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NORTH BEACH WATER DISTRICT
WIEGARDT WELL 1
CONSTRUCTION AND TESTING REPORT

DECEMBER 2013

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Introduction

Robinson Noble, Inc. provided hydrogeologic services for the construction and testing of Wiegardt Well 1 to North Beach Water District (District) of Ocean Park, Washington. Wiegardt Well 1 is located on parcel number 1211331300 (Figure 1) within the SW ¼, NE ¼ of Section 33, Township 12 North, Range 11 West, in Pacific County, Washington.

Wiegardt Well 1 is the first in a series of wells to be drilled to augment or replace the District's existing source wells that have shown declining yields during their lifespan. This replacement well was constructed and tested under Washington State Department of Ecology water right certificate number G2-00174C. The Pacific County Health Department (acting for Washington State Department of Health) conducted a well site evaluation and approved the District's application for the location of Wiegardt Well 1. The site meets the requirements under WAC 246-290-135, Source Protection.

Drilling

Bison Well Drilling & Septic, LLC (Contractor) of Spanaway, Washington mobilized their Bucyrus Erie Model 22W cable-tool drilling rig and equipment to the site on August 14. Drilling started with a 12-inch temporary casing drilled to a depth of 20 feet below ground surface (bgs). Eight-inch casing was installed and drilled to a depth of 175 feet by the end of the day on August 26. A geologic log of the materials penetrated is shown on Figure 2.

The District has experienced poor water quality in the shallower portions of the aquifer the Wiegardt well penetrates. Robinson Noble's technical specifications called for the Contractor to stop drilling when requested by our hydrogeologist and use a small pump to collect a clear water sample for water quality analysis. Several sample collection procedures were attempted including pumping at low rates, pumping at higher rates, then allowing for recovery and bailing. Water samples were collected at 71, 103, 114, 124.5, 129, 135, 145.5, and 166 feet below ground. Several of these samples were submitted for lab analysis of iron, though most were simply checked with field instruments. Field analysis of the water samples indicated that conductivity and pH were relatively consistent throughout the aquifer material. The uppermost sample had higher iron content than the deeper water samples, which was also evident in the taste of the water.

After drilling was completed, Robinson Noble completed sieve analysis and permeameter analysis of the formation samples collected. This information, coupled with the evaluation of the water quality and observations made by Robinson Noble and the Contractor, indicated that the well should be completed between 118 and 139 feet. A gravel-packed screen design was selected to provide optimal efficiency and control of the fine formation sand. Once the screen design was complete and the target aquifer zone was selected for completion, the 8-inch casing was cut off at 151 feet, and the remnant was backfilled with clean pea gravel in preparation for the well screen installation.

Construction and Development

During drilling, representative samples of the sediments encountered were collected approximately every ten feet and at formation changes. Samples were collected more frequently within the target aquifer zone. Grain-size analyses were completed by Robinson Noble for samples collected between 112 and 152 feet below ground. Additionally, selected samples within this region were tested with a falling-head permeameter. Samples were also rinsed on a #100 sieve, then retested with the permeameter to simulate the removal of fine materials during well development. The sieve analyses are included in the appendix.

The design of Wiegardt Well 1 includes 21 feet of 6-inch telescope size (5.6 inch OD, 5" ID), type 304 stainless-steel well screen with a slot size of 0.020 inch, placed from 118 to 139 feet, as shown on Figure 2 and Table 1. The screen is surrounded by a filter pack of 10-20 Colorado Silica sand. The transmitting capacity of this well screen is approximately 330 gpm at the manufacturers recommended entrance velocity of 0.1 feet per second.

Table 1. Screen assembly details

Item	Top (feet BGS)	Bottom (feet BGS)	Comments
Riser 6-inch	96.5	117.5	Mild steel pipe with "J" slot
Bell Reducer	117.5	118	6" to 5"
Five-inch 0.020-inch slots	118	139	Stainless-steel well screen
Tailpipe 5-inch	139	149	Mild steel pipe with bail bottom

Notes: All screens are 5-inch inside diameter
All screens are Type 304 stainless-steel, v-wire construction
All measurements are referenced to ground surface at the time of well construction

The well screen was installed by the Contractor on September 11. The filter-pack material was placed into the 5- to 8-inch annulus as the 8-inch casing was pulled back with hydraulic jacks to expose the screen to the formation. After the 8-inch casing was pulled back to 119 feet, the pack was settled by pulling a bailer through the screen assembly. The pack reserve was filled, and then a centrifugal pump was used to clear the water column prior to starting development. Pumping at approximately 50 gallons per minute (gpm) resulted in about five feet of drawdown below the static water level of 8.5 feet bgs for an initial specific capacity of about 10 gpm per foot of drawdown (gpm/ft).

Cable-tool surge-and-bail development started on September 12 by surging each 2.5-foot interval of well screen for ten minutes, starting at the top of the well screen assembly and working towards the bottom. The depth of the pack sand was checked periodically and the annulus filled as needed. Following this initial development, the well was pumped at a rate of about 60 gpm to clear the well of dirty water. Pumping caused six feet of drawdown and maintained the specific capacity of about ten gpm/ft observed in the initial test.

In an effort to accelerate the removal of fines from the formation sand during development, Johnson NuWell 220 dispersant was injected into the well screen. This solution is used to reduce the surface tension of silt and clay particles and allow for their easier removal during development. After injection of the NuWell 220, per the manufacturer's directions, development continued with a second run through the 21 feet of well screen. The third run through was conducted while simultaneously pumping the well at about 60 gpm. This run was done at a higher speed and for a longer duration. Each pass of surging brought fine formation sand into the well. The sand was removed from the tail pipe during the development with a small sand-pump bailer. Well screen development was considered complete on September 16, and the well was made ready for testing.

Testing

Following development, Bison installed their submersible test pump for step-rate and constant-rate testing. During testing, water levels were measured both manually and electronically. The manual water level data are included in the appendices.

The District made two observation wells available for installation of electronic water level data transducers. The observation wells are located as shown on Figure 1. South wellfield Well 2 is approximately 680 feet northwest of Wiegardt Well 1. South wellfield Well 4 (observation well 2) is approximately 810 feet east. The approximate elevations and distances were taken from an air photo and are listed in Table 2. Prior to the start of testing, Robinson Noble's hydrogeologist installed electronic data loggers in Wiegardt Well 1, South Well 2, and South Well 4.

All three wells show a response to the tidal changes along the Pacific coast. Wiegardt Well 1 and South Well 2 show a more muted response than South Well 4. Though the period of record was limited to the duration of the testing of Well 1, tidal fluctuations at Wiegardt Well 1 and South Well 2 are on the order of 0.05 feet, while South Well 4 is closer to 0.1 feet. This range of fluctuation is not significant.

Table 2. Observation well monitoring

Well	Distance Pumping Well (Feet)	Drawdown, September test (Feet)	Elevation of ground surface (est. Feet)
Wiegardt Well 1	0	18.01	50'
South Well 2	690	0.07	23
South Well 4	820	0.13	25

The step-rate test was conducted on September 17. Step-test results are shown on Figure 3 and are listed in Table 3. The overnight data are presented on a hydrograph in Figure 4. The aquifer shows a slight response to tidal changes at each well as is evident on the overnight hydrograph plot and the drawdown plot presented in Figures 4 and 5, respectively. The wells did not show any response to changes in barometric pressure.

Based on the step-test results, a 150-gpm rate was selected for the 24-hour test. The 24-hour test was started on September 18 at 9:00 AM. Test results are shown in Table 3 and on Figures 5, 6, and 7.

Table 3. Pumping test results

Date	Discharge Rate (gpm)	Elapsed Time (hrs)	Drawdown (feet)	Specific Capacity (gpm/ft)
9/17	100	0.5	11.33	8.80
	151	0.5	17.61	8.57
	180	0.5	20.85	8.63
9/18-19	151	24	18.01	8.30

During the constant-rate test, Wiegardt Well 1 produced 151 gpm for 24 hours with a drawdown of 18.01 feet from a static water level of 11.25 feet below the measuring point. The resulting specific capacity was 8.4 gpm/ft. The aquifer recovered to the original static water level in 30 minutes and to 0.07 feet above the original static water level after 80 minutes. Drawdown at the conclusion of the 24-hour test at 151 gpm was 0.07 feet at South Well 2 and 0.13

feet at South Well 4 (Table 2). Figure 7 is a distance-drawdown graph for the 30-minute pumping condition illustrating the decline in drawdown away from the well.

The results of our testing indicate the pumping water level dropped to approximately seven feet below sea level at Wiegardt Well 1 after 24 hours of pumping 151 gpm. As drawdown decreases radially from the well, this suggests the water level within the aquifer will remain above sea level once the radial distance is greater than 50 feet from the pumping well.

Hydrogeologic Analysis

The response of the aquifer during testing can be characterized with several parameters. Aquifer transmissivity (T) is a measure of the amount of water that can be transmitted horizontally by the full saturated thickness of the aquifer under a hydraulic gradient of one. Storage coefficient is the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer. Storage coefficients below 0.001 indicate that the aquifer is confined, while a higher storage coefficient suggests an unconfined aquifer.

Calculating transmissivity is typically a straightforward process, requiring a semi-log plot of the water level and time series with depth to water plotted on a linear scale and time plotted on a log scale. Typically, we can use this sort of plot, as presented in Figure 5 to readily calculate transmissivity via the Cooper-Jacob straight line method; however, that method does not appear to be valid for this pumping test. Casing storage changes the response during the earliest portion of the testing, making the analysis invalid for the first 3 minutes. The effects of partial penetration of the well screen (20 feet of screen in an aquifer that is 150 feet thick) and the presence of a positive recharge boundary change the response during the later portion of the testing. As such, the Cooper-Jacob approach cannot be applied to the entire data set, but rather only the portion between where the casing storage effects and the positive boundary effects skew the results. For our analysis, we selected data between five minutes and 30 minutes after pumping started as being representative of aquifer conditions. This results in a transmissivity of 58,600 gallons per day per foot of aquifer width (gpd/ft).

Given the difficulties applying the Cooper Jacob solution, we investigated the applicability of the classic Theis method, where the data is matched to an appropriate type curve to calculate the aquifer's transmissivity and storage coefficient. Unfortunately, the same two issues discussed above preclude the use of a Theis solution for Wiegardt Well 1 without windowing the data. Results of the Theis solution for the same data set suggest a transmissivity of 74,400 gpd/ft.

The Theis analysis of South Well 2 suggests a transmissivity of 240,000 gpd/ft and a storage coefficient of 0.000006. These numbers appear to be unrealistic, as they are several orders of magnitude higher than those calculated at Wiegardt Well 1. The Theis analysis of South Well 4 resulted in a transmissivity of 130,000 gpd/ft, and a storage coefficient of 0.00019. While the transmissivity value is still extraordinarily high, the storage coefficient seems to be more reasonable. With the distance-drawdown data, we calculated a storage coefficient of 0.00015 to 0.00019, suggesting that the aquifer is confined.

Though a rising tide overprinted the recovery, we also analyzed the recovery data from Wiegardt Well 1 with the Cooper-Jacob method. Transmissivity values ranging from 36,200 to 63,300 were calculated, which correspond reasonably well to the values calculated with the drawdown data.

The inability to easily and accurately calculate the transmissivity and storage coefficient from the data generated during testing of Wiegardt Well 1 in no way suggests that the well is not capable of producing water at the design rate, but rather suggest that the rate at which the well was tested was not adequate to stress the well and aquifer sufficiently for more accurate testing.

Hydrogeology

The geology of the Ocean Park area is dominated by recent beach sand deposits. Wells (1989)* mapped the area as recent beach deposits, which is consistent with our observations in the area. Drilling penetrated sands typical of a beach deposit until the clay at 174 feet below ground was encountered. The siltier material present in the upper portion of the aquifer serves as a confining layer.

Undoubtedly, the sand deposits comprising the aquifer extend to the east, below Willapa Bay, and west, well out past the beach. This puts the Pacific Ocean in direct contact with the aquifer material, providing an infinite source of water for recharge should aquifer stresses be too high. The eastern portion of the aquifer present below Willapa Bay is likely capped with the finer-grained bay sediments limiting recharge in that direction. The aquifer is well protected from saltwater intrusion via upconing from below by the presence of the clay layer. Still, there is saltwater present on both sides of the Long Beach Peninsula, so this aquifer has a relatively high susceptibility for saltwater intrusion via lateral encroachment, and as such, we do not recommend pumping rates higher than 200 gpm.

The groundwater is predominantly recharged by the precipitation falling on the aquifer area, though there are also some contributions from the percolation of irrigation water as well as leakage from irrigation ditches and streams. The groundwater discharges as subsurface flow to saltwater, flow to streams and springs, and as withdrawals from wells.

Water Quality

Water quality samples were collected for analysis as required for a new groundwater source. Samples were taken to Water Management Laboratories, Inc. in Tacoma for inorganic, volatile organic, synthetic organic, bacteriological, and radionuclide analysis. Water quality results are included in the appendices.

Inorganic Test Results

The water is of good quality and is clear and free of sand with a temperature of 51 degrees Fahrenheit. Inorganic test results show water with all measured parameters to be below the Department of Health's maximum contaminant levels (MCL) required for safe drinking water with the exception of the regulated contaminant arsenic. The arsenic result of 0.016 mg/L exceeds the MCL of 0.010 mg/L. This concentration of arsenic will require some form of treatment or mixing before it is distributed. However, we recommend additional pumping and sampling be completed before committing to design of a treatment program, as it is common for a newly-constructed well to have slightly elevated turbidity, often resulting in slightly elevated levels of metals. The turbidity of Wiegardt Well 1 was still 0.8 NTU at the time the sample was collected, which is somewhat higher than would be expected from a fully-developed groundwater source.

* Wells, R. E., 1989, Geologic map of the Cape Disappointment-Naselle River area, Pacific and Wahkiakum Counties, Washington, United States Geological Survey Miscellaneous Investigations Series Map I-1832, 1:62,500

Inorganic Disinfection Byproducts Results

Analysis shows all measured parameters to be below the detection level for each compound tested.

Volatile Organic Test Results

Analysis shows all measured parameters to be below the detection level for each compound tested.

Synthetic Organic Test Results

Analysis shows all measured parameters to be below the detection level for each compound tested.

Bacteriological Test Results

Bacteriological analysis results are satisfactory.

Radionuclide Test Results

The radionuclide analysis results show gross alpha and beta were not detected.

Findings

Wiegardt Well 1 performed very well with a specific capacity of 8.4 gpm/ft of drawdown at the design pumping rate of 150 gpm. After 24 hours of pumping, the water level was 26.71 feet below ground, which is 18.01 feet of drawdown from the static level. The pumping water level after 100 days of pumping 150 gpm, estimated from the drawdown slope of the 24-hour test, should be about 29 feet bgs. Aquifer transmissivity, calculated from drawdown and recovery data from the 24-hour tests, range from 58,600 to 74,400 gpd/ft.

The 24-hour test indicated minimal amounts of drawdown at South Well 2 and South Well 4 at distances of about 690 feet and 820 feet respectively. The distance drawdown graph shows the cone of influence extends about 750 feet from Wiegardt Well 1 and was used to calculate storage coefficients of 0.00015 to 0.00019, indicating the aquifer is confined. Testing shows the cone of influence, at 24 hours, intercepts sea level at a distance of approximately five feet from the well when pumping 150 gpm. This means the water level in the aquifer near the coast stays above sea level.

Water levels in this confined aquifer showed a slight response to changes in tide, but do not appear to respond to changes in barometric pressure (though barometric changes were not significant during the duration of well testing). The initial chemical analysis, though the sample still had a slightly elevated turbidity, suggests the water quality is acceptable with treatment. The water is sand free and meets drinking water standards for all water-quality parameters tested with the exception of the regulated contaminant arsenic. We recommend additional pumping and the analysis of at least one additional lower turbidity sample prior to committing to the design of a treatment system. Use of this well is not expected to cause saltwater intrusion or impairment of other wells in the area under normal operations as per our recommendations.

Recommendations

Robinson Noble recommends installation of a submersible pump inside of the 8-inch well casing with the pump intake set no lower than 90 feet. The District should consider installation of a variable-speed pump that is capable of rates between 125 and 200 gpm. We estimate the pumping water level will be about 27 feet after one day and 29 feet after 100 days of continuous pumping at 150 gpm (not including tidal effects). Two one-inch water level sounding tubes should be installed with the pump. A water level transducer should be installed in the well as soon as possible to generate a baseline hydrograph for the aquifer at this location. We recommend an AquiStar PT2X submersible temperature/pressure sensor offered by Instrumentation Northwest (or equivalent) be installed in a 1-inch tube at the top of the pump at a depth of approximately 85 feet. This well should be added to the District's manual or electronic monitoring program to record water level changes.

We recommend that static and pumping water levels be measured manually weekly and recorded along with total production and instantaneous discharge rate. Chloride should be tested quarterly once the well is put into operation. The water quality issue of elevated arsenic concentration should be addressed as early in the system design as possible. It is possible that treatment requirements may alter the recommended sizing of pumping equipment. However, prior to committing to the design of a treatment system for arsenic, we recommend additional pumping and the analysis of additional water samples, as elevated turbidity may increase dissolved arsenic concentrations. Such a pumping event could be completed during future aquifer and/or wellfield testing.

The statements, conclusions, and recommendations provided in this report are to be exclusively used within the context of this document. They are based upon generally accepted hydrogeologic practices and are the result of analysis by Robinson Noble staff. This report, including any attachments to it, is for the exclusive use of the North Beach Water District. Unless specifically stated in the document, no warranty, expressed or implied, is made.