Appendix D

Risk Assessment Calculations

QRA for Whittier Matrix Project: Proposed Operations Fault Trees

Summary	Frequency	Return
Scenario 1 Wellhead Area Rupture during drilling, per pad	3.8E-02	26
Scenario 1b Wellhead area leak during drilling	7.8E-02	13
Scenario 2 Wellhead Area Rupture during production, per pad	1.8E-02	56
Scenario 2 Wellhead Area Leak during production, per pad	5.3E-04	1,902
Scenario 2 Wellhead Area Rupture during production - non-pressurized wells - per pad	2.1E-06	481,745
Scenario 2b Wellhead area leak during production -pressurized and non-pressurized wells	7.3E-03	137
Scenario 3 Rupture at produced gas pipelines at Well Site and Processing Site	1.0E-05	95,256
Scenario 3b Leak at produced gas pipelines at Well Site and Processing Site	2.3E-05	43,100
Scenario 4 Rupture at Gas Plant separators, scrubbers to compressors - low pressure	3.1E-04	3,255
Scenario 4b Leak at Gas Plant through inlet scrubbers to compressors - low pressure	3.0E-03	328
Scenario 5 Rupture at Gas Plant LTS, scrubbers and compressors - mid pressure	3.9E-04	2,568
Scenario 5b Leak at Gas Plant LTS, scrubbers and compressors - mid pressure	4.2E-03	240
Scenario 6 Rupture at Gas Plant scrubbers and compressors - high pressure	1.0E-04	9,670
Scenario 6b Leak at Gas Plant scrubbers and compressors - high pressure	1.1E-03	889
Scenario 7 Rupture at natural gas pipeline along Loop Road and at meter	8.2E-05	12,152
Scenario 7b Leak at natural gas pipeline along Loop Road and at meter	1.6E-04	6,406
Scenario 8 Loss of Containment from odorant storage/transfer	8.4E-02	12
Scenario 9 Release of Crude Oil and Subsequent Fire	1.8E-04	5,624
Scenario 10a Release of Crude Oil Storage/Pumping with subsequent spill outside containment	9.4E-07	1,068,795
Scenario 10b Release of Crude Oil from Piping/Equipment outside of containment within Preserve (Ru	3.7E-03	272
Scenario 11 Rupture of Natural gas Pipeline along Colima	1.89E-04	5,285

Reference	Event	Failure rate or probability	Units	Number	Event rate or probability	Reference	Total rate
Scenario 1 Wellhead Area Rupture during drilling, per pad							**3.84E-02**
Scenario 2 Wellhead Area Rupture during production, per pad							**1.78E-02**
Scenario 2 Wellhead Area Leak during production, per pad							**5.26E-04**
Scenario 2 Wellhead Area Rupture during production - non-pressurized wells - per pad							**2.08E-06**
1a1	Years of drilling	5	number	1	5	Based on matrix Schedule	
1a2	Max number of wellheads during production, per pad	52	number	1	52	Proposed number of wells minus water injection	
1a3	Max number of wells drilled in one year	12	number	1	12	Estimated based on applicant data, assumes 60 wells over 5 years, all wells assumed drilled at the same pad in one year	
1a4	Number of well workovers in one year, per pad	52	number	1	52	Applicant indicates one per well per year	
1a5	Number of re-drills in one year	3	number	1	3	Applicant information, assume to occur at one pad	
1a6	Full bore pipe rupture, per pad	9.00E-08	/m.yr	260	2.34E-05	Rijnmond 1981, release of gas upstream of choke valve, estimated at 5m per well	
1a7	Full bore valve rupture, par pad	7.30E-07	/valve.yr	104	7.59E-05	release of gas upstream of choke valve, 2 valves per well	
1a8	Pipe leak, per pad	2.63E-06	/m.yr	100	2.63E-04	Rijnmond, 1981, for larger pipe, estimated as 20 wells at a pad, 5m per well	
1a9	Valve leak, per pad	6.57E-06	/valve.yr	40	2.63E-04	Assume 90% of releases are significant leaks but not catastrophic. Assume 20 wells, 4 valves per well	
1a8	Drilling Phase - blowout	5.20E-03	per well	1	5.20E-03	MMS, loss of well control, incident rate between 1996-2005	
1a9	Production phase - blowout	1.40E-04	per well-yr	1	1.40E-04	HLID, gas well, uncontrolled blowout per well year	
1a10	Well Workovers - blowout	7.30E-04	per workover	1	7.30E-04	HLID, workovers gas wells, per workover	
1a11	Fraction catastrophic blowouts	3.30E-01	per demand	1	3.30E-01	Fraction loss of well controls that are catastrophic. Based on MMS accident prevention reports for blowouts.	
1a12	Failure to close safety valve	2.09E-02	per demand	1	2.09E-02	CCPS failure to operate on demand, increased by 10 due to sand and well-hole environment	
Scenario 1b Wellhead area leak during drilling							**7.78E-02**
Scenario 2b Wellhead area leak during production -pressurized and non-pressurized wells							**7.31E-03**
2b1	Fittings per well	10	number	1	1.00E+01	Estimated	
2b2	Rupture of small fitting	7.30E-07	per fit-year	520	3.80E-04		
2b3	Leak at valve	6.57E-06	/valve.yr	104	6.83E-04	Rijnmond 1981, release of gas upstream of choke valve, estimated at 5m per well	
2b4	Leak in pipe	5.26E-06	/m.yr	260	1.37E-03	Rijnmond, 1981	
Scenario 3 Rupture at produced gas pipelines at Well Site and Processing Site							**1.05E-05**
3a1	Full bore pipe rupture	1.76E-07	/m.yr	150	2.64E-05	OPS rate for gas transmission pipelines, years 1984-2004, assumes 150m of pipe	
3a2	Rupture fraction	3.70E-01	fraction	1	3.70E-01	OPS data on ruptures, 37%, for years 2001-2004	
3a3	Full bore valve rupture	7.30E-07	/valve.yr	1	7.30E-07	Lees, WASH	
Scenario 3b Leak at produced gas pipelines at Well Site and Processing Site							**2.32E-05**
3b1	Full bore pipe rupture	1.76E-07	/m.yr	150	2.64E-05	OPS rate for gas transmission pipelines, years 1984-2004, assumes 150m of pipe	
3b2	Leak fraction	6.30E-01	fraction	1	6.30E-01	OPS data on ruptures, 37%, for years 2001-2004	
3b3	Leak at valve	6.57E-06	/valve.yr	1	6.57E-06	Rijnmond 1981,	
Scenario 4 Rupture at Gas Plant separators, scrubbers to compressors - low pressure							**3.07E-04**
4a1	Full bore pipe rupture	9.00E-08	/m.yr	50	4.50E-06	Estimated piping length	
4a2	Full bore valve rupture	7.30E-07	/valve.yr	27	1.97E-05	Estimated based on Applicant PFD	
4a3	PSV fails wide open	2.13E-03	/yr	6	1.28E-02	WASH, lifts light, assume 1% wide open	
4a4	Flare fails to ignite	2.07E-02	/yr	1	2.07E-02	CCPS 3.78 failures per year, 2 hrs per failure, 1989	
4a5	Vessel rupture	1.00E-06	/yr	4	4.00E-06	Rijnmond 1982	
4a6	Heat exchanger failure	1.49E-05	/yr	1	1.49E-05	HLID, 10% to full rupture	
Scenario 4b Leak at Gas Plant through inlet scrubbers to compressors - low pressure							**3.05E-03**
4b1	Leak in pipe	2.63E-06	/m.yr	50	1.32E-04	Rijnmond, 1981, for larger pipe	
4b2	Leak at valve	6.57E-06	/valve.yr	27	1.77E-04	Assume 90% of releases are significant leaks but not catastrophic.	
4b3	Rupture of small valve	7.30E-07	/valve.yr	54	3.94E-05	Estimated twice as many small valves as large ones	

Reference	Event	Failure rate or probability	Units	Number	Event rate or probability	Reference	Total rate
4b4	PSV fails leaks	2.13E-02	/yr	6	1.28E-01	WASH, lifts light	
4b5	Leak in vessel	1.00E-05	/yr	4	4.00E-05	Rijnmond 1981	
4b6	Leak in heat exchanger	1.49E-04	/yr	1	1.49E-04	HLID	
Scenario 5 Rupture at Gas Plant LTS, scrubbers and compressors - mid pressure							**3.89E-04**
5a1	Full bore pipe rupture	9.00E-08	/m.yr	150	1.35E-05	Estimated piping length	
5a2	Full bore valve rupture	7.30E-07	/valve.yr	21	1.53E-05	Estimated based on Applicant PFD	
5a3	PSV fails wide open	2.13E-03	/yr	8	1.70E-02	WASH, lifts light, assume 1% wide open	
5a4	Flare fails to ignite	2.07E-02	/yr	1	2.07E-02	CCPS 3.78 failures per year, 2 hrs per failure, 1989	
5a5	Vessel rupture	1.00E-06	/yr	3	3.00E-06	Rijnmond 1982	
5a6	Full bore compressor failure	5.50E-03	/yr	1	5.50E-03	Base failure of 0.66/yr with 10% catastrophic HLID 1992. Included SCAQMD fugitive rule inspection frequency.	
5a7	Low pressure shut off failure	1.00E-03	on demand	1	1.00E-03	Rijnmond 1982, failure on demand - high rate used - low testing frequency (6 months assumed)	
5a8	Heat exchanger failure	1.49E-05	/yr	4	5.96E-05	HLID, 10% to full rupture	
Scenario 5b Leak at Gas Plant LTS, scrubbers and compressors - mid pressure							**4.17E-03**
5b1	Leak in pipe	2.63E-06	/m.yr	150	3.95E-04	Rijnmond, 1981, for larger pipe	
5b2	Leak at valve	6.57E-06	/valve.yr	21	1.38E-04	Assume 90% of releases are significant leaks but not catastrophic.	
5b3	Rupture of small valve	7.30E-07	/valve.yr	42	3.07E-05	Estimated twice as many small valves as large ones	
5b4	PSV fails leaks	2.13E-02	/yr	8	1.70E-01	WASH, lifts light	
5b5	Leak in vessel	1.00E-05	/yr	3	3.00E-05	Rijnmond 1981	
5b6	Compressor leak	5.50E-02	/yr	1	5.50E-02	HLID 1992	
5b7	Leak in heat exchanger	1.49E-04	/yr	4	5.96E-04	HLID	
Scenario 6 Rupture at Gas Plant scrubbers and compressors - high pressure							**1.03E-04**
6a1	Full bore pipe rupture	9.00E-08	/m.yr	50	4.50E-06	Estimated piping length	
6a2	Full bore valve rupture	7.30E-07	/valve.yr	6	4.38E-06	Estimated based on Applicant PFD	
6a3	PSV fails wide open	2.13E-03	/yr	2	4.25E-03	WASH, lifts light, assume 1% wide open	
6a4	Flare fails to ignite	2.07E-02	/yr	1	2.07E-02	CCPS 3.78 failures per year, 2 hrs per failure, 1989	
6a5	Vessel rupture	1.00E-06	/yr	1	1.00E-06	Rijnmond 1982	
6a6	Full bore compressor failure	5.50E-03	/yr	1	5.50E-03	Base failure of 0.66/yr with 10% catastrophic HLID 1992. Included SCAQMD fugitive rule inspection frequency.	
6a7	Low pressure shut off failure	1.00E-03	on demand	1	1.00E-03	Rijnmond 1982, failure on demand - high rate used - low testing frequency (6 months assumed)	
Scenario 6b Leak at Gas Plant scrubbers and compressors - high pressure							**1.12E-03**
6b1	Leak in pipe	2.63E-06	/m.yr	50	1.32E-04	Rijnmond, 1981, for larger pipe	
6b2	Leak at valve	6.57E-06	/valve.yr	6	3.94E-05	Assume 90% of releases are significant leaks but not catastrophic.	
6b3	Rupture of small valve	7.30E-07	/valve.yr	12	8.76E-06	Estimated twice as many small valves as large ones	
6b4	PSV fails leaks	2.13E-02	/yr	2	4.25E-02	WASH, lifts light	
6b5	Leak in vessel	1.00E-05	/yr	1	1.00E-05	Rijnmond 1981	
6b6	Compressor leak	5.50E-02	/yr	1	5.50E-02	HLID 1992	
Scenario 7 Rupture at natural gas pipeline along Loop Road and at meter							**8.23E-05**
7a1	Full bore pipe rupture	1.76E-07	/m.yr	1230	2.16E-04	OPS rate for gas transmission pipelines, years 1984-2004, piping along access road	
7a2	Rupture fraction	3.70E-01	fraction	1	3.70E-01	OPS data on ruptures, 37%, for years 2001-2004	
7a3	Full bore valve rupture	7.30E-07	/valve.yr	3	2.19E-06	Lees, WASH, counts meter as a valve	
Scenario 7b Leak at natural gas pipeline along Loop Road and at meter							**1.56E-04**
7b1	Full bore pipe rupture	1.76E-07	/m.yr	1230	2.16E-04	OPS rate for gas transmission pipelines, years 1984-2004	
7b2	Leak fraction	6.30E-01	fraction	1	6.30E-01	OPS data on ruptures, 37%, for years 2001-2004	
7b3	Leak at valve	6.57E-06	/valve.yr	3	1.97E-05	Rijnmond 1981,	
Scenario 8 Loss of Containment from odorant storage/transfer							**8.45E-02**
8a1	Hole in odorant pipe	2.63E-06	/m.yr	10	2.63E-05		
8a2	Leak at a odorant valve	5.54E-04	/valve.yr	10	5.54E-03	Assume 90% of leaks are significant but not catastrophic rupture	
8a3	Rupture of small threaded connection	2.08E-05	/conn.yr	100	2.08E-03	CCPS with correction for annual fugitive I&M program, 10% ruptures	
8a4	Rupture of small welded connection	2.63E-06	/conn.yr	0	0.00E+00	WASH 1400, weld leaks, 10% to rupture	
8a5	Odorant pump leak	1.70E-02	/yr	1	1.70E-02	HLID, leakage, 10% to rupture	
8a6	Hole in odorant vessel	1.00E-05	/yr	1	1.00E-05	Rijnmond 1982	
8a7	Hole in loading hose	4.00E-04	/operation	1	4.00E-04	Shell rupture per operation. Leaks assumed to be 10 times great probability.	
8a8	Incorrect hose coupling	4.40E-03	/operation	1	4.40E-03	Rijnmond 1982	
8a9	Carbon canister or vapor recovery procedure failure	5.50E-02	/operation	1	5.50E-02	Rijnmond 1982, failure to follow instructions	
8a10	Loading operations	1	Operations	1	1.00E+00	Number of annual loading operations	
Scenario 9 Release of Crude Oil and Subsequent Fire							**1.78E-04**
9a1	Crude oil tank failure	9.99E-05	/yr	3	3.00E-04	Atmospheric metallic vessel - Catastrophic failure. CCPS, 1989	
9a2	Major earthquake	1.00E-03	/yr	1	1.00E-03	Based on a probabilityof a 0.5g or greater earthquake, USGS data.	
9a3	Crude oil tank pipe rupture	9.00E-08	/m.yr	100	9.00E-06	length estimated	

Reference	Event	Failure rate or probability	Units	Number	Event rate or probability	Reference	Total rate
9a4	Probability of ignition - 5%	5.00E-02	on demand	1	5.00E-02	OPS data for crude releases at pump stations 1986-2000, 5% produce fires	
9a5	Probability of earthquake tank failure	1.00E-01	on demand	1	1.00E-01	Estimated at 10%	
9a6	Pumping area major spill	3.15E-03	/yr	1	3.15E-03	HLID leaks/ruptures for recip pumps, 1% major + 50m piping + 4 large valves	
9a7	Number of drainings per year	6	number	1	6	assumed drained 12 times per year	
9a8	Failure to close drain valve after draining	1.90E-03	on demand	1	1.90E-03	Rijnmond, failure to close a valve properly	
9a9	Failure to notice drains valves not closed during a subsequent inspection	1.00E-01	on demand	1	1.00E-01	R&MIP failure to notice incorrect status on inspection	
9a10	Frequency of drain valve inspections	52	number	1	52	weekly inspections	
Scenario 10a Release of Crude Oil Storage/Pumping with subsequent spill outside containment							**9.36E-07**
Scenario 10b Release of Crude Oil from Piping/Equipment outside of containment within Preserve (Rupture or Leak)							**3.67E-03**
10a1	Major earthquake	1.00E-04	/yr	1	1.00E-04	Based on a probabilityof a 1.0g or greater earthquake, USGS data. 1.0g or greater assumed needed to produce piping failure	
10a2	Crude oil pipe rupture	9.00E-08	/m.yr	1230	1.11E-04	length based on distance between gas plant and Colima	
10a3	Crude oil pipe leak	2.63E-06	/m.yr	1230	3.23E-03		
10a4	Probability of earthquake piping failure	1.00E-01	on demand	1	1.00E-01	Estimated at 10%	
10a5	Leak at valve	7.88E-05	/valve.yr	4	3.15E-04	Assume 90% of releases are significant leaks but not catastrophic. No AQMD leak inspection. Estimated 4 valves	
Scenario 11 Rupture of Natural gas Pipeline along Colima							**1.89E-04**
11a	Incident rate	2.83E-04	/mile.yr	1.80	5.09E-04	OPS rate for gas transmission pipelines, years 1984-2004, piping along Colima road	
11b	Rupture fraction	3.70E-01	fraction	1	3.70E-01	OPS data on ruptures, 37%, for years 2001-2004	
11c	Full bore valve rupture	7.30E-07	/valve.yr	1	7.30E-07	Lees, WASH, counts valve at Lambert	
Scenario 11b Leak of Natural gas Pipeline along Colima							**3.27E-04**
11a	Incident rate	2.83E-04	/mile.yr	1.80	5.09E-04	OPS rate for gas transmission pipelines, years 1984-2004, piping along Colima road	
11b	Rupture fraction	6.30E-01	fraction	1	6.30E-01	OPS data on ruptures, 37%, for years 2001-2004	
11c	Full bore valve rupture	6.57E-06	/valve.yr	1	6.57E-06	Lees, WASH, counts valve at Lambert	

Notes

PSV lifts light	*4.25E-02*	*Average value of WASH, Rijnmond, Lees and CCPS*	
PSV fraction of light lift that are wide open	*0.1*	*Estimated based on general leak/rupture estimate of 10%.*	
Fugitive leaks Inspection Frequency	*6*	*times/yr*	*based on SCAQMD requirements info*
PSV inspection frequency	*1*	*times/yr*	*estimated*
Piping age factor	*1.0*		*new equipment, no age factor*
Vessel/Heat Exchanger age factor	*1.0*		*new equipment, no age factor*

Whittier Matrix QRA Modeling Results

	1 proposed project - Well Blowouts				2 - Wellheads Production				3 - Roadway Piping			
Natural Gas Releases	**Rupture - 1000 psi**		**Rupture - 2500 psi**		**Leak**		**Rupture**		**Leak**		**Rupture**	
Expansion	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Pressure, pa	6,892,857	101,325	17,232,143	101,325	172,321	101,325	172,321	101,325	172,321	101,325	172,321	101,325
Pressure, psi	1,000	14.7	2,500	14.7	25	14.7	25	14.7	25	14.7	25	14.7
Temperature, K	322	178	322	154	322	306	322	306	322	306	322	319
Temperature, F	120	-139	120	-182	120	91.4	120	91	120	91.4	120	115
Diameter, inches	3	10.1	3	15.7	1	1.0	4	4.0	1	1.0	6	6.0
Diameter, m	0.0762	0.2577	0.0762	0.3998	0.0254	0.0254	0.1016	0.1016	0.0254	0.0254	0.1524	0.1524
Area, m2	0.00456	0.05216	0.00456	0.12554	0.00051	0.00051	0.00811	0.00811	0.00051	0.00051	0.01824	0.01824
Velocity, m/s	420	726	375	685	339	339	330	330			141	141
Mass Flow, kg/s	42	42	111	111	0.11	0.11	1.77	1.77	0.11	0.11	1.6	1.6
Discharge Duration, s	1200		1200		1200	-	1200	-	1200		1200	-
Crater Area m2 (if applicable)												
Jet Direction		Horz.		Horz.		Horz.		Horz.		Horz.		Horz.
Impacts												
Thermal	**Flame Jet**		**Flame Jet**		**Flame Jet**		**Flame Jet**		**Flame Jet**		**Flame Jet**	
10 kw/m2 dist, m	62		101		-		-		3		-	
5 kw/m2 dist, m	77		125		-		-		5		-	
Other												
Overpressure/BLEVE												
Distance to 1 psi, m	-		-		-		-		-		-	
Distance to 0.3 psi, m	-		-		-		-		-		-	
Distance to 80 kj/m2-s, m	-		-		-		-		-		-	
Distance to 25 kj/m2-s, m	-		-		-		-		-		-	
Vapor Cloud and Met Condition	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**
LFL distance, m	41	45	77	86	2	2	8	9	2	2	11	14
LFL width, m	6	7	10	11	0.5	0.5	1.5	1.5	0.5	0.5	2	2
1/2 LFL distance, m	98	121	179	237	3	3.5	19	26	3	3.5	23	34
1/2 LFL width, m	10	12	17	22	0.7	0.8	3	3	0.7	0.8	3	4
Notes	3", 1m piping length to 10" pipeline to simulate well hole releases. Methane		3", 1m piping length to 10" pipeline to simulate well hole releases. Methane		1m piping length to large vessel. No offsite impacts		1m piping length to large vessel		100m piping length to large pipeline vessel		100m piping length to large pipeline vessel	

Before and after denote conditions associated with the released material before and after expansion from operating pressure to atmospheric pressure

Whittier Matrix QRA Modeling Results

	4 - Gas Plant Low Pressure				5 - Gas Plant mid pressure				6/7 - Gas Plant high pressure, metering			
Natural Gas Releases	**Leak**		**Rupture**		**Leak**		**Rupture**		**Leak**		**Rupture**	
Expansion	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Pressure, pa	689,286	101,325	689,286	101,325	3,446,429	101,325	3,446,429	101,325	6,892,857	101,325	6,892,857	101,325
Pressure, psi	100	14.7	100	14.7	500	14.7	500	14.7	1,000	14.7	1,000	14.7
Temperature, K	322	-	322	284	322	-	322	189	293	160	293	153
Temperature, F	120		120	52	120		120	-119	67	-171	67	-184
Diameter, inches	1	0.0	6	6.8	1	0.0	3	7.3	1	3.2	3	10.1
Diameter, m	0.0254		0.1524	0.1726	0.0254		0.0762	0.1849	0.0254	0.08213	0.0762	0.2575
Area, m2	0.00051	0.00000	0.01824	0.02340	0.00051	0.00000	0.00456	0.02685	0.00051	0.00530	0.00456	0.05208
Velocity, m/s	433	-	436	614	366	-	429	731	392	686	389	670
Mass Flow, kg/s	0.4	-	11.75	11.75	2.4	-	20.5	20.5	4.5	4.5	45.3	45.3
Discharge Duration, s	1200	-	1200	-	1200	-	1200	-	1200	-	1200	
Crater Area m2 (if applicable)												
Jet Direction		Horz.		Horz.		Horz.		Horz.		Horz.		Horz.
Impacts												
Thermal	**Flame Jet**		**Flame Jet**		**Flame Jet**		**Flame Jet**		**Flame Jet**		**Flame Jet**	
10 kw/m2 dist, m	-		32		-		43		-		66	
5 kw/m2 dist, m	-		41		-		54		-		81	
Other												
Overpressure/BLEVE												
Distance to 1 psi, m	-		-		-		-		-		-	
Distance to 0.3 psi, m	-		-		-		-		-		-	
Distance to 80 kj/m2-s, m	-		-		-		-		-		-	
Distance to 25 kj/m2-s, m	-		-		-		-		-		-	
Vapor Cloud and Met Condition	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**	**D/4**	**F/2**
LFL distance, m	2	2	18	20	2	2	26	28	10	11	45	50
LFL width, m	0.5	0.5	3	3	0.5	0.5	4	5	2	2	6	7
1/2 LFL distance, m	3	3	46	57	3	3	63	76	24	28	106	135
1/2 LFL width, m	0.8	0.8	6	7	0.8	0.8	7	8	4	4	11	14
Notes	20m piping length to large pipeline vessel. No offsite impacts		20m piping length to large pipeline vessel		1m piping length to large vessel. No offsite impacts		1m piping length to large vessel		1m piping length to large vessel		1m piping length to large vessel	

Before and after denote conditions associated with th

Whittier Matrix QRA Modeling Results

	8 - Odorant Release	9 - Crude Spill with Fire	11 - Colima Pipeline 6", 500 psig	
Natural Gas Releases	**Crude Dike Fire**	**Crude Dike Fire**	**Rupture**	
Expansion			**Before**	**After**
Pressure, pa	101,325	101,325	3,446,429	101,325
Pressure, psi			500	14.7
Temperature, K	300	300	293	185
Temperature, F			67	-126
Diameter, inches	1	-	6	7.9
Diameter, m	-	-	0.1524	0.2004
Area, m2	28	1337	0.01824	0.03154
Velocity, m/s	-	-		618
Mass Flow, kg/s	-	-	20.8	20.8
Discharge Duration, s	-	-	60	60
Crater Area m2 (if applicable)				
Jet Direction				Horz.
Impacts				
Thermal	**Toxic**	**Thermal**	**Flame Jet**	
10 kw/m2 dist, m		29	48	
5 kw/m2 dist, m	Toxic: ERPG-2: 48m length, 13 m width	39	59	
Other	ERPG-3: within fenceline		52m for 20 kw/m2, 10% fatality at 30 seconds	
Overpressure/BLEVE				
Distance to 1 psi, m			-	
Distance to 0.3 psi, m			-	
Distance to 80 kj/m2-s, m			-	
Distance to 25 kj/m2-s, m			-	
Vapor Cloud and Met Condition			**D/4**	**F/2**
LFL distance, m			18	20
LFL width, m			3	3
1/2 LFL distance, m			46	57
1/2 LFL width, m			6	7
Notes	Odorant release based on spill to ground producing a pool with a vapor evolution rate of 0.008 kg/s	Crude composition based on Honolulu Terrace and butane mix fraction, with 120' square dike area	0.1m piping length to 1.8 mile, 6" vessel	

Before and after denote conditions associated with th