Oregon Department of Environmental Quality

Road Map Supplemental Document

Fuel Tank Seismic Stability Program

June 27, 2025

Introduction

The Oregon Department of Environmental Quality has recently completed the review of all Seismic Vulnerability Assessment reports submitted by the facilities subject to Oregon Administrative Rules Chapter 340 division 300. Subsequently, DEQ hosted meetings with several of the facility operators and their engineering teams to discuss the path to completion of final SVA reports and early stages of planning for preparation of the Risk Mitigation Implementation Plans. The meetings have facilitated constructive exchange addressing project goals and expectations, and highlighted topics to which questions are commonly posed by the assessment teams. In response to these meetings, DEQ has prepared this document that serves as a supplement to other resources, such as the "Roadmap to Compliance with Oregon Administrative Rules: Chapter 340 Division 300" (March 2024). The intent of this document is to provide a general framework for completion of the SVA reports and transition into the RMIP phase of the program. This supplement builds on the Roadmap Document and is considered a living document that will likely be updated as additional feedback is provided by the project teams, then posted on FTSS website.

It is the intent of the Fuel Tank Seismic Stability Program that a two-phase process leading to risk reduction is followed. The first phase SVA identifies vulnerabilities in the existing facilities when subjected to seismic demands associated with design-level ground motions and formally documents these vulnerabilities in a series of component-specific forms provided by DEQ. The second phase of the program uses the findings of the SVA Phase in the development of an integrated plan for possible risk mitigation measures throughout the facility (RMIP Phase). In general, the SVA Phase has been completed using standards of practice for advanced screening-level analyses, and "Early Engineering" assessments (geotechnical). In addition,

methods of rapid visual screening and performance ratings (structural) in the absence of rigorous analysis. Both have included assessment based on industry standards for initial screening, project experience, and engineering judgment. As an example, the seismic performance of the items identified in DEQ Forms 1 through 9 should ultimately be evaluated for the effects of transient inertial loading, displacement demand associated with permanent ground displacement (kinematic loading), and the combination of the two. At many sites, the characterization of ground motions required for assessment of inertial loading (e.g., ground surface acceleration response spectrum) was completed in an adequate manner for existing conditions, but in the absence of the effects of liquefaction. These motions were used in geotechnical standard of practice procedures for estimation of ground displacements (lateral and vertical), and large deformations were often obtained. At several of the facilities, subsequent structural assessments acknowledged that many of the components would not likely satisfy the seismic performance requirements, which define the Maximum Allowable Uncontained Spill when subjected to the combination of inertial and kinematic loads. This qualitative assessment was made, in large part, based on the experience and engineering judgment of the project engineers at specific facilities. In many cases, analysis of the structural and mechanical components was not deemed necessary to arrive at a conclusion that the vulnerability of pertinent structures and components is high. These conclusions are considered adequate for the sake of identifying and documenting vulnerabilities ("deficiencies") and completion of the SVA forms provided in the Roadmap. However, it will be necessary to address these deficiencies with supporting analysis of seismic performance for post-mitigation conditions in the RMIP phase of the program. The facility operators and their project teams should be aware that the RMIP must be submitted to DEQ no later than 180 calendar days after DEQ's approval of the SVA. Facility specific comments and this supplemental document are intended to encourage plans to cover this in a sequence that satisfies that program schedule.

For structures or components that are shown for existing conditions to be vulnerable to damage under inertial loading only, no further analysis involving the impact of kinematic loading is required in the SVA. However, the RMIP will require that both inertial and kinematic loading are

applied. The RMIP will benefit from an integrated geotechnical – structural approach to evaluating seismic performance for the conditions that may exist for the post-mitigation configuration and foundation conditions. For example, the engineering team may develop a range of acceptable seismically induced ground displacements that limit kinematic loading and can be tolerated by the structural systems. Once the maximum ground displacement is assigned, methods of geotechnical mitigation can be evaluated (e.g., ground improvement, enhanced foundations), and hazards associated with ground shaking and permanent displacement re-evaluated for the improved, post-mitigation conditions. At this time the structural performance evaluation considering both inertial and kinematic loading can be completed. It is anticipated that this will be an iterative process involving the geotechnical and structural members of the team. This approach will also facilitate preliminary cost estimation associated with geotechnical mitigation, structural retrofit or replacement, and other associated risk mitigation measures. It is understood that this is an important factor in short- and long-range planning for continued operations, risk reduction, and possible redevelopment.

The following sections addressing the SVA and RMIP phases of the program are provided to assist project teams in planning for the transition to, and completion of, timely and complete RMIP submittal. It is acknowledged that each facility is unique, and each team may pursue a different path to the completion of the RMIP. DEQ encourages a site-specific approach that is integrated, comprehensive and consistent with the intent and target schedules set forth in the Fuel Tank Seismic Stability Program.

SVA Phase

1. **(GEO– Form 1)** – Complete a desktop study of the site characterization using existing geologic, geotechnical, and geophysical reporting at the site. This may be supplemented by geotechnical data from adjacent sites and regional investigations in similar soil units. In the absence of geotechnical data necessary to establish site stratigraphy (i.e. soil layering and variability) site-specific geotechnical investigation is required. Geotechnical and geophysical procedures should be applied to establish likely ranges of soil properties and parameters

used in subsequent analyses (e.g., SPT, CPT, shear wave velocity, Vs). In addition, laboratory data should be compiled for the prevalent soil units.

The site classification used in pertinent codes, such as ASCE 7, ASCE 41, and ASCE 61, should be determined using site-specific data, preferably measured Vs trends, used to compute Vs30. The site classification can first be determined using measured, or estimated, Vs trends in the absence of liquefaction considerations; however, provisions applicable for sites with liquefiable soil units must also follow the Site Class F designation.

Hazards associated with liquefaction of sand-like soil and cyclic degradation of transitional, silt-rich or clay-like soil must be evaluated for potential ground failure and displacement. This includes flow failure, lateral spreading, deep-seated slope displacement, and seismic and post-seismic settlement.

Guidance on the scope of potential geotechnical evaluations for the SVA is provided in Seismic Vulnerability Assessment Forms (*Form 1: Questions for the Geotechnical Assessment of Each Facility*). Once the site characterization has been completed the seismic demands associated with transient inertial loading and permanent ground displacement (i.e., kinematic loading, or displacement demand) can be assessed. The assessment of hazards associated with seismic loading, dynamic soil behavior, and ground failures is then tabulated in *Form 10*: *Assessment Findings Statement* [1] and submitted for DEQ's approval. Geologic and geotechnical hazards that may contribute to poor performance of structures, components, and items storing and distributing products covered by the statute must be addressed in Form 10, using the checklist of Form 1.

The general procedure for assessment includes the following steps:

[1] Form 10 (Revision 2) can be downloaded from the DEQ website. It will serve as a living register of all the deficiencies identified at the facilities during the SVA and RMIP phases. It will be used to track the progress of the mitigations.

1.1. Evaluate the seismic hazard by performing regional Probabilistic Seismic Hazard Analysis, PSHA, (e.g. USGS NSHMP on-line tools) for the site-specific Vs30 or site class designation based on other site-specific geotechnical data. Code-based ground motions using resources such as the on-line ASCE Hazard Tool may also be used for screening-level assessment of ground surface motions.

1.2. Establish the characteristics of strong motions at the ground surface (e.g., peak ground acceleration and velocity, acceleration response spectrum or spectra, significant duration, and energy [e.g., Arias Intensity, Cumulative Absolute Velocity]), as needed for geotechnical and structural analysis. The ground motions should be explicitly presented as representative of the non-liquefied conditions (i.e., use of site-specific Vs30 and PSHA, or Total Stress Analysis for dynamic site response) or with excess pore pressure generation that may include liquefaction and cyclic degradation (i.e., dynamic site response performed using Effective Stress Analysis).

1.3. Conditional Mean Spectra, addressed in ASCE 7 and ASCE 41, may be applied with short-period and long-period conditioning selected to be consistent with the primary seismic sources in the region, as identified in the PSHA. This approach or alternative methods of ground motion characterization that are supported by codes and standards may be used to reduce possible over-conservatism associated with assigning peak ground motion parameters (e.g., PGA, PGV, SA) from the Uniform Hazard Spectrum or MCER to all seismic sources. Use of alternative methods should be presented to DEQ for approval.

1.4. Evaluate the vulnerability of soils to liquefaction/cyclic degradation, and hazards associated with liquefaction, such as ground failure due to lateral spreading or deep-seated slope displacement, ground settlement in the free field due to the effects of post-cyclic volumetric strain. In the case of structural foundations, the reduction in soil stiffness and strength associated with generation of excess pore pressures in foundation soils during cyclic loading must also be evaluated for the increase in soil deformability and reduced bearing capacity, respectively. Also, the increase in active earth pressures on bulkheads or other retaining structures, possible decrease in passive resistance adjacent to bulkheads, walls,

and anchors, and the seismic performance of deep foundations should be addressed, if applicable.

1.5. Complete Form 10 for review by DEQ. The “deficiencies” (i.e., hazards) noted in Form 10 and submitted with the SVA report will be used as the basis for developing the risk mitigation implementation plan for the facility.

2. **(TNK - Form 2)** – Tanks – The tank assessment can be considered as a two-step process, especially for sites evaluated in Form 1 with potential excessive ground deformations due to liquefaction. The initial step is the assessment considering the kinematic loading with the current site conditions. Even if the ground deformations are excessive for the integrity of the tanks in the first step, perform a separate analysis in the second step to verify that the tanks meet current API 650 Appendix E and API 653 for the seismic demand associated with inertial loading only (i.e., a scenario of the tank on a competent foundation using the site-specific Vs30). Note that satisfying the initial, as-designed criteria of a geriatric tank is not sufficient. The latest inspection and API codes should be used in this assessment. This does NOT consider any soil deformation, but merely the structural response of the tanks to inertial effects alone; to evaluate if they are acceptable (i.e., with all DCRs < 1.0) based on SUG I, for the seismic demand determined in the regional PSHA or site-specific dynamic site response analysis. Analysis should be based on the most recent inspections and the best estimates of material properties. If multiple tanks have the same characteristics, fluid types/height, then a typical one of the many can be used for the analysis. All of the tank properties and anticipated foundation deformations should be documented in the response to the checklist in Form 2. If any DCRs >1.0 then the related structural deficiencies should be documented on Form 10.
3. **(PIP – Form 3)** – Pipeline systems – all available design information along with current inspection data is required with the filling in of Form 3. The existing ground conditions and the ground displacements anticipated to be imposed on pipeline systems should be used for this initial assessment. Is there adequate flexibility to accommodate all of the potential ground deformations? A preliminary pipe stress analysis may be necessary to evaluate. If

the responses to Form 3 questions identify deficiencies and if there are DCRs > 1.0 in the pipe stress analyses, then they should be summarized in Form 10.

4. **(MOT – Form 4)** – Wharf and trestle – Form 4 provides the questions and input required to evaluate wharves, piers, and trestles. From the geotechnical reports/investigations, the existing offshore geotechnical characterization and bathymetry need to be considered in the evaluation. Inertial loads and potential kinematic loads on deep foundations due to slope displacement need to be evaluated. All deficiencies identified in the response to Form 4 and all DCRs >1.0 in the analyses should be entered in Form 10. Compliance would satisfy ASCE/COPRI 61-14 (later 2025 soon to be released).
5. **(LNG – Form 5)** – Tanks, piping systems and secondary containment for LNG – Form 5 provides the questions and input to evaluate the LNG tank, its secondary containment and the associated LNG pipelines. For the purposes of the initial assessment with inertial loading only, the ground motions can be defined based on the site-specific Vs30 and use of PSHA (i.e., in the absence of liquefaction effects). Additionally, the foundation should be evaluated using the existing soil conditions. The foundation evaluation including the effects of hazards associated with liquefaction and ground displacement should be performed in which the soil properties are defined for cyclic loading and potentially for liquefaction effects (i.e., cyclic softening and reduction of strength and stiffness). The assessment of the tank and all LNG pipelines should be documented in response to Form 5, and all deficiencies with DCRs > 1.0 should be provided in Form 10.
6. **(BER – Form 6)** – Berms and Secondary Containment (SC) – The berms should be evaluated with reference to Form 6 and ASCE 7 Section 15.6.5, noting requirements for assessment due to aftershocks. All deficiencies identified in the response to Form 6 are summarized in Form 10. All deficiencies showing a DCR > 1.0 in the calculations should be included in Form 10. While the initial analysis might be based on existing soil conditions and recent inspection data, it will be beneficial to evaluate the performance of the berms with the proposed ground mitigation condition as well.
7. **(BLG – Form 7)** – Buildings critical for operations and emergency response – All buildings critical to the facility's operations and emergency response should be checked using

following the guidance provided in Form 7 considering the current soil conditions (before possible remediation). All the critical buildings should be documented in response to Form 7 and all the deficiencies with DCRs > 1.0 should be listed in Form 10.

8. **(FDS – Form 8)** – Fire detection and suppression systems – The fire detection/suppression system should be checked with Form 8 and all deficiencies recorded in Form 10. Ground motions estimated with the current site conditions should be considered in the continuing availability of the system.
9. **(CON – Form 9)** – Control systems, conduits and critical components – Critical control systems, conduits and other essential components should be checked with Form 9 and all deficiencies recorded on Form 10. Ground motions estimated with the current site conditions should be considered for the continuing availability of the system.

If at this point the facility may decide that it is not economically justified to implement a facility-wide mitigation program to continue operations; partial or complete abandonment or decommissioning may be the appropriate next step. This step/process is subject to approval by DEQ.

RMIP PHASE

The Risk Mitigation Plan will address all deficiencies recorded in Form 10 for all of the components listed in the SVA. Per DEQ regulations, the risk mitigation plan is due six months after the approval of the SVA by DEQ.

The first step of the RMIP is to propose a plan to mitigate the risk of uncontained release of product exceeding the statute requirement of 1 bbl/tank. The plan should address geotechnical, structural, and mechanical aspects of seismic performance and all identified deficiencies, in an organized, coordinated manner and with a proposed schedule of implementation (e.g. with a comprehensive Gantt chart).

The implementation of ground improvement, if proposed, may result in a change of “Site Class” in pertinent codes or standards. This may occur by one of the following conditions:

1. Mitigation of liquefaction hazards can eliminate the “Site Class F” designation required for liquefiable sites and associated code-based requirements.
2. Implementation of ground treatment that is extensive enough to increase Vs30 to change the site class designation.

In either case, the RMIP should include consideration of the anticipated post-mitigation soil conditions, “Site Class”, and ground motions. In this manner, the global dynamic response of all structures and components should be evaluated using representative ground motions, and the seismic performance should be acceptable, subject to individual structural rehabilitation if necessary. In addition, the kinematic demand representative of the post-mitigation condition should be applied to piles, berms, bulkheads, or other embedded structures for the complete evaluation of seismic performance. The structural and mechanical teams should agree that with proposed methods of geotechnical and structural mitigation, the target DCRs of all components will be less than 1.0, and the requirements of DEQ will be satisfied with the proposed mitigation program.

Before implementation of the proposed RMIP, the plan must be approved by DEQ. The implementation will be monitored by DEQ at years 1, 3 and 5 (per DEQ340-300-0004 (3). All improvements are to be completed within 10 years from the approval of the RMIP.

If the proposed RMIP cannot satisfy the goals and performance objectives of the DEQ regulation, then complete or partial decommissioning/abandonment may be the next step and is subject to DEQ review and approval.

1. **(GEO)** – The objective of a geotechnical mitigation plan is to reduce the ground deformations to within tolerable, allowable limits. This may include control of displacements associated with permanent displacement of slopes or earth retaining systems, liquefaction related sand boils and ejecta, post-seismic settlement of soil, and loss of foundation support. The implementation of ground treatment with possible structural mitigation may be required to facilitate an acceptable structural performance of all components within the facility.

Coordination between the geotechnical and structural members of the team during development of the proposed remediation should focus on the seismic performance goals required by the statute. As previously noted, the ground motions used in analysis supporting the RMIP should reflect post-improvement conditions and possibly even a change in the "Site Class", if it can be demonstrated that implementation of ground treatment mitigates the liquefaction hazards and in addition may change the site-specific Vs30.

2. **(TNK)** – The seismic performance of tanks should be evaluated for both inertial and kinematic loading representative of the site conditions and dynamic response anticipated with or without mitigation measures, as defined by the team. If the ground motions representative of remediated soil conditions are consistent with the ground motions applied during the SVA phase, then the SVA assessment of the tanks for inertial loading (only) should be acceptable with all DCRs < 1.0 and the tank(s) should satisfy SUG I. The secondary containments for the tanks evaluated with SUG I should satisfy ASCE 7-22 Section 15.6.5 criteria (MCE when empty and 2/3 MCE when full) with the mitigated soil condition, if proposed. Tanks without a proper secondary containment are required to satisfy the design criteria with SUG III / Risk Category IV. All of the new deficiencies are recorded in Form 10 and mitigated during the RMIP. Possible immediate "fixes" to vulnerable tank(s) might include a reduction in product volume, flexible connections to pipelines, installation of anchors to tanks or other means to qualify the tank and appendages. Some of these are discussed in WA 173-180-330. Any of these "fixes" without tank rehabilitation is subject to DEQ review and approval.
3. **(PIP)** – The pipelines and pipeline systems may require flexible connections to all "hard points" (e.g. connections to tanks), when subjected to the initial ground conditions, including all geotechnical hazards. All of the deficiencies listed in Form 10 should be addressed during the RMIP process. All pipelines and pipeline systems should obtain DCRs < 1.0 and all deficiencies on Form 10 should be resolved.
4. **(MOT)** – The marine terminal consists of a wharf/pier plus a trestle and pipelines to shore. The seismic performance of these structures, appurtenant structures, and ancillary components should be evaluated for inertial and kinematic loads representative of the soil

conditions, with ground treatment if proposed, current or proposed topography and bathymetry, and condition of the structures. All structural components (e.g. piles, decks, pipeline supports, trestle) should be evaluated based on ASCE/COPRI 61-14 (or 61-25 after it is released), resulting in DCRs < 1.0.

5. **(LNG)** – The LNG tank and all LNG pipelines has been evaluated in Form 5, with all deficiencies carried over to Form 10 during the SVA phase. This includes the LNG and all LNG pipelines and secondary containment. If the remediated soil condition remains consistent with the post-mitigation "Site Class" assumed during the SVA phase, then the SVA assessment of the tanks should be acceptable with all DCRs < 1.0. The foundation and the piles should be assessed with the kinematic demand for the post-mitigation condition. All deficiencies listed in Form 10 should be addressed to achieve all DCRs < 1.0.
6. **(BER)** – Berms and secondary containment (SC) are checked in Form 6 and with soil and site characteristics representative of post-mitigation conditions. The structural assessments should show that all DCRs < 1.0 in the post-mitigation condition. The secondary containments should satisfy ASCE 7-22 Section 15.6.5 criteria (MCE when empty and 2/3 MCE when full) with the mitigated soil condition, if proposed.
7. **(BLG)** – For critical, all the deficiencies in Form 10 should be addressed. The critical buildings with deficiencies should be mitigated to comply with performance objective of MAUS or satisfy design checks with earthquake loads per ASCE 7 Risk Category IV and with all DCRs < 1.0. Foundation performance and dynamic response should represent mitigated ground conditions, if proposed.
8. **(FDS)** – Fire Detection/Suppression – Form 8 provides guidance for tank farms, overall facilities and also marine terminals. Although not specifically addressing seismic vulnerability, the review should include protective measures such that after an earthquake, the fire suppression system will remain operational and serve to extinguish any fires as a result of the ground deformation and inertial effects. Form 8 provides the list to check, and all deficiencies should appear in Form 10 with all deficiencies resolved with the RMIP.
9. **(CON)** – Control buildings, panels, critical cables, all should be verified using Form 9, and all deficiencies recorded in Form 10 should be resolved with the RMIP.

Upon approval by DEQ, the RMIP is ready to be implemented, such that after completion, all structures will comply with performance criteria (MAUS or ASCE7 Risk Category IV). Significant upgrades of all structures/tanks may be required during this phase. Marine facilities should satisfy ASCE/COPRI 61-25 (to be released soon). In this process, all deficiencies from the checklists in Forms 1 through 9 should be corrected and summarized in a final comprehensive Form 10.

The risk mitigation implementation has milestones at years 1, 3 and 5 after the approval of RMIP by DEQ and monitored by required annual status reports. DEQ will incrementally approve/disapprove of the progress and/or lack of compliance. At this point, the facility and DEQ will agree to a deadline to complete all required ground mitigation as well as upgrades for all tanks and structural components. At the conclusion, the facility should satisfy all the requirements of the DEQ regulations, and Form 10 should show that all deficiencies have been corrected.

ADDITIONAL STEPS OR ALTERNATIVES:

1. In order to reduce the steps described above, the facility may implement alternative methods to demonstrate that there would be no spills greater than the 1 bbl (42 gallons) per tank prescribed in OAR 340-300-0004 (1)(a).
2. If there is a major spill/earthquake prior to the completion of the RMIP process, the facility should define how the hydrocarbons would be removed “in a short period of time”. Additionally, there may be adjacent facilities with the same amount of spillage. Possible ignition sources and a potential tank farm fire need to be considered. This step is subject to DEQ approval and may involve resources outside the facility boundary, as well as facility accessibility. Similarly, the potential for municipal water supply interruption or unavailability for fire suppression after a major earthquake need to be considered. Personnel access to the site may also be limited due damage to roads and bridges.
3. Other issues may arise during the RMIP process and will be addressed by DEQ on a case-by-case basis.

Contact

Killian Stoltenburg

Fuel Tank Seismic Stability Program Administrative Coordinator
971-295-8734
Killian.STOLTENBURG@deq.oregon.gov

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800-452-4011 | TTY: 711 | deqinfo@deq.oregon.gov

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