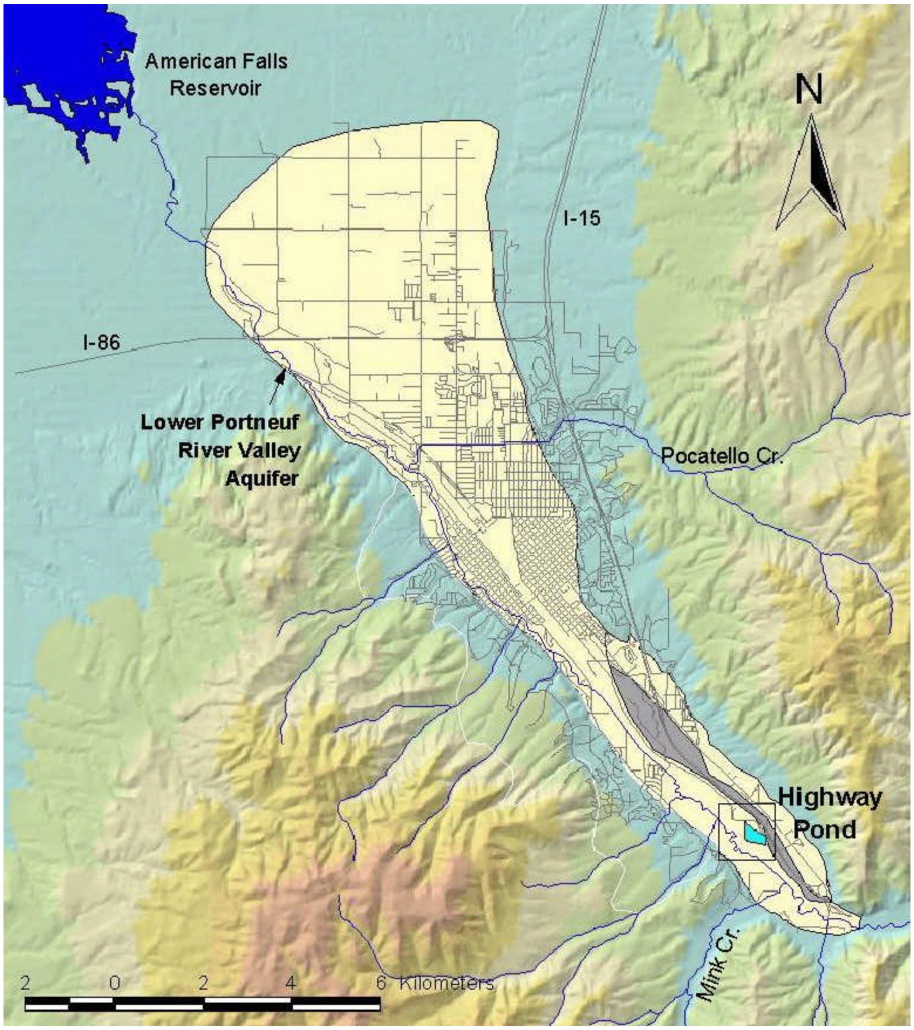

Figure 1. Location of the study area (rectangle) in the lower Portneuf River valley.

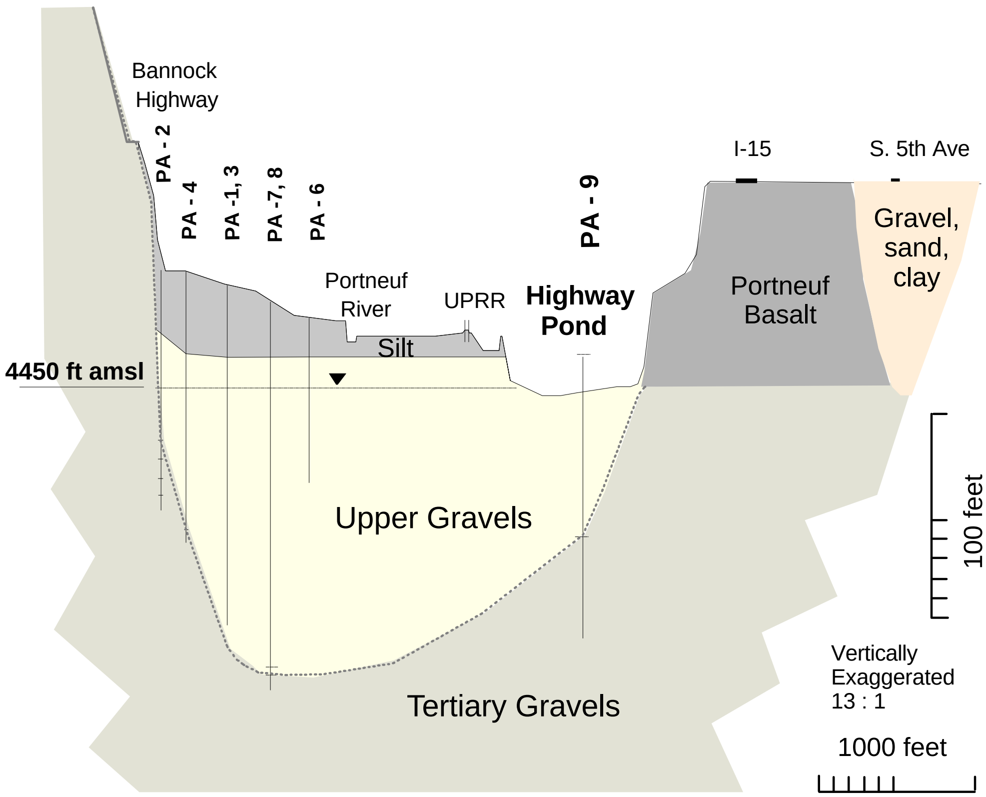

Figure 2. Geologic cross-section across the valley in the area of the Highway Pond, based on geologic information and cross-section in Welhan et al. (1996). developed from drilling data obtained by CH²M-Hill (1995) and elevation information in this report. Elevation of the water table based on well PA-9 agrees almost exactly with the elevation of Pond water in the gravel pit on May 9, 2000.

HISTORICAL SUMMARY

The Highway Pond gravel pit was first excavated during the construction of Interstate-15. Since then, one or more surface water bodies have existed at various times and to varying degrees in the gravel pit; this collection of water bodies has come to be known as the Highway Pond. Throughout this report, this water body will be referred to as the Highway Pond or simply, the Pond.

The U.S. Geological Survey 1:24,000 topographic map of the Pocatello-South quadrangle depicts the Highway Pond as one large, contiguous water body. The map represents features which existed at the time of compilation in 1971 and was photo-inspected in 1974 prior to publication, so it can be surmised that this extensive surface area of water-filled gravel pit known as the Highway Pond persisted during this period of time. In contrast, during the latter years of the drought of 1986-1993, the gravel pit was essentially empty.

The degree to which the gravel pit has been water-filled has varied over time: from completely dry in the last major drought (1986-1993), to completely full in the early 1970s and again in the mid-1980s. In mid-1996, the Pond was at its highest level in the past decade, with most of the floor of the gravel pit submerged. Since about mid-1998 and as of May, 2000, the gravel pit has contained no water except in an approximately one-acre area that was intentionally deepened in early 1996.

The Highway Pond has been a popular location for anglers since the Idaho Department of Fish and Game (IDFG) began stocking the Pond with trout fingerlings ca. 1977 (several years after a local resident, Mr. Bud Hildreth, demonstrated the feasibility of doing so). A portion of the gravel pit was intentionally deepened in 1996, with the intent of promoting a year-round stocked trout fishery. The Pond provides a recreational area conveniently close to the city for canoeists and kayakers, plus space and trails for off-road and all-terrain vehicle enthusiasts in the mined and unmined areas surrounding the Pond.

Public access to the Pond and gravel pit has not been regulated in the past, other than during gravel extraction and crushing operations. Thus, vehicles of all sorts, including cars and trucks, have driven to and parked at the water's edge, leaving litter, used motor oil, auto batteries, scrap metal and plastic, and assorted garbage in and around the pit; dog and gull feces are found over the entire pit area, and portable toilets installed by IDFG have been vandalized and on occasion overturned into the Pond. Dumping of refuse (domestic waste, raw sewage, hazardous materials, and plant and tree waste) and vandalism in and around the pit area (including signs posted by IDFG and ITD) has been a long-standing problem.

Since 1996, Mr. Hildreth has contended that coliform / e.coli bacterial contamination of his private well originates from the Highway Pond. Of seven samples of Pond water collected since September, 1997 from open water in the gravel pit, all have contained total coliform and six have had e. coli bacteria. A study commissioned by ITD (Rocky Mountain Environmental, 1997) did not rule out the Pond as a possible source of bacterial contamination in the well, and pointed out that other possible sources were present, including local seepage along an improper or nonexistent surface seal at the well in question.

Because of the exposure of the aquifer gravels due to removal of soil cover in the mined areas in the Highway Pond pit, the City of Pocatello has been concerned about the possible impact of the Pond on water quality in the aquifer. In particular, the City is concerned that uncontrolled public access to the Pond increases the risk of accidental or intentional releases of contaminants to the Pond and thence to the aquifer. Discussions between the City, ITD and IDFG over the possible risk posed by the Highway Pond commenced in late 1996. At the request of the City, a working group chaired by the Idaho Geological Survey was convened in 1999 to assess the situation and make recommendations. The working group included the original parties, Bannock Paving (a private aggregate mining concern), Mr. Hildreth and concerned citizens, and various regulatory agencies, including District Health, Idaho Division of Environmental Quality, and Idaho Department of Lands (Minutes of Highway Pond Working Group, February - June, 1999). The working group chose not to focus on the causes of bacterial contamination alleged at the time but on the water quality risks posed by removal of soil cover, uncontrolled public access, and operating practices of mining and crushing conducted in the pits.

As a result, public access controls, enforcement of approved operating practices for contractors, and enhanced reclamation requirements following the cessation of mining were negotiated among the parties, including an agreement between IDEQ and IDL to develop coordinated guidelines for gravel mining management practices under conditions such as the Highway Pond. An agreement with ITD was reached to eventually cease gravel mining activities after 2003 and to reclaim and cover the pits, and the City of Pocatello subsequently purchased Bannock Paving's property interests immediately south of the ITD pit. Through a combination of grading, soil cover, and seeding, that property is being reclaimed to restore it to grassland conditions, albeit to elevations that are below the surrounding area where gravel was removed. In addition, ITD relocated a gravel stockpile from the center of its pit to the northern corner, in order to protect nearby private wells from future exposure to ground water which outcropped in that area of the pit.

In 1999 Mr. Hildreth initiated legal action against ITD, claiming the Pond was responsible for bacterial contamination of his drinking water well (Hildreth Well 2) and seeking compensation for a new domestic supply well he drilled in 1999 to replace the contaminated well. The new well was completed in the less permeable gravels beneath the shallow aquifer to ensure that any alleged contamination originating from the Pond via the shallow aquifer would not influence the replacement water well. Since it was disinfected and purged after drilling, this well (Hildreth Well 4) has tested clean for coliform bacteria. However, Hildreth Well 2 has not been resampled for coliform since August, 1999 when its pump was removed and installed in the new well. Thus, it is impossible to evaluate whether its coliform problem has responded to subsequent hydrologic changes and ITD's remediation activities in the northern corner of the gravel pit.

GROUND-WATER SOURCE OF THE HIGHWAY POND

The water in the Pond is chemically very similar to ground water in the shallow aquifer (Meehan and Welhan, 1994; Welhan et al., 1996). As shown in Table 1, the chemical composition of well water in Hildreth Well 2 reported by Rocky Mountain Environmental (1997) is also very similar to previous analyses from this and other wells around the Pond - and to the Pond itself. The exception is sulfate, whose concentration in Hildreth Well 2 was almost three times higher in June, 1994. Meehan and Welhan (1994) proposed and tested a chemical reaction model in which sulfate originating from a

Table 1. Hildreth Well 2 water quality comparison. Data (in mg/liter) are summarized from Rocky Mountain Environmental (1997) and Meehan and Welhan (1994).

		Hildreth Well 2:				**Katsilometes:**	**Hildreth Well 1:**		
		RME (1997):	Meehan and Welhan (1994):			(upgradient)	(downgradient)		
		10/27/97	**06/15/93**	**12/06/93**	**Average**	**06/15/93**	**06/15/93**	**12/06/93**	**Average**
pH		7.6	7.6	7.6	7.6	7.5	7.6	7.5	7.6
Alkalinity	as CaCO3	230	217.2	183.6	200.4	205.0	206.8	186.1	196.4
Hardness	as CaCO3	250	350.4	282.8	316.6	280.3	303.3	292.5	297.9
Chloride		61	54.2	45.0	49.6	43.5	36.5	36.0	36.3
Sulfate		46	127.0	60.0	93.5	44.0	53.0	43.0	48.0
Nitrate as N		0.6 *	3.4	2.0	2.7	1.4	2.4	1.9	2.1
Sodium		35	53.7	46.2	50.0	45.1	45.6	38.1	41.9
Calcium		54	77.0	70.7	73.9	66.4	71.0	77.9	74.5
Magnesium		27	38.4	25.8	32.1	27.8	30.6	23.8	27.2
TDS		330							

*as NO3+NO2 -N

		Highway Pond Water:						
		North Pit:			South Pit:			
		06/04/93	**06/21/93**	**12/06/93**	**06/04/93**	**06/21/93**	**12/06/93**	**Average**
pH		7.2	7.7	7.6	8.2	8.2	8.1	7.8
Alkalinity	as CaCO3	203.1	200.1	208.0	183.6	176.9	180.6	192.1
Hardness	as CaCO3	318.2	293.5	360.3	283.4	235.3	332.2	303.8
Chloride		32.0	34.5	41.5	33.5	42.2	33.5	36.2
Sulfate		42.0	44.0	39.0	42.0	44.0	38.0	41.5
Nitrate as N		1.7	1.6	1.7	1.6	0.8	1.6	1.5
Sodium		n.a.	36.1	43.5	n.a.	30.0	44.0	38.4
Calcium		74.0	73.0	93.0	66.0	50.7	85.7	73.7
Magnesium		32.4	27.0	31.1	28.8	26.4	28.7	29.1

		Portneuf River Water:				
		Norvitch & Larson (1970):				
		04/14/60	**08/03/60**	**06/21/93**	**12/06/93**	**Average**
pH		7.8	8.2	8.3	8.4	8.2
Alkalinity	as CaCO3	n.a.	n.a.	154.3	222.0	188.2
Hardness	as CaCO3	318.2	293.5	360.3	0.0	283.4
Chloride		30.0	42.0	27.7	36.0	33.9
Sulfate		34.0	39.0	27.0	45.0	36.3
Nitrate as N		0.7	0.6	0.6	1.6	0.9
Sodium		27.0	39.0	24.0	48.4	34.6
Calcium		64.0	55.0	61.3	96.2	69.1
Magnesium		25.0	31.0	20.8	38.7	28.9
TDS		358	396.0			

stockpile of crushed aggregate situated across the road from the Hildreth well infiltrated to the water table directly upgradient of the well. The well's sulfate level appears to be significantly lower since this putative sulfate source was removed.

It has been known for some time that the Pond represents the surface of the water table where the aquifer intersects the pit floor (Welhan and Meehan, 1994; Welhan et al., 1996; Figure 2); this area therefore is essentially an "open window" on the aquifer where the protective layer of low-permeability silt loam has been removed from the surface and excavation has exposed the aquifer.

Pond water levels have fluctuated synchronously with the rise and fall of the aquifer's water table. Photos in Appendix I document the changes at different times as water table levels have varied. It has been observed that rising pond water level lags rising river stage in the Portnuef River during spring runoff events (B. Brown, written communication, 2000), thus mimicking the local water table, which also lags spring runoff (Welhan et al., 1996). As documented below, ground-water levels in the LPRV aquifer fluctuate seasonally (reflecting summer pumping stress) as well as secularly (in response to long-term variations in Bannock Range precipitation and hence recharge).

Ground water in this area of the aquifer generally moves from southeast to northwest at rates of 10-40 feet per day (Welhan and Meehan, 1994; CH^2M-Hill, 1995; Welhan et al., 1996). When the water table is high and the water table is exposed in the gravel pit, ground water would be expected to flow through the Pond, entering along its southern edge and exiting (reentering the aquifer) along its downstream side.

IMPACTS OF WATER TABLE EXPOSURE ON WATER QUALITY

If ground-water quality were unaffected by this subaerial emergence, then water reentering the aquifer at the north side of the Pond would have no impact on aquifer water quality. However, where ground water discharges into a surface water body it naturally undergoes a variety of chemical modifications aside from any changes induced by additions of foreign substances. For example, by its exposure to the atmosphere, the relatively high dissolved carbon dioxide content of ground water will be reduced, thereby raising the pH and promoting mineral precipitation. If the dissolved oxygen content of ground water has been lowered by chemical oxidation in the aquifer prior to its emergence, the oxygen content will increase upon exposure to air, also initiating a potential chain of chemical readjustments. Organic photosynthesis and respiration reactions due to surface water biota will similarly affect dissolved gas concentrations, organic matter content, metals uptake and mobility, nutrient levels and other chemical characteristics.

In addition to these and other natural chemical changes, accidental or intentional releases to the surface water body of fertilizers, pesticides, petroleum hydrocarbons, metals, sediment, and sewage or fecal waste will alter the chemistry of water reentering the aquifer. Regardless of the particular chemical changes, the impact of exposing the water table in a situation such as the Highway Pond is always to alter ground-water quality in the surface exposure and in the aquifer downgradient of the Pond. The chemical impact of surface water infiltration into an aquifer is well known; if these changes are minimal or of a nature that allows natural chemical reactions between ground water and the aquifer sediments to reestablish a new chemical equilibrium, then infiltrating surface water will have no impact. However, if water quality is altered in a way that natural chemical equilibrium cannot be reestablished then aquifer water quality can be detrimentally affected.

SCOPE OF THIS EVALUATION

This report has two objectives: 1) to assemble relevant background information on the Highway Pond in relation to the local water table, and 2) to evaluate the nature of impacts on the aquifer due to the existence of a Pond. Background information and knowledge have been assembled from existing sources; new water level information was collected from five private wells north of the Pond; and the water level of the Pond itself was measured and evaluated in relation to the local water table. Because of the drawdown created by Pocatello Municipal Well 44 south of the Pond, the water level survey and this analysis were restricted primarily to the area of the Pond itself and wells immediately to the northwest.

DESCRIPTION OF METHODS

SURVEYING

An elevation and position survey was carried out April 18, 2000 by a registered land surveyor contracted by Mr. Bud Hildreth. Surveying of all wellhead measuring points and Pond water surface was performed with Trimble 4800 Global Positioning System (GPS) instrumentation, with a vertical accuracy of 1 cm. Results were summarized as a digital file of x, y, and z coordinates (D. Klatt, written comm., 2000) and provided to the IGS. A temporary benchmark was installed on the southern lip of the main ITD gravel pit as a reference point for monitoring future Pond water level changes. All location data were imported into ArcView GIS software for plotting and analysis.

WATER LEVEL MEASUREMENTS

Water levels in private wells were measured with a Solinst electrical water level tape graduated in 0.05-foot increments. Measurements were made 4/18, checked for reproducibility on 4/21, and again for short-term changes on 5/09; a spot measurement was also made in Hildreth Well 3 on 10/13. Neither Hildreth or Grady wells were affected by irrigation pumping at the time of the survey and none of the domestic wells were being pumped during either visit to the wells. Because of the very high permeability of this aquifer and the resultant rapid recovery rate of water levels in pumped wells (Welhan et al., 1996), all water level readings were considered to be static readings. Reading accuracy is +/- 0.025 ft; an estimate of measurement precision is provided by the degree of reproducibility attained in measurements at the same well taken three days apart and is less than 0.03 ft (rms difference).

Pocatello Municipal Well 28 in Ross Park is 2.5 miles directly downgradient of the Highway Pond. Water level data from Well 28 were collected from two sources: manual water levels collected monthly by City personnel from 1971 to 1993, and from a Unidata Macro data logger and pressure transducer installed in the well and recording at hourly intervals since 1993. Manual measurement precision is unknown but is likely better than 1 feet; data logger measurement precision is +/- 0.1 feet. All data for Well 28 have been reported relative to an assumed measurement point elevation of 4457 ft amsl; the City of Pocatello had the floor of Well 28’s pump house surveyed in May, 2000 and its actual elevation is 4460.32 ft amsl. Therefore, water levels reported here should be corrected by ca. +4 ft for absolute comparisons to other wells. However, for the purposes of this discussion it is the relative water level variation as recorded at Well 28 that is of greatest interest.

Although Well 28 is an active production well, its water level is still a useful gauge of static water level trends and for estimating year-to-year differences in water table elevations. This is because its maximum drawdown during pumping is less than 3 feet, and because its water level recovers very rapidly when pumping ceases. Only non-pumping measurements from the manually-collected water level data (pre-1993) are considered here; the automatically-recorded data (post-1993) include both pumping and non-pumping water levels.

POND AREA

A Trimble GeoExplorer II was used to survey the area of the currently exposed water table, the major low-lying areas of the gravel pit that have been inundated in the recent past (1996 to 1999), and the areal extent of gravel back-fill placed on another low-lying area in the northernmost corner of the pit[1]. All GPS data were collected and differentially-corrected with base-station data logged at Idaho State University (http://134.50.65.125/GPS/); mean horizontal positional precision of the corrected coordinates varies between 5 and 10 feet.

RESULTS AND INTERPRETATION

Figure 3 shows salient features in the study area, including monitoring wells for which historic water table information is available, the locations of private wells surveyed in this study, and Pocatello Municipal Well 44. Table 2 summarizes the survey and water level data. The area of the ITD gravel pit is approximated by the areal extent of the Highway Pond shown on topographic maps (U.S. Geological Survey, 1974). The dark area within the pit is the currently exposed area of the water table; other irregular areas within the pit are low-lying areas that have been chronically submerged in the past six years, including the back-filled low area in the north corner of the pit.

WATER TABLE GRADIENT

Figure 4 depicts water level elevations in feet above a datum of 4440 ft (relative to mean sea level). Note that the water level in Hildreth Well 4 is not considered representative of the shallow aquifer in which all other measured wells are completed because this well is completed in and draws water from a deeper aquifer. The water levels in the shallow aquifer have been contoured manually and are shown in Figure 3 as solid lines extending between the rail line and the edge of the Portneuf basalt. The interpreted

[1] ITD voluntarily initiated this measure in mid-1999 to reduce possible risk to Hildreth Well 2 from ground water exposed in the northern corner of the gravel pit.

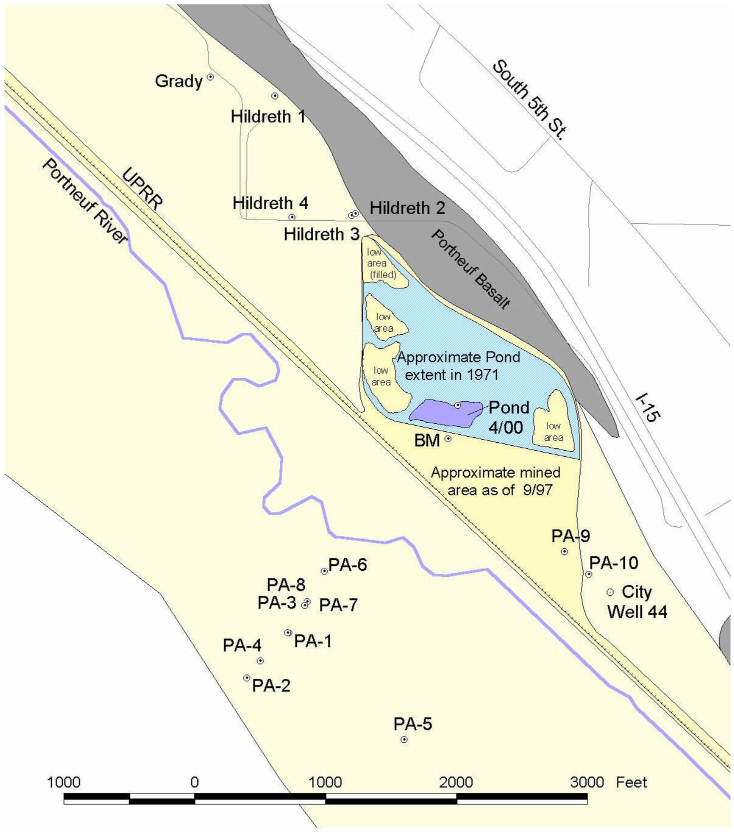

Figure 3. Study area showing relevant features. The area in blue represents the approximate extent of the gravel pit under totally submerged conditions shown in 1974 U.S. Geological Survey topographic map. Extent of mined area is from the geologic map of Othberg and Rodgers (1999). Dark area in gravel pit is exposed water as of May, 1999. Low-lying areas and area of back-filled gravel are also shown. PA-series wells are monitoring wells installed by CH²M-Hill (1995). Location of the cross-section shown in Figure 2 is along the line of wells from PA-2 to PA-6 extended across the valley to the gravel pit, with well PA-9 projected into the plane of the section.

Table 2 - Well survey and water level measurements

					Date of Measurement:					
					4/18/00		4/21/00		5/09/00	
Name	**Easting, ft**	**Northing, ft**	**Z (MP)**	**Location**	**btc**	**swl**	**btc**	**swl**	**btc**	**swl**
Hildreth 1 MP	596541.14	419703.66	4486.91	Hildreth domestic (rental well)	40.31	4446.60	40.35	4446.56	not meas.	-
Hildreth 2 MP	597152.10	418805.76	4493.10	Hildreth old domestic well	45.34	4447.76	45.38	4447.73	45.98	4447.12
Hildreth 3 MP	597126.69	418791.87	4491.78	Hildreth irrig'n well	not meas.	-	44.03	4447.76	not meas.	-
Hildreth 4 MP	596671.45	418779.19	4484.55	Hildreth new domestic well	37.15	4447.40	37.15	4447.40	not meas.	-
Grady MP	596047.66	419846.29	4467.00	Grady domestic/irrig'n well	21.00	4446.00	21.00	4446.00	not meas.	-
Pond Elev.	597935.28	417342.47	4448.91	Highway Pond surface		4448.91		-	not meas.	-
Well PA-9*	598749.75	416229.06	4481.10	Monitoring well		-		-	32.40	4448.70
Well PA-10*	598934.44	416057.28	4482.74	Monitoring well		-		-	34.50	4448.24
Well TH-5	not meas.	not meas.	(4481.9)	Monitoring well (approximate elevation)		-		-	37.05	4444.87
Bench Mark (temporary)	597861.62	417089.90	4476.12	Bench mark, top of pit, west side						

MP = measuring point
btc = feet below top of casing
swl = static water level, feet above mean sea level
* = survey information from CH2M-Hill (1995)

flow net is discussed in a later section.

The water level in the Pond reflects the level of the local water table, albeit averaged over its length in the direction of the water table slope. It is well known that where a water table intersects the topographic surface so as to create a surface water body such as the Highway Pond, the elevation of the surface of the Pond will be slightly lower than the elevation of the water table at the upgradient edge of the Pond and slightly above the elevation of the water table at its downgradient edge. Thus, ground water flows from the aquifer into the Pond, and subsequently back into the aquifer. This is reflected in the localized warping of water table contours around the Pond (as described in a later section on Ground-Water Flow Direction).

The water table data are consistent with ground-water flow that is parallel to the edge of the Portneuf basalt. Hence, the water table elevation difference between Hildreth

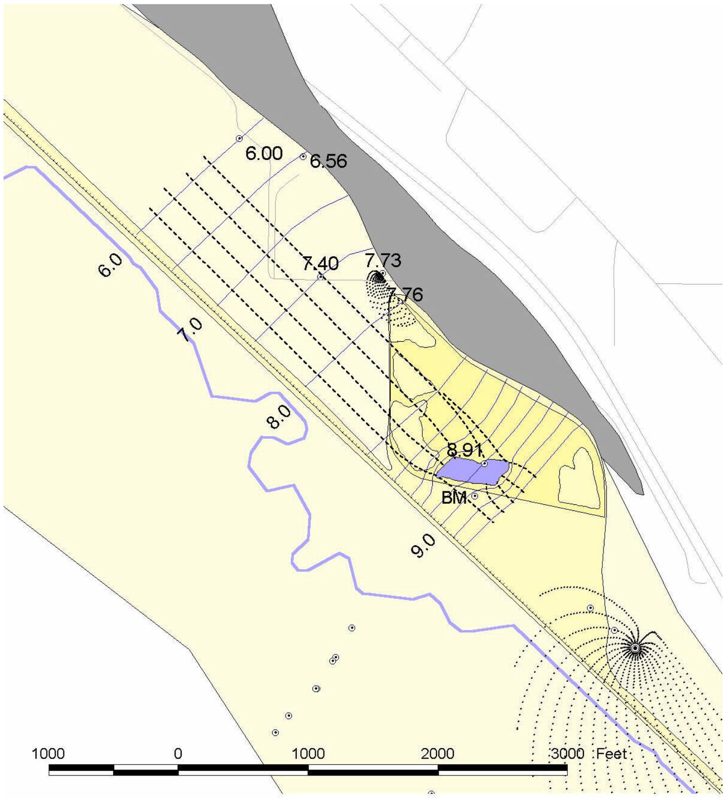

Figure 4. Representation of the ground-water flow field at low water table elevations (May, 2000), into and out of the Pond, together with predicted impacts of pumping wells. Water table elevation contours are shown labeled as feet above 4400 foot datum, with a variable contour interval to show effects near the Pond. Ground-water flow paths into and out of the Pond are shown as dashed lines. One-year capture zone shown for continuous pumping at Pocatello Well 44; six-month capture zone shown for Hildreth irrigation Well 3. Dotted lines indicate ground-water flow paths converging on the pumping wells.

Well 1 and Well 2 (1.16 ft) provides a good approximation of the hydraulic gradient (water table slope) between these wells (a distance of 1100 ft). The gradient so determined is 0.00105 or 0.11%; between Hildreth Well 2 and Grady's well, it is 0.00115. As discussed in the following section, the magnitude of these gradients is entirely consistent with previous water table interpretations based on more wells over a wider area of the aquifer (CH^{2}M-Hill, 1995; Welhan et al., 1996).

The average gradient between the Pond and Grady's well is 0.00094, decreasing to the southeast from a high of approximately 0.0013 near Grady's well to ca. 0.0007 between the Pond and Hildreth Well 2. The decrease appears to be systematic and may be due to several factors: the complex three-dimensional hydraulic interaction between ground water and the surface water body through which it flows (Townley and Trefry, 2000), aquifer inhomogeneity (that is, permeability around the gravel pit differs from that beneath Grady's property), or the effect of Well 44's essentially continuous pumping since it was put into production in August, 1999. Of these possible effects, the latter is probably of greatest significance.

Well 44’s zone of influence is distorted by its proximity to the aquifer boundary, but nevertheless the well’s drawdown creates an artificial ground-water divide and flow reversal between the Pond and the well. Southeast of this divide, the slope of the water table and direction of ground-water flow is toward Well 44; at the divide, the hydraulic gradient is zero; and northwest of it, the gradient gradually steepens to the northwest. The capture zone shown in Figure 3 under-represents the actual extent of the well’s impact on aquifer water levels; in particular, water levels northwest of the well would be reduced as the aquifer seeks a new quasi-equilibrium. Because Well 44 has been pumping continuously since coming on line in August, 1999 (F. Ostler, pers. comm., 2000), its hydraulic impact on the aquifer is assumed to have reached a quasi-steady state for the purposes of this analysis.

Water levels in Hildreth well 2 and monitoring wells PA-9 and PA-10 measured on May 9 (Table 2) corroborate the expected gradient reversal. The apparent hydraulic gradient between Hildreth well 2 and PA-9 is 0.0005 (sloping to the northwest), whereas between PA-9 and PA-10, it is reversed (sloping southeast) and much steeper (0.0018); the gradient at the production well exceeds 0.020 (based on well TH-5’s water level relative to PA-10).

COMPARISON WITH PAST WATER TABLE VARIATIONS

Figure 5 summarizes water level data measured in a number of wells in the study area on May 12, 1994 (CH^{2}M-Hill, 1995) prior to the installation of Pocatello Municipal Well 44. Water levels are shown relative to the 4440 ft datum. Contours of the water table indicate a general ground-water flow direction that is parallel to the valley axis and the aquifer's boundaries. This is consistent with historic water level records dating back to

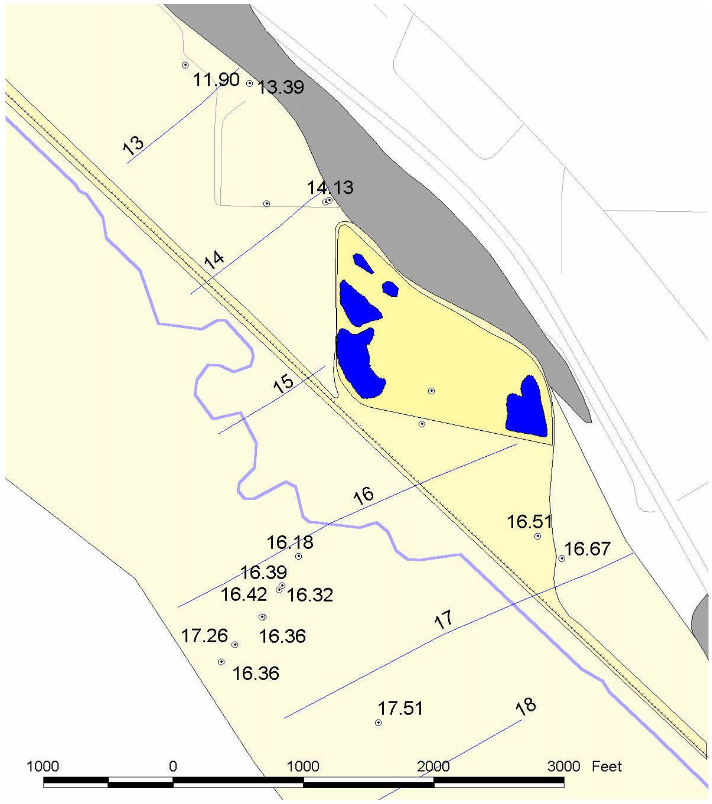

Figure 5. Water table elevations in wells relative to 4400 foot datum, as measured May 12, 1994 (CH^2M-Hill, 1995). Contours have been simplified to reflect a hydraulic gradient that is predominantly along the axis of the valley. Dark blue areas in gravel pit represent approximate extent of areas submerged in 1994 (see photo D, Appendix I).

1981 (Welhan et al., 1996) and underscores the uniform nature of the water table in this portion of the valley in the absence of pumping disturbances. From the spacing of these water table contours, the average hydraulic gradient in this area of the aquifer is 0.00090. This is almost identical to the average hydraulic gradient of 0.00094 determined from the April, 2000 water level survey discussed above.

Figure 6 summarizes the water level record at Well 28 (measured when the well was not pumping), together with total annual precipitation recorded at the National Research and Conservation Service's SnoTel station on Wildhorse Divide in the Bannock Range, the aquifer’s principal recharge area (Welhan et al., 1996). Well 28's response over three decades shows a consistent pattern of (a) pumping-induced drawdowns of the order of 1-2 feet at pump rates of 800-1200 gallons per minute, (b) a general summertime pumping period decline of the order of 5-10 feet, followed by (c) a post-pumping period of recovery and a variable amount of spring recharge-induced water level increase, and (d) a suggestion of a secular correlation between total precipitation (maximum available recharge) and aquifer water level. It is apparent that static water levels in the Ross Park

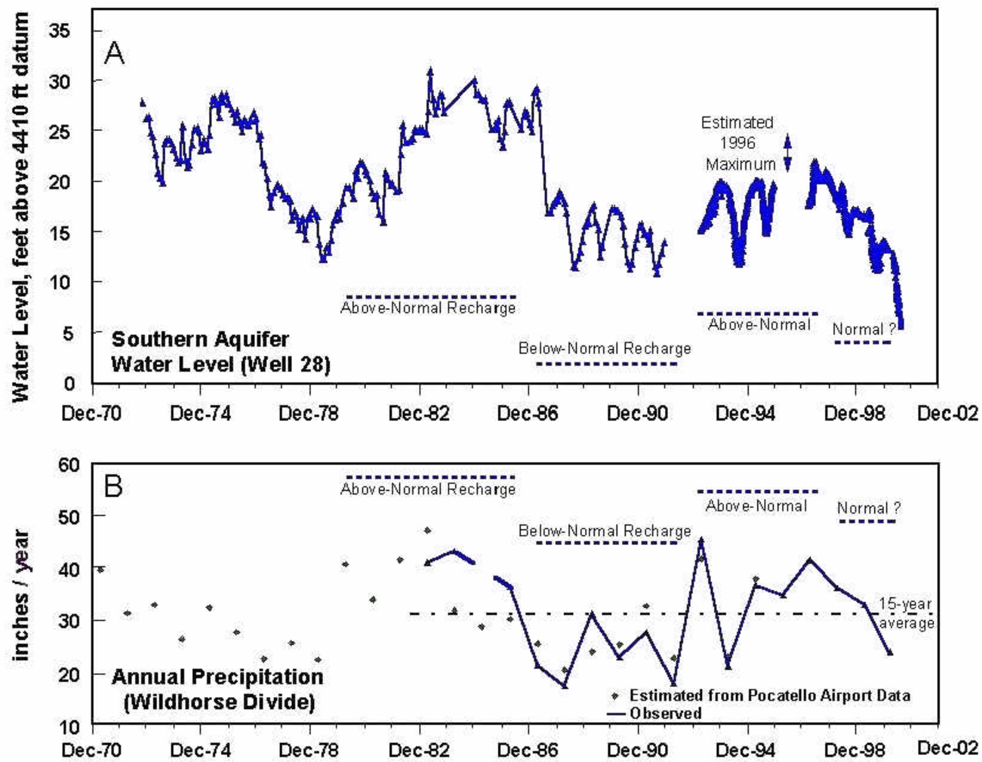

Figure 6. (A) Water levels in Municipal Well 28. (B) Total annual precipitation measured at Wildhorse Divide SnoTel station in the aquifer's principal recharge source area. No water level data are available for 1996 due to data logger battery failure; an approximate maximum range was estimated from a contemporaneous rise at the Highway Pond (compare photos for 1994 and 1996 in Appendix I).

area have varied significantly in the past. They have been almost 25 feet higher than current levels, notably during the early-1970s and mid-1980s.

A comparison of water level variations at Well 28 and in wells near the Highway Pond is illuminating. From photo documentation presented in Appendix I, the degree of inundation in the gravel pit correlates with long-term changes of water table elevation measured at Well 28. Measurements at Well 28 appear to provide a reasonable representation of changes in water table elevation in the vicinity of the Pond. Water levels measured 18 days apart (between April 21 and May 9, 2000) in Hildreth Well 2 and Well 28 showed very similar changes (declines of 0.61 and 0.72 feet, respectively), within the precision of the measurements. Between May 12, 1994 and April 21, 2000 (2171 days), water level in Hildreth Well 2 decreased by 6.40 feet; water levels in the Hildreth Wells 1 and 2 and the Grady well (compare Figures 3 and 4) decreased an average of 6.38 feet (range: 5.90 to 6.83 ft). In the same period, water level at Well 28 decreased 5.17 feet. The greater rate of decline in the Pond area may be a reflection of the proximity to Well 44, which has been pumping almost continuously since August, 1999.

Based on the above information, the conclusion is that Well 28's water level is a reasonable surrogate for relative water table fluctuations in the area of the Highway Pond.

IMPACTS OF THE POND ON LOCAL GROUND-WATER FLOW

To infer ground-water flow directions from the water level measurements on April 21, a flow net was created to approximate the two-dimensional areal nature of ground-water flow and the effect of the exposed water table. A flow net is a map showing contours of equal water table elevation and resultant ground-water flow directions. Because of the three-dimensional complexity of flow that arises around surface water bodies communicating with ground water (Townley and Trefry, 2000), the effect of aquifer inhomogeneity, and Well 44's known impact on ground-water elevations south of the Pond, an analytical model of the flow net was not computed. An approximate flow net was created manually using standard methods (Freeze and Cherry, 1979). The flow net interpretation was constrained by measured water levels, the exposed area of the Pond, and the assumptions of a homogeneous, isotropic porous medium, a hydrologic steady-state, and laminar (Darcian) flow. The adjacent aquifer boundary along the basalt was assumed to be impermeable.

The flow net shown in Figure 4 expresses the relationship between water table elevation and inferred ground-water flow direction arising from that water table configuration. Solid lines extending southwestward from the basalt are contours of equal water table elevation; dashed lines represent ground-water flow moving into and emanating from the Pond. Note that the flow net shown upgradient of the Pond is unconstrained because of the lack of measurements and the influence of Well 44.

The flow net analysis provides a visual approximation of the areas of the aquifer affected by infiltration of water from the Highway Pond. Currently, the area of impact is limited to the area directly downgradient of the exposed Pond. Thus, under such conditions, Hildreth Well 2 is not in the Pond's area of impact unless locally induced water table gradients distorted the flow lines shown in Figure 4.

Hildreth Well 3 is an irrigation well some 30 feet from Hildreth Well 2; during the growing season it pumps at more than 300 gallons per minute (B. Hildreth, pers. comm., 2000). Aquifer permeability has not been determined at this well, but is assumed to be similar to that at Well 44 (740 ft/day, unpubl. data and analysis). The dotted area shown in Figure 4 converging on Hildreth Well 3 represents a six-month capture zone for a continuous 30 gallons per minute pumping rate, approximately the maximum continuous pumping rate at which its capture zone would not intercept Pond-derived water. Since Hildreth Well 3 pumps substantially more than this during the irrigation season (ca. 300 gpm), its actual capture zone would encompass a much larger area. The implication is that Hildreth Well 3’s pumping impact could draw Pond water toward Hildreth Well 2 even under the condition of a low water table and little exposed water in the gravel pit.

In the past, when the water table was considerably higher, a much larger area of the gravel pit was flooded. Although we do not have measurements of the Pond area or water level data to construct a flow net under such conditions, an approximate scenario can be evaluated. Based on photographs and personal visits to the Highway Pond following the rapid rise in Pond level in the spring of 1996, an essentially contiguous area spanning the length of the main pit was submerged through most of 1996 and 1997.

Figure 7 shows the approximate extent of the area submerged under moderate- to high-water table conditions. A larger area of the water table is exposed and the pattern of ground-water flow around the Pond is altered over a much larger area. Although this is an approximate representation of the ground-water flow net, constrained solely by the area of the exposed water table and previous assumptions, it represents the salient features of the ground-water flow field to be expected under these conditions. Note how the water table contours are warped immediately upgradient and downgradient of the Pond, thereby spreading water which seeps from the Pond over a much larger area of the aquifer (including areas west of the rail line). In comparison with the flow net of Figure 3, the

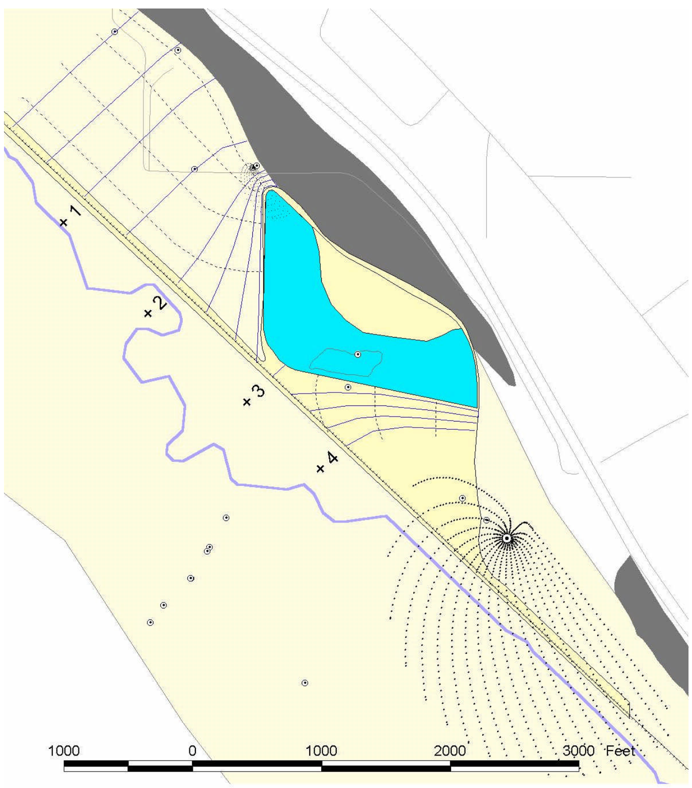

Figure 7. Representation of the ground-water flow field at moderately high water table approximating the 1996-97 level of the Pond (shown in blue; cf. Figure E in Appendix I). Well capture zones from Figure 3 are shown for reference. Water table elevations are shown as feet above 4400 datum, with a variable contour interval.

conclusion is inescapable that a larger pond surface area exposes a larger area of the aquifer to water that has resided in the Pond.

The preceding flow net analysis suggests that Hildreth Well 2 is more likely to be exposed to water seeping from the Highway Pond under high water table conditions (i.e. when the Pond surface area is large). However, under the influence of pumping at Hildreth Well 3, Pond water may be drawn toward Hildreth Well 2 under low water table conditions, as well.

BACTERIAL CONTAMINATION

Photographs (Appendix I) show that the main pit area was dry in 1992 and, based on past ground-water level variations (Figure 5), it was probably dry prior to 1990. Based on photographs and examination of the pit area in the past decade, the northern corner of the gravel pit is a low-lying area which has had water exposed in it for much of the time that water was exposed in other low-lying areas of the pit (Figure 2). The northern corner contained water in the spring of 1993 and retained it through at least 1994; it was entirely flooded in 1996-97, and held a dimishing pool of water before going dry sometime in 1998.

Thus, the water table was exposed in the northern corner of the gravel pit almost continuously for about four years (spring, 1993 - summer, 1998), directly upgradient of Hildreth Well 2. Thus, Hildreth Well 2 was continuously within about 500 feet of exposed water, and within about 200 feet when the water table was high in 1996-97. From the USGS topographic map, the northern corner of the pit is known to have been full in the early 1970s; from Well 28's record, it is probable that the water table was also exposed in this area of the pit during the mid-1980s.

Given Hildreth Well 2's location and proximity downgradient of exposed water in the pit, it is possible that water quality variations originating in the Pond have impacted the well. Previous studies of ground-water quality around the Pond (Meehan and Welhan, 1994) found elevated sulfate in Hildreth well 2 (60-127 mg/l) at a time when a stockpile of crushed slag on the asphalt-mixing tarmac adjacent to the north corner of the pit provided a source of readily leachable sulfate (Meehan and Welhan, 1994). After the stockpile was removed, sulfate levels in Hildreth Well 2 returned to normal levels of 40-50 mg/l (Rocky Mountain Environmental, 1997).

Table 3 shows coliform analyses of Pond and well water samples collected by Mr. Hildreth (summarized from District 6 Health Department laboratory reports). Coliform bacteria have been detected in the Pond since 1997 when the first samples were collected; six of seven samples contained e.coli bacteria. In contrast, coliform detection in wells on the Hildreth property has not been as consistent and e.coli detected less frequently.

E. coli are retarded relative to the flow rate of water through a porous medium, but are known to migrate rapidly where preferential flow paths such as root channels,

Table 3 - Coliform data summary. Samples collected by Bud Hildreth, results summarized from District 6 Health Department laboratory reports.

1=Present; 0 = Absent

Sample Location	***Type***	***Date Coll'd***	***Analyzed***	***Tot.Coliform***	***E. Coli***	***Notes***
Hildreth well 2 near residence and irrigation well						
8424 Hildreth Rd.	Outside faucet	05/20/96	05/21/96	1	0	
	Outside faucet	06/10/96	06/11/96	1	1	
	Outside faucet	08/19/96	08/20/96	1	0	
	Outside faucet	06/18/97	06/19/97	1	0	
	not specified	09/16/97	09/17/97	1	1	
	not specified	11/06/97	11/07/97	0	-	' - ' = no analysis
	Outside faucet	04/29/98	04/30/98	0	-	
	Kitchen faucet	05/11/98	05/12/98	0	-	
	not specified	07/15/98	07/16/98	1	0	
	not specified	09/16/98	09/17/98	1	0	
	Outside faucet	11/17/98	11/18/98	1	0	
	not specified	12/04/98	12/07/98	1	0	
	Outside faucet	02/18/99	02/19/99	0	-	
	Outside faucet	03/25/99	03/26/99	0	-	
	Outside faucet	06/08/99	06/09/99	1	0	<- gravel stockpile has been moved into
	Outside faucet	07/12/99	07/13/99	1	0	northern corner of pit
Hildreth well 1, at rental house						
8498 Hildreth Rd.	not specified	05/23/96	not specified	1	0	
	Outside faucet	06/11/96	06/12/96	0	-	
	Outside faucet	04/29/98	04/30/98	1	0	
	not specified	05/11/98	05/12/98	1	0	
	Outside faucet	06/01/98	06/02/98	1	0	
	Outside faucet	07/15/98	07/16/98	1	0	
	not specified	09/16/98	09/17/98	1	0	
	Outside faucet	11/17/98	11/18/98	1	0	
	Outside faucet	02/18/99	02/19/99	0	-	
	Outside faucet	03/25/99	03/25/99	1	0	
	Outside faucet	06/08/99	06/09/99	1	0	<- gravel stockpile has been moved into
	outside tap	07/12/99	07/12/99	0	-	northern corner of pit
	Kitchen faucet	09/20/99	09/21/99	0	-	
	Kitchen faucet	10/15/99	10/15/99	0	-	
	Kitchen faucet	12/16/99	12/16/99	0	-	
	Kitchen faucet	03/06/00	03/06/00	0	-	
Hildreth well 3 (irrigation well)						
8424 Hildreth Rd.	not specified	08/09/99	08/10/99	1	0	
	not specified	10/15/99	10/16/99	1	0	
Hildreth well 4 (new well)						
8424 Hildreth Rd.	not specified	08/09/99	08/10/99	1	0	newly drilled well, prior to disinfecting
	Kitchen faucet	09/20/99	not specified	0	-	4 days after chlorine treatment
	Kitchen faucet	10/15/99	not specified	0	-	
	not specified	12/16/99	not specified	0	-	
	Kitchen faucet	03/06/00	not specified	0	-	
Highway Pond,						
various locations	North corner of pond	09/16/97	not specified	1	1	
	North corner of pond	05/11/98	not specified	1	1	
	South end of pond; north is dry	03/25/99	not specified	1	1	
	not specified	07/12/99	07/12/99	1	0	<- gravel stockpile has been moved into
	Main fishing hole, low water	08/09/99	08/09/99	1	1	northern corner of pit
	Deepened area, south side of pit, otl	10/15/99	10/15/99	1	1	
	Deepened area, south side of pit, otl	04/25/00	04/25/00	1	1	

MISCELLANEOUS NOTES:

Well at 8498 Hildreth Rd. started showing coliform later than at 8424 Hildreth Rd.

After road aggregate was stockpiled above Hildreth well (no date known, but pre-1993), Hildreth recalls the water started to taste bad within ca. 3-4 years; Hildreth sampled wells for coliform at that time, and no bacteria were detected (although no records are available)

Hildreth sampled annually after that, but analysis records were not retained until coliforms were first detected

Previous chemical analyses showed that the road aggregate was a source of leachable sulfate (Meehan and Welhan, 1994); elevated sulfate concentrations in water impart a noticeable taste, suggesting that leachate from the aggregate moved rapidly to the well

After the road aggregate stockpile was removed, well water taste has steadily improved (Hildreth's perception; appears to be corroborated by Rocky Mountain Environmental report's water quality analysis, showing sulfate has declined from 1994

Since Hildreth drilled a new well and moved the pump out of the old well, bacterial analyses have been unavailable cracks, and macropores exist (McCurry et al., 1998). Macropores (or zones of enlarged pore diameter) provide less bacterial filtration capacity relative to smaller pores of fine-grained soil. Similarly, the relatively large pore throats characteristic of coarse, permeable gravels in the LPRV aquifer may offer little filtration capacity to retard bacterial migration. The effective grain size (defined as the size at which 10% by weight of a soil is finer) provides an estimate of the characteristic pore diameter (Freeze and Cherry, 1979). Based on sieve analyses (B. Brown, written comm., 1996), the effective grain size of Highway Pond gravels in the ITD gravel pit is of the order of 0.15 - 0.25 mm. In comparison, the effective grain size for silt loam soil is two orders of magnitude smaller (Pudney, 1994).

Tracer experiments in permeable aquifers demonstrate that bacteria can migrate rapidly when injected into flowing ground water. For example, in a sandy aquifer on Cape Cod where ground-water flow is more than ten times slower than in the Highway Pond aquifer, bacteria moved 30 feet in three weeks (Harvey and Garabedian, 1991). Where bacteria are transported in the aquifer together with dissolved or suspended organic matter to sustain their growth, bacterial migration in excess of 3000 feet from the source is possible (Harvey et al.,1989). Since water in the Highway Pond is visibly rich in organic matter (derived from a variety of sources, e.g., algal mats, fish, fish waste, gull and dog feces, food waste and garbage, etc.), conditions appear to be conducive for allowing bacteria originating in the Pond to survive and migrate through the aquifer over considerable distances from the Pond.

Although definitive proof is lacking, conditions in the Highway Pond area suggest that rapid bacterial migration in the Highway Pond gravels may be possible if their relatively large pore diameters promote bacterial mobility in a manner similar to macropore flow in structured soils. However, it is important to note that other possible sources for the coliform contamination observed in Hildreth Well 2 have not been ruled out, and that more than a single source of bacterial contamination may be responsible for the coliform detections in the Hildreth wells.

The northernmost corner of the gravel pit was back-filled with rejected gravel in mid-1999 to prevent exposure of the water table immediately upgradient of Hildreth Well 2 and as a precaution against the possible impact of this exposure on ground-water quality. Based on the results of the flow net analysis discussed above, this measure should afford a level of protection for Hildreth Well 2 in all but periods of very high ground water by minimizing the well's exposure to Pond water. However, the effect of Hildreth Well 3's pumping may be to exacerbate any Pond influence by inducing flow of Pond water toward Well 2. Also, if the Highway Pond rises at some point in the future as much as it has in the past (ca. 25 feet), the Pond would fill to within 5-10 feet of the southern lip of the gravel pit and submerge almost the entire pit area as it was in the early 1970s (USGS topographic map, 1974) and in 1984 (Appendix I). Under such circumstances, water would inundate the gravel back-fill in the northern corner of the pit and exposed ground water would infiltrate directly toward Hildreth Well 2.

IMPLICATIONS FOR FUTURE GRAVEL PIT RECLAMATION

The direct coupling between water level in the Highway Pond and aquifer water table variations has implications for future planning of alternative land uses in the gravel pit. As shown above, the water level record at Municipal Well 28 can be used as a surrogate indicator of water level variations in the Highway Pond. Given the magnitude of past water table fluctuations (a ca. 20 - 25 foot variation between high and low water levels) and the recurrence frequency of high water level conditions (e.g. the water table at Well 28 has been 15 feet or more above current low water levels during 5 out of 27 years of record), we can expect that such high water levels are not unusual and that the pit will refill with water whenever low-lying areas in the pit intersect the level of the future water table. For example, at 15 feet above May, 2000 levels the Pond would again be essentially full (approximating the area of open water in the 1974 topographic maps). As it did in 1996, ground-water level can rise very rapidly (within a few weeks) during large spring runoff events.

The impact of rapid rises in ground-water level should be considered in any future reclamation plan for the pit area (e.g., landscaping, soil cover, vegetation, engineering design of a wetland, etc.). Whether a decision is ultimately made to retain an open water area for aquatic recreation or to fill in the deepest mined areas and landscape the entire area, the impact of a rapid rise in the water table on the stability of landscaping and vegetation and on the manner in which the reclaimed area will be used will likely be an important factor in any future reclamation design.

SUMMARY OF CONCLUSIONS

WATER TABLE - POND LEVEL INTERPRETATION

Water table elevations were measured in five private wells immediately northwest of the Idaho Transportation Department's (ITD) Highway Pond gravel pit and related to the water level in the Pond. The survey was conducted April 18 and 21, 2000 prior to spring recharge. Although the operation of Pocatello Municipal Well 44 south of the gravel pit has affected the local water table gradient over a large area of the aquifer south of the Highway Pond, the water level survey shows that the Pond surface continues to reflect the elevation of the local water table. The uniform decrease in water table elevation northwestward from the Pond indicates that ground water continues to flow essentially parallel to the low-permeability boundary of the aquifer defined by the edge of the Portneuf basalt, as it did prior to Well 44's installation. This conclusion is consistent with previous interpretations of water table elevation and of the Pond being an area in which the water table has been exposed by gravel mining since the Highway Pond gravel pit was excavated in the mid-1960s.

GROUND-WATER FLOW DIRECTION

The specific direction of ground-water flow away from the Pond was inferred from the water level data. A small area of exposed water table (as it currently is) does not greatly alter the ground-water flow field and the aquifer is affected by infiltrating Pond water only in the area directly downgradient of the Pond; thus, under current low water table conditions the Pond does not affect the domestic well (Hildreth Well 2) thought to be contaminated by fecal bacteria originating from the Pond. However, when the water table is higher, a much larger area of the water table is exposed in the gravel pit and ground-water flow directions are substantially altered by the exposed water table.

ASSESSMENT OF HISTORIC WATER LEVEL DATA

Water level records from Pocatello Municipal Well 28 (Ross Park) show that the water table fluctuates on seasonal (due to pumping) and secular (due to variations in recharge) time frames. In the past, the water table has risen almost 25 feet above its present elevation, notably in the early 1970s and again in the mid-1980s. When the level in the Highway Pond rises by this much in future, the surface of the Pond will be less than 10 feet below the southern lip of the gravel pit, thereby submerging almost the entire pit area as it was in the 1974 topographic map. Under such conditions, the Pond would once again affect a much larger area of the aquifer down-gradient from the Pond, including Hildreth Well 2.

IMPLICATIONS FOR BACTERIAL CONTAMINATION

Since the spring of 1996 and through at least mid-1998, the low-lying northern corner of the gravel pit directly upgradient of Hildreth Well 2 contained exposed ground water. Bacterial analyses of Pond water collected since 1997 have shown coliform bacteria present in all samples and e.coli in six of seven samples, suggesting that a standing crop of coliform bacteria is to be expected under current access and land use conditions. Although bacteria are known to move rapidly in flowing ground water in permeable aquifers, further information linking the bacteria in the Pond to bacteria detected in Hildreth Well 2 is needed before a causal relationship can be demonstrated. However, the high permeability (740 ft/day), the coarse nature of the subsurface gravels, and the availability of organic matter to support microbial growth suggests that it may be possible for bacteria to migrate readily from the Pond in the shallow aquifer.

IMPLICATIONS FOR FUTURE RECLAMATION AND LAND USE

The response of the Highway Pond's water level to large water table fluctuations in the past has implications for future reclamation of the gravel pit. Given the frequency of past high water table excursions, and the possibility of rapid rise during Spring recharge, it is only a matter of time before high water levels in the gravel pit recur and threaten the stability and viability of any low-lying soil cover, vegetation, or engineered wetland area. Whether a decision is ultimately made to retain an open water area for aquatic recreation or to fill in the deepest mined areas and landscape the entire area as parkland, the impact of water table rise on soil and vegetation stability and on the manner in which the reclaimed area can or will be used will have to be taken into account in future reclamation plans.

ACKNOWLEDGMENTS

The elevation survey was sponsored by Mr. Bud Hildreth. Mr. Hildreth and Mr. Maurice Grady kindly granted permission to access their wells for water level measurements; Mr. Hildreth also made available the bacterial analysis results on his wells and the Pond. Mr. Fred Ostler, City of Pocatello Water Superintendent, provided access to municipal wells for water level measurements and made city records available for analysis. I thank Jerome Hansen, Idaho Fish and Game, and Ed Bala and his staff at the Idaho Transportation Department for reviewing the draft report and providing many valuable comments and suggestions. A ground-water database created for Pocatello, Chubbuck, Bannock County, and Fort Hall was used to create supporting GIS coverages used in this analysis. Personnel in Idaho State University's Geology GIS computer laboratory and the GIS Training and Research Center provided access to GIS software and assistance with use of the database, GPS equipment, and GPS base station data.

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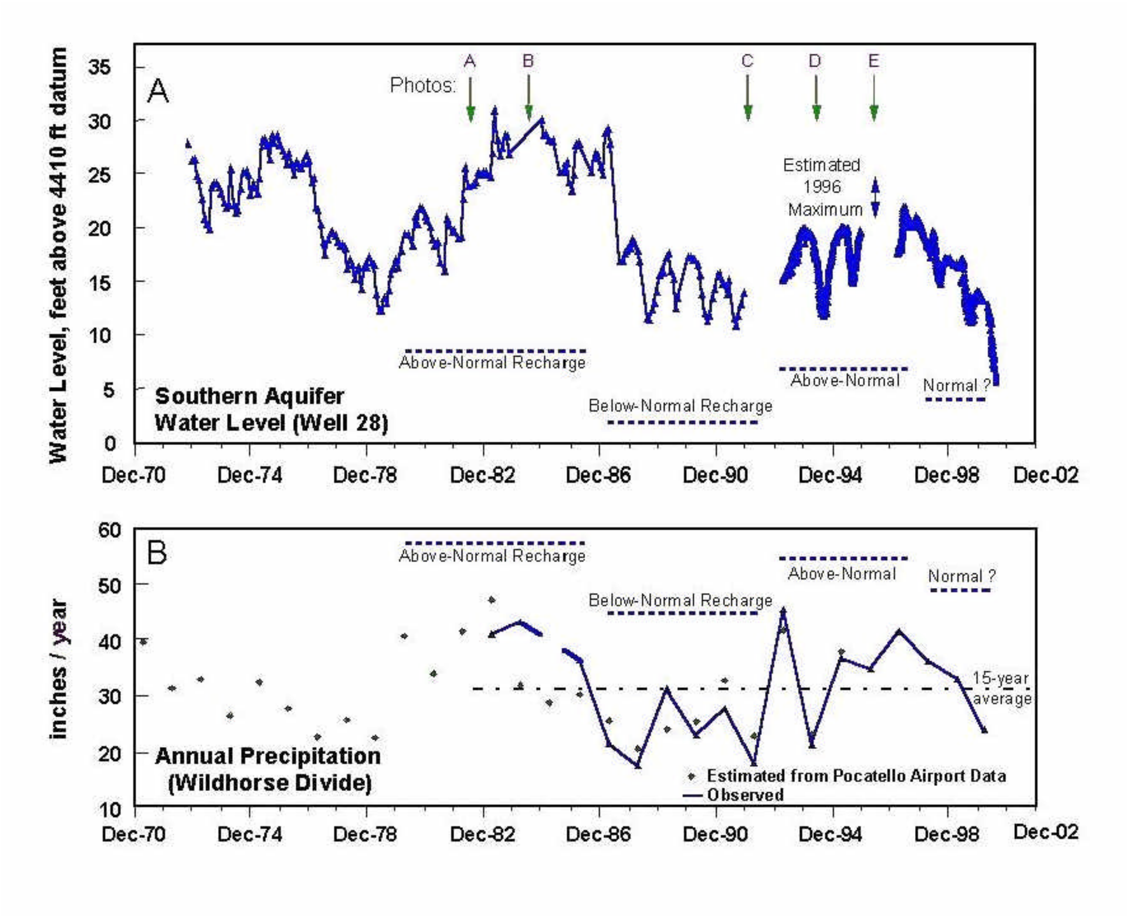
Appendix I - Photographic Records of Highway Pond Water Levels

Figures A though E document the magnitude of changing water levels in the gravel pit and submerged areas. The approximate times at which the photos were taken are shown in the figure below, relative to periods of high and low ground-water levels recorded at Pocatello Well 28 and relative to extended periods of above- and below-normal recharge recorded at Wildhorse Divide in the Bannock Range aquifer recharge area.



1982 or 83

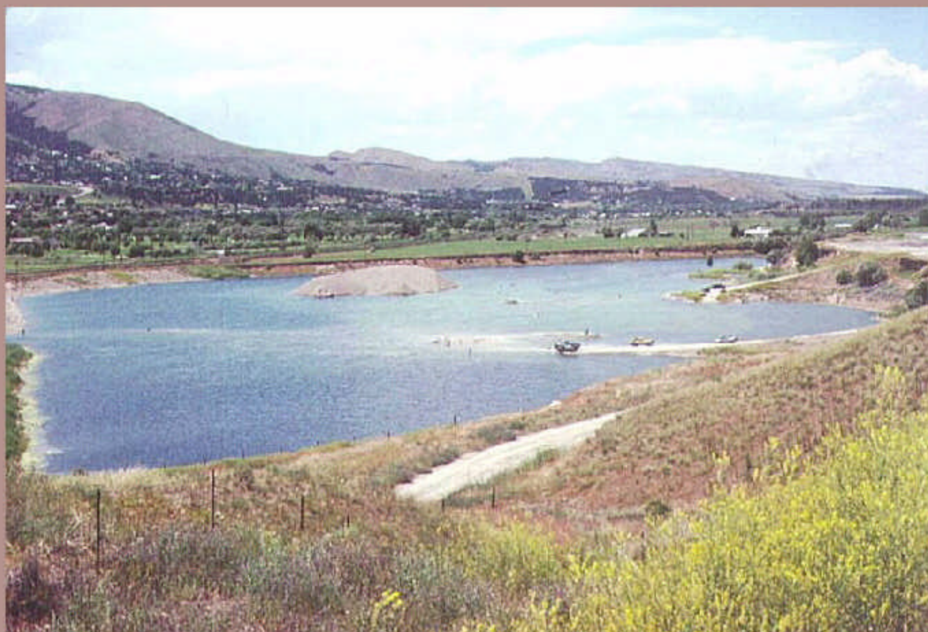
A.
1982 or
1983
Source:
Keith
Hildreth

1984 6-8-84

B.
Summer
1984
Source:
Bud
Hildreth

C.
Winter
1991-92
Source:
Author

D.
Spring
1994
Source:
Author



1996

E. Summer 1996 Source: Author

Appendix II - Summary of Available Lithologic Information

Available Lithologic Logs

PA-series Monitoring Wells

Purpose: characterize and monitor extent of trichloroethylene contamination
Source: CH^{2}M-Hill (1995) geotechnical report
Thickness of Surface Silt Unit: 12 ft (PA-9), 11 ft (PA-10)
Depth to base of Upper Gravel: 98 ft (PA-9), >69 ft (PA-10)

Pocatello Test Drilling for Well 44 Siting

Purpose: locate sufficient saturated thickness for production well
Source: unpublished descriptive lithologic logs (IGS, Pocatello Branch Office)
Thickness of Surface Silt Unit: 5-8 ft (TH-3, 4) to 10-12 ft (TH-1, 2, 5, 6)
Depth to base of Upper Gravel: 29-32 ft (TH-1, 2, 3) to 64-74 ft (TH-4, 5, 6) bls

Hildreth Well 4

Purpose: replacement drinking water supply
Source: unpublished descriptive lithologic log (IGS, Pocatello Branch Office)
Thickness of Surface Silt Unit: 7 ft
Depth to base of Upper Gravel: 70-75 ft bls

Other Lithologic Data

ITD test borings in the Highway Pond gravel pit

Purpose: for gravel resource estimation, grain size analysis
Source: ITD Source Plat BK-142-S extraction plan (5/95)
Thickness of Surface Silt Unit: reported as thin (E. Bala, pers. comm., 1999)
Depth to base of Upper Gravel: n.a.

Appendix III - Unpublished Lithologic Logs

Well Logs for Pocatello City's Test Wells Drilled in the Siting of Well 44

Test holes were drilled by Vollmer Drilling Inc., using air rotary with foam additive and 6" casing
Lithology was logged by sampling cuttings during drilling
Bagged samples were collected every 5 ft, or where lithology changed significantly
Depth was estimated in feet below land surface to within 0.5 ft, considered accurate to within 1.5 ft
Logging personnel: J. Kaser (ISU), J. Welhan (IGS)

Note: Intervals not containing mention of fines in bold font appeared to be silt/clay-poor in bagged samples that were inspected after drilling

Note: all gravel/coarse sand clasts look to be of similar composition in all six test holes (mixed quartzite and metasediments; colors: pink, purple, green, white)

Test Hole 1 (TH-1)

0-10: Dark brown silt, silt clasts, dark brown silt loam
10-11: Dark sand
11-12: Dark gravel (rounded quartzite)
12-12.5: Dark gravel and sand
14-17: Dark gravel, found a white mollusk shell (fresh water oyster)
17-17.5: Dark sand and gravel, complete white grastropod shells
17.5-18.5: Dark gravel
20-29: Med.-coarse gravel, less silty   Base of Upper Gravel
29-30: Very sudden transition into **silt-rich**, coarse gravel
30-32: **Silt-rich**, med.-coarse gravel
32-35: Cleaner, still **silty**, coarse gravel (again, with sudden transition)
35-38: Coarse, clean gravel, with some med.-coarse sand
38-40: Thin **clay** seam
40-45: **Silty** med. gravel
45-55: Relatively clean, med.-coarse gravel, with sand
57: Another **silt** layer, some clay, no sand or gravel
57-60: Grading back into **silty**, med.-coarse gravel
60: **Silty** med.-fine gravel, some sand

Test Hole 2 (TH-2)

0-12: Dark brown silt
12-15: Dark gravel and sand
15-19: Dark gravel
21-22: Brown silt and dark gravel
22-32: Dark gravel Base of Upper Gravel
32-36: **Brown clay** and sand
36-36.5: Dark sand
36.5-38: Gray **clay** and gravel
38-39: **Clay** color change to a deep brown, dark gravel
39-40: Sand, silty, clayey
40-43: Dark sand and gravel, some brown clay
43-47: **Brown clay** and gravel layers
47-49: **Brown clay** and dark gravel
49-51: **Brown clay**
51-53: Dark gravel and brown clay
53-55: Dark gravel and sand
55-56.5: **Brown clay**
56.5-57: Dark gravel
57-58: Dark sand with some gravel
58-58.5: Mostly dark sand and some dark gravel
59-59.5: Dark sand
59.5-60: Dark gravel and sand – water encountered
60-62: **Brown clay**. No water
62-63: Dark sand; drilling ceased at an obstruction at 63 ft, casing could not be advanced further. Cuttings contain various clasts (gray mudstone, yellow and red-brown quartzite) mixed with sand.

Test Hole 3 (TH-3)

0-2: Dark brown topsoil
2-5: Brown clay and dark gravel, white gastropod shells
5-10: Dark gravel, some complete white gastropod shells
10-13: Dark gravel and sand, white gastropod shells
13-14: Mostly dark sand with some dark gravel
14-18: Dark gravel and sand, white gastropod shells
18-19: Dark gravel and sand
19-23: Dark gravel and sand, white gastropod shells
23-25.5: Dark gravel, drill moving slowly through
25.5: Brown clay, dark gravel and sand
25.5-28: Mostly dark gravel with brown clay and some sand — Base of Upper Gravel?
28-29: Brown clay with gravel and sand
29-29.5: Brown clay
29.5-30: Brown clay, gravel and sand
30-31: Conspicuous **brown silt, some clay**
31-33: Brown clay and dark gravel
33-35: Brown clay and dark sand
35-38: Brown clay with some dark sand
38-38.5: Brown clay (some clay chips found)
38.5-39: Dark sand with some dark gravel, sand is brown to dark red
39-41: Brown clay, brown to dark red sand, and dark gravel
41-43: Gravel, pink and dark red quartzites or granite with black basalt or mudstone
43-46: Brown clay, pink to dark red sand and dark gravel
46-49: **Brown silt/clay,** dark sand and dark gravel, several thin layers of brown clay
49-50.5: Gravel
50.5-51.5: **Brown clay** and dark gravel
51.5-52: Dark gravel and dark sand
52-53: **Brown clay**, dark gravel and dark sand
53-55: **Brown clay**, dark sand and dark gravel
55-57: **Brown clay**, dark gravel and dark sand
57-59: Brown clay with minor amounts of dark sand
59-62: Brown clay, dark sand and dark gravel
62-63: Brown clay
63-68: Brown clay, dark gravel and dark sand
69: Difficult drilling
69-71: Gravel 'hardpan' and sticky clay was penetrated with difficulty
71-72: Dark gravel
72-74: Brown clay and dark gravel
74-75: Brown clay and sand with minor amounts of gravel
75-77: Pink gravel (pink to red quartzites, some gray and black slate or mudstone) and coarse sand
77-79: Pink gravel and sand
79-99: Pink gravel and coarse sand (Note: Gravel from 75-100' looks clean, low silt/clay)

Test Hole 4 (TH-4)

0-3: Dark brown topsoil
3-8: Brown topsoil
8-10: Brown clay, and dark gravel
10-16: Dark gravel and sand, white shell fragments
16-20: Dark gravel and sand with white shell fragments
20-21: Dark gravel and sand with little amounts of clay
21-23: Dark gravel and sand
22-24: Brown clay, dark gravel and sand
24-26: Pink and red gravel
26-30: Pink and red gravel, pink and red coarse sand
30-30.6: Brown clay, pink-red gravel and sand
30.6-35: Pink and red gravel, pink and red coarse sand
35-36: Cobble or boulder obstruction. Broke through obstruction: gray slate- or mudstone-like.
36-37: Pink and red gravel, pink and red coarse sand.
37-38: Pink and red sand mostly, with minor amounts of pink and red gravel
38-39.6: Pink and red gravel, pink and red coarse sand, and **brown water**.
39.6-45: Pink-red, white, gray, and black gravel
45-47: Pink-red, white, gray, and black gravel and coarse sand
47-48: Dark brown clay, pink-red, white, gray, and black gravel and coarse sand
48-54: Pink-red, white, gray, and black gravel and coarse sand. Higher volume of dark brown water
54-55: Light brown-dark orange **silt, some clay** mixed with fine to coarse sand; no water.
55-55.5: Pink-red gravel and sand.
55.5-56: Some brown-orange clay stuck to pink-red gravel and coarse sand
56-59: Pink-red, white, and gray-black gravel (mostly quartzites) and coarse sand
59-62: Mostly coarse sand with some pink-red, white, and gray-black gravel
62-62.5: Orange-brown clay, coarse sand and some pink-red, white, and gray-black gravel, no water
62.5-64: Pink-red, white, and gray-black gravel and coarse sand (mostly pink-red quartzites)
64-65: Mostly coarse sand and some pink-red, white, and gray-black gravel
65-70: Pink-red, white, and gray-black gravel and coarse sand.
70-71: Brown clay, pink-red, white, and gray-black gravel and coarse sand; less water
71-72: Pink-red, white, and gray-black gravel and coarse sand; less water
72-74: Pink-red, white, and gray-black gravel and coarse sand; water (dark brown) is less dirty
74-74.5: Coarse dark sand Base of Upper Gravel
74.5-75: **Brown clay** and sand, no water
75-75.5: Pink-red, white, and gray-black gravel and coarse sand, some water
75.5-75.6: Brown clay, pink-red, white, and gray-black gravel and coarse sand
76-77: Pink-red, white, and gray-black gravel and coarse sand, some water
77-78: **Brown clay**, and coarse sand
78-79: Pink-red, white, and gray-black gravel and coarse sand
79-81: **Brown clay**, fine gravel and coarse sand, no water
81-84: **Brown clay** and gravel, no water
84-89: Pink-red, white, and gray-black gravel and coarse sand, no water
89-93: **Brown clay**, pink-red, white, and gray-black gravel and coarse sand
93-95: **Brown clay** and coarse sand, no water
95-99: Mostly coarse sand with some **brown clay**, and pink-red, white, and gray-black gravel
99-107: Some brown clay, fine pink-red, white, and gray-black gravel and coarse sand, no water
107-115: Pink-red, white, and gray-black gravel, coarse sand, no water
115-118: Fine pink-red, white, and gray-black gravel and coarse sand
118-119: More **clay**; mostly coarse sand and some fine pink-red, white, and gray-black gravel, no water

Test Hole 5 (TH-5)

Upper portion of hole was not logged; driller stated that topsoil extends to 10 ft bls and that cuttings from 10 to 59 ft bls were silt/clay gravel, with abundant water.

59-61: A lot of dark brown groundwater, silt/clay, dark gravel
61-64: Pink-red, gray-black fine gravel and coarse sand — Base of Upper Gravel
64-65: **Brown clay** and coarse sand
65-67: Appearance of more pink-red gravel
67-69: Mostly coarse sand, some fine gravel, some brown clay.
69-71: Coarse dark sand and **brown clay**. No water
71-72: **Brown clay** and dark gravel. No water

Test Hole 6 (TH-6)

0-10: Dark brown topsoil
10-12: Dark gravel
12-16.5: Sand and brown clay, white shell fragments. Note: drilling is rapid to this point.
16.5-17: Brown clay and dark gravel
17-18: Dark brown clay and dark gravel.
18-19: Dark gravel.
19-23: Fine dark gravel and coarse sand.
23-24: Coarse sand and sand-sized gravel cuttings. Pink, white quartzite; gray, black slate or mudstone
24-29: Dark gravel and sand. No water
29-30: Dark gravel coarse to fine sand. Some water.
30-40: Pink-red, gray-black, and white gravel.
40-47: Pink gravel and coarse sand. Little water.
47-55: Coarse sand and fine red-pink, black-gray, and some white gravel.
55-65: Coarse sand, some gravel, with some brown clay.
65-66: Coarse sand, some gravel, with some hard brown clay clasts.
66-68: Coarse sand, fine gravel, and brown clay.
68-69: Fine gravel, with some coarse sand. — Base of Upper Gravel
69-70: Coarse sand and fine gravel, and **brown clay**.
70-72: Fine gravel, with some coarse sand.
72-74: Coarse sand and fine gravel, and brown clay.
74-76: Fine gravel, with some coarse sand. **Some brown clay** and **clay balls**.
76-79: Pink, black-gray, and some white gravel, with some coarse sand. Little water.
79-92: Red-pink, black-gray, and some white gravel, with some coarse sand. No water.
92-98: Coarse sand and fine gravel.
98-99: Red-pink gravel with some coarse sand, and a thin layer of brown clay.
99-103: Red-pink, black-gray gravel, some coarse sand, and some **brown clay**. Note: 80-100 interval looks clean

Hildreth Well 4

Drilled by Cushman Drilling Inc.; bagged samples were collected by Monty Staples every 5 ft.
J. Welhan arrived when drill bit was at 165 ft bls.
Log is based on examination of bagged samples and driller's description of drilling conditions encountered.

1-7ft: Silt, topsoil
7-45: Fine-med. sand and gravel
45-55: Med.-coarse sand and gravel
55-75: Fine-med. sand and gravel
75: Hard drilling, **clay zone** , possibly indurated
75-90: Transition zone
90-120: S**ilt-rich**, fine-med. sand and gravel
120-145: Med.-coarse gravel, **silt-rich**
145-165: Med.-coarse gravel with sand, much less silt and clay
165-215: Same as above

Note: water at ca. 30' bls
<u>Base of Upper Gravel</u>
Note: 10 ft discrepancy between bagged samples and driller's notes; depth of contact is approximate and gradational
Note: several clay zones 90-145 ft
Note: hole 90-200 ft stayed open overnight

IDWR lithology filed by Cushman Drilling for the same well:

0-5: Hard pan clay
5-10: Sandy clay and gravel
10-20: Sand and gravel
20-70: Sand and gravel — <u>Base of Upper Gravel</u>
70-110: Compacted gravel
110-145: Clay and gravel
145-160: Clay and some gravel
160-170: Compacted gravel
170-174: Clay
174-200: Clay and gravel
200-215: Brown clay