APPENDIX E

COMMENTS RELEVANT TO DR. YEATS' E-MAIL LETTER TO "DEAR SKEA FOLKS" TRANSMITTED JULY 12, 2006 BY E-MAIL FROM EMMA DIXON

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Dr. Robert Yeats submitted an e-mail letter to SKEA on Friday, July 7, 2006, the day following the USGS visit to the Brightwater site. Dr. Yeats' e-mail letter contains nine paragraphs; our comments are limited to those paragraphs with technical information. Our comments below are indexed to those paragraphs.

Paragraph 4

The southern trench showed a zone of high-angle faulting. This statement differs from what is included in the "USGS Site Visit Report, July 6, 2006" (see Appendix D of this report). The USGS Site Visit Report, paragraph 3, sentence 3 states "A near vertical fault in glacial deposits in the northern half of trench 1 appeared to offset several strata and large-scale folds were observed." In fact, the feature referred to in the USGS Site Visit Report has a variable strike to the north and dips to the west at 38° to 55° and therefore is not accurately characterized as either 'high-angle' or 'near vertical'. Observations of this feature indicate that is contains injected sand and silt in delicate filaments that do not appear to be offset or sheared, leading us to conclude that it is an injection feature rather than a tectonic fault. Furthermore, the injection feature is present in very dense sand that clearly must have been overridden by glacial ice, and the injected sand and silt filaments are as dense as the adjacent sand. Regardless of its origin, however, the overlying glacial gravels, also compacted to a very dense condition by glacial ice, were present across the injection feature (called a near vertical fault in the USGS Site Visit Report).

Adjacent to it was a zone of liquefaction, and adjacent to that, a zone of folding. The folding and liquefaction features were not separate zones. The liquefaction and folding features were in the same very dense sand as the injection feature. The liquefaction features and folds were in very dense sand and overlying glacial gravels, also compacted to a very dense condition by glacial ice, were present stratigraphically above the liquefaction features and area folding.

Brian thought that the deformation was similar to that at the Beef Barley trench and appeared to be tectonic. The Beef Barley trench is the name given by the USGS to the trench that they excavated across Lineament 4 in the North Mitigation Area of the Brightwater site. The deformation in that trench was documented by Sherrod et al. (2005a, b) and in SEIS Technical Appendix A. Glacially overridden deposits were not exposed in the Beef Barley trench, but glacially overridden deposits were almost the only type of deposit exposed in the trenches visited by the USGS on July 6, 2006. Several significant differences exist between the geologic features exposed in the Beef Barley and more recent investigative trenches. For example, the deformation of glacial recessional outwash deposits exposed in the Beef Barley trench consisted of a down-to-the-southwest monoclinal fold with two minor northeast-dipping high-angle reverse faults. The deformation in post-glacial wetland deposits in the Beef Barley trench consisted of liquefaction and some warping. In contrast, however, the “southern trench” visited by the USGS on July 6, 2006, exposed very dense sand deposits with liquefaction and folding features. The “near vertical fault” mentioned in the USGS Site Visit Report had a north strike and west dip, unlike the two minor northwest-striking, northeast-dipping faults in the Beef Barley trench. Furthermore, any suggestion of displacement along the “near vertical fault” mentioned in the USGS Site Visit Report would be down-to-the-west normal displacement, unlike the up-on-the-northeast reverse displacement of the two minor faults in the Beef Barley trench. We believe that the contrast in deformation between the two trenches is striking. Furthermore, all deformation features exposed in the “southern trench” were covered by unfaulted and undeformed subglacial gravel and diamict deposits of the Vashon glaciation. Regional radiocarbon dates reported by Porter and Swanson (1998) document the advance and recession of Vashon glacial ice in the Seattle area. The advance began approximately 17,590 cal yr B.P. and recession was nearly complete approximately 16,570 cal yr B.P. Therefore, any deformation covered by undeformed Vashon-age deposits is greater than 11,000 years old (pre-Holocene) and would be inactive by the definition of an active fault in the 2003 International Building Code (IBC). Inactive deformation need not be considered for siting or design using 2003 IBC criteria.

Paragraph 5

Keaton interpreted the features as "periglacial", that is, related to glaciation and not active faulting. This statement does not accurately reflect the discussion that occurred while the USGS was visiting the trenches. “Periglacial” refers to an environment that is adjacent to or near glaciers or is very cold (well below the freezing temperature of water at atmospheric pressure). The liquefaction features and folding exposed in the “southern trench” could be created by pressures generated by overriding ice or by earthquake shaking. “Active faulting” (meaning displacement along a fault plane) clearly did not create the liquefaction or folding features exposed in the “southern trench”. The injection feature that is called a “near vertical fault” in the USGS Site Visit report is an ambiguous feature that has qualities that appear to be related to a minor amount of discrete displacement or to injection of fluidized sand and silt. Both of these qualities could be created by subglacial processes (processes acting at the sole of a glacier while the weight of the ice and its movement are putting forces into the underlying sediments). Both of these qualities also could be created by seismotectonic (earthquake) processes. The injected sand and silt in delicate filaments that do not appear to be offset or sheared supports a conclusion that it is an injection feature rather than a tectonic fault. The origin of these features is moot relative to the 2003 IBC, however, because they are overlain by very dense, glacial gravel deposits that are unfaulted and undeformed. All glacial deposits in the Seattle region are more than 16,000 cal yr old, which is greater than the 11,000-yr age (Holocene) specified in the 2003 IBC definition of an active fault.

Brian thought that the high angle fault plus the liquefaction made Keaton's interpretation untenable, but Keaton apparently would not consider any other interpretation. The USGS Site Visit Report states that "A near vertical fault in glacial deposits in the north half of trench 1 [the "southern trench"] appeared to offset several strata and large-scale folds were observed. A zone containing at least four liquefaction features immediately southeast of the fault is marked by manganese/iron staining." During discussions in the trench on July 6, 2006, Dr. Sherrod made a comment when he saw the "near vertical fault" that it was an ambiguous feature that could be caused by glaciotectonic loading, earthquake-induced liquefaction, or tectonic faulting. Apparently, by the time the USGS prepared its Site Visit Report, Dr. Sherrod rejected the glaciotectonic loading and earthquake-induced liquefaction processes, and instead concluded that the feature was a tectonic fault. King County's consultants examined this feature in detail and conclude that it is most likely an injection feature rather than a tectonic fault for the following reasons:

- Sand and silt in delicate filaments oriented along the feature appear to be unfaulted and unsheared.
- The sand and silt filaments are consistent with injection of fluidized sediment but not consistent with concentrated shear along a tectonic fault plane.
- The strike of the feature is variable, but generally north-trending. We would expect a tectonic fault produced by shear deformation to have a uniform strike over the 10- to 20-foot distance between the walls of the trench.
- The dip of the feature is to the west, but variable (as steep as 55° and as gentle as 38°). We would expect a tectonic fault produced by shear deformation to have a uniform dip over the 10- to 20-foot distance between the walls of the trench.

These observations were discussed in the field with the USGS during their July 6, 2006, site visit. Dr. Keaton and other scientists advising King County considered all possible interpretations and arrived at an interpretation that was consistent with all observed data. The observed data includes the uniform density of the sand adjacent to the injection feature as well as the sand and silt filaments within the injection feature and the overlying glacial gravel deposits that are unfaulted and undeformed. The last observation is critical in an interpretation of the significance of the feature to the proposed facilities: regardless of its origin, it is too old to be active by the 11,000-yr (Holocene) criteria in the 2003 IBC.

Paragraph 6

Normally in a case like this where there is a difference of opinion that affects the earthquake hazard, the consultant would consider both interpretations and weigh one against the other, which we call a logic-tree analysis. The characteristics of the deformation features described in the previous comment are a clear indication that all interpretations were considered in arriving at an interpretation. The difference of opinion about the origin of the deformation features in this case does not affect the conclusion that deformation features are inactive by the definition in the 2003 IBC because they are overlain by unfaulted and undeformed sediments of glacial age which are pre-Holocene (more than 11,000 years old). Dr. Yeats' statement is an inaccurate application of a logic-tree analysis. Yeats et al. (1997) states that the logic-tree approach is "simply a means of formalizing and systematizing the thought process when several sequential decisions are to be made in a complex analysis, and each decision in the sequence is given an estimated probability of being correct." Reiter (1990) refers to Coppersmith and Youngs (1986) description of the logic-tree approach as

> "a decision flow path consisting of nodes and branches. Each branch represents a discrete choice of a parameter, for example whether [earthquake magnitude] = 6.0, 6.5, or 7.0. Each branch is assigned a likelihood of being correct. The nodes are the connecting points between the input elements (for example zonation, maximum magnitude, and ground motion) as determined by the general logical progression of assumptions and the specifics that may be required as a result of a particular branch. The determination that a fault is active would require different types of decisions (fault length, slip history etc.) to determine maximum magnitude than if earthquake occurrence was assumed to occur randomly in a seismotectonic province."

Reiter (1990) states that "the likelihood of a particular scenario being correct is simply the product of the likelihoods associated with each branch comprising the scenario."

Thus, a logic tree is a graphic representation of alternative paths that could be taken to calculate a desired parameter in a way that allows uncertainty to be quantified. A logic-tree approach was appropriately used in the probabilistic seismic hazard analysis of the Brightwater site (SEIS Technical Appendix B) to develop a value of horizontal acceleration for use in designing plant facilities. A logic-tree approach is not an appropriate way to determine if a feature was caused by tectonic faulting or injection of fluidized sand and silt.

In Brian's view, most knowledgeable paleoseismologists would interpret the features as tectonic. Deformation features exposed in the "southern trench" were entirely within sediments deposited in a glacial environment. The sand in which liquefaction features and folds were observed was overlain by Vashon diamict and gravel that were unfaulted and undeformed. The injection feature (called a "near vertical fault" in the USGS Site Visit report) was in very dense sand and diamict deposits that were overlain by unfaulted and undeformed Vashon gravel. Possible causes for the deformation features are loading related to glacial processes, earthquake-induced liquefaction, and tectonic faulting. We use all geologic qualities of the features to conclude that they are most likely caused by glacial processes or earthquake shaking. We use the unfaulted and undeformed glacial deposits overlying all deformation features to conclude that they are not active by the definition used in the 2003 IBC. The inactive nature of the deformation features reduces their significance to the location and design of plant facilities, even though they may be of interest to the USGS in their consideration of the broader seismic history of the Puget Lowland.

Paragraph 7

At issue is the age of the deformed sediments: are they Vashon advance or recessional deposits? The issue of concern for Brightwater is the age of the deformation in the context of the definition of an active fault in the 2003 IBC. The 2003 IBC definition includes a historic slip rate of 1 mm/yr or more and geologic evidence of seismic activity within the Holocene (the past 11,000 years). All deformation features in the "southern trench" are overlain by unfaulted and undeformed glacial sediments. All glacial sediments in the site region are older than Holocene (Porter and Swanson, 1998). Therefore, all deformation features are older than Holocene, so they are not active by the 2003 IBC definition. Furthermore, the deposits contain masses of diamict and are all very dense indicating that they have been overridden by glacial ice: These are subglacial and advance outwash deposits of the Vashon glaciation.

If they are older, then even if they are faulted, the deposits faulted would be older, which affects the time since the last event at the site. As stated previously, King County geologists have considered the geologic features in the context of the surrounding sediments and concluded that the anomalies are likely not due to tectonic faulting, Additionally, even if they were, such faulting would not meet the 2003 IBC definition of an active fault.

Of course, the SWIF has already been shown to have multiple events, but not at the chemical building site. We agree with this statement. "Multiple events" means two or possibly three folding events occurred in post-glacial time, with the most recent folding event apparently accompanied by minor faulting and liquefaction (Sherrod et al., 2005b). No events have occurred at the chemical building site.

Paragraph 8

The northern trench was not really a trench. It was 200 feet long, but for most of that length it was a "scoop" in the earth rather than a steep-walled trench, deeper at one end. The trench walls were sloped for stability and safety, but the lower four feet of the walls were vertical. The southwest end was deeper than the middle and northeast end because of the thickness of fill deposits. Vashon diamict was exposed along the entire length of the trench except where drain pipes were encountered.

It was only 6 feet deep, and the upper four feet was fill. The thickness of fill was variable, but it is important to note that Vashon diamict was exposed along the entire length of the trench except where drain pipes were encountered.

Brian observed a lot of fractures in the bottom 2 feet, but the shallowness of the trench prevented any meaningful analysis by him or anyone else. The Vashon diamict was fractured, but still provided for meaningful analysis. Fractures are common in the Vashon diamict (Troost et al., 2005). The fractures exposed in the "northern trench" had a simple tension crack mode interpreted by the parallel character of the sides of non-planar fractures with thin fine sand filling. Two fractures had features of minor amounts of left-lateral separation; one of these fractures was cut across by another sand-filled fracture that was continuous and the other fracture showed a minor (0.01 ft) difference in thickness of the sand filling in an irregular shape of the fracture. The sand filling the fractures was uniformly very dense, indicating that it had been overridden by ice after it was in place. It is useful to point out that the interpretation of absence of active fault features in the "northern trench" is consistent with the continuity of glacially scoured upland ridges and absence of scarps in LiDAR data adjacent to the site.

The trench did not serve the purpose of evaluating faulting at the northern chemical building. We are confident that if an active fault had been exposed in the "northern trench" that it would have been detected. An active fault by the 2003 IBC definition would have displaced the ground within the past 11,000 years, which is several to many thousand years after the Vashon ice had completely melted at the site. Our interpretation of absence of active fault features in the "northern trench" is consistent with the continuity of glacially scoured upland ridges and absence of scarps in LiDAR data adjacent to the site.

References

Porter, S.C., and Swanson, T.W., 1998, Radiocarbon age constraints on rates of advance and retreat of the Puget Lobe of the Cordilleran Ice Sheet during the last glaciation: Quaternary Research, v. 50, p. 205-213.

Reiter, L., 1990, Earthquake hazard analysis: New York, Columbia University Press, 254 p.

Sherrod, B.L., Barnett, E., and Kelsey, H.M., 2005a, Excavation Logs of Two Trenches Across a Strand of the Southern Whidbey Island Fault Zone Near Grace, Washington: US Geological Survey Open-File Report 2005-1013 (http://pubs.usgs.gov/of/2005/1013/), one sheet.

Sherrod, B.L., Blakely, R.J., Weaver, C., Kelsey, H., Barnett, E., and Wells, R., 2005b, Holocene fault scarps and shallow magnetic anomalies along the Southern Whidbey Island fault zone near Woodinville, Washington: U.S. Geological Survey Open-File Report 2005-1136, 35 p.

Troost, K.G., Booth, D.B., Wisher, A.P., and Shimel, S.A., 2005, The geologic map of Seattle - a progress report: U.S. Geological Survey Open-File Report 2005-1252 (pubs.usgs.gov/of/2005/1252), scale 1:24,000, one sheet.

Yeats, R.S., Sieh, K., and Allen, C.R., 1997, The geology of earthquakes: New York, Oxford University Press, 568 p.