# APPENDIX D

# COMMENTS RELEVANT TO USGS SITE VISIT REPORT, JULY 6, 2006

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King County invited representatives of the U.S. Geological Survey (USGS) to visit the Brightwater site after its consultants had worked in the Chemical Building Seismic Trenches for nearly three weeks. On Thursday, July 6, 2006, Drs. Craig Weaver, Brian Sherrod, and Ralph Haugerud visited the site and toured the excavations near the south and the north chemical buildings. Dr. Weaver sent an e-mail message with the subject line “USGS Site Visit Report, July 6, 2006” to Bob Peterson at King County Department of Natural Resources Wastewater Division; the time stamp on the e-mail was Friday, July 07, 2006 4:26 PM. Dr. Weaver’s e-mail message contained seven paragraphs; our comments are limited to those that have technical information about the seismic trenches. The comments below are indexed to those paragraphs.

### Paragraph 3

This paragraph contains six sentences, five of which contain technical information and are reproduced below in *italics*, followed by our comments.

*The southern trench (trench 1) shows evidence of deformation and liquefaction in glacial deposits*. We agree, but would add the following detail. The ‘southern trench’ consisted of four exposures, as described in our report on the Chemical Building Seismic Trenches. The deformation and liquefaction features were localized to areas exposed in Trench South 1 and Trench South 1c. No deformation features were exposed in Trench South 1a, and very minor deformation features exposed in Trench South 1b could be attributed to melt out of buried ice incorporated into the glacial deposits

*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*. The ‘near vertical fault’ refers to a feature exposed in Trench South 1 and Trench South 1c. This feature has a variable, but generally north-trending strike and dips to the west at 55° to 38°. The feature contains delicate filaments of fine sand and silt which appear to be neither displaced nor sheared; therefore, we interpret it to be an injection feature. The strata that might have appeared to be offset at one location in Trench South 1 did not have the same appearance in Trench South 1c. Furthermore, a glacial gravel deposit sufficiently dense that it must have been overridden by ice was present vertically above the injection feature in Trenches South 1 and 1c, and exposed in Trenches South 1a and 1b along the range of projections of the injection feature approximately 40 feet to the northwest. This glacial gravel deposit was undeformed and unfaulted. Thus, we conclude that the observed anomaly probably is not the result of a seismic ground rupture event and is not a seismically active fault.

*A zone containing at least four liquefaction features immediately southeast of the fault is marked by manganese/iron staining*. The liquefaction features were distributed along the same unit which was very dense sand. The density of this sand is important for two reasons: 1) the density is sufficiently high that the sand is not susceptible to present-day liquefaction processes when exposed to strong earthquake shaking, and 2) the high density must have been caused by the weight of glacial ice compacting the sand which makes the age of the liquefaction features contemporaneous with the Vashon glacial advance. Additionally, the sand containing the liquefaction features is overlain by Vashon diamict unaffected by liquefaction. Clearly, these liquefaction features have an early Vashon age (between 17,590 and 16,950 cal yr B.P.; Porter and Swanson, 1998). Furthermore, the manganese/iron staining seemed to be on a generally northward trend, in contrast to the northwest trend of the SWIF.

*The timing of the deformation does not seem resolvable with the available information.* We disagree with this statement for the reasons described in our comments addressing the previous two sentences and conclude that the deformation likely occurred prior to or during the early Vashon age due to the presence of the compacted soils caused by glacial processes.

*The entire sequence exposed in the trench may be related to the Vashon*. We agree with this statement. In fact, the presence of diamict units in the stratigraphic sequence is clear and unequivocal evidence of deposition by glacial ice. The Vashon advance is the most recent glacial activity in the Seattle region. Therefore, we believe that the deposits exposed in the ‘southern trench’ are entirely Vashon glacial and subglacial deposits.

**Paragraph 4**

This paragraph contains three sentences, which are reproduced below in *italics*, followed by our comments.

*Although it may be possible to develop a defensible argument that all of the deformation is related to glacio-tectonics, an equally convincing argument could be constructed for some or all of the observed deformation resulting from regional seismotectonics*. We are convinced that some of the deformation must be caused by glacial processes alone, whereas other deformation may be caused by glacial processes or earthquake processes. However even if earthquake processes are involved, no active fault was found in the trenches. Regional seismotectonics refers to strong shaking generated by earthquakes on seismic sources in the region, which could be responsible for the liquefaction features exposed in the ‘southern trench’. Regional seismotectonics refers to earthquake-related displacement and permanent ground deformation along fault zones, as well as strong shaking generated by local or distant active faults. From the perspective of facilities at the Brightwater site, the deformation exposed in the ‘southern trench’, the presence of unfaulted and undeformed glacial deposits overlying the glacial units containing the deformation features is critically important for an understanding of the significance of the deformation features, including the ‘near vertical fault’ mentioned in Paragraph 3 of Dr. Weaver’s Site Visit Report. Regardless of their cause, the deformation features are inactive because 1) all glacial features in the Seattle region are greater than 11,000 years old (older than Holocene) and 2) undeformed glacial deposits overlie the deformation features.

*In particular, we are struck with similiarities* [sic] *between the deformation pattern in trench 1 compared with the trench dug on lineament 4 at the north end of the Brightwater site*. The trench dug on Lineament 4 is the USGS Beef Barley trench (Sherrod et al., 2005a, b) which is the same as King County Trench 2a (SEIS Technical Appendix A). It is unclear what deformation pattern in 'trench 1' is similar with the trench dug on Lineament 4. From our perspective they were not similar. The trench on Lineament 4 exposed glacial recessional outwash and post-glacial wetland deposits. Liquefaction features were exposed, along with a northwest-trending monoclinal fold that had two minor northwest-trending, north-dipping faults with small amounts of apparent reverse separation. The deformation features exposed in the 'southern trench' are quite different from anything exposed in the trench across Lineament 4. Lineament 4 was identified by the USGS on the basis of lineaments in aeromagnetic data and LiDAR data (Blakely et al., 2004); the trench on Lineament 4 exposed a northwest-trending deformation features. The 'southern trench' exposed north-trending liquefaction features, an injection feature (interpreted by the USGS to be a near-vertical fault), and inclined strata, all of which were overlain by undeformed glacial deposits (diamict or gravel).

*The estimated width of the deformation zone in trench 1 is consistent with USGS interpretations of a regional seismotectonic cause for deformation zones of similar width in other trenches in the area*. Regardless of the cause of deformation in 'trench 1', it is overlain by undeformed glacial deposits. Any deformation exposed in 'trench 1' is inactive because overlying glacial deposits which must be more than 11,000 years old (older than Holocene) are unfaulted and undeformed. Therefore, the glacial-age deformation features are not significant for location and design of facilities at the Brightwater site, even though they may be of interest to the USGS in its consideration of the broader seismic history of the Puget Lowland.

**Paragraph 5**

This paragraph contains ten sentences, which are reproduced below in *italics*, followed by our comments.

*The northern trench (trench 2), was dug to a very shallow depth for most of its length*. The northern trench was dug deep enough to expose diamict deposits of the Vashon glaciation.

*We understand that there were tough field issues--compact till and drainage pipes--that may preclude digging a deeper trench*. The compactness of the till (diamict) made excavation difficult and slow, but the primary limiting factor was the presence of active drainage pipes. Several pipes were encountered in the northern trench, but none of them were known from utility plans or field activities prior to late June 2006. Three utility trenches had been backfilled with pea gravel, which made them relatively easy to find during excavation so that the buried pipes could be avoided. One pipe was severed during excavation near the northeast end of the trench, resulting in partial flooding of the trench. The broken pipe was backfilled immediately, and the area was treated carefully so that water from the broken pipe would not flood the rest of the trench. Seepage was encountered in a few areas indicating that the bottom of the trench was close to the ground water level.

*Despite this limitation, the available exposures are rich in potential information*. We logged the discontinuous stratifications and fractures exposed in the diamict. The buried pipes crossed the trench at an angle, so that diamict exposures on opposite sides of the trench could be examined for features that would have a northwest trend, which would be parallel to the SWIF, an important orientation for evaluating the seismic significance. In some places, the floor of the trench was swept clean so that the crack pattern could be examined in detail.

*Numerous cracks, some tight and some open and filled with fine sand, that strike approximately northwest, sub-parallel with the northwest strike of lineament 4 and lineament X were observed over most of the trench's length*. Numerous cracks or fractures were exposed in the diamict in the northern trench. Most fractures were tight or filled with fine sand; no fractures were open. Those fractures filled with fine sand had small apertures – on the order of 3 mm or 0.01 ft. The fracture-filling sand was very dense. The strikes of fractures were variable, and those exposed on the floor of the trench showed polygonal patterns. No preferred northwest trend was noticed in the fractures.

*Details of the cracks remain undetermined, but they appear to be consistent with an origin of strike-slip shearing*. The fractures in the northern trench were logged in detail and photographed. We disagree with the conclusion that the fractures appear to be consistent with an ‘origin of strike-slip shearing’. Two fractures showed very minor amounts of left-lateral separation (Figure D-1). One tight fracture shows about 0.05 ft of left separation of three thin fine sand dikes (half arrows in Photo A on Figure D-1) and a single fine sand dike that is continuous across the tight fracture (opposing arrows in Photo A on Figure D-1). The other fracture is irregular and shows a slight difference in thickness (approximately 0.01 ft) of the fine sand filling (Photo B on Figure D-1). Therefore we conclude that the most likely explanation for the cracks is glacial processes, and Troost et al. (2005) indicate that fractures are common in deposits of Vashon till.

*Some King County consultants suggested that the cracks could be related to frozen ground during glaciation, but there was no indication that they had checked this suggestion with local experts at the University of Washington who have studied temperature distribution during the last ice episodes*. The polygonal character of fracture in some area (Photo C on Figure D-1) was reminiscent of shrinkage cracks. We considered ice-wedge polygons among the possible causes of the fractures, but decided that the frozen ground concept was not worth pursuing. The density of the sand filling the cracks and the simple tension crack opening mode of most fractures, among other factors, seemed to consistently support the conclusion that the cracks were normal fractures in the diamict, as Troost et al. (2005) indicate are common.

*As we noted in the field, our quick look at these cracks suggested a similarity to cracking observed in one of our trenches on the Tacoma fault*. We believe that this comment refers to the trench across the Catfish Lake scarp (Sherrod et al., 2003). We have not seen this trench, but have reviewed the USGS Open-File Report 03-455 with descriptions and the trench log. Few fractures are shown on the trench log or mentioned in the text. All fractures are low angle, as are the faults, one of which is reported to have 30 cm of reverse slip in post-glacial soil overlying Vashon diamict. The cracks described in this reference and shown on the trench log appear to be quite different from the fractures in diamict exposed in the North Trench.

*There, the cracks were in deformed glacial till above the tip of Tacoma fault*. The report describing the Catfish Lake scarp trench (Sherrod et al., 2003) indicates that the trench was excavated across high-amplitude anomalies in seismic, gravity, and aeromagnetic geophysical data which corresponded to a scarp in LiDAR data that ranges from less than 1 m to 3 m. These qualities of the Catfish Lake scarp are completely different from the conditions near the North Chemical Building at the Brightwater site.

*Once again, with the available field information, it would appear to be very tough to develop a strong argument for the timing of the cracks*. The simple tension crack appearance of most fractures and their high to moderately high angle of dip is consistent with the commonly fractured character of the Vashon till and diamict deposits described by Troost et al. (2005). Furthermore, the high density of deposits filling the fractures is consistent with compaction by the weight of glacial ice, implying that the fractures and the fracture-filling deposits are essentially as old as the glacial deposits themselves. The continuity of glacially scoured upland ridges adjacent to the east and west of the Brightwater site and the absence of scarps in the LiDAR data also are consistent with our interpretation of the exposures in the North Trench.

*Our informal suggestion to your group in the field was to deepen this trench to better understand the nature of these cracks*. We excavated a pit on the north side of the North Trench to better expose a feature that appeared to be a zone where fluidized sand and silt had been injected into the diamict. The injection feature had a strike of N65°W and a dip of approximately 45° to the southwest. During cleaning of the trench, the sand and silt filaments in this injection feature appeared to be slightly softer or less dense than the adjacent diamict deposits. During excavation of the supplemental pit, our engineering geologist paid particular attention to the density of the injected deposits. The pit was excavated with a smooth-tooth bucket, so the density could be observed clearly after each pass of the bucket. Without question, the sand and silt filaments in the zone injected along this feature were uniformly very dense. The sand and silt filaments were continuous without features that could be attributed to shearing or post-injection displacement.

**Paragraph 6**

This paragraph contains five sentences, two of which contain technical information and are reproduced below in *italics*, followed by our comments.

*Thus, both trenches contain considerable food for thought*. We have thought a lot about the features exposed in the trench and believe that the information consistently supports a conclusion that no active faults were exposed in the Chemical Building Trenches.

*Some of the issues, particularly timing and ultimate cause for the deformation, may not be resolveable to your satisfaction with the available information in these trenches*. We believe that the geologic reasoning about the density of sand where liquefaction features were exposed, the unfaulted and undeformed nature of glacial deposits overlying projections of deformation features, and the uniform high density of fine sand filling fractures and of sand and silt in injection features is consistent with the LiDAR data of the site area which shows continuity of glacially scoured upland ridges and absence of scarps. Our attempts at obtaining radiocarbon dates from trenches did not result in meaningful information, but the ages of the glacial deposits can be inferred with high confidence from the dates published by Porter and Swanson (1998).

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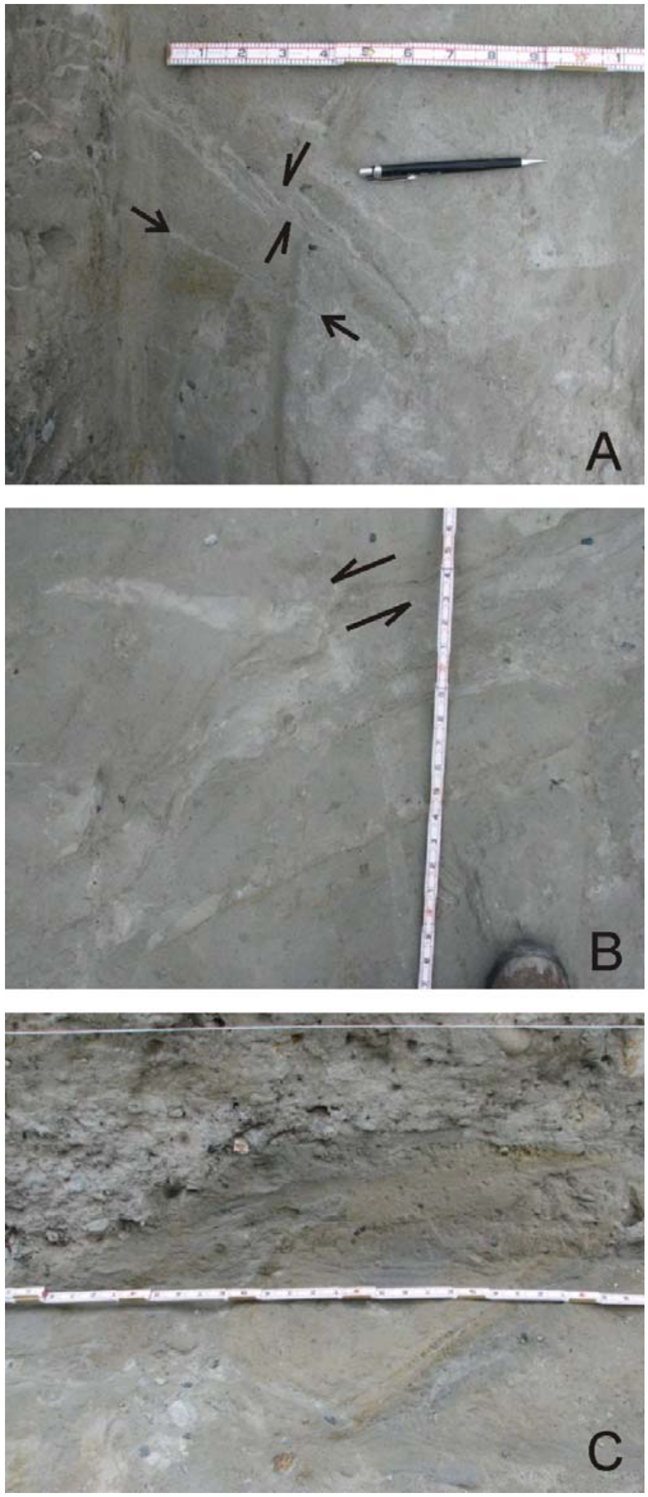


Figure D-1. Photographs of fractures in the diamict exposed in the North Trench. A. Apparent left-lateral separation of sand dikes (half arrows) and continuity of single sand dike (opposing arrows). B. Apparent left-lateral separation of irregular sand-filled fracture. C. Polygonal pattern of fractures.