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Memo

To: Gerald Steel

From: Llyn Doremus

Date: July 17, 2009

Re: Technical review of: Water Supply and Groundwater Impact Analysis
Pleasant Harbor Marina and Golf Resort – November 20, 2008 (SDEIS)
Recommendations for Additional Hydrogeologic Testing at Black Point

Background

The Pleasant Harbor Marina and Golf Resort is planned for construction on the Black Point Peninsula in Hood Canal. The peninsula is surrounded by salt water for more than 75% of it's shoreline. At least 15 wells are located along the Black Point eastern and northern shorelines that are at risk of seawater intrusion. Hood Canal is known to have a serious problem with depleted dissolved oxygen content, which has resulted in what has been termed a "dead zone". The dead zone creates conditions where a wide range of sea life that requires dissolved oxygen in the waters of their environment cannot survive. The depleted oxygen condition is known to result from enhanced activity of bacteria and algae that is promoted by discharge of nutrients (nitrogen and phosphorus) dissolved in surface and groundwater to Hood Canal. The two conditions: seawater surrounding the Black Point Peninsula and the potential for seawater intrusion to degrade water quality in shoreline wells, and extreme sensitivity of Hood Canal biologic health to the release of nutrients generate a very delicately balanced hydrogeologic environment in which the Resort is proposed for construction.

The Resort water supply for residential, commercial and irrigation purposes has been proposed through a combination of rainwater capture, reuse, reclamation, infiltration, and groundwater withdrawal processes. While the general scheme of the supply system has been outlined in previous documents, the specifics of how each of the components will operate has not yet been accurately defined. The potential for negative impacts of the various supply system components on the delicately balanced hydrogeologic environment is high. A sophisticated understanding of the Black Point hydrogeologic system is mandated to assess potential for degradation from the proposed water supply scheme to dissolved oxygen levels in Hood Canal, to seawater intrusion into the Black Point aquifer, and for the design, maintenance and operation of that system to function without degrading the Black Point aquifer and Hood Canal.

These comments address the hydrogeologic characterization presented in the report: *Water Supply and Groundwater Impact Analysis, Pleasant Harbor Marina and Golf Resort* by Subsurface Group, LLC. November 20, 2008 (Report) with respect to the information necessary for characterization, design and operation of a water supply system that does not degrade the Black Point aquifer. The accuracy and completeness of the Report assumptions, information and conclusions are assessed, and recommendations for additional testing to fill in the information gaps in the Report are listed.

Hydrogeologic System

Groundwater moves through the sediments and rock, which, along with the other water moving through the system, defines the hydrolgeologic system of a specific site. Sediment tends to form in layers, which can be visualized as a “layer cake” type configuration. Sediments and rock layers with a large percentage of void spaces typically transmit water more quickly, which is termed a high permeability hydrogeologic unit. Sediment layers that are more dense, with tiny void spaces are termed “low permeability” or “impermeable”. Low permeability sediment layers impede downward migration (infiltration) of groundwater, and tend to accumulate water on their upper surface. This is normally how unconfined aquifers form. The permeability of an aquifer is usually determined by conducting a pump test. With the exception of the single pump test of the American Campground well, and the marginal data generated from that test, there is no data presented on the aquifer properties of the various hydrogeologic units on the Black Point Peninsula.

RECOMMENDATION FOR ADDITIONAL TESTING

The Report describes results from a pump test conducted in the American Campground well for 48 hours to assess the permeability and other aquifer properties in the well vicinity. The data generated by the test was found to be insufficient to assess the aquifer properties, because the drawdown in the monitoring wells was almost undetectable. Pump testing should be conducted in all of the wells that are proposed for water supply purposes. The pumping rate used should be equivalent to the rate at which water is proposed for withdrawal for the water supply needs of the resort (at a minimum 75 gallons per minute to provide the 121 acre feet annual use projection), because of the likelihood that individual wells may be relied upon for the full volume for the resort water demand when problems with water level drawdown and seawater intrusion occur. The tests should be run for sufficient duration (minimum 72 hours) to derive measurable drawdown curve in at least one of the monitoring wells, so that reliable aquifer properties can be calculated.

The direction of groundwater movement is defined by the groundwater gradient. Groundwater moves from locations of high water elevation level to low elevation discharging eventually to lower-elevation surface water bodies. The groundwater elevation pattern often mimics the ground surface topographic elevation pattern. Downgradient (lower groundwater elevation) locations manifest the affects of groundwater movement and withdrawal in higher elevation locations. It is important to understand the directions of groundwater movement in order to assess the magnitude and distribution of ground water level decreases associated with groundwater withdrawal (pumping from wells). In particular, reduction in the groundwater levels in shoreline areas increases the risk of seawater intrusion into water supply wells.

The Report presents an interpretation of groundwater flow direction towards the center of the peninsula and then to the east (discharging into Hood Canal). The groundwater surface elevation contours are illustrated in Figure 4 of the Report, and suggest that a groundwater high point (at MW-2) dominates groundwater flow direction on the entire peninsula. That single data point (MW-2 water level elevation) is disproportionally valued in interpreting the groundwater flow directions.

RECOMMENDATION FOR ADDITIONAL TESTING

Groundwater levels should be measured in every accessible Black Point Peninsula well on the same date, so that a groundwater elevation contour level map can be constructed that is reliable for use in interpreting the direction(s) of groundwater movement. A better understanding of the direction of groundwater movement will support a better interpretation of the groundwater withdrawal impacts to private wells on the Black Point Peninsula and seawater intrusion risk.

Diagrams of the Black Point Peninsula hydrogeologic system are presented in the Report Figures 11, 12 and 13. Much of the site is covered with dense, low permeability till. About one third of the site has additional sediments deposited on top of the till that are higher in permeability and allow water to migrate more quickly through them. Water that migrates downward through these higher permeability sediments might slow down and accumulate in a "perched" aquifer upon encountering the underlying low-permeability till. There is no evidence of perched conditions at this site presented in the Report.

Basalt bedrock is shown in Figures 13 in wells located on the northern part of the site. The contribution of groundwater flow transmitted through bedrock to the Black Point aquifer is not well characterized in the Report, nor is the bedrock permeability, or the hydraulic connection between bedrock and the overlying unconsolidated sediments. With the exception of the single pump test of the American Campground well, and the marginal data generated from that test, there is no data presented on the aquifer properties of the bedrock or unconsolidated sediment hydrogeologic units on the Black Point Peninsula, or on the hydraulic continuity between unconsolidated sediment units and the bedrock underlying them. Further pump testing (as previously described) is necessary to better define aquifer properties of the hydrogeologic units and the hydraulic continuity with bedrock on the site.

Water Budget

A water budget uses estimates or measurements of each component of the hydrologic cycle to assess the entire movement of water through a specific hydrologic system annually. For the purposes of characterizing the impact of the proposed water management scheme on the the Black Point Peninsula aquifer and hydrogeology, the water budget should encompass the entire Peninsula. To prevent or at least minimize detrimental impacts it is essential that the components of the water budget are defined as accurately as possible.

A typical equation for a water balance is as follows.

$Ppt = E + Q + dS_g + dS_s$

Where:

> Ppt = annual precipitation
>
> E = annual evaporation plus transpiration (evapotranspiration)
>
> Q = stream flow or surface water runoff
>
> dS_s = the change in quantity that is stored as surface water for the year (negative for a decrease in the water quantity in surface storage)

dS_g = the change in the water quantity that is stored as groundwater for the year (negative for a decrease in the groundwater storage, indicating a drop in groundwater levels)

Surface Water Flow

Although surface water is not flowing onto the proposed Pleasant Harbor Resort site, the quantity of water discharged from Black Point Peninsula as stream flow impacts the water budget for the Peninsula. Accurate stream flow measurements help reduce uncertainty in other portions of the hydrologic budget that are more difficult to estimate. Stream flow emitting from the lake in the eastern-central portion of Black Point Peninsula, as well as any other stream flow on the Peninsula needs accurate assessment in order to calculate its contribution to the water budget, and its influence on the other components of the budget.

RECOMMENDATION FOR ADDITIONAL TESTING (Q)

Stream flow emitting from the lake on the eastern-central margin of the Peninsula, and flowing to the east shoreline should be monitored to assess the rate of surface water runoff from the Peninsula.

Surface Water Storage

Surface water is typically stored in lakes and wetlands. To better understand the changes in surface water storage that are ongoing under current conditions (dSs), and that may be expected from the proposed use of kettles as water storage facilities, the water stored in Lake (on the eastern margin of the Peninsula) should be monitored for changes in lake elevation. It is likely that the lake is in hydraulic continuity with groundwater, and receives groundwater discharge. A better delineation of lake level variations, and their relationship to precipitation quantities and timing, and groundwater levels will improve the understanding of how groundwater moves through the Peninsula hydrogeologic system.

RECOMMENDATION FOR ADDITIONAL TESTING (dSs)

Monitor lake level elevation over the period of a year (concurrent with other monitoring data collected).

Precipitation

Precipitation provides water that supports the various water uses and hydrologic components. Annual precipitation at this site is poorly understood because of the variability in precipitation along the north south extent of Hood Canal, and the lack of monitored data collected in the Black Point Peninsula or Brinnon vicinity.

RECOMMENDATION FOR ADDITIONAL TESTING (Ppt)

Precipitation should be monitored on the Black Point Peninsula for an entire year. In addition, the data available from the NOAA approved weather station at location AS461 on the west side of Hwy. 101 across from Pleasant Harbor should be analyzed. See Attachment 1 hereto.

Groundwater Storage

Groundwater that is stored in an aquifer is the amount of water that is added to the aquifer over the course of the year (termed recharge) minus the amount withdrawn or discharged from the aquifer. Recharge to an aquifer derives from precipitation that infiltrates into the ground. Discharge from an aquifer typically goes to stream flow (Q), or it may be pumped for water supply or irrigation purposes, or, in this case, includes flow into Hood Canal to diminish salt water intrusion into the fresh water supply. The difference between the amount recharged and the amount discharged is the change in storage (dSg). Quantification of recharge is an important factor in assessing the storage changes in groundwater, as is quantification of the discharge.

Recharge of an aquifer results from vertical infiltration of precipitation that falls on the ground surface overlying the aquifer. Aquifers are more rapidly recharged when the sediment overlying the aquifer is of “high permeability” and when there is high annual precipitation. Consider if the precipitation that infiltrates to recharge the aquifer is half (50%), the standard assumption when data is not available to calculate actual recharge rates. For this site the annual precipitation rate is not well known, which makes the annual recharge rate even more difficult to assess. Table 3 lists 55 inches for annual precipitation in Quilcene (the closest site monitored). Half of this is 27 inches, or 2.3 feet. For this 220 acre site, this provides an annual recharge of 504 acre feet (significantly less than the 783 acre feet claimed in the Report on page 17). The presence of low permeability till will slow down groundwater infiltration, and likely reduce the rate of groundwater recharge to the aquifer even further than estimated using these assumptions.

There will be substantial additional evapotranspiration caused by the watering of the golf course and other vegetation in the hot months of the year. This has not been adequately considered.

RECOMMENDATION FOR ADDITIONAL TESTING (dSg)

Groundwater levels in the three monitoring wells (MW-1, MW-2 and MW-3) should be monitored for at least one year, to determine the variation in groundwater elevation. Precipitation should be monitored on the site for at least one year to determine the actual precipitation received annually (concurrently with other monitoring data collected). Analyses of recharge quantities and rates should be done using monitored data, and presented in the calculation of the water budget for the site. A separate set of calculations should be done assuming serious drought conditions – perhaps an estimated 500-year drought.

Quantification of groundwater discharge is calculated using measurements of changes in groundwater elevation, stream flow measurements, pumped quantities from the aquifer, and precipitation measurements. It is important to delineate the groundwater flow direction and to delineate locations of groundwater discharge, to more accurately assess the annual amount of groundwater discharging from the aquifer. The change in groundwater storage calculated amount (dSg) relies upon an accurate estimation of annual groundwater discharge and its relative value with respect to the annual recharge amount. Additionally, discharge of groundwater from beneath the proposed resort to Hood Canal, that contains contaminated landscaping chemicals (especially nitrate and phosphorus) poses a significant risk to the environmental health of Hood Canal.

Evapotranspiration

The information presented in the Report on estimations of evapotranspiration (24.1 or 24.2 inches per year), need to be presented with data, formulas, tables, and assumptions used in those calculations, as part of the comprehensive water budget estimation.

Summary of Recommendations for Additional Testing

To better understand the hydrogeologic response to the proposed water supply management scheme in this relatively sensitive groundwater environment, each of the components of the hydrologic cycle should be more accurately quantified. In addition, the aquifer properties must be better defined to design a supply system that does not overstress the aquifer. The following tests are recommended in order to gather that information.

Aquifer properties

Aquifer testing – pump tests should be conducted for a minimum of 72 hours in any wells that might be proposed for water supply purposes (American Campground Well, Pleasant Tides Coop Well (Sam Boling Water System/Black Point Water Company) and MW-2). Pump tests should be conducted for long enough to generate a measurable drawdown in at least two monitoring wells in the vicinity.   Pumping rate at the Pleasant Tides Coop Well should include the 300 gpm for existing water rights plus the proposed new withdrawal.

- Pump testing at MW-2 should include installation of a monitoring well, at a location that is as close as existing wells are to the eastern shoreline, in line with the MW-2 well. Chloride testing of water pumped from the aquifer should be done when the MW-2 is pump tested.
- Pump testing at the Pleasant Times Coop Well should include monitoring for water level drawdown and for chloride at the other Black Point Water Company wells, the Babare well, the Tudor well and the other Pleasant Harbor Beach Tract Owners wells.

Seawater intrusion

Chloride content in groundwater should be determined in samples collected from wells pumped adjacent to the marine shoreline over the duration of the pump tests. At a minimum one sample should be collected prior to initiation of pumping, another after at least 12 hours of pumping and a third shortly before pumping is stopped. More samples provide more confidence in the data collected, and the interpretations derived from that data. Chloride concentrations between 100 and 200 mg/l indicate wells at moderate risk for seawater intrusion, with 200 mg/l being the trigger for high risk, according to Island County's Seawater Intrusion Policy (a copy is included with these comments as Attachment 2).

Groundwater movement

Groundwater levels should be measured in every accessible well on the same date, so that a groundwater elevation contour level map can be constructed that is reliable for interpreting the direction(s) of groundwater movement. A better understanding of the direction of groundwater movement will support a better interpretation of the groundwater withdrawal impacts to private wells on the Black Point Peninsula and seawater intrusion risk.

Water Budget

The presentation of the water budget in the Report makes it impossible to assess the individual components of the water budget, their relationship to each other, and what data was used to derive them. A comprehensive explanation of the water balance calculations must be provided. This should include:

- water budget equation used
- Values for each component the equation

- data, calculations and assumptions used to derive each value

In particular the following components need better delineation.

Precipitation

Precipitation should be monitored on the Black Point Peninsula site for the duration of a year (concurrent with other monitoring data collection).

Recharge

Groundwater levels should be monitored with continuous electronic logs in the three monitoring wells, and reported for the duration of a year to assess the range of groundwater level variation, and the recharge resulting from precipitation events. Precipitation monitoring should coincide with groundwater level monitoring periods. Precipitation should be used to evaluate the changes in groundwater levels associated with precipitation events (i.e. recharge)

Evapotranspiration

Evapotranspiration calculations, and the data and assumptions used in those calculations needs to be presented in report form.

Streamflow

Stream flow emitting from the lake on the eastern margin of the Peninsula, and flowing to the east shoreline should be monitored to assess the rate of surface water runoff from the Peninsula.

Lake Level

Monitor lake (located in the central-eastern portion of Black Point Peninsula) level elevation over the period of a year concurrent with other monitoring data collected.