APPENDIX A EMISSIONS INVENTORY

The development of an emissions inventory requires information on the emission rates for an activity (i.e., the expected emissions for a given unit or volume of the activity) combined with information on the frequency with which the activity is conducted. Neither type of information was readily available for vacuum truck operations at the beginning of this rule development process. In order to estimate vacuum truck emissions and potential reductions for the proposed rule, staff developed emission factors and estimates of vacuum truck activity.

Emission Rates

Virtually no information on vacuum truck emission rates was available when District staff began this rule development effort. For many types of emissions sources, the United State Environmental Protection Agency has conducted research and has developed emission estimation methodologies that are available in its AP-42, *Compilation of Air Pollutant Emission Factors*. No AP-42 methodology is available for vacuum trucks, although a method is available for estimating emissions from loading hydrocarbon liquids into cargo tank trucks such as those that transport gasoline to gas stations (AP-42, Chapter 5.2). This AP-42 method may be useful in estimating emissions from loading hydrocarbon liquids into vacuum trucks, but it probably underestimates emissions when significant agitation or "lifting" of liquids is involved, as is common in vacuum truck operations. In addition, because an important factor in the AP-42 methodology is the vapor pressure of the material being loaded, the approach is probably not useful for mixtures of hydrocarbons and water because the vapor pressure of such mixtures is difficult to measure or estimate. Given the prevalence of aqueous mixtures among the materials moved by vacuum trucks, the AP-42 method appears to have limited utility.

Lacking any existing emission rate information, District staff conducted 32 source tests of vacuum truck operations, primarily at Bay Area refineries. The tests were conducted by District personnel from fall 2010 to fall 2011. The tests presented many scheduling difficulties, because much vacuum truck activity is unplanned and is conducted as needed for maintenance and clean-up activities. In addition, most activity is very brief, typically lasting less than a half-hour and involving relatively small quantities of materials. Of the 32 tests conducted, the majority involved wastewater and waste oils. A small number involved gasoline and other volatile materials. The test results are set forth in Table A-1 on the following two pages.

Table A - 1: Summary of Vacuum Truck Source Tests

Source Test #	Facility	Location	Date	Duration (mins)	Flowrate (SDCFM)	TOC (ppm as $C_{1)}$	TOC (lbs)	TOC (lbs/hr)	Notes
11050	Tesoro	Tank # 622	09/15/10	13	15	3	0.00003	0.00014	Processed low sulfur diesel
11051	Tesoro	Naptha pipeline # 107	09/15/10	60	8	83,500	1.70	1.70	Tanks 876 & 432; Processed Naptha & Natural Gas
11054	Tesoro	Tank # 701	09/22/10	24	118	4,760	0.56	1.40	Rated capacity of vac was 350 sdcfm. Processed Waterborne light crude.
11070	Valero	Pump # 602	10/21/10	4	76	3,400	0.043	0.65	Processed unspecified material.
11070	Valero	Transmix valve # 94959	10/21/10	3	45	3,370	0.019	0.38	Processed transmix.
11070	Valero	Waste area	10/21/10	4	38	34,700	0.22	3.30	Processed unspecified material.
11070	Valero	Reclaim pump site	10/21/10	9	0	1,750	0	0.0	Processed reclaimed material
11163	Chevron	Bioreactor inlet	03/23/11	36	150	58,200	12.7	21.17	Estimated TOC pounds for event is 127. Processed Oil layer from pond.
11164	Chevron	Tank # 3194	03/23/11	20	170	32,900	4.6	13.80	Processed heavy FCCU Feed.
11165	Chevron	Vessel # 265388	03/23/11	12	70	23,600	0.9	4.50	Processed recovered oil.
11175	Conoco Phillips	Odor Compressor Filter	03/30/11	11	174	28,400	0.41	2.24	Processed waste oil from filters.
11178	Conoco Phillips	Unit # 100, Tank # 501	03/30/11	27	20	419	0.01	0.02	Processed skimmed oil from water treatment plant.
11179	Chevron	250 ft pond	04/06/11	27	95	501	0.05	0.11	Processed oil layer from pond.
11180	Chevron	Cutter Rack - Low Flow	04/06/11	31	19	24,300	0.63	1.22	Processed cutter diesel.
11181	Chevron	Cutter Rack - High Flow	04/06/11	13	35	11,600	0.24	1.11	Processed cutter diesel.
11182	Chevron	Tank # 3126	04/07/11	24	173	18,370	1.37	3.43	Estimated TOC pounds for event is 57. Processed reclaimed oil.
11188	Chevron	Tank # 3126	04/20/11	15	136	6,240	0.46	1.84	Estimated TOC pounds for event is 20. Processed reclaimed oil containing cutter diesel.
11189	Chevron	Vessel # 254822	04/20/11	18	24	37,600	0.54	1.80	Estimated TOC pounds for event is 4. Processed recovered oil.
11200	Shell	API Sand Filter	04/21/11	12	88	3,600	0.17	0.85	Processed recovered oil.
11201	Shell	Tank # 544	04/21/11	46	20	37,500	1.43	1.87	Assumed max. Q = 20 scfm & carbon to be saturated. Processed a water/crude oil mix.
11201	Shell	Tank # 544	04/21/11	36	20	34,200	1.03	1.72	Used assumed max. Q = 20 scfm. Processed a water/crude oil mix.

Source Test #	Facility	Location	Date	Duration (mins)	Flowrate (SDCFM)	TOC (ppm as $C_{1)}$	TOC (lbs)	TOC (lbs/hr)	Notes
11202	Shell	FRAC Tank	04/21/11	8	95	12,000	0.38	2.85	Processed recovered oil.
11203	Shell	Lake	04/21/11	28	95	4,600	0.5	1.07	Processed recovered oil.
11214	Kinder Morgan	Tanks 8 & 9	05/10/11	54	41	178,000	17.4	19.33	Processed transmix.
12022	Plains - Martinez	Tank 100-8-37	08/23/11	26	244	196,000	55	126.9	Processed "carbob"
12023	Chevron	Tank # 3076	08/24/11	83	110	142,000	53.5	38.67	Processed slop + cutter; 65 bbls. T.O. abated truck
12028	Chevron	Tank # 254591	08/31/11	10	71	3,050	0.09	0.54	API separator sludge
12031	Chevron	Bioreactor inlet	08/31/11	11	106	58,900	2.84	15.49	Processed waste oil.
12048	Chevron	JP8 Fuel Filters V-810- A&B	09/27/11	131	13.7	331,984	21.5	9.85	Processed 15 barrels of JP8 fuel
10249	Chevron	Tank # 1637	09/27/11	29	160	1,872,592	326	674.5	Processed 12 barrels of regular unleaded gas.
12052	Valero	Tank # 1805	10/12/11	9	28	185,000	2.0	13.0	Processed 20 barrels of transmix using DP.
12052	Valero	Tank # 1805	10/12/11	8	88	319,000	8.9	69.4	Processed 20 barrels of transmix using vacuum.
Averages	**32 Tests**			**26.3**	**79.6**	**117,251**	**16.10**	**32.33**	

Table Notes:
All facilities are refineries except Kinder Morgan and Plains-Martinez, which are bulk terminals.
All data in each row come from the source test report listed in the first column.
Duration indicates both the duration of the event and of the source test.

Though measured emission rates varied significantly even for loading operations involving similar materials, the test results could be grouped into two major categories: (1) wastewaters and waste oils, which produced relatively low emissions when loaded, and (2) gasoline and gasoline blending stocks, which produced relatively high emissions when loaded. This result is not unexpected given the significant difference in volatility between the two categories of materials. The AP-42 methodology for tank truck loading would predict a similar difference in the two categories, in part because one of the primary terms in the equations is the vapor pressure of the material being loaded.

Using data from the source tests, staff derived two emission factors: (1) a "wastewater / waste oil" emission factor, and (2) a "gasoline / light product" emission factor. The derivation of each factor is set forth in Table A-2 and A-3, below. Emission factors are expressed as pounds of emissions per barrel of material loaded (lbs TOC/bbl). To derive the emission factors, staff used those source tests for which material quantity or a means of estimating quantity was available. In many cases, the quantity estimates are approximations because exact quantities are not recorded by vacuum truck instrumentation or source test instruments.

Table A - 2: Wastewater / Waste Oil Emission Factor

ST#	Facility	Location	Emission Factor (lbs/bbl)	Material
11054	Tesoro	Tank #701	0.027	Waterborne crude
11163	Chevron	Bioreactor inlet	0.475	Oily layer on pond
11165	Chevron	Vessel #265388	0.072	Recovered oil
11175	ConocoPhillips	Odor compressor filter	0.013	Waste oil
11178	ConocoPhillips	Unit #100, Tank #501	0.003	Skimmed oil
11179	Chevron	250 ft pond	0.003	Pond oil layer
11180	Chevron	Cutter rack – low flow	0.19	Cutter diesel
11181	Chevron	Cutter rack – high flow	0.04	Cutter diesel
11182	Chevron	Tank #3126	0.044	Reclaimed oil
11188	Chevron	Tank #3126	0.019	Reclaimed oil / cutter diesel
11189	Chevron	Vessel #254822	0.126	Recovered oil
11200	Shell	API sand filter	0.011	Recovered oil
11202	Shell	Frac tank	0.022	Recovered oil
11203	Shell	Lake	0.030	Recovered oil
12031	Chevron	Bioreactor inlet	0.150	Waste oil
Average			**0.082**	

Table A - 3: Gasoline / Light Product Emission Factor

ST#	Facility	Location	Emission Factor (lbs/bbl)	Notes
11051	Tesoro	Naptha pipeline #107	1.19	Naptha
11070	Valero	Transmix valve #94959	0.002	Transmix
11214	Kinder Morgan	Tanks 8&9	2.39	Transmix
12022	Plains – Martinez	Tank 100-8-37	1.27	Gasoline
12049	Chevron	Tank #1637	11.44	Gasoline
12052	Valero	Tank #1805	0.10	Transmix
12052	Valero	Tank #1805	0.45	Transmix
Average			**2.41**	

Emission Rates With Controls

The emission rates discussed above are uncontrolled emission rates, the rates at which emissions would be released without the use of any technology to control emissions. As discussed in section II.C of the staff report, a number of technologies are available to reduce emissions. For the purpose of this inventory, control technologies other than positive displacement pumps are assumed to reduce emissions by 95%. Positive displacement pumps are assumed to reduce emissions by 75%.

Petroleum Refinery Throughput

According to refinery operators, a Bay Area petroleum refinery will generally retain anywhere from 2 to 7 vacuum trucks on their premises every day. For the Bay Area refineries taken together, approximately 22 vacuum trucks operate daily. When a refinery performs a turnaround, many more vacuum trucks may be necessary. A large turnaround may employ 20 additional trucks or more for several weeks.

Refineries do not closely track quantities and types of materials moved by vacuum trucks. This appears to be because little of the material leaves the site, which would require hazardous waste manifests and much more detailed documentation. In addition, many of the vacuum truck operations are unscheduled and are performed as needed for maintenance operations. Among the Bay Area refineries, Chevron keeps the most thorough records of the types and amounts of materials that are loaded into vacuum trucks on a daily basis. Chevron uses a job form that generically identifies the pickup and drop-off locations for vacuum truck loading events and, for many operations, identifies the type and amount of material. Chevron's records indicate that they move approximately one million barrels of materials with vacuum trucks annually, although not

all vacuum truck activity appears to be recorded on job forms. Nevertheless, the Chevron data set was the best available information on refinery vacuum truck operation.

The District estimated vacuum truck throughput for the other Bay Area refineries by scaling the Chevron data based on the ratio of each refinery's capacity to Chevron's capacity. Table A-4 below shows the 2008 crude oil refining capacity for each Bay Area Refinery as provided by the California Energy Almanac and the corresponding fraction of Chevron's capacity.

Table A - 4: 2008 Crude Oil Capacity of Bay Area Refineries

Bay Area Refinery	2008 Refining Capacity (Barrels/Day)	Fraction of Chevron Capacity
Chevron U.S.A. Inc., Richmond Refinery	242,900	1.000
Tesoro Refining & Marketing Company, Golden Eagle (Avon/Rodeo) Refinery	166,000	0.683
Shell Oil Products US, Martinez Refinery	155,600	0.641
Valero Benicia Refinery	144,000	0.593
ConocoPhillips, Rodeo San Francisco Refinery	76,000	0.313

Chevron estimated that 2% of the materials moved were light hydrocarbons, such as gasoline, ethanol, or transmix. These are the regulated materials subject to the provisions of the rule. Vacuum truck operators contacted during source tests thought that light hydrocarbons constituted a larger share of the activity. Responses from over 15 drivers queried ranged from 20% to 30%. Given the uncertainty about the light hydrocarbon share, District staff selected the midpoint between the average driver response, 25%, and the Chevron response, 2%, assuming for purposes of the inventory that 13.5% of vacuum truck throughput is "regulated material."

Table A-5 illustrates the estimated gross yearly overall throughput for materials serviced at Bay Area refineries as well as the yearly throughput for regulated materials that will be subject to the provisions of Regulation 8, Rule 53.

Table A - 5: Vacuum Truck Material Throughput at Bay Area Refineries

Refinery	Total Throughput of All Materials (barrels/yr)	Regulated Material (13.5% of total – barrels/yr)
Chevron	1,000,000	135,000
Tesoro	683,409	92,260
Shell	640,593	86,480
Valero	592,836	80,032
ConocoPhillips	312,961	42,450
Total	**3,229,799**	**436,022**

Emissions from some loading of materials are already controlled, which must be reflected in the inventory estimates. Refineries estimated that they utilize external control technology to minimize emissions from approximately 5% of the vacuum truck operations. Two refineries currently use positive displacement (PD) pumps a significant percentage of the time. Overall, the District estimates that controls and PD pumps combined are used on approximately 20% of vacuum truck operations at Bay Area refineries. This estimate is based on communications with refineries, District staff observations while conducting source tests at refineries, and communications with vacuum truck operators.

Terminals, Bulk Plants and Organic Liquid Pipeline Facility Throughput

Bulk terminals, marine terminals, bulk plants, and organic liquid pipeline facilities do not use vacuum trucks nearly as much as Bay Area petroleum refineries do. Based on limited feedback from facilities as well as vacuum truck service providers, staff estimates that approximately 2 vacuum trucks operate per day at all terminals, bulk plants, and organic liquid pipeline facilities combined. As with refineries, few records of vacuum truck operations are kept in these facilities.

Based on partial throughput information, as well as interviews with vacuum truck operators and companies that provide control technology service, staff estimates that each terminal, bulk plant, and organic liquid pipeline facility has a yearly average throughput of 250 barrels of regulated material into vacuum trucks for a total of 10,000 barrels from these facilities taken together. These facilities tend to load a much greater percentage of refined products into vacuum trucks than do refineries because terminals exclusively deal with refined product. Thus the “gasoline / light product” emission factor was used to calculate emissions.

Very limited information was available regarding the use of control technology for vacuum truck operations at these facilities. A few terminals were able to provide estimates regarding the frequency with which controls and PD pumps are used. Based on

this information and additional information from vacuum truck operators, District staff estimate that, for loading events involving regulated materials, terminals already utilize control equipment for approximately 3% of events and PD pumps for approximately 17% of events. This same percentage was applied to marine terminals and organic liquid pipeline facilities.

Emissions Calculations

Refineries

Emissions from vacuum truck operations in refineries involving regulated materials are calculated as follows:

(Regulated material throughput) x (emission factor) / (2000 lb/ton) x (365 days/yr) =
(436,022 barrels/yr) x (2.41 lbs/barrel) / (2000 lb/ton) x (365 days/yr) = 1.44 tons per day

Of the regulated material processed by vacuum trucks, some is already controlled. Based on communications with refinery representatives, staff estimates that 15% of vacuum truck loads are already controlled by PD pumps and 5% of vacuum truck loads are already controlled by external abatement equipment, so emissions from regulated materials equal:

1.44 **x** 15% **x** (1 - .75)(PD pump reduction) = (emissions after use of PD pump) +
1.44 **x** 5% **x** (1 - .95)(abatement reduction) = (emissions after use of abatement) +
1.44 **x** 80% (remaining uncontrolled emissions) = **1.21 tons per day**

The estimated emissions for non-regulated materials in refineries, most of which is waste water, is calculated as follows:

Non-regulated material throughput x emission factor =
2,793,777 barrels/yr x 0.082 lbs/barrel = 0.31 tons per day.

The extent to which either PD pumps or abatement equipment are used for non-regulated materials is unknown, however, should the use of PD pumps and abatement control be consistent with estimates for the regulated materials, organic emissions would be calculated as follows:

0.31 **x** 15% **x** (1 - .75)(PD pump reduction) = (emissions after use of PD pump) +
0.31 **x** 5% **x** (1 - .95)(abatement reduction) = (emissions after use of abatement) +
0.31 **x** 80% (remaining uncontrolled emissions) = **0.26 tons per day**

The total emissions from vacuum truck operations at refineries from both regulated and non-regulated materials are **1.21 + 0.26 = 1.47 tons per day**.

Other Facilities

Emissions from vacuum truck operations in for other facilities (bulk terminals, plants, marine terminals and pipeline facilities) involving regulated materials are calculated as follows:

(Regulated material throughput) x (emission factor) / (2000 lb/ton) x (365 days/yr) =
(10,000 barrels/yr) x (2.41 lbs/barrel) / (2000 lb/ton) x (365 days/yr) = 0.03 tons per day

As at refineries, some of the vacuum truck operations are already controlled or conducted with PD pumps. Based on communications with facility representatives, staff estimates that only 3% of vacuum truck loads are already controlled by PD pumps, but that 17% of vacuum truck loads are already controlled by external abatement equipment. Emissions from regulated materials equal:

0.033 **x** 3% **x** (1 - .75)(PD pump reduction) = (emissions after use of PD pump) +
0.033 **x** 17% **x** (1 - .95)(abatement reduction) = (emissions after use of abatement) +
0.033 **x** 80% (remaining uncontrolled emissions) = **0.027 tons per day**

These facilities also have occasion to load materials mixed with water, such as from a sump after a spill. The total throughput is estimated to be about 75% regulated materials and 25% non-regulated materials. The emissions for these non-regulated materials are negligible (less than 1/1000 of a ton per day), so are not included.

Total Emissions

Staff estimates organic emissions from vacuum trucks in all facilities designated by the rule to be **1.47 + 0.027 = 1.497 (1.50) tons per day.** This does not include vacuum truck emissions at other facilities not subject to the rule.

Passive emissions also occur from vacuum trucks. When vacuum trucks are loaded with materials and drive to another location, emissions can occur passively from the truck's barrel. Organic emissions can also occur when material are unloaded from vacuum trucks. These emissions are not included in this inventory.