PACIFIC groundwater GROUP

October 11, 2007

Don Bache
Port of Olympia
915 Washington Street NE
Olympia, WA 98501

Re: Deep Aquifer Hydrogeology
Cascade Pole Site, Olympia, WA

Dear Don:

The purpose of this report is to summarize and interpret existing information regarding groundwater flow in the deep aquifer beneath the Port of Olympia's Cascade Pole site. Mohsen Kourehdar of the Washington State Department of Ecology (Ecology) is currently drafting a Cleanup Action Plan for the site. As part of that Plan, Ecology requires an evaluation of the deep aquifer addressing the following questions:

- What is the direction of groundwater flow? Does the deep aquifer discharge into Budd Inlet?
- Is this aquifer used as a drinking water source? Identify the public and private drinking water supply wells within a one-mile radius of the site.
- Is there a vertical gradient between the surficial fill unit and the lower aquifer zones?
- Is this aquifer in communication with Budd Inlet (tidally influenced)?

This work was performed, and this report prepared, in accordance with hydrogeologic practices generally accepted at this time in this area, for the exclusive use of the Port of Olympia and their agents, for specific application to the Cascade Pole site. No other warranty, express or implied, is made.

SITE DESCRIPTION

The Cascade Pole site is located at 1100 Washington NE, Olympia WA. The location of the site is indicated in Figure 1. The 18-acre site occupies a man-made peninsula at the southern end of Budd Inlet. From 1957 to 1986, the Cascade Pole Company operated a wood treatment facility on property leased from the Port of Olympia. A number of substances associated with wood treatment have been detected in the shallow aquifer beneath the site. A slurry and sheet pile containment wall combined with a pump and treat system provide control of shallow onsite groundwater. However, the potential for migration to the deep aquifer has not been evaluated.

HYDROGEOLOGIC UNIT DESCRIPTIONS

Much of the peninsula was once a tideflat between the mouths of Moxlie Creek and the Deschutes River. An artificial fill of soil and demolition debris (Qf) was added to provide space for lumber and marine-related industries and port operations. The fill thickness ranges from about 5 to 10 feet. The upper aquifer extends to a depth of 18 to 30 feet beneath the site, within the fill and underlying naturally occurring soils

The fill overlies fine-grained bay sediments (unit Qgof) that were transported to the bay by streams related to the receding Vashon Glacier about 12,000 years ago, and, more recently, by Moxlie Creek and the Deschutes River. This unit consists of interbedded silty sand, silt, clayey silt, and clay, with silt and clay predominating. The known thickness of this unit ranges from 45 to 95 feet (PGG, 2005). Because of the predominantly silt and clay particle sizes, unit Qgof has relatively low permeability and is classified as an aquitard. This aquitard is responsible for creating the well-known artesian aquifer of downtown Olympia. Well logs near the Cascade Pole site indicate that this unit is present throughout the peninsula.

Beneath the aquitard is unit Qgos, with more than 400 feet of fine- to medium-grained sand and interbedded silt. This unit has relatively higher permeability and is the deep confined (aka artesian) aquifer of interest for this report. The sands also were deposited by north-flowing streams that formed after the melting Vashon glacier had receded northward of the mouth of the Straits of Juan de Fuca. The unit was recently identified and mapped as the “Tumwater sand” by geologists at the Washington Division of Geology and Earth Resources (Walsh and others, 2003). At the Cascade Pole site, this unit appears to be much thinner since an aquitard is present at a depth of approximately -70 feet below mean sea level. However, the Tumwater sand contains silt beds and further sand units are likely present beneath the aquitard.

GROUNDWATER FLOW CONCEPTUAL MODEL

The site conceptual model is defined largely by the influence of the adjacent Budd Inlet. At the intersection of subsurface fresh and marine waters, fresh water is forced upward and tends to discharge in a narrow zone along beach areas due to the higher density of marine saltwater (Figure 2). This results in an upward gradient in groundwater within an unconfined aquifer near a shoreline.

The fine-grained marine silt and clay aquitard that overlies the Tumwater Sand aquifer serves to retard the upward flow of groundwater from the deeper sediments, probably causing it to discharge farther from the mouth of the river and creek than would occur without the aquitard. Nonetheless, the groundwater eventually percolates slowly upward through the aquitard to discharge to the bay. In this way, the Tumwater Sand is in continuity with Budd Inlet.

The retardation of groundwater flow by the aquitard creates a backpressure effect in the groundwater, so that the head (potential energy) of the groundwater is several feet higher than both land surface and the saltwater level in Puget Sound. When wells are drilled through the aquitard and into the Tumwater Sand aquifer, the groundwater finds an easier path to the surface and flows out of pipes to a height of several feet above the land surface. This is the hydrogeologic phenomenon of artesian flow.

TIDAL INFLUENCE

Ocean-tide fluctuations can cause oscillations (sinusoidal waves) in groundwater levels, just as in the open ocean. The oscillations are progressively reduced in amplitude and lagged in time as the effects move inland (Barlow, 2003; Merritt, 2004). Tidal fluctuations can occur miles inland in a confined aquifer. In unconfined aquifers, tidal oscillations only occur close to the shore. Tidal influence can be transmitted directly through coarse grained aquifer material or across fine grained aquitards.

Flour Danial GTI (1998) found that the deep aquifer was tidally influenced but the shallow aquifer was not. Water levels varied by as much as five feet in the deep aquifer wells. Tidal influence in the unconfined aquifer was found to be less than one inch in the wells within 100 feet of the bay.

Presence of a tidal influence requires specific techniques for evaluating horizontal and vertical hydraulic gradients within and between aquifers. Single point measurements of groundwater flow (or snapshots) are not valid since they are highly dependent on the tidal cycle. In order to depict groundwater flow accurately in a tidally influenced aquifer, groundwater elevations should be averaged over a number of tidal cycles, preferably over a number of weeks. This type of analysis has not been completed for the Cascade Pole site so site scale horizontal and vertical flow cannot be evaluated.

GROUNDWATER FLOW DIRECTION

Groundwater elevations and flow directions in the deep aquifer were mapped by Drost and others (1998) and are presented in Figure 3. The figure indicates that groundwater generally flows towards the closest saltwater body. Therefore, deep groundwater at the Cascade Pole site likely flows towards Budd Inlet. This is consistent with the conceptual model presented above.

Flour Daniel GTI (1998) has depicted local groundwater flow directions in the deep aquifer in their analysis of the Cascade Pole site. The water levels were measured on October 6, 1998, and indicate groundwater flow was towards the northeast and southwest at that time. However, as mentioned above, single point measurements of groundwater flow directions are not conclusive in tidally influenced aquifers. Therefore the groundwater flow directions presented in the Flour Daniel GTI report should not be considered to represent overall flow conditions.

VERTICAL GRADIENT DIRECTION

Vertical gradient is an indication of the tendency of water to flow up or downward between aquifers. At Cascade Pole, the gradient is measured between the shallow and deep aquifers.

No thorough analysis of vertical gradient has been completed at the Cascade Pole site. Single point snapshot measurements have been taken and indicate both upward and downward gradients as would be expected in a tidally influenced aquifer. However, as noted above, average conditions should be used to evaluate vertical groundwater flow.

Artesian conditions in nearby downtown Olympia may also be used to infer vertical gradient conditions at the Cascade Pole site. Thurston County Health completed a comprehensive inventory of artesian wells in downtown Olympia in 1994. They identified 94 artesian well and spring sites based on historic records, and found 31 of those in the field. These artesian conditions are indicative of an upward gradient between the Tumwater Sand aquifer and overlying sediments. As indicated in Figure 2, upward gradients are more likely closer to saltwater bodies. Therefore, the artesian conditions seen in downtown are also likely present beneath the Cascade Pole site.

WATER SUPPLY WELLS

Within one mile of the subject site, five water supply wells have been identified, as shown in Figure 1. The locations of these wells were gathered from three sources: Department of Ecology well log database, Department of Health (DOH), and Drost and others (1998). Three wells were identified from the DOH, two wells from Drosts and others. No wells were identified from the Ecology well log database. Well logs for the identified wells were not available although DOH may have logs in their water system files.

All of the wells identified are located upgradient of the site and, therefore, are unlikely to be affected by water quality issues from the Cascade Pole site.

Sincerely,

Pacific Groundwater Group

Stephen Swope
Principal Hydrogeologist

Attachments: Figure 1: Site and Nearby Production Well Locations
Figure 2: Conceptual Model of Shoreline Groundwater Flow Showing Upward Gradient
Figure 3. Groundwater Contour Map (after Drost, 1998)

REFERENCES

Barlow, P., 2003, *Ground Water in Freshwater-Saltwater Environments of the Atlantic Coast*. U. S. Geological Survey, Circular 1262.

Drost, B. W., and others, 1998. *Hydrology and Quality of Ground Water in Northern Thurston County, Washington*. U. S. Geological Survey, Water-Resources Investigation Report 92-4109 (revised), Tacoma, Washington.

Fluor-Daniel GTI, 1998. *Hydrogeological Site Investigation, Port of Olympia.* Project 105560, December.

Merritt, M. L., 2004. *Estimating Hydraulic Properties of the Floridan Aquifer System by Analysis of Earth-Tide, Ocean-Tide, and Barometric Effects, Collier and Hendry Counties, Florida*. U. S. Geological Survey, Water-Resources Investigation Report 03-4267.

Pacific Groundwater Group, 2005. *Proposed City Of Olympia Artesian Well Background Information On Groundwater Flow And Quality In Downtown Olympia*. Prepared for the Friends of the Artesians.

Thurston County Environmental Health, 1994. *Artesian Well Survey*. Olympia, WA.

Walsh, T. J., Logan, R. L., Schasse, H. W., and Polenz, M., 2003. *Geologic Map of the Tumwater 7.5-minute Quadrangle, Thurston County, Washington*. Washington Div. of Geology and Earth Resources, Open File Report 2003-25, Olympia, WA.

CascadePoleReport.doc

- DOH Drinking Water Sources (3 Wells within 1-mile)
- Wells from USGS Study (2 Wells within 1-mile)
- DOE Well Logs (0 Well logs within 1-mile)
- Sections

2006 Orthophoto

N

0 Feet 2,500

0 Miles 1

Figure 1
Site Location and Nearby Domestic Well Locations

JS0710

PGG

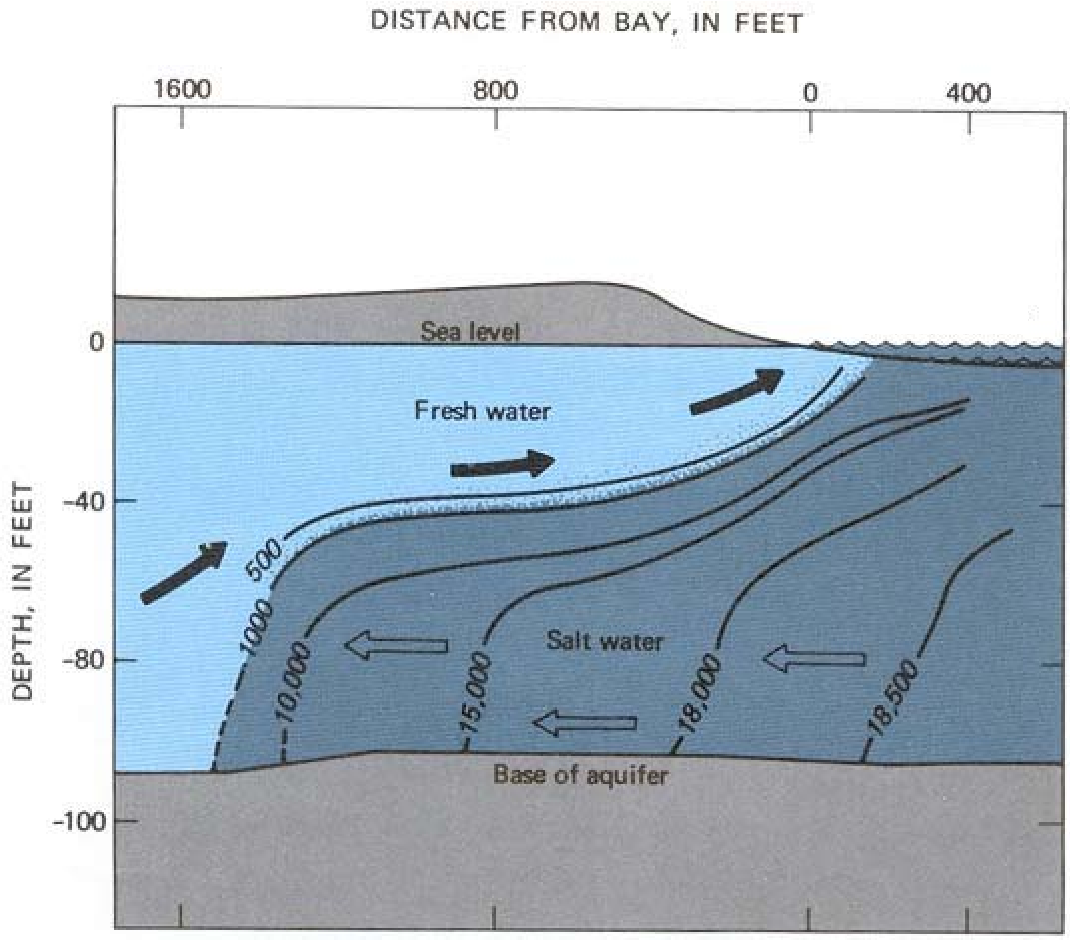
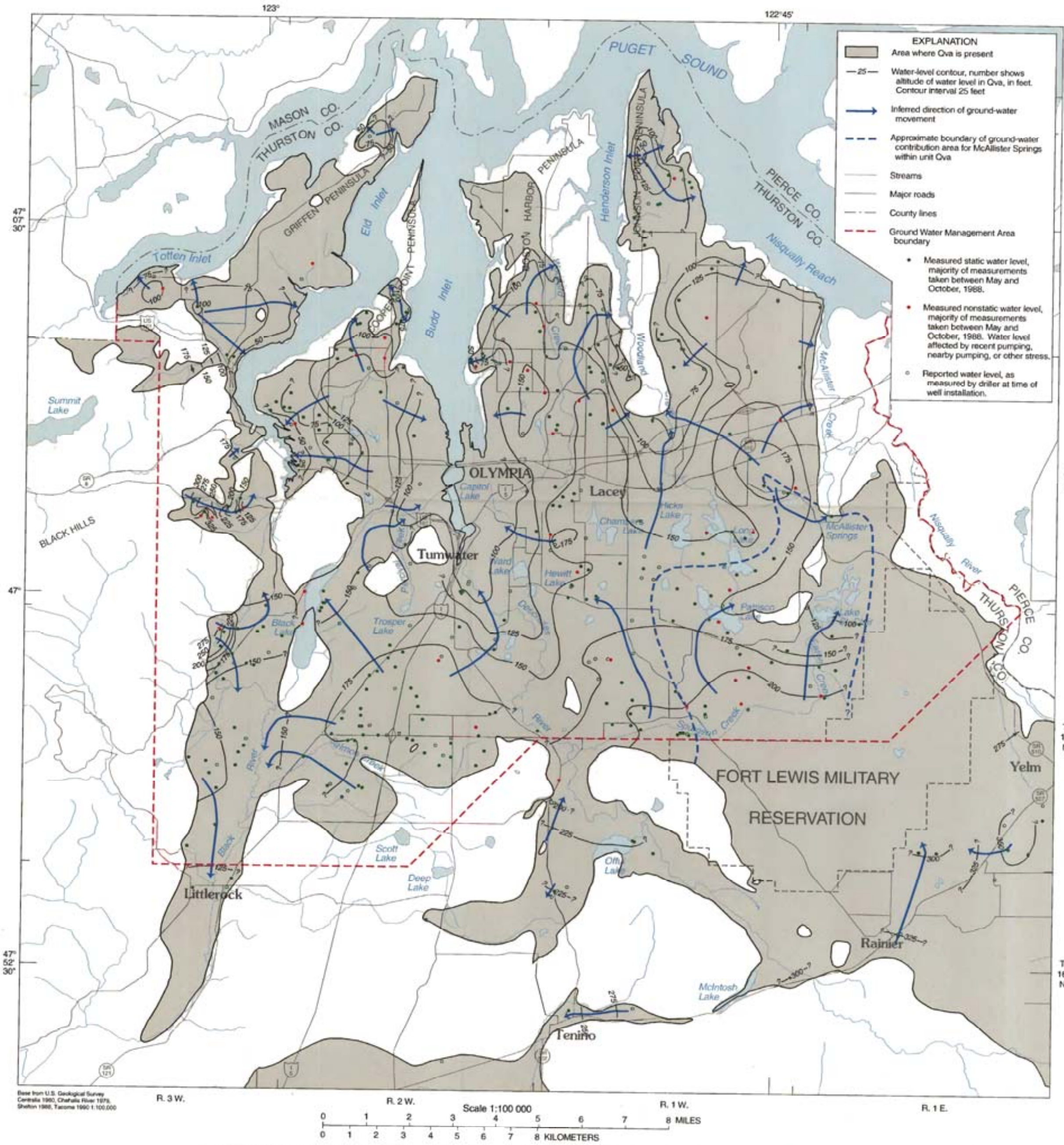


Figure 2. Conceptual Model of Shoreline Groundwater Flow Showing Upward Gradient

Cascade Pole JS0710



a. Water Levels and Flow Directions in Geohydrologic Unit Qva,1988

Figure 3. Groundwater Contour Map (From Drost and others, 1998)

Cascade Pole JS0710

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