Technical Review of Draft Environmental Impact Statement for the Proposed Tesoro Savage Vancouver Energy Distribution Terminal Facility

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Introduction

At your request, I conducted a technical review of the Draft Environmental Impact Statement (DEIS) for the proposed Tesoro Savage Vancouver Energy Distribution Terminal Facility (Tesoro Savage) located along the Columbia River at the Port of Vancouver in Vancouver, Washington. I am an Associate Professor of Civil and Environmental Engineering at the University of Washington and have expertise in geologic hazards.[1] The Tesoro Savage project involves construction and operation of industrial port facilities to receive, contain and transport crude oil. Oil will be shipped by tank car to the facility along a BNSF railroad corridor. Once received, oil will either be pumped to marine transport vessels or pumped through pipelines to aboveground tanks where it will be temporarily stored until transferred to a marine vessel. Additional details of the Tesoro Savage project are presented in the DEIS.

My technical review focused mainly on three sections of the DEIS: (i) Chapter 2, which addresses proposed actions and alternatives for the project, (ii) Chapter 3, which discusses affected environment, impact, and mitigation for the project, and (iii) Appendix C, which presents an independent evaluation of seismic hazards at Tesoro Savage.

Seismic Hazards

The Affected Environment, Impact, and Mitigation section of the DEIS (Chapter 3) focuses on earthquake potential and associated secondary seismic effects including strong ground shaking, and most significantly, soil liquefaction. The emphasis on earthquake hazards is appropriate since the Port of Vancouver (and a large portion of the BNSF railroad corridor) is situated in the Cascadia subduction zone, a region of the Pacific Northwest that has a very high rate of seismic activity. The United States Geological Survey (USGS) estimated that there is a ~14% chance that a "Great" Cascadia subduction earthquake (Magnitude 8 or greater) will strike the region within the next 50 years[2] (50

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[1] Appendix I provides a more detailed professional biography and an abbreviated curriculum vitae for Dr. Joseph Wartman.
[2] Peterson, M. D. et al. (2002) "Simulations of Seismic Hazard for the Pacific Northwest

years is considered the typical design life of a facility in the U.S.). The USGS considers this probability to be "quite high." [2] Seismic hazard analysis (DEIS, Appendix C) indicates that the design standard (i.e., 2475-year return period) peak ground acceleration (PGA) ground motion at the Tesoro Savage site is ~0.4 g. It is well known that ground shaking of this intensity can cause significant damage to industrial port facilities. For example, during the 1995 Great Hanshin, Japan earthquake, local ground shaking of PGA = 0.31g caused major damage to the port of Kobe, a modern industrial harbor facility. Included among the many effects at the port of this earthquake were damage to quay walls, deep foundation-supported structures, and industrial equipment such as large cranes.[3]

The high seismicity of the region and local geologic conditions together make the site highly susceptible to soil liquefaction, a secondary geologic hazard that is a major cause of damage during earthquakes. Soil liquefaction causes granular soils (such as the alluvial geologic materials that underlie the project site) to soften and loose significant strength in an earthquake. Its effects are especially severe in subduction earthquakes due to the long duration of ground shaking. The Washington State Department of Natural Resources indicates that the Port of Vancouver and the surrounding area has a "moderate-to-high" liquefaction hazard.[4] The consequences of soil liquefaction at industrial port faculties have been well documented during multiple earthquakes over the past several decades in the United States, Japan, Peru, Chile, Mexico, and other countries. These consequences have routinely included "ground failure" (i.e., permanent deformation of the ground surface), which has significantly damaged buildings, tanks, retaining structures, utilities, and other system components.[5] At the Tesoro Savage site, liquefaction-induced ground failure would be expected to damage oil pipeline and tank system components, including associated emergency containment structures (e.g. lining systems, containment berms). The DEIS acknowledges that even with the proposed ground improvement actions, the impacts of soil liquefaction could be expected to range from moderate to major (p. 3.1-26).

Landslide Hazards

The DEIS describes the landslide hazard within the Tesoro Savage-associated BNSF rail corridor. This description principally focuses on precipitation-induced landslides, which occur under non-seismic conditions. However, it is equally important to recognize that

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of the United States from Earthquakes Associated with the Cascadia Subduction Zone, *Pure Appl. Geophys.* Vol. 159, pp. 2147–2168

[3] Werner, S. and Dickenson, S. (1996) *Hyogo-Ken Nanbu Earthquake of January 17, 1995: A Post-Earthquake Reconnaissance of Port Facilities*, ASCE Press.

[4] Palmer, S.P., S.L. Magsino, J.L. Poelstra, and R.A. Niggemann. 2004. Liquefaction Susceptibility Map of Clark County. Washington Based on Swansons Groundwater Model. *Washington State Department of Natural Resources, Division of Geology and Earth Resources*. September 2004.

[5] Werner et al. (1998) Experiences form Past Earthquakes (Chapter 2), in *Seismic Guidelines for Ports*, ASCE Press.

even moderate magnitude earthquakes (i.e., Magnitude 5 and above) are capable of simultaneously triggering many hundreds of coseismic landslides across wide region.[6] In past earthquakes, coseismic landslides have been observed to disproportionally affect transportation corridors, such as the BNSF rail corridors, which typically traverse oversteepened, artificial cuts. The consequences of coseismic landsliding will vary based on the size and travel velocity of landslide debris, among other factors, but could reasonably be expected to include derailment of rail cars[7] used to transport oil to the terminal sites.

Mitigation

An independent seismic review of the project commissioned by the Washington State Energy Facility Site Evaluation Council (EFSEC) found important technical deficiencies with the Tesoro Savage seismic mitigation plan. These concerns, which are detailed in Appendix C of the DEIS, notably include the following.

• The foundation soils underlying the secondary containment berm surrounding the storage tanks ("Area 300") are subject to liquefaction, which could severely damage the berm and make it inoperative. This ground failure hazard is not mitigated in the proposed Tesoro Savage project plan.

• The portion of Tesoro Savage proposal near the dock and adjacent pipeline ("Area 400") has a high risk of liquefaction-induced lateral spreading and ground deformation, which could severely damage the transfer pipeline infrastructure and result in the release of oil. In addition, the proposed ground improvement measures do not fully penetrate the liquefiable soils and therefore will not mitigate the lateral spread risk.

• The proposed deep soil mix panels proposed for Area 400 are not a well established liquefaction mitigation technology, and additionally, their design is not supported by sufficient engineering analyses.

• Ground improvement in the tank-to-shoreline pipeline area ("Area 500") does not fully penetrate liquefiable soils leaving the ground failure hazard unmitigated. Ground failure at this location could damage the pipeline system and cause a release of oil.

The EFSEC has indicated that these deficiencies should be addressed in the planning and design documents; however, these are not yet available and therefore the efficacy of any alternative mitigation actions is unknown.

[6] Keefer (1984) Landslides caused by earthquakes, *Bull. of the Geol. Soc. of America.*
[7] The 2013 derailment of an Amtrak train near Everett serves as a recent local example of landslide-caused train event.

Summary

The Tesoro Savage project is located in a seismically active region where there is a high likelihood of a large earthquake occurring during the long-term operation of the facility. Seismic hazard analyses indicate that the design standard PGA (~0.4g) at the site is high enough to potentially cause significant damage to industrial port facilities and components. The site is highly susceptible to soil liquefaction, which commonly results in ground failure-induced damage to buildings, tanks, retaining structures, utilities, and other critical components at ports. The BNSF rail corridor associated with the project is also subject to geologic risks posed by precipitation- and earthquake-induced landslides, which are capable of derailing tank cars. Overall, the geologic hazards at the Tesoro Savage facility together with the potentially severe consequences of failure combine in a manner that poses a significant risk to the public and the environment.

An independent seismic review of the project commissioned by the EFSEC indicated that the current Tesoro Savage seismic mitigation plan is inadequate. The efficacy of alternative mitigation actions is unknown. Regardless, it must be recognized that no mitigation measures are capable of completely mitigating geologic risks at the facility.

APPREVIATED CV

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EDUCATION

Ph.D.	University of California, Berkeley, Civil and Environmental Engineering, 1999 Dissertation: "*Physical Model Studies of Seismically Induced Deformations in Slopes*"
M.Eng.	University of California, Berkeley, Civil Engineering, 1996 Minors: Geology and Construction Management Thesis: "*A Laboratory Study of the Effects of Fly Ash on the Geotechnical Properties of a Soft Clay*"
M.S.	University of California, Berkeley, Civil Engineering, 1996
B.C.E.	Villanova University, Civil Engineering, 1990

PROFESSIONAL POSITIONS

Associate Professor of Civil and Environmental Engineering *University of Washington, Seattle, Washington*	2010 to current
Associate Professor of Civil, Architectural and Environmental Engineering *Drexel University, Philadelphia, Pennsylvania*	2006 to 2010
Assistant Professor of Civil, Architectural and Environmental Engineering *Drexel University, Philadelphia, Pennsylvania*	2000 to 2006
Project Manager *Golder Associates, Inc., Oakland, California*	1999 to 2000
Graduate Student Researcher/Graduate Student Instructor *University of California, Berkeley, California*	1995 to 1999
Associate Project Engineer *Weston Solutions, West Chester, Pennsylvania*	1990-1994

VISITING APPOINTMENTS

Visiting Science Fellow *Institute of Geological and Nuclear Sciences, New Zealand*	2013
Visiting Scholar *Universidad Politècnica de Catalunya, Barcelona, Spain*	2007-2008

AWARDS AND HONORS

Commendation, (as International Expert to *Port Hills Response Group*), New Zealand Society of Earthquake Engineering, 2014

Visiting Scientist Fellowship, Institute of Geological and Nuclear Sciences, New Zealand, 2013

Prakash Research Award, Shamsher Prakash Foundation, 2011

Frontiers of Engineering selectee, National Academy of Engineers, 2011

Henry Roy Berg Endowed Professorship in Engineering, University of Washington, 2010 to 2015

Geotechnical Engineer of the Year, American Society of Civil Engineers, Philadelphia Section, 2007

John J. Gallen Memorial Award for Technical Advancements, Villanova University, 2005

National Science Foundation Faculty Early Career Development (CAREER) Award, 2002

Sigma Xi Scientific Research Society, 2002 to current

Outstanding Graduate Student Instructor Award, University of California, Berkeley, 1999

Jane Lewis Fellowship, University of California, Berkeley, 1994

College of Engineering Award for Meritorious Service, Villanova University, 1990

Chi Epsilon Civil Engineering Honor Society, 1989 to current

PUBLICATIONS

Journals

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Andrejack, T. L. and Wartman, J. (2008) "Development of a Multi-Axial Test for Geotextiles," *Proc., First Pan American Geosynthetics Conference & Exhibition,* Cancun, Mexico, March 2-5

Silva, W., Rodriguez-Marek, A., and Wartman, J. (2007) "Development of synthetic ground motions for the June 23rd 2001 Southern Peru Earthquake," *Proc., 13th PanAmerican Conference on Soil Mechanics and Geotechnical Engineering*, Isla de Margarita, Venezuela, July 15-19

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Ozkahriman, F. Nasim, A. and Wartman, J. (2007) "Topographic Effects in a Centrifuge Model Experiment," *Proc., 4th Intl. Conf. on Earthquake Geotechnical Engineering*, Thessaloniki, Greece, June 25-28

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Member, *Managing Board*, ASCE Delaware Valley Geo-Institute, 2001-2004
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