VALERO

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November 19, 2013

Crude by Rail Project Geotechnical Report
Valero Refining Company – CA
Benicia Refinery

Mr. Tim Morgan
Project Manager
ESA Energy
1425 N. McDowell Boulevard, Suite 200
Petaluma, CA 94954

Dear Mr. Morgan:

Enclosed is the latest geotechnical report prepared by Kleinfelder and IRC for the Benicia Refinery's Crude by Rail Project. The geotechnical report is used by the project design team to assure that the project considers requirements of the 2010 California Building Code section 1803 and the Federal Railroad Administration.

The track installed as part of the crude offloading project will be included in the Benicia Refinery's railroad track inspection and maintenance program which encompasses the safe operation of rail.

Please contact me at 707-745-7203 if you have any questions or need additional information.

Sincerely,

Susan K Gustofson

Susan K. Gustofson, P.E.
Staff Environmental Engineer

SKG/tac

Enclosures:
Geotechnical Report, 11/15/2013
IRC Response to Geotechnical Report, 11/19/2013

ecc: Amy Million, City of Benicia

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November 15, 2013
Project No. 131669

Mr. Chris Riley
Project Manager, OSBL
Valero Refining Company - California
3400 East Second Street
Benicia, CA 94510
(Chris.Riley@valero.com)

**SUBJECT: Geotechnical Seismic Deformation Modeling Report
Rail Car Offloading Facilities Project
Valero Refinery, Benicia, California**

Dear Mr. Riley:

Valero requested Kleinfelder to prepare this report to comply with the 2010 California Building Code (CBC), Section 1803 that requires a geotechnical investigation associated with Valero's Railcar Offloading Facilities Project (Project). In compliance with the CBC, this report presents the results of seismic ground deformation analyses performed by Kleinfelder for the Project located at the Valero Refinery in Benicia, California (Plate 1). This report refines information presented in Kleinfelder's February 2013 memorandum.

PROJECT BACKGROUND AND PURPOSE

The Project will consist of three sets of 4-foot-8.5-inch gage tracks running parallel in approximately the north-south direction along what is currently Avenue A. Sulphur Springs Creek is present to the east of the proposed track improvements and an existing tank farm is located to the west. The two westerly tracks will be for offloading of crude oil from tank cars while the most easterly track will be used for assembling empty, outgoing trains. The two westerly tracks will be supported by precast, pre-stressed concrete mats that are 8 feet in width and 14 inches thick (except at recessions that accommodate the rail which are 7 inches thick). The easterly track will use precast concrete ties that are 8.5 feet long, 11 inches wide and 9 inches tall.

As described in our previous memorandum dated February 18, 2013, there is potential for liquefaction and lateral spreading to occur at the site in the area of the proposed improvements. Based on the results of the simplified empirical methods (Youd et al.

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2002[1], Tokimatsu & Seed 1987[2]) used in the February 2013 study, lateral spreading displacements of 0 to 15 feet, and total and differential post-liquefaction reconsolidations settlements of approximately 2 and 1 inches, respectively could occur.

The purpose of this current study was to perform more detailed seismic deformation analyses using advanced analytical techniques to provide more refined estimates of the magnitude and distribution of lateral spreading and seismic settlements in the Project area. The results of this more detailed analysis can then be used by the project rail engineers to ensure the project is designed to comply with the California Building Code requirements.

SITE CHARACTERIZATION

Kleinfelder prepared a *Geotechnical Data Report* dated May 17, 2013 presenting field and laboratory data collected for the Project. To supplement the existing data, two additional seismic cone penetrometer tests (SCPT) with shear wave velocity measurements were advanced at the site to depths of 43.6 and 99.2 feet below ground surface on June 26, 2013 (Appendix A).

ANALYSIS METHODOLOGY

The seismic deformation analyses were performed for two representative cross sections within the Project area (Sections A-A' and B-B') as shown on Plate 2, *Site Exploration Plan*. Soil stratigraphy and engineering properties were established based on the field and laboratory data collected at the site and on our experience. The soil layering for the two cross sections is presented in Plates 3 and 4, and the soil engineering parameters used in the analyses are presented in Tables B3 and B4.

Two-dimensional (2D) dynamic non-linear time history analyses were performed using the computer program FLAC (Fast Lagrangian Analysis of Continua) 2D Version 7.0 developed by Itasca Consulting Group. FLAC solves the equations of motion in the time domain using a Lagrangian approach and the explicit finite difference solution method. The soil domain within the FLAC model is subdivided into elements, and the stress-strain behavior of each element is prescribed using a constitutive model. The elements comprise a mesh with interaction between adjacent elements. After initial static equilibrium is established, the base of the model is excited using a digitized earthquake time history, and the dynamic response of the model is calculated. The model behavior included liquefaction-related excess porewater pressure buildup and softening and strength loss in the Liquefiable Alluvium layer. Results that can be extracted from the

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[1] Youd, L.T., Hansen, C.M., Bartlett, S.F., 2002, "Revised Multilinear Regression Equations for Predicting Lateral Spread Displacement", *J. Geotech. Geoenv. Engr.*, 128(12), ASCE.
[2] Tokimatsu, K. and Seed, H.B. (1987). "Evaluation of settlement in sands due to earthquake shaking," J. of Geotech. Engr., 113(8), ASCE, pp. 861-878.

model include the distribution (throughout the mesh) and magnitude of permanent (post-shaking residual) displacements that may result from liquefaction and lateral spreading.

To account for potential variations, a total of three time histories were developed and used as input for the FLAC model. Since time histories are asymmetric, analyses were performed for both positive and negative polarities. With two cross sections, three time histories and two polarities, the total number of dynamic runs was 3x2x2=12.

The methods used in the time history development are presented in Appendix B. Additional details of the soil parameter development and modeling approach are also presented in Appendix B.

As a comparison to and check of the lateral spreading displacements calculated with FLAC, a simplified Newmark-type sliding block analysis was also performed to estimate lateral spreading displacements (Bray and Travasarou 2007[3]). Details of this methodology are presented in Appendix B.

RESULTS

Contour plots of residual (post-earthquake) horizontal and vertical displacements calculated using the FLAC model are presented in Appendix B in Plates B7 through B18 for Section A-A' and in Plates B22 through B33 for Section B-B'. Table B5 in Appendix B presents a summary of calculated lateral spreading displacements in the Project area which range from about 8 to 39 inches.

Using the simplified Bray & Travasarou (2007) method, lateral displacements between 4 and 20 inches with a median of 9 inches were calculated in the Project area. The generally good agreement with the Bray & Travasarou (2007) method provides validation of the FLAC results. Since the FLAC model is more detailed and incorporates more of the site specific features, the displacements calculated using FLAC are considered most reliable among the three methods used. Therefore, the FLAC results are used subsequently herein to develop conclusions and recommendations for design.

The FLAC horizontal displacements are generally greatest along the creek bank (east edge of existing Avenue A) and diminish toward the west. The gradient of horizontal displacements results in extensional strains in the ground of about 0.7% to 2% for the majority of the cases. In the field, such extensional horizontal strains can be concentrated as ground separation (separation lineaments would be aligned parallel to the creek in the north-south direction). The FLAC model we used is a continuum model and cannot predict ground separation. But ground separation size can be estimated by considering that 0.7% to 2% extensional strain acts over a 25-foot distance, resulting in ground separation 2 to 6 inches in size.

[3] Bray, J. and Travasarou, T. (2007). "Simplified Procedure for Estimating Earthquake-Induced Deviatoric Slope Displacements," *J. Geotech. Geoenviron. Eng.*, 133(4), 381–392.

The FLAC model provides estimates of vertical settlements that occur in conjunction with the lateral spreading displacements. The FLAC model is limited in its ability to estimate vertical settlements that results from post-liquefaction reconsolidation. To estimate the total seismic settlements, the FLAC lateral spreading-related settlements were added to the reconsolidation settlements that were previously calculated and reported in Kleinfelder's February 18, 2013 memorandum. The total seismic settlements range from 5 to 11 inches and differential settlements occurring over an 8.5-foot long railroad tie are up to 3 inches. Scaling this differential settlement from the 8.5-foot tie length to the 4-foot-8.5-inch rail gage width results in a maximum differential settlement across the tracks of 2 inches.

CONCLUSIONS AND RECOMMENDATIONS

Dynamic seismic deformation analyses were performed to estimate the magnitude and distribution of horizontal displacements and vertical settlements associated with liquefaction and lateral spreading hazards at the Project site. In our opinion, the liquefaction and lateral spreading hazards can be mitigated for the project by designing the railroad for the following seismic ground displacements.

Total seismic lateral displacements of 8 to 39 inches should be considered for design. We recommend that the railroad ties and slabs be analyzed to evaluate the effect of up to a 6 inch wide horizontal ground separation oriented parallel to Avenue A (Plate 5).

To evaluate rail car tipping potential, we recommend that a differential settlement of up to 2 inches across the gage width be considered (Plate 6).

LIMITATIONS

This work was performed in a manner consistent with that level of care and skill ordinarily exercised by other members of Kleinfelder's profession practicing in the same locality, under similar conditions and at the date the services are provided. Our conclusions, opinions and recommendations are based on a limited number of observations and data. Kleinfelder makes no other representation, guarantee or warranty, express or implied, regarding the services, communication (oral or written), report, opinion, or instrument of service provided.

This report is intended to be used only by the Valero project design team for the purposes stated for this specific engagement within a reasonable time from its issuance, but in no event later than two (2) years from the date of the report.

Recommendations contained in this report are based on our field observations and subsurface explorations, limited laboratory tests, and our present knowledge of the proposed construction. If the scope of the proposed construction, including railroad layout, changes from that described in this report, the conclusions and recommendations contained in this report are not considered valid unless the changes are reviewed, and the conclusions of this report are modified or approved in writing by Kleinfelder.

CLOSURE

We appreciate this opportunity to provide geotechnical and earthquake engineering consulting services for this project. If you have any questions or require additional information please Jim Gingery at 858.320.2047.

Sincerely,

KLEINFELDER WEST, INC.

Cyndi Lopez, EIT
Staff Engineer

James R. Gingery, PE, GE
Principal Geotechnical/Seismic Engineer

CL/JRG/jmk

Attachments:
- Plate 1 – Site Vicinity Map
- Plate 2 – Site Exploration Plan
- Plate 3 – FLAC Mesh and Soil Layers for Section A-A'
- Plate 4 – FLAC Mesh and Soil Layers for Section B-B'
- Plate 5 – Design for Seismic Ground Separation
- Plate 6 – Design for Differential Seismic Settlement
- Appendix A – Field Investigation
- Appendix B – FLAC Analysis
- Appendix C – Newmark-type Deformation Analysis

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Via Email

November 19, 2013

Mr. Chris Riley
Project Manager, OSBL
Valero Refining Company - CA
3400 East 2nd St.
Benicia, California 94510

Re: Response to Geotechnical Seismic Deformation Modeling Report
Railcar Offloading Facilities Project, Valero Benicia Refinery

Dear Mr. Riley:

IRC has reviewed the "Geotechnical Seismic Deformation Modeling Report" prepared by Kleinfelder, dated November 15, 2013. In their report Kleinfelder is recommending that the track design consider the effects of up to a 6-inch wide horizontal separation running parallel to the tracks, and up to a 2-inch settlement across the track gauge width.

Track is expected to settle during routine operations and Federal Track Safety Standards (49 C.F.R. § 213) allow for such settlement to occur while maintaining safe operations. Track can undergo post-earthquake settlement of 2-inches across gauge width, as described in Kleinfelder's report, and still be compliant as prescribed in 49 C.F.R. § 213.63 for Class 1 track.

Because track defects can occur during normal railroad operations, Federal Track Safety Standards mandate a program of thorough monthly inspections. Additionally, in the event of an incident with potential for track damage, such as an earthquake, an inspection shall be made as soon as possible after the occurrence and, if possible, before the operation of any train over that track (49 C.F.R § 213.239).

If you have any questions please contact me at 510-724-1117.

Sincerely,

Marc Foster, PE
Industrial Railways Company

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