BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

IN RE APPLICATION NO. 99-1 SUMAS ENERGY 2 GENERATION FACILITY	EXHIBIT _________ (MM-T)

APPLICANT'S PREFILED TESTIMONY

MARK MOLINARI

Q. Please introduce yourself to the Council.

A. My name is Mark Molinari. My business address is URS Corporation, Century Square, 1501 4th Avenue Suite 1400, Seattle, Washington 98101

Q. What is the subject of your testimony?

A. My testimony will address four topics:

First, I will describe my background and experience as an Associate Engineering Geologist and a professional geologic consultant.

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Second, I will discuss the seismic conditions at the SE2 site and how these conditions compare to other areas in the Sumas valley, the Puget Sound Lowland and the Fraser River valley.

Third, I will address statements made by Professor Donald Easterbrook regarding seismic conditions at the SE2 site.

Fourth, I will describe the seismic analyses that SE2 has proposed in the Second Revised Application.

Background

Q. What is your title and occupation?

A. I am an Associate Geologist with URS Corporation providing project management and senior level technical services on a wide range of geologic and seismic hazard, environmental permitting, and environmental assessment and restoration projects.

Q. Please describe your education and experience.

A. I have a B.A. and M.S. in Geology, and 20 years experience performing paleoseismic investigations and seismic hazard assessments for power plants, petroleum production and refining facilities, dams and other engineered structures throughout the western United States and internationally. The last 10 years I have been based in Seattle, Washington and have performed geologic and seismic hazard assessments for proposed pipeline routes, power plants, and industrial and governmental structures. I am a Registered Geologist and Certified Engineering Geologist in California, and

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have applied for similar registrations in Washington under the recently enacted registration program. A copy of my resume is provided as Exhibit MM-1.

Q. What work have you done to evaluate the seismic conditions and risks at the SE2 site?

A. I was responsible for preparing Sections 2.15 and 3.1 of the revised (January 10, 2000) application submitted by SE2, and I reviewed the initial submittal and the supporting documents referenced in the revised application. Among other things, in preparing these sections, I drew upon my 20 years of experience as a professional geologist, including my past 10 years of experience performing assessments of geologic and seismic hazards in western Washington. This experience also includes my having been invited to participate in several U.S. Geological Survey workshops where the newest research on seismic hazards of the region and how these hazards will be modeled for the national seismic hazard maps for the updated building code is presented and discussed. In response to Dr. Easterbrook's and his colleagues' statements regarding increased seismic risks in the Sumas area, I read Dr. Easterbrook's affidavit attached to the Joint Motion to Reopen the Record for Limited Purpose filed by Council for the Environment and Whatcom County, as well as the "Summary of the Geology of the Sumas and Vedder MT. Faults" — authored by Professor Dr. Easterbrook and his colleagues, Dr. D.C. Engebretson and D.J. Kovanen — that was attached to the affidavit. I also reviewed a similar report dated April 2001, the most detailed report I have seen by these three authors, that was posted on the Generations Affected by Senseless Power ("GASP") website. Finally, I reviewed a Master's thesis by one of Dr. Engebretson's former students, Lori Roberts,

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and I re-reviewed various published geologic maps, reports, and articles that are referenced in these materials in order to assess whether or not they support Dr. Easterbrook's interpretations. A list of these references is presented in Exhibit-MM2

<u>Seismic Conditions at SE2 Site</u>

Q. Please describe the seismic conditions at the SE2 site.

A. The SE2 site is located in the northern portion of the Puget Sound Lowland of western Washington (bounded by the Cascade and Olympic mountains on the east and west, the Fraser River to the north and the Chehalis River to the south). Historically, the Sumas Valley area has a similar or lower level of seismicity than other areas of the Puget Sound Lowland and the Fraser River Valley of Canada. Potential sources of earthquakes of engineering significance in the site region include magnitude (M) 8+ earthquakes on the Cascadia subduction zone offshore of Washington and Vancouver Island, M 6+ deep intraplate earthquakes beneath the Puget Sound Lowland similar to the 2001 Nisqually earthquake, and earthquakes on shallow crustal faults that may be present along the valley margin or in the vicinity of the Sumas Valley.

Q. What are the seismic risks at the SE2 site?

A. The potential seismic risks at the SE2 site are strong ground shaking from a local or regional earthquake, and liquefaction of loose, saturated soils in the shallow subsurface. Unlike, Dr. Easterbrook, I do not think that the available data indicate a significant potential for surface fault rupture at the SE2 site; nor is there a landslide hazard at the SE2 site.

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Q. Are these risks greater at the SE2 site than elsewhere in the Sumas Valley?

A. No. For any given earthquake, the intensity of strong ground shaking generally decreases with distance from the earthquake hypocenter (location within the earth where the earthquake is centered). Therefore ground shaking from distant (regional) sources would be expected to be similar throughout the valley. If an earthquake were to occur on a shallow crustal fault located beneath or near the valley, the portions of the valley closest to the hypocenter may experience slightly stronger ground shaking than more distant locations. In addition, most of the Sumas Valley is characterized as having a moderate to high liquefaction potential. Therefore, the risks at the SE2 site are not greater than other areas of the Sumas Valley.

Q. To put the risks at the SE2 site in perspective, please compare the seismic conditions and seismic risks at the SE2 site to other locations in the Pacific Northwest.

A. The seismic risks at the SE2 site are comparable to or less than other locations within the Puget Sound Lowland and Fraser River Valley with similar soil conditions. In other words, the risks are similar to other locations within river valleys incised into uplands in the region. These valleys are underlain by unconsolidated alluvial soils consisting of a mixture of sand, silt, gravel and clay, and are generally considered to have a moderate to high liquefaction potential. Dense glacial soils or rock that are not susceptible to liquefaction generally underlie the upland areas. The unconsolidated soils within the valleys may also cause some amplification of the strong ground shaking. On the other hand, while other locations in Puget Sound are situated in the proximity of known active faults such as the Seattle fault, the existence

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of the Sumas fault is uncertain and, as discussed below, neither the hypothetical Sumas nor Vedder Mountain faults have been demonstrated to be active faults.

Q. In your opinion, do the seismic conditions at the SE2 site make the site unsuitable for the SE2 energy generation facility?

A. No. There is nothing in the existing geological data for the Sumas area to indicate that seismic risks at the SE2 site are exceptional compared to other areas of the Puget Sound region or to otherwise indicate that the site is unsuitable for an energy generation facility such as SE2 due to seismic risks.

Professor Easterbrook's Statements

Q. Are you familiar with statements made by Professor Donald Easterbrook regarding seismic conditions and risks at the SE2 site?

A. Yes. As mentioned above, I have read Dr. Easterbrook's affidavit, his "Summary of the Geology of the Sumas and Vedder MT. Faults" and his slightly more detailed report that is posted on the GASP website.

Q. Have you obtained and reviewed Professor Easterbrook's research?

A. No. Dr. Easterbrook and his colleagues have not published this research in a peer-reviewed professional journal or formal report that provides the level of detail necessary to substantiate their claims consistent with the generally accepted standard of practice for professional consulting geologists or academic publications. Since their interpretations and summary information regarding the seismic hazards of the Sumas Valley and SE2 site were made public in November 2000, SE2 repeatedly

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requested additional data or reports documenting their research. However, nothing was provided. Eventually, I was permitted to interview Drs. Easterbrook and Engebretson at the Whatcom County Courthouse on June 8, 2001. At this interview, they confirmed that their research is preliminary and ongoing and they do not have additional data that could be provided other than the 1999 Master's thesis by Lori Roberts on the historical, shallow seismicity of the northern Puget Sound Lowland.

Q. Can you summarize Professor Easterbrook's opinions regarding seismic conditions and risks at the SE2 site?

A. Dr. Easterbrook and his colleagues have interpreted the Sumas Valley to be a graben bounded by two active faults, the Sumas fault on the northwest and Vedder Mountain fault on the southeast. They believe these faults extend from the Fraser Valley, northeast of Sumas, to near Bellingham and possibly beyond on the southwest. While other researchers in this area have previously mapped the Vedder Mountain fault, they have not previously mapped the hypothetical Sumas fault. The evidence cited for the presence of the Sumas fault is: (1) the subsurface configuration of bedrock beneath the valley; (2) the morphology of the valley as shown by a digital elevation model of the area; and (3) two possible areas of surface scarps along the hypothesized fault trace that have not been verified. They interpret the historical seismicity of the area to indicate that the Vedder Mountain fault, and possibly the Sumas fault, is seismically active. Based on his interpretations regarding the Vedder Mountain fault and his hypothesis regarding the supposed Sumas fault, Professor Easterbrook concludes that the potential for surface fault rupture on the Sumas fault, and the potential for other related seismic hazards such as strong ground shaking, liquefaction, and landslides

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associated with earthquakes on the Sumas or Vedder Mountain fault are too great to be mitigated for a structure such as SE2 at the SE2 site.

Q. Do you agree with Professor Easterbrook's opinions?

A. No.

Q Why not?

A. Based on the available data, I think that: (1) some of his interpretations of fault locations are possible but there are other interpretations that are equally or more likely; (2) the seismic risks of the SE2 site are not as significant as he indicates; and (3) the risks can be assessed and mitigated to an acceptable level using standard scientific and engineering practices. As presented in this testimony, it is my professional opinion that based on the currently available data and information, there is not sufficient evidence to demonstrate that the Sumas fault is present as inferred by Dr. Easterbrook. In addition, if it is present, it is not a seismically active fault and the surface trace would be located west of the SE2 site. Therefore, it does not pose a surface rupture hazard at the SE2 site. It is also my opinion that there is not a landslide hazard at the site, and that typical seismic hazard assessment and design methods can characterize and mitigate the potential ground shaking and liquefaction hazards.

Q. Professor Easterbrook and the proponents of his statements claim that his research presents "new" information regarding seismic conditions in the Sumas area. Do you agree?

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A. The only “new” information presented by Dr. Easterbrook and his colleagues in the aforementioned documents is the digital elevation model (DEM) attached as a figure to Dr. Easterbrook’s affidavit, and reproduced as Figures 1 and 3 in their report on the GASP website. This DEM allows a better visualization of the topography of the Sumas Valley and the rest of Whatcom County and southern British Columbia adjacent to the county. However, the other information presented on which they base their interpretation is not new, as outlined below, nor do they present sufficient data or information to substantiate this interpretation.

As Professor Easterbrook indicates in his affidavit, the Vedder Mountain fault and the Sumas fault have been known to be present for a long time. My review of readily available geologic maps and reports indicates that the Vedder Mountain fault was previously documented (e.g. Gordy, 1988; Jones, 1996; Dragovich et al., 1997), but the presence of the Sumas fault has not been documented and it is best characterized as a hypothetical or inferred fault. Dr. Easterbrook indicated that the length of the Vedder Mountain fault across Whatcom County is greater than previously indicated. However, Jones (1996) indicated previously that the Vedder Mountain fault “extends in the subsurface to north of Bellingham, Wash., and potentially as far west as the Mount Vernon fault.” Dr. Engebretson and his former student, Lori Roberts, had previously evaluated the historical seismicity of the northern Puget Sound Lowland (e.g. Roberts, 1999). The subsurface geology of Whatcom County and southern British Columbia was previously characterized by the U.S. Geological Survey (Jones, 1996; Cox and Kahle, 1999). They used water well logs and geophysical survey results for Whatcom County, and published reports for southern British Columbia.

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Thus, as mentioned, the only “new” information presented by Professor Easterbrook and his colleagues is the DEM attached to his affidavit and posted on the GASP website. Setting aside the DEM, therefore, the only thing new about Professor Easterbrook’s report are some of his interpretations of existing data.

Q. In his affidavit, Professor Easterbrook states that the Sumas and Vedder Mountain faults underlying the Sumas Valley are larger and more seismically active than previously thought. Do you agree?

A. No. At this time, the presence of the Sumas fault has not been substantiated and if it is present, its level of activity has not been established. As noted above, the Vedder Mountain fault was previously inferred to Bellingham or beyond. There is some data suggesting that low magnitude seismicity may be associated with the Vedder Mountain fault, but there currently is no geologic data indicating that it has generated large magnitude earthquakes in the recent geologic past. Consequently, it is a significant exaggeration of the available scientific data to conclude that the faults are “larger and more seismically active than previously thought”.

Q. What does Professor Easterbrook indicate as his basis for concluding that the Sumas and Vedder Mountain faults are seismically active?

A. Dr. Easterbrook does not indicate what criteria he uses to determine whether a fault is active or whether the available data for the Vedder Mountain and hypothetical Sumas faults meet his criteria.

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The State of Washington does not have a formal definition of an "active fault." However, a generally accepted definition used for seismic hazard assessments for most facilities is that an active fault is one which has exhibited tectonic displacement or deformation of geologic deposits during the Holocene epoch (i.e., in the past 10,000-11,000 years) and/or had associated historical earthquakes. Displacement of the ground surface or near-surface geologic deposits is typically associated with earthquakes of M 6 and greater on shallow crustal faults. Thus it is a good indication of a large pre-historic earthquake. The Holocene activity criteria is used in the California definition of an active fault (California Division of Mines and Geology, 1997), and also served as the basis for establishing active source zones for the Uniform Building Code Seismic Zone 4 near-source calculations. In Washington, and other areas of the western United States, the recurrence period for large earthquakes on an individual fault is typically on the order of hundreds to several thousand years. Therefore, evidence of Holocene activity is an appropriate definition for an active fault for most applications, including power plants such as SE2.

Q. Does the information and data provided by Dr. Easterbrook and his colleagues indicate whether the Sumas and Vedder Mountain faults are seismically active according to the generally accepted criteria outlined above?

A. In my opinion, the available data do not indicate that the hypothetical Sumas fault and Vedder Mountain fault are seismically active, although it cannot be precluded. Dr. Easterbrook et al.'s bases for indicating the hypothetical Sumas fault and Vedder Mountain fault are seismically active are: (1) historical seismicity in the general vicinity of Sumas Valley and (2) the paleotopography of the bedrock below the Sumas

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Valley. Based on the currently available data and criteria outlined above, neither of the faults would be considered as an active fault at this time.

Q. What does the historical seismicity data provided by Dr. Easterbrook and his colleagues as well as the surface geology of the area indicate about the activity of the Sumas and Vedder Mountain faults?

A. Between 1970 and 1991, instrumentally recorded, small magnitude earthquakes occurred in a northeast-southwest trending zone near the Vedder Mountain fault. These earthquakes had a magnitude (M) of greater than 1.0 and less than 5.0. Several of these earthquakes had focal mechanisms indicating reverse faulting and occurred at depths of between 17 to 20 kilometers (10 to 12.5 miles) (Roberts, 1999). The instrumentally recorded earthquakes have location and depth uncertainties of several kilometers. Low-magnitude earthquakes occur regularly throughout the Puget Sound Lowland and are not necessarily associated with faults capable of generating large earthquakes of engineering significance. Therefore, while these earthquakes are suggestive of activity on the Vedder Mountain fault, these are not conclusive. A more detailed analysis of the instrumentally recorded earthquakes considering the uncertainty in the depth and location of the earthquakes, as well as the subsurface geometry of the Vedder Mountain fault would be necessary to make a conclusion regarding the potential activity of this fault.

Easterbrook et al. also indicate two pre-instrumental earthquakes of M 5.0 (1964) and 6.0 (1909) occurred along the projected traces of the Sumas and Vedder Mountain faults, respectively. The pre-instrumental earthquakes are based on felt reports

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recorded in newspapers and other historical documents; thus there is considerable uncertainty in the location of the earthquake epicenter (point on the earth's surface above the hypocenter). The 1909 earthquake was located in the San Juan Islands and could just as likely been located on the Haro or Mount Vernon faults. In addition, the 1909 earthquake is characterized as a "deep" earthquake (Noson et al., 1988) which suggests it may not have occurred on a shallow crustal fault such as the Vedder Mountain fault.

The inferred trace of the hypothetical Sumas fault by Easterbrook et al. and mapped trace of the Vedder Mountain fault cross geologic deposits at the ground surface mapped as Sumas Stade (glacial advance) glacial deposits (Easterbrook, 1976; Dragovich et al., 1997). The Sumas Stade deposits are approximately 10,000 to 11,300 years old (Easterbrook et al., 1996; Cox and Kahle, 1999) and thus are earliest Holocene in age. Dragovich et al. (1997) show the Vedder Mountain fault as buried by Sumas Stade deposits (Exhibit MM-3), and there is no surface evidence of displacement of Sumas Stade deposits present along the inferred trace of the hypothetical Sumas fault southwest of the SE2 site (Easterbrook, personal communication; Exhibit MM-4). Consequently, the available data indicate the most recent surface displacement in the Sumas Valley is pre-Holocene.

Q. What does bedrock topography indicate about the activity of the Sumas and Vedder Mountain faults?

A. With regard to the bedrock paleotopography, the depth and geometry of the bedrock is not in itself an indication of the presence, amount of displacement, or recency of

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activity of a fault. Dr. Easterbrook et al. indicate that the Sumas Valley is an approximately 1,000-foot deep graben and that the total displacement on the Vedder Mountain fault is at least 2,500 feet based on the elevation at the top of Vedder Mountain. A graben is a basin, typically longer than wide, that has been downdropped relative to the adjacent rocks along basin-bounding faults. Dr. Easterbrook does not specify the time frame for the inferred 1,000 to 2,500 feet of displacement, but implies it was in the recent geologic past. While I agree that the Sumas Valley is a basin that is bounded on the southeast by the Vedder Mountain fault, I do not think there is sufficient evidence to conclude that: (1) the hypothetical Sumas fault is present on the northwest margin of the basin, and (2) the depth of the basin is due solely to tectonic displacement on one or two faults.

In order to conclude that the approximately 2,500 feet elevation difference between the top of Vedder Mountain and the bedrock surface below Sumas Valley is tectonic displacement, it must be shown that the rock in both locations is the same type and age. Dr. Easterbrook has not demonstrated this and to our knowledge there is not existing subsurface data that would allow this to be determined. Furthermore there are several other lines of evidence that indicate: (1) the basin may not be a graben and (2) much of the apparent elevation difference is either very old tectonic movement and not related to geologically recent activity on the fault, and/or is due to glacial erosion.

First, the bedrock paleotopography is best shown by Jones (1996) and Cox and Kahle (1999) who used available well logs and geophysical survey results. Exhibit MM-5

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shows a contour map of the thickness of unconsolidated deposits (equal to depth to bedrock). The distribution and thickness of these deposits are related to the configuration of pre-glacial bedrock surface, the hardness of the bedrock, the location and extent of post-glacial influx of marine waters, and the positions of pre-glacial, glacial and post-glacial drainage channels. In the vicinity of SE2, the bedrock is shown as a deep (1,200 foot) trough within a broad basin that is typically at least 600 feet deep except at the margins. The trough shallows and becomes less distinct to the southwest. During the multiple Quaternary glacial advances, ice migrating from the Coast Ranges north and northeast of Chilliwack was funneled through the trough between Sumas Mountain (in southern British Columbia) and Vedder Mountain. Narrower troughs of similar depth area are shown near Langley and Clearbrook that have not been attributed to faulting (Exhibit MM-5). The depth and configuration of the bedrock trough beneath Sumas Valley is similar to other erosional troughs formed and/or significantly modified by glacial processes, such as those within Puget Sound (e.g. Hood Canal) and the valley occupied by Lake Chelan. These processes include both erosion by ice and subglacial water (Booth and Hallett, 1993 and Booth, 1994) and could have accounted for the depth of the basin with or without associated tectonic displacement on the Vedder Mountain fault. In addition, the presence of the Vedder Mountain fault likely provided a zone of fractured and altered rock that was more easily eroded than unfractured/unaltered rock.

Second, the projected surface trace of the hypothetical Sumas fault of Easterbrook et al. and the mapped trace of the Vedder Mountain fault correlate well with the bedrock paleotopography northeast of Sumas where the basin is well constrained by Vedder

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Mountain and Sumas Mountain in British Columbia; however, these traces do not correlate well further to the southwest of Sumas. Exhibits MM-6 and MM-7 present a series of geologic cross-sections prepared by the U.S. Geological Survey (Cox and Kahle, 1999) that show the subsurface configuration of the bedrock and overlying unconsolidated deposits in the Whatcom County area. The location of these cross-sections is shown on Exhibit MM-4. The approximate location of the surface traces of the Vedder Mountain and hypothetical Sumas fault indicated by Dr. Easterbrook (Figures 1 and 3 of GASP website report) are shown on Exhibit MM-4. The approximate subsurface projection of these faults has been added to the U.S. Geological Survey cross-sections shown on Exhibits MM-6 and MM-7. As shown on these exhibits, the Sumas Valley bedrock trough shallows and becomes less distinct to the southwest of Sumas. In addition, there is no apparent correlation between the inferred Sumas fault with the bedrock surface or apparent discontinuities in the overlying unconsolidated deposits to the southwest (see cross sections G through J on Exhibit MM-7).

Third, the Vedder Mountain fault was initiated during the Miocene and experienced significant extensional displacement from approximately 25 million to 16 million years before present (Monger, 1991). If the Sumas valley is truly a graben, it was probably formed during this time frame and modified since then. The Quaternary epoch (last 1.6 million years) and current tectonic stress regime of the Puget Sound region is compressional, not extensional. Thus much of the displacement and bedrock relief of tectonic origin likely occurred prior to the Quaternary and the

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multiple glacial advances that shaped the most of the paleotopography and current topography of the Puget Sound Lowland.

Q. Does the surface inferred trace of the hypothetical Sumas fault run directly below the SE2 site?

A. No. Based on the available data, if the fault were present as currently hypothesized by Professor Easterbrook, its surface trace would be west of the SE2 site and would dip beneath the site in the subsurface (see cross-section A-A' on Exhibit MM-6). The inferred surface trace as shown on the figures in Professor Easterbrook's reports is west of the SE2 site. Interpretation of the subsurface geology by Cox and Kahle (1999) do not show a fault present beneath the site (Exhibits MM-6 and MM-7). If a fault were present along the interface between bedrock and the alluvial soils filling the valley shown by Cox and Kahle, as suggested by Professor Easterbrook, the projection of this interface to the ground surface would be west of the SE2 site. As noted above, there is currently no evidence for Holocene displacement of the ground surface along the inferred surface trace, and as indicated on Figure 3.1-3 in the application, there is nothing in the subsurface soil units to suggest offset by a fault.

Q. Professor Easterbrook mentions four potential seismic hazards in the Sumas area: shaking, ground failure (liquefaction), offset, and landslides. Turning first to shaking, do you agree with Professor Easterbrook's conclusion that the Sumas area is especially vulnerable to earthquake damage from shaking?

A. No. The Sumas Valley is vulnerable to damage from ground shaking but no more so than other areas of the Puget Sound Lowland and Fraser River Valley underlain by

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unconsolidated soils. As previously noted, the strength of ground shaking at a specific location is a principally a function of the soil type, earthquake magnitude, and depth and distance from the earthquake hypocenter to the site.   Therefore, other sites at similar distances from potential earthquake sources situated on unconsolidated soils would experience similar ground shaking.

Q. Regarding liquefaction, Professor Easterbrook states that his data "suggests that Sumas lies on top of a thick fill of unconsolidated sediments that have a moderate to high potential for liquefaction." What is your response to this statement?

A. Based on the available data, I agree that saturated, loose fine-grained granular soils (sand and silty sand) are present in the near-surface soils that likely have a "moderate to high" potential for liquefaction in the event of an earthquake that causes significant strong ground shaking at the SE2 site. However, I do not agree with his overall characterization of the potential hazard.

Like Professor Easterbrook, I am a geologist, not a geotechnical engineer, and I therefore am not an expert with respect to analyzing the effect of seismic ground movement on soils. However, I work on a regular basis with such experts, and have conducted preliminary liquefaction susceptibility assessments for other projects. I thus have a general understanding of the basic principles of liquefaction.
Liquefaction is the transformation of a saturated granular soil from a solid to a liquefied state as a result of increased pore-water pressure (Youd, 1973). Increased pore-water pressure can occur as a result of the cyclic shaking associated with a large

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earthquake. Liquefaction can result in ground deformation, such as settlement and lateral spreading, which can affect engineered structures.

In order for liquefaction to occur, the soils must be saturated with groundwater, within a certain range of grain-size distribution, and sufficiently loose. Sand and silty sand soils are most susceptible to liquefaction. Clay and silt rich soils, and relatively coarse-grained sand and gravel are typically significantly less susceptible to liquefaction. Liquefaction is also typically limited to saturated soils at depths of 30 to 40 feet or less. At greater depths, there is typically sufficient overburden pressure from the overlying soils to preclude liquefaction (e.g. Tinsley et al., 1985; National Academy Press, 1985; Obermeier and Pond, 1999).

Even within an area of "moderate to high" liquefaction potential, liquefaction occurrence is typically localized and discontinuous. Based on the available information, it is not a certainty that liquefaction would occur beneath the SE2 site or other nearby areas of the Sumas Valley in the event of strong ground shaking. For example, liquefaction associated with the 2001 Nisqually earthquake was most predominant on Harbor Island and in the filled tidelands area south of downtown Seattle (Sodo district). However, not every property with similar soil conditions located in the Sodo-Harbor Island area or other areas closer to the earthquake epicenter (e.g. Kent-Tukwila area and Duwamish River and Puyallup River valleys) experienced liquefaction induced ground deformations (Exhibit MM-8).

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With respect to lateral spreading, this can occur when a soil liquefies and flows laterally toward a free face such as a slope, bluff, incised river channel, or man-made embankments such as a dam. This can undermine or cause significant settlement of a structure foundation. The site is located on relatively level ground and there are no slopes, bluffs, or man-made embankments nearby that could facilitate lateral spreading. Johnson Creek is incised approximately 10 feet below the ground surface but is approximately 0.25 or more miles from the site. Thus it is very unlikely that lateral spreading into the Johnson Creek channel could affect the SE2 site.

As previously mentioned, like Professor Easterbrook, I am not a geotechnical or structural engineer. However, I am aware of standard, proven engineering measures that can be applied to reduce the potential for liquefaction to occur or mitigate the potential effects on a structure. These include removal or in-situ improvement of liquefaction susceptible soils, structural and foundation design measures, and relieving and controlling excess pore water pressures (National Academy Press, 1985). Allan Porush, a structural engineer who specializes in designing large structures such as power generation facilities will testify in greater detail regarding such issues.

Q. Professor Easterbrook states that the third seismic hazard, offset along the fault, is "considerable" in this case because Sumas is situated on a fault and 15 to 20 feet of displacement can occur during a single event. Do you agree with this assessment?

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A. No. While it is true that surface displacements of 15 to 20 feet have occurred on faults associated with historical and pre-historical (paleoseismic) earthquakes, these have almost always occurred along faults with evidence of prior displacement. For example, there is evidence of two or three prior Holocene surface displacement events on a fault associated with the 20 feet of uplift of Bainbridge Island approximately 1,100 years ago. As previously indicated, there is no evidence of a fault trace through the SE2 site, nor is there evidence of Holocene surface displacement along Easterbrook et al.'s inferred surface trace of the Sumas fault. Therefore, the hypothesized Sumas fault is not considered an active fault according to the generally accepted definition, and there is not a fault rupture hazard at the SE2 site.

Q. Professor Easterbrook also claims that the SE2 facility faces seismic hazards from earthquake-generated landslides, which can have very serious effects. Do you agree with Professor Easterbrook that earthquake-generated landslides pose a serious seismic risk for the SE2 facility?

A. No. The site is too distant from the western range front of the Vedder Mountains and eastern escarpment of the Lynden upland where seismically induced landslides could occur. The SE2 site is located approximately 2½ miles from the Vedder Mountain range front where large landslides could potentially be generated. There is no evidence of pre-historic landslides from Vedder Mountain extending anywhere near this far into and across the relatively flat topography of Sumas Valley.

Q. To the extent they exist, would the four seismic hazards identified by Professor Easterbrook be limited to the SE2 site?

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A. No. These would be applicable to virtually all development within Sumas Valley, with structures located near the base of the Vedder Mountains and Lynden upland being more susceptible to landslides, and structures directly overlying the surface trace of the faults being susceptible to surface fault displacement. As such, any constraints to development or impacts from the level of seismic hazards implied by Dr. Easterbrook would apply to any existing or new development in the Sumas area.

Q. In the conclusion of his affidavit testimony, Professor Easterbrook recommends that a "seismic risk assessment" be performed. Will SE2 perform such an assessment?

A. Yes. SE2 has committed to performing a probabilistic seismic hazards assessment (PSHA) as part of the facility design process consistent with the standard engineering practice. This will include consideration of both site-specific and Whatcom County geologic and seismologic conditions.

Q. What is the purpose of the seismic risk assessment?

A. The purpose of the assessment will be to further evaluate the available geologic and seismologic data and estimate expected strong ground motions at two or more probability levels as required by the engineers designing the facility. The assessment would consider site specific soil conditions. The engineers would then use the more stringent criteria from either Seismic Zone 3 or the results of the PSHA.

Q. In your experience, at what point in the development of industrial projects are seismic risk assessments performed?

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A. For industrial projects such as SE2, a PSHA is typically performed after initial siting and permitting studies and preliminary design has been completed. The results are then used for the final project costing and design. Typically there is sufficient data and information available to assess the site suitability and feasibility of a planned facility without performing the more time-consuming and costly PSHA and detailed design. The information provided by the PSHA is needed by the structural engineers doing the more detailed design, which is not usually performed until it is certain that the project is going to be implemented.

Q. Professor Easterbrook claims that the SE2 site is not an appropriate location for an industrial facility like SE2 because the seismic risks cannot be addressed through engineering. Do you agree?

A. I am surprised at Professor Easterbrook's claim because power plants and other types of large industrial facilities that have been designed and constructed in areas with similar or higher seismic risk and similar soil conditions (e.g. California) have experienced significant strong earthquakes and performed acceptably with respect to the design criteria. However, like Professor Easterbrook, I am a geologist, and not a seismic or structural engineer. Seismic and structural engineering are highly specialized fields. I therefore defer such questions to my colleague, Allan Porush, who is a structural engineer and an expert in this area.

Proposed Seismic Analysis

Q. Please describe the seismic analysis proposed in the Second Revised Application.

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A. As part of the PSHA proposed in the Second Revised Application, available geologic and seismologic information will be further evaluated, and aerial photographs will be reviewed and a reconnaissance field investigation will be conducted. The purpose of this will be to further assess the presence/absence of a surface trace of the Sumas fault as well as geologic evidence, if any, for recent displacement on the Vedder Mountain fault and Sumas fault. The data obtained will be used to develop a seismic source model to be used by the earthquake engineer to calculate the probabilistic ground motions at the specified probability levels using standard methods. In the event that there is significant uncertainty as to any of the information used to develop the model, *e.g.*, activity rate, earthquake magnitude, etc., the use of multiple values will be considered with a relative probability assigned to each value.

Q. Will this analysis address ground shaking, liquefaction, fault rupture and landslide hazards at the SE2 site?

A. Yes, except for landslide hazards which do not warrant further assessment because the site is flat and is sufficiently distant from any slope that could fail during a future earthquake.

Q. Why is this analysis proposed prior to construction rather than being performed prior to an application for site certification?

A. As previously stated, it is common for more detailed seismic hazard assessment to be performed as part of the final design process. It was not performed prior to the site certification process because it was our opinion that the seismic risks could be adequately assessed using currently available data to determine the geologic and

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seismic suitability of the site for the planned SE2 facility within the requirements of WAC-463-43-265 and WAC-463-43-302. In addition, Sumas Energy did not require that level of assessment for their project planning, costing and preliminary design.

Q. In your professional opinion, are the seismic assessments performed and proposed by SE2 sufficient to analyze potential seismic hazards at the site?

A. Yes. It is my opinion that the assessment performed to date is sufficient to assess potential seismic hazards of the SE2 site for the planning and certification process. As outlined in the revised application and reiterated herein, it is my opinion that there is no surface fault rupture or landslide hazard at the site. The expected ground shaking and liquefaction at the site is similar to other sites in the Sumas Valley, as well as other locations in the Puget Sound Lowland and the Fraser River Valley with similar soil conditions. The ground shaking and liquefaction hazards will be further evaluated as part of the PSHA and final design process and, although I am not a geotechnical or structural engineer, I am aware of other similar projects with similar seismic conditions that have been designed for these conditions as further described by my colleague, Alan Porush.

END OF TESTIMONY

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