Final Report

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Railroad Crude Oil Release Rate Analysis for Routes between: Roseville, CA and San Luis Obispo, CA, and Colton, CA and San Luis Obispo, CA

Christopher P.L. Barkan, Ph.D.
Professor and Executive Director
Rail Transportation and Engineering Center (RailTEC)
Department of Civil and Environmental Engineering, MC-250
University of Illinois at Urbana-Champaign, Urbana, IL 61801
Telephone: (217) 244-6338, Facsimile: (217) 333-9464
E-mail: cbarkan@illinois.edu

M. Rapik Saat, Ph.D.
Research Assistant Professor
Rail Transportation and Engineering Center (RailTEC)
Department of Civil and Environmental Engineering, MC-250
University of Illinois at Urbana-Champaign, Urbana, IL 61801
Telephone: (217) 244-6974, Facsimile: (217) 333-9464
E-mail: mohdsaat@illinois.edu

Xiang Liu, Ph.D.
Postdoctoral Research Associate
Rail Transportation and Engineering Center (RailTEC)
Department of Civil and Environmental Engineering, MC-250
University of Illinois at Urbana-Champaign, Urbana, IL 61801
Telephone: (217) 244-8525, Facsimile: (217) 333-9464
E-mail: liu94@illinois.edu

EXECUTIVE SUMMARY

The results indicate that the estimated rate of occurrence of a crude oil train release incident exceeding 100 gallons on the route from Roseville to the Santa Maria Refinery (SMR) via the Altamont Pass ranges from 0.0057 to 0.0218 per year, or an average interval between incidents of 46 to 176 years. The estimated occurrence rate for the route from Roseville to the SMR via Oakland ranges from 0.0044 to 0.0170 per year, or about once per 59 to 225 years. The route from Colton to the SMR has an estimated annual rate of a release incident ranging between 0.0034 to 0.0132 per year, which corresponds to an average interval between incidents of between 76 to 291 years. The range in the rate for each of these routes is due to the differing levels of accident performance of the different tank car options proposed by PHMSA (2014) and the design that is proposed for use by the Applicant.

1. INTRODUCTION

The purpose of this analysis was to estimate the annual release rate of trains transporting petroleum crude oil on the routes from Roseville, CA or Colton, CA to the Phillips 66 Santa Maria Refinery (SMR) in unincorporated San Luis Obispo County California. The analysis was conducted based on segment-specific rail infrastructure information and tank car safety design.

2. METHODOLOGY

2.1. Crude Oil Train Release Rate Model

The occurrence of a crude oil train release incident is the result of a sequence of events that are affected by a number of factors. The following model was used to estimate crude oil train release rate:

$$P(R) = \sum_{i=1}^{N} Z_i S_i L_i P_i (R \mid A) \quad (1)$$

Where:

$P(R)$ = annual crude oil train release rate

Z_i = train derailment rate per train-mile on the ith segment

S_i = number of trains on the ith segment

L_i = segment length (miles)

$P_i(R|A)$ = probability of at least one tank car releasing per crude oil train derailment

N = number of track segments on the route

2.2. Parameters in Risk Analysis

2.2.1. Train Derailment Rate, Z

Train derailment rate is the likelihood that a train derails per unit of traffic exposure (e.g., per million train-miles traveled). Average U.S. train derailment rate over the 5-year period 2005 – 2009 has previously been estimated using data from the U.S. Department of Transportation, Federal Railroad Administration (FRA) Rail Equipment Accident (REA) database combined with traffic data from the rail industry (Liu et al, 2014). The FRA database records all accidents that exceed a specified monetary damage cost to on-track equipment, signals, track, track structures, and roadbed (FRA, 2012). Train derailment rate has been shown to vary with infrastructure and operating characteristics

such as: FRA track class, method of operation and traffic density (Liu et al, 2014). Higher FRA track classes (corresponding to higher operational speeds and more stringent safety standards) and signaled trackage demonstrate lower derailment rates, compared to lower FRA track classes and non-signaled trackage (Figure 1).

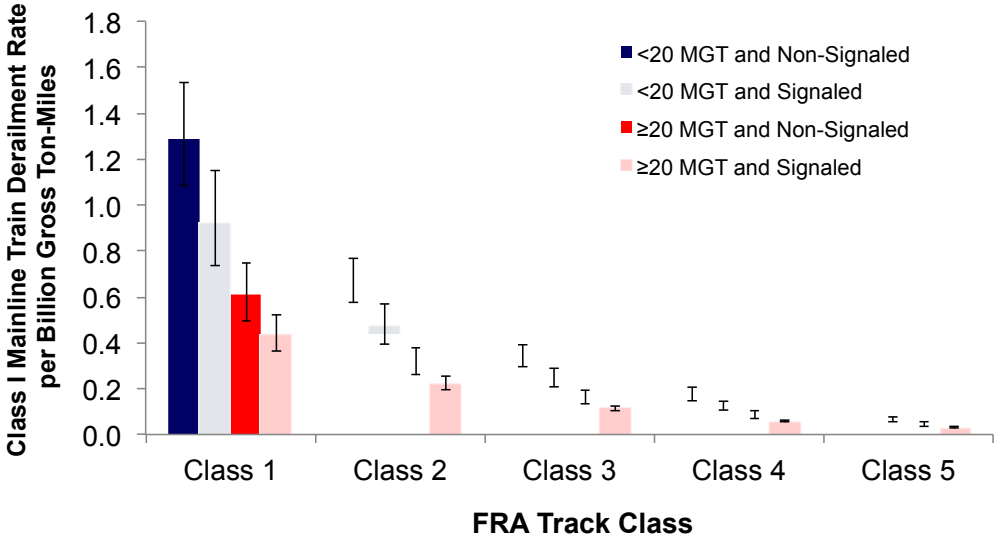

Figure 1: Estimated Class I mainline freight-train derailment rates by FRA track class, method of operation and annual traffic density (error bars represent 95% confidence intervals) (Liu, 2013)

The train derailment rates presented in Figure 1 were developed using accident data from the FRA Rail Equipment Accident (REA) database, combined with rail industry traffic exposure data. In addition to normalized rates that can be used for comparative purposes they permit absolute rates to be estimated for any particular route and combination of characteristics (Liu et al, 2014). These rates, combined with route characteristics, were used to estimate the derailment rate on this line as discussed below.

2.2.2. Probability of at Least One Car Releasing in a Crude Oil Train Derailment

The probability of at least one tank car releasing per crude oil train derailment can be estimated using the following equation:

$$P(R \mid A) = 1 - (1 - CPR)^{D} \quad (2)$$

Where:

D = number of crude oil cars derailed per train derailment

CPR = conditional probability of release from a tank car derailed or damaged in an FRA-reportable accident

The median number of cars derailed per FRA-reportable, freight-train derailment on Class I mainlines was six (Liu et al., 2013). In this analysis, we assumed that all derailed cars were crude oil tank cars (D = 6). The conditional probability of release (CPR) represents tank car safety performance in accidents and was estimated based on the latest statistics developed by the Railway Supply Institute (RSI) – Association of American Railroads (AAR) Railroad Tank Car Safety Research and Test Project. The RSI-AAR Tank Car Project analysis accounts for tank car safety design features and accident characteristics. The RSI-AAR Project has also calculated a similar statistic, $CPR_{(>100)}$, which is the conditional probability of release of more than 100 gallons from an individual tank car involved in an FRA-reportable accident. Releases smaller than this amount are not believed to pose a substantial threat, so this is the principal metric being used by the rail and tank car industries in their consideration of different tank car safety designs. $CPR_{(>100)}$ is used in the risk analysis described here to be consistent with other documents related to this subject.

The U.S. Department of Transportation (DOT) recently issued Notice of Proposed Rulemaking (NPRM) HM-251 (PHMSA 2014) in which they propose for consideration three options for enhanced safety design tank cars for transportation of flammable liquids, including petroleum crude oil (Table 1). The outcome of this rulemaking is unknown at this time so a risk analysis was conducted for each of these three options. The risk analysis results for the non-jacketed CPC-1232 tank car with ½" tank thickness are also presented for comparison to the three designs being considered in the PHMSA HM-251 NPRM. The non-jacketed CPC-1232 tank car has been included since this is the design that the Applicant has proposed to use as part of the project description.

Table 1 Summary of Tank Car Design Options being Considered in U.S. DOT NPRM HM-251 (Table 2 in PHMSA, 2014)

TABLE 2—SAFETY FEATURES BY TANK CAR OPTION

Tank car	Bottom outlet handle	GRL (lbs)	Head shield type	Pressure relief valve	Shell thickness	Jacket	Tank material *	Top fittings protection **	Thermal protection system	Braking
Option 1: PHMSA and FRA Designed Tank Car.	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident.	286k	Full-height, ½ inch thick head shield.	Reclosing pressure relief device.	9/16 inch Minimum.	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight.	TC–128 Grade B, normalized steel.	TIH Top fittings protection system and nozzle capable of sustaining, without failure, a rollover accident at a speed of 9 mph.	Thermal protection system in accordance with § 179.18.	ECP brakes.
Option 2: AAR 2014 Tank Car.	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident.	286k	Full-height, ½ inch thick head shield.	Reclosing pressure relief device.	9/16 inch Minimum.	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight.	TC–128 Grade B, normalized steel.	Equipped per AAR Specifications Tank Cars, appendix E paragraph 10.2.1.	Thermal protection system in accordance with § 179.18.	In trains with DP or EOT devices.
Option 3: Enhanced CPC 1232 Tank Car.	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident.	286k	Full Height ½ inch thick head shield.	Reclosing pressure relief device.	7/16 inch Minimum.	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight.	TC–128 Grade B, normalized steel.	Equipped per AAR Specifications Tank Cars, appendix E paragraph 10.2.1.	Thermal protection system in accordance with § 179.18.	In trains with DP or EOT devices.
DOT 111A100W1. Specification (Currently Authorized).	Bottom Outlets are Optional.	263K	Optional; Bare Tanks half height; Jacket Tanks full height.	Reclosing pressure relief valve.	7/16 inch Minimum.	Jackets are optional.	TC–128 Grade B, normalized steel.*	Not required, but when Equipped per AAR Specifications Tank Cars, appendix E paragraph 10.2.1.	Optional	Not required.

* For the purposes of this figure, TC–128 Grade B normalized steel is used to provide a consistent comparison to the proposed options. Section 179.200–7 provides alternative materials which are authorized for the DOT Specification 111.

** Please note that the PHMSA does not propose to require additional top fittings protection for retrofits, because the costs are not supported by corresponding benefits. Newly constructed cars, however, are required to have additional top fittings protection. Except for additional top fittings protection, the requirements for newly constructed tank cars and retrofits are the same.

The RSI-AAR Tank Car Safety Project has calculated the $CPR_{(>100)}$ for tank cars conforming to PHMSA design options 2 & 3 (Treichel, 2014). Option 1 is similar to Option 2 except that it incorporates a new, more damage-resistant design of top-fittings protection. There is not yet sufficient empirical experience with this new design of top-fittings protection to statistically quantify its performance in accidents; however, based on previous work with similar designs we assume that it will reduce $CPR_{(>100)}$ by about 25%. Using Equation (2), we estimated the probability of at least one tank car releasing more than 100 gallons if a crude oil train derailed in an FRA-reportable accident (Table 2). For example, if a train containing Option 2 tank cars is derailed, in an FRA-reportable accident, there is a 16% chance that this will result in at least one tank car releasing more than 100 gallons.

Table 2 Probability of at least one tank car releasing more than 100 gallons per crude oil train derailment (assuming six tank cars derailed per derailment)

Tank Car Type	$CPR_{(>100)}$	P(R|A)
Option 1*	0.022	0.125
Option 2	0.029	0.163
Option 3	0.046	0.244
Non-Jacketed CPC-1232	0.103	0.479

**Option 1 has similar tank safety design as Option 2, except the addition of the "rollover" top fittings protection. Treichel (2014) did not estimate the benefit of the rollover protection. In this analysis we assumed a 25% overall CPR reduction from Option 2. The estimate is subject to change as more refined analysis of this new design is conducted.*

3. RESULTS

3.1. Route Information

The route information is presented in Figure 2 and Table 3.

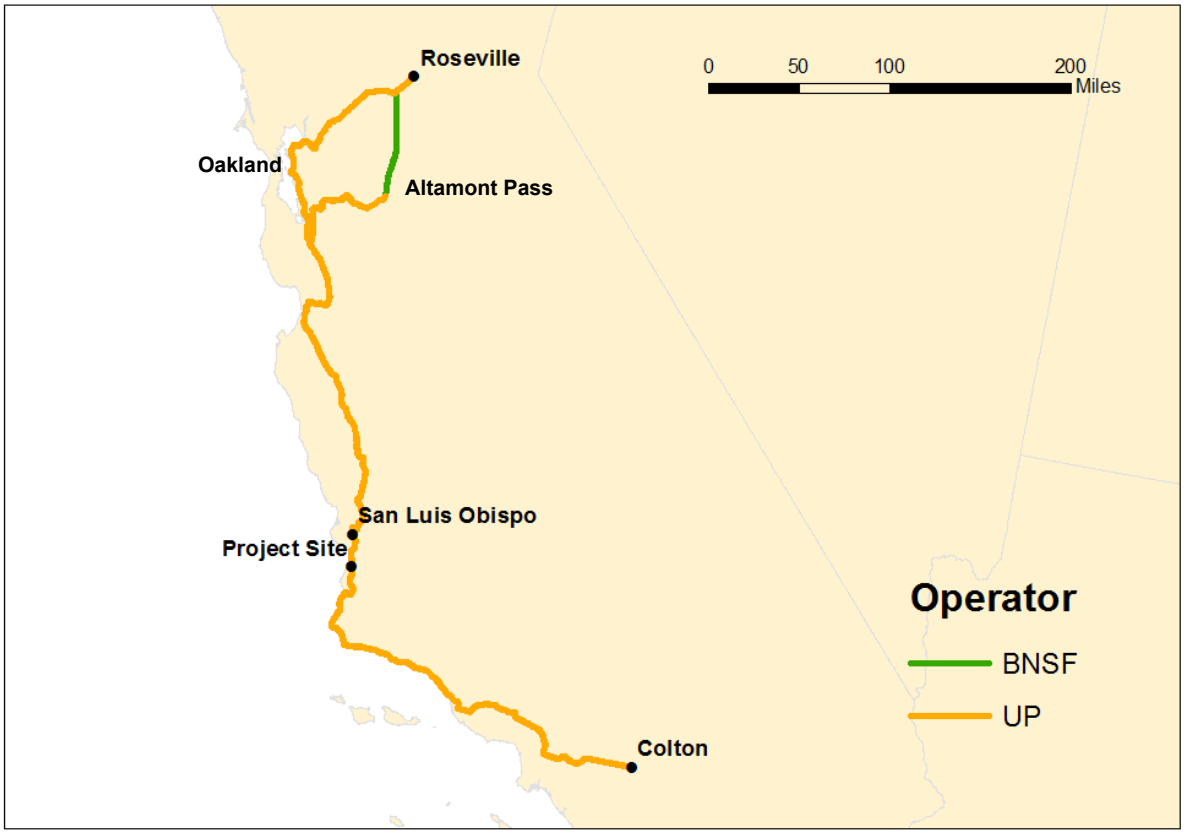

Figure 2: Potential crude oil transportation routes to project site

Table 3 Train derailment rate and estimated mileage by FRA track class (signaled trackage)

Roseville to the SMR via Altamont Pass (BNSF and UP) – 359.2 miles

FRA Track Class	Train Derailment Rate Per Million Train-Miles	Estimated Percentage of Mileage
1	3.10	5.1%
2	1.67	0.0%
3	0.84	0.0%
4	0.41	77.7%
5	0.20	17.2%
Weighted Average	0.51	

Roseville to the SMR via Oakland (UP) – 367.3 miles

FRA Track Class	Train Derailment Rate Per Million Train-Miles	Estimated Percentage of Mileage
1	3.10	0.4%
2	1.67	0.0%
3	0.84	4.4%
4	0.41	71.6%
5	0.20	23.6%
Weighted Average	0.39	

Colton to the SMR (UP) – 258.9 miles

FRA Track Class	Train Derailment Rate Per Million Train-Miles	Estimated Percentage of Mileage
1	3.10	0.4%
2	1.67	0.0%
3	0.84	2.9%
4	0.41	93.6%
5	0.20	3.1%
Weighted Average	0.43	

The mileage-weighted average train derailment rate was estimated based on track-class-specific derailment rate and the estimated mileage distribution of FRA track class over the entire route. For example, the average train derailment rate over the Roseville to the SMR via Oakland is approximately 0.39 derailments per million train miles (calculation below):

3.10 × 0.4% (class 1) + 1.67 × 0% (class 2) + 0.84 × 4.4% (class 3) + 0.41 × 71.6% (class 4) + 0.20 × 23.6% (class 5) = 0.39 train derailment rate per million train-miles

3.2. Annual Train Release Rate

We calculated annual route-specific crude oil train derailment and release rates using the particular route characteristics and the methodology described above (Table 4). Based on information provided the annual number of trains was assumed to be 250.

Table 4 Estimated annual train derailment and release rates

a) PHMSA Option 1 tank car

	Roseville to the SMR via Altamont Pass	Roseville to the SMR via Oakland	Colton to the SMR
Train Derailment Rate per Million Train-Miles	0.51	0.39	0.43
Crude Oil Train Release Rate per Million Train-Miles	0.0633	0.0483	0.0531
Annual Crude Oil Train Derailment Rate	0.0456	0.0355	0.0275
Probability of Train Derailments Involving Releases	0.1248	0.1248	0.1248
Annual Crude Oil Train Release Rate	0.0057	0.0044	0.0034
Average Interval between Release Incidents (Years)	176	225	291

b) PHMSA Option 2 tank car

	Roseville to the SMR via Altamont Pass	Roseville to the SMR via Oakland	Colton to the SMR
Train Derailment Rate per Million Train-Miles	0.51	0.39	0.43
Crude Oil Train Release Rate per Million Train-Miles	0.0829	0.0633	0.0695
Annual Crude Oil Train Derailment Rate	0.0456	0.0355	0.0275
Probability of Train Derailments Involving Releases	0.1634	0.1634	0.1634
Annual Crude Oil Train Release Rate	0.0074	0.0058	0.0045
Average Interval between Release Incidents (Years)	134	172	222

c) PHMSA Option 3 tank car

	Roseville to the SMR via Altamont Pass	Roseville to the SMR via Oakland	Colton to the SMR
Train Derailment Rate per Million Train-Miles	0.51	0.39	0.43
Crude Oil Train Release Rate per Million Train-Miles	0.1242	0.0947	0.1041
Annual Crude Oil Train Derailment Rate	0.0456	0.0355	0.0275
Probability of Train Derailments Involving Releases	0.2447	0.2447	0.2447
Annual Crude Oil Train Release Rate	0.0112	0.0087	0.0067
Average Interval between Release Incidents (Years)	90	115	148

d) CPC-1232 non-jacketed tank car

	Roseville to the SMR via Altamont Pass	Roseville to the SMR via Oakland	Colton to the SMR
Train Derailment Rate per Million Train-Miles	0.51	0.39	0.43
Crude Oil Train Release Rate per Million Train-Miles	0.2431	0.1855	0.2038
Annual Crude Oil Train Derailment Rate	0.0456	0.0355	0.0275
Probability of Train Derailments Involving Releases	0.4791	0.4791	0.4791
Annual Crude Oil Train Release Rate	0.0218	0.0170	0.0132
Average Interval between Release Incidents (Years)	46	59	76

3.3. Discussion & Interpretation

All of the estimated release rates are affected by which tank car options is used (Table 4), consequently there are a range of results for each route, with the lowest rate associated with PHMSA Option 1 and the highest, with the non-jacketed CPC-1232. The estimated rate of occurrence of a crude oil train release incident that exceeds 100 gallons on the route from Roseville to the SMR via Altamont Pass ranges from 0.0057 to 0.0218 per year, or an average of about once per 46 to 176 years. The estimated occurrence rate for the route from Roseville to the SMR via Oakland ranges from 0.0044 to 0.0170 per year, or about once per 59 to 225 years. The route from Colton to the SMR has an estimated annual rate of a release incident ranging from 0.0034 to 0.0132 per year, which corresponds to an average interval between incidents of between 76 to 291 years.

The risk estimates described here may be conservative, i.e. they might over estimate the risk for several reasons. The railroad industry's hazardous materials release accident rate has declined in the years since the rate estimates were developed (2005 – 2009) (Figure 3). Thus the average rate calculated over that time interval is probably higher than if the same rate were calculated using more current data. More broadly, the railroads' accident rate has been declining for decades and this trend will probably continue due to continued investment in infrastructure and various new technologies

that are being developed to improve operating safety. Furthermore, the accident rates used in this analysis do not take into account the effect of various additional safety practices specific to rail transportation of petroleum crude oil that are being implemented by the railroads (AAR, 2014; Union Pacific, 2014). The risk analysis described here did not account for any of these potential reductions in accident rate.

On the other hand, it is assumed that the infrastructure condition, rolling stock and operating practices will stay the same or improve over the period of time being considered in this analysis. If any of these, or other factors change in a manner that would increase the likelihood of an accident or release, then the risk estimates could be higher than those presented here. Furthermore, these risk results are based on national averages for Class 1 railroads. There may be factors or conditions unique to these routes that either increase or reduce the estimated risk.

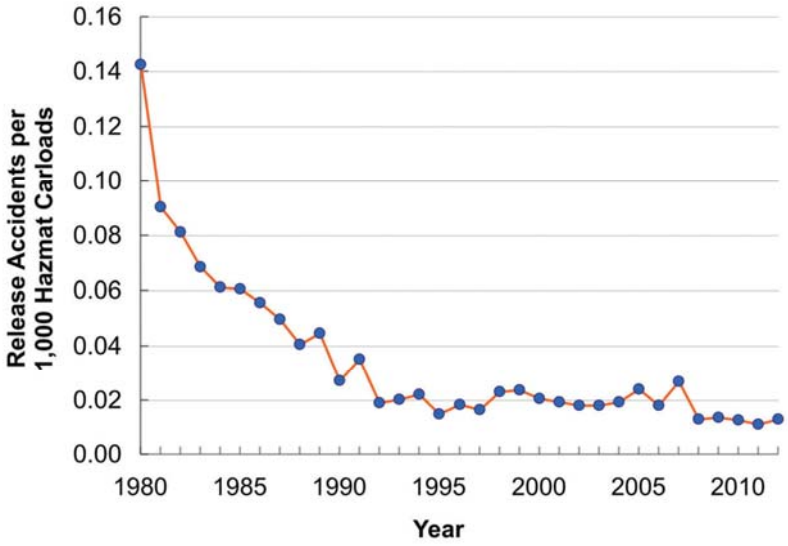

Figure 3: Railroad accident hazardous materials release rate 1980 – 2012 (FRA data, presented in Barkan et al., 2013)

Finally, it is important to understand that the accidents considered in this analysis are probabilistic events that will generally be independent of one another. This means that one or more events might occur at any time in the average estimated interval between events, or they might not happen at all during that time.

4. Summary

The major factors understood to affect railroad hazardous materials releases were quantitatively analyzed. These include FRA track class, method of operation, tank car safety design and traffic exposure. The estimated rate of occurrence of a crude oil train release incident exceeding 100 gallons on the route from Roseville to the SMR via Altamont Pass ranges from 0.0057 to 0.0218 per year, or an average of about once per 46 to 176 years. The estimated occurrence rate for the route from Roseville to the SMR via Oakland ranges from 0.0044 to 0.0170 per year, or about once per 59 to 225 years. The route from Colton to the SMR has an estimated annual rate of a release incident ranging from 0.0034 to 0.0132 per year, which corresponds to an average interval between incidents of between 76 to 291 years. The range in the estimated release rate for each of these routes is due to the differing levels of accident performance of the different tank car options proposed by PHMSA (2014) in NPRM HM-251 and the design that is proposed for use by the Applicant.

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