

## **Appendix C**

### **Risk Assessment Calculations**



**QRA for Existing Maintenance Facility: Propane Tank**

Reference	Event	Failure rate or probability	Units	Number	Event rate or probability	Reference	Total rate
<b>Scenario 1a Rupture at propane system, including truck loading - liquid only</b>							<b>1.68E-05</b>
1a1	Full bore pipe rupture - after auto valve	9.00E-07	/m.yr	1	9.00E-07		
1a2	Full bore valve rupture - after auto valve	4.38E-06	/valve.yr	1	4.38E-06	assumes an excess flow valve	
1a3	Pump failure - after auto valve	1.70E-03	/yr	1	1.70E-03	HLID, 10% rupture	
1a4	Full bore pipe rupture - before auto valve	9.00E-07	/m.yr	0	0.00E+00		
1a5	Full bore valve rupture - before auto valve	4.38E-06	/valve.yr	0	0.00E+00		
1a6	Pump failure - before auto valve	1.70E-03	/yr	0	0.00E+00	HLID, 10% rupture	
1a7	Vessel rupture	2.00E-06	/yr	1	2.00E-06		
1a8	Automatic Valve Failure	1.00E-03	demand	1	1.00E-03	Lees, failure to operate	
<b>Scenario 1b Leak at propane system including truck loading - liquid or vapor</b>							<b>2.16E-03</b>
1b1	Leak in pipe - after auto valve	5.66E-05	/m.yr	1	5.66E-05		
1b2	Leak at valve - after auto valve	3.94E-05	/valve.yr	1	3.94E-05		
1b3	Rupture of small valve - after auto valve	4.38E-06	/valve.yr	2	8.76E-06		
1b4	Pump leak - after auto valve	1.70E-02	/yr	1	1.70E-02	HLID, pump leaks	
1b5	Leak in pipe - no auto valve	5.66E-05	/m.yr	0	0.00E+00		
1b6	Leak at valve - no auto valve	3.94E-05	/valve.yr	0	0.00E+00		
1b7	Rupture of small valve - no auto valve	4.38E-06	/valve.yr	0	0.00E+00		
1b8	Pump leak - no auto valve	1.70E-02	/yr	0	0.00E+00	HLID, pump leaks	
1b9	Leak in vessel	2.00E-05	/yr	1	2.00E-05		
1b10	PSV fails wide open	2.13E-03	/yr	1	2.13E-03		
1b11	Automatic Valve Failure	1.00E-03	demand	1	1.00E-03		
<b>Scenario 1c Explosion due to Catastrophic release at propane vessel systems</b>							<b>6.00E-09</b>
1c1	Catastrophic vessel rupture	6.00E-08	/yr	1	6.00E-08	Shell 1993 Rupture of LPG Tank	
1c2	Ignition conditional probability	1.00E-01	on demand	1	1.00E-01	Estimated	
1c3	Explosion fraction of rupture releases, calculated				0.00036		
<b>Scenario 1d BLEVE at propane vessels due to impingement release</b>							<b>3.66E-07</b>
1d1	Ignition conditional probability	1.00E-01	on demand	1	1.00E-01	Estimated	
1d2	Leak at large valve, close to liquid space	3.94E-05	/valve.yr	0	0.00E+00	leak before or including automatic shutdown valve	
1d3	Leak at large pipe close to vessel liquid space	5.66E-05	/m.yr	1	5.66E-05	leak before or including automatic shutdown valve	
1d4	Leak at large valve close to vapor space	3.94E-05	/valve.yr	0	0.00E+00	leak before or including automatic shutdown valve	
1d5	Leak at large pipe close to vessel vapor space	5.66E-05	/m.yr	0	0.00E+00	leak before or including automatic shutdown valve	
1d6	Rupture at small valve close to liquid space	4.38E-06	/valve.yr	1	4.38E-06	leak before or including automatic shutdown valve	
1d7	Rupture at small pipe close to liquid space	9.00E-07	/m.yr	1	9.00E-07	leak before or including automatic shutdown valve	
1d8	Rupture at small valve close to vapor space	4.38E-06	/valve.yr	0	0.00E+00	leak before or including automatic shutdown valve	
1d9	Rupture at small pipe close to vapor space	9.00E-07	/m.yr	0	0.00E+00	leak before or including automatic shutdown valve	
1d10	Leak at large valve after MOV, close to liquid space	3.94E-05	/valve.yr	0	0.00E+00	leak after automatic shutdown valve	
1d11	Leak at large pipe after MOV, close to liquid space	5.66E-05	/m.yr	0	0.00E+00	leak after automatic shutdown valve	
1d12	Leak at large valve after MOV, close to vapor space	3.94E-05	/valve.yr	0	0.00E+00	leak after automatic shutdown valve	
1d13	Leak at large pipe after MOV close to vapor space	5.66E-05	/m.yr	0	0.00E+00	leak after automatic shutdown valve	
1d14	Serious leak/rupture in vessel	2.00E-06	/yr	1	2.00E-06	Rijnmond	
1d15	Catastrophic explosion at propane loading facility	2.63E-08	/yr	1	2.63E-08		
1d16	Automatic Valve Failure	1.00E-03	demand	1	1.00E-03	Lees, failure to operate	
1d17	Probability flame strikes vessel vapor space	1.00E-01	demand	1	1.00E-01	Estimated based on distance of piping from vessel and open area	
1d18	Probability flame strikes vessel liquid space	5.00E-01	demand	1	5.00E-01	Estimated based on distance of pipe from vessel and confined area under vessels	
1d19	PSV Fails, blocked	1.00E-04	on demand	1	1.00E-04	Fails to open on Demand, Shell, LPG	
1d20	Long duration	1.00E-01	on demand	1	1.00E-01	estimated	
1d21	Fire fighting/cooling inadequate, deluge system	1.00E+00	on demand	1	1.00E+00	No deluge	
1d22	Operator fails to activate firefighting	1.00E-03	on demand	1	1.00E-03	Rijnmond 1982, operator fails to respond	
1d23	Fireproofing material fails	1.00E+00	on demand	1	1.00E+00	No fireproofing material currently installed	
1d24	BLEVE fraction of rupture releases				0.021757		
<b>Scenario 1e Rupture at Propane Loading system - liquid only</b>							<b>1.31E-05</b>
1e1	LPG Truck trips per year				12	1 per month	
1e2	LPG Truck hours per loading operation	0.50	fraction	1	0.50	Fraction time truck is at facility = 30 minutes per load	
1e3	LPG Truck Vessel rupture	1.00E-06	/yr	1	1.00E-06	No correction for vessel age	
1e4	LPG Truck Full bore valve rupture	8.76E-06	/valve.yr	2	1.75E-05	No correction for valve sniffing	
1e5	LPG truck Full bore pipe rupture	9.00E-07	/m.yr	1	9.00E-07		
1e6	LPG Truck Hose rupture per loading	4.00E-05	/hose.loading operation	1	4.00E-05	Shell 1993 Rupture of LPG hose, probability per operation, mild steel braid	
1e7	LPG Truck Driver pulls back	5.00E-07	/loading operation	1	5.00E-07	Driver pulls away with shut off valve open. Shell International Petroleum Co. Ltd, Supply and Marketing Division, July 1993	
1e8	LPG Truck Operator fails to respond	1.00E-03	on demand	1	1.00E-03	Rijnmond 1982	
1e9	LPG Truck Check Valve Failure	2.60E-02	on demand	1	2.60E-02	Shell LPG failure to check on demand	
<b>Scenario 1f Catastrophic Explosion of LPG Truck at Propane Loading system</b>							<b>2.63E-08</b>
1f1	Catastrophic truck vessel rupture	1.00E-06	/yr	1	1.00E-06	No correction for vessel age	
1f2	Ignition conditional probability	1.00E-01	on demand	1	1.00E-01	estimated	
1f3	Fraction of rupture releases to catastrophic	2.00E-02	on demand	1	2.00E-02	Estimated, CCPS BLEVE fraction	
1f4	Explosion fraction of rupture releases				0.00201		

**QRA for E&B Hermosa Project: Proposed Operations Fault Trees**

Summary	Frequency	Return
Scenario 1 Wellhead Area Rupture during drilling	3.1E-03	323
Scenario 1b Wellhead area leak during drilling	4.2E-02	24
Scenario 2 Wellhead Area Rupture during production	1.7E-06	604,127
Scenario 2b Wellhead area leak during production -pressurized and non-pressurized wells	1.7E-03	576
Scenario 3 Rupture at Gas Plant separators, scrubbers to compressors - low pressure	1.0E-04	9,831
Scenario 3b Leak at Gas Plant through inlet scrubbers to compressors - low pressure	8.5E-04	1,180
Scenario 4 Rupture at Gas Plant LTS, scrubbers and compressors - mid pressure	8.1E-05	12,412
Scenario 4b Leak at Gas Plant LTS, scrubbers and compressors - mid pressure	1.0E-03	1,004
Scenario 5 Rupture at Gas Plant compressors 2nd stage - high pressure	4.2E-05	23,980
Scenario 5b Leak at Gas Plant compressors 2nd stage - high pressure	7.3E-04	1,366
Scenario 6 Rupture at natural gas pipeline along Valley Dr and at meter	1.1E-04	9,065
Scenario 6b Leak at natural gas pipeline	1.2E-04	8,418
Scenario 7 Loss of Containment from odorant storage/transfer	6.9E-02	14
Scenario 8 Release of Crude Oil and Subsequent Fire	2.7E-04	3,660
Scenario 9 Release of Crude Oil Storage/Pumping with subsequent spill outside containment	1.6E-07	6,421,148
Scenario 10a Rupture at refrigeration system	3.5E-05	28,448
Scenario 10b Leak at refrigeration system	4.0E-04	2,478
Combined Facility Gas Rupture	3.5E-03	289
Combined Facility Gas Leak	4.7E-02	21
Combined Facility Gas Rupture: No Drilling	3.7E-04	2,695
Combined Facility Gas Leak: no Drilling	4.8E-03	207
Bercha Comparison rupture	3.4E-04	2,977
Bercha Comparison leak	4.4E-03	226

Ref	Event	Failure rate or probability	Units	Number	Event rate or probability	Reference	Total rate
<b>Scenario 1 Wellhead Area Rupture during drilling</b>							<b>3.09E-03</b>
<b>Scenario 2 Wellhead Area Rupture during production</b>							<b>1.66E-06</b>
1a1	Years of drilling	2.5	number	1	2.5	Based on Applicant Schedule	
1a2	Max number of wellheads during production	30	number	1	30	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 30 wells over 2.5 years	
1a4	Number of well workovers in one year	12	number	1	12	Applicant indicates one per well per year	
1a5	Number of re-drills in one year	0	number	1	0	Estimated based on applicant data. No redrills while drilling. Assume redrills not pressurized	
1a6	Full bore pipe rupture	9.00E-08	/m.yr	150	1.35E-05	Rijnmond 1981, release of gas upstream of choke valve, estimated at 5m per well	
1a7	Full bore valve rupture	1.10E-06	/valve.yr	60	6.57E-05	release of gas upstream of choke valve, 2 valves per well	
1a8	Pipe leak	2.63E-06	/m.yr	150	3.95E-04	Rijnmond, 1981, for larger pipe, estimated at 5m per well	
1a9	Valve leak	9.86E-06	/valve.yr	120	1.18E-03	Rijnmond 1981, Assume 90% of releases are significant leaks but not catastrophic. Assume 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	1.00	1.40E-04	HLID, gas well, uncontrolled blowout per well year. Assumes only pressurized for 30 days after drilling	
1a10	Well Workovers - blowout	7.30E-04	per workover	0	0.00E+00	HLID, workovers gas wells, per workover. No pressure in well during workovers	
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 well-hole environment	
1a13	Fraction of wells drilled annually that produce blowout potential	3.00E-01	per well	1	3.00E-01	Based on 9 wells out of 30 from Redondo Beach that showed strong+ flow during drillstem tests	
1a14	Days a well stays pressurized after drilling	3.00E+01	per well	1	30	Assumes a well is pressurized 30 days after drilling	
1a15	Fraction reduction due to the use of Class III BOPE	5.00E-01	per well	1	0.5	Estimated. Includes a reuction due to use of 3r party BOPE verification and use of blind shear rams	
<b>Scenario 1b Wellhead area leak during drilling</b>							<b>4.18E-02</b>
<b>Scenario 2b Wellhead area leak during production -pressurized and non-pressurized wells</b>							<b>1.74E-03</b>
2b1	Fittings per well	10	number	1	1.00E+01	Estimated	
2b2	Rupture of small fitting	1.10E-06	per fit-year	300	3.29E-04		
2b3	Leak at valve	9.86E-06	/valve.yr	60	5.91E-04	Rijnmond 1981, release of gas upstream of choke valve, estimated at 5m per well	
2b4	Leak in pipe	5.26E-06	/m.yr	150	7.89E-04	Rijnmond, 1981	
<b>Scenario 3 Rupture at Gas Plant separators, scrubbers to compressors - low pressure</b>							<b>1.02E-04</b>
4a1	Full bore pipe rupture	9.00E-08	/m.yr	242	2.18E-05	Estimated piping length from Applicant	
4a2	Full bore valve rupture	1.10E-06	/valve.yr	44	4.82E-05	Estimated based on Applicant information	
4a3	PSV fails wide open	5.31E-04	/yr	11	5.84E-03	WASH, Rijnmond, Lees and CCPS lifts light, assume 1% wide open	
4a4	Flare fails to ignite/VRU system fails	1.00E-03	on demand	1	1.00E-03	to VRU system	
4a5	Vessel rupture	1.00E-06	/yr	11	1.10E-05	Rijnmond 1982	
4a6	Heat exchanger failure	1.49E-05	/yr	1	1.49E-05	HLID, 10% to full rupture	

Ref	Event	Failure rate or probability	Units	Number	Event rate or probability	Reference	Total rate
<b>Scenario 3b Leak at Gas Plant through inlet scrubbers to compressors - low pressure</b>							<b>8.47E-04</b>
4b1	Leak in pipe	2.63E-06	/m.yr	242	6.37E-04	Rijnmond, 1981, for larger pipe	
4b2	Leak at valve	9.86E-06	/valve.yr	44	4.34E-04	Assume 90% of releases are significant leaks but not catastrophic.	
4b3	Rupture of small valve	1.10E-06	/valve.yr	88	9.64E-05	Estimated twice as many small valves as large ones	
4b4	PSV fails leaks	5.31E-03	/yr	11	5.84E-02	WASH, Rijnmond, Lees and CCPS lifts light	
4b5	Leak in vessel	1.00E-05	/yr	11	1.10E-04	Rijnmond 1981	
4b6	Leak in heat exchanger	1.49E-04	/yr	1	1.49E-04	HLID	
<b>Scenario 4 Rupture at Gas Plant LTS, scrubbers and compressors - mid pressure</b>							<b>8.06E-05</b>
5a1	Full bore pipe rupture	9.00E-08	/m.yr	178	1.60E-05	Estimated based on Applicant	
5a2	Full bore valve rupture	1.10E-06	/valve.yr	28	3.07E-05	Estimated based on Applicant	
5a3	PSV fails wide open	5.31E-04	/yr	7	3.72E-03	WASH, Rijnmond, Lees and CCPS lifts light, assume 1% wide open	
5a4	Flare fails to ignite/VRU system fails	1.00E-03	on demand	1	1.00E-03	to VRU system	
5a5	Vessel rupture	1.00E-06	/yr	7	7.00E-06	Rijnmond 1982	
5a6	Full bore compressor failure	8.25E-03	/yr	1	8.25E-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	1	1.49E-05	HLID, 10% to full rupture	
<b>Scenario 4b Leak at Gas Plant LTS, scrubbers and compressors - mid pressure</b>							<b>9.96E-04</b>
5b1	Leak in pipe	2.63E-06	/m.yr	178	4.69E-04	Rijnmond, 1981, for larger pipe	
5b2	Leak at valve	9.86E-06	/valve.yr	28	2.76E-04	Assume 90% of releases are significant leaks but not catastrophic.	
5b3	Rupture of small valve	1.10E-06	/valve.yr	56	6.13E-05	Estimated twice as many small valves as large ones	
5b4	PSV fails leaks	5.31E-03	/yr	7	3.72E-02	WASH, Rijnmond, Lees and CCPS lifts light	
5b5	Leak in vessel	1.00E-05	/yr	7	7.00E-05	Rijnmond 1981	
5b6	Compressor leak	8.25E-02	/yr	1	8.25E-02	HLID 1992	
5b7	Leak in heat exchanger	1.49E-04	/yr	1	1.49E-04	HLID	
<b>Scenario 5 Rupture at Gas Plant compressors 2nd stage - high pressure</b>							<b>4.17E-05</b>
6a1	Full bore pipe rupture	9.00E-08	/m.yr	175	1.57E-05	Estimated piping length	
6a2	Full bore valve rupture	1.10E-06	/valve.yr	12	1.31E-05	Estimated based on Applicant PFD	
6a3	PSV fails wide open	5.31E-04	/yr	3	1.59E-03	WASH, Rijnmond, Lees and CCPS lifts light, assume 1% wide open	
6a4	Flare fails to ignite/VRU system fails	1.00E-03	on demand	1	1.00E-03	to VRU system	
6a5	Vessel rupture	1.00E-06	/yr	3	3.00E-06	Rijnmond 1982	
6a6	Full bore compressor failure	8.25E-03	/yr	1	8.25E-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)	
<b>Scenario 5b Leak at Gas Plant compressors 2nd stage - high pressure</b>							<b>7.32E-04</b>
6b1	Leak in pipe	2.63E-06	/m.yr	175	4.59E-04	Rijnmond, 1981, for larger pipe	
6b2	Leak at valve	9.86E-06	/valve.yr	12	1.18E-04	Assume 90% of releases are significant leaks but not catastrophic.	
6b3	Rupture of small valve	1.10E-06	/valve.yr	24	2.63E-05	Estimated twice as many small valves as large ones	
6b4	PSV fails leaks	5.31E-03	/yr	3	1.59E-02	WASH, Rijnmond, Lees and CCPS lifts light	
6b5	Leak in vessel	1.00E-05	/yr	3	3.00E-05	Rijnmond 1981	
6b6	Compressor leak	8.25E-02	/yr	1	8.25E-02	HLID 1992	
<b>Scenario 6 Rupture at natural gas pipeline along Valley Dr and at meter</b>							<b>1.10E-04</b>
<b>Scenario 6 Rupture at natural gas pipeline along Valley Dr: near facility</b>							<b>3.15E-05</b>
7a1	Full bore pipe rupture	2.89E-07	/m.yr	805	2.33E-04	OPS rate for gas transmission pipelines, years 2003-2012, for California, piping along 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/meter	1.10E-06	/valve.yr	3	3.29E-06	Lees, WASH, counts meter as a valve	
7a4	Catastrophic earthquake > 1.5g	2.10E-05	/yr	1	2.10E-05	Based on a probability of a 1.5g or greater earthquake. USGS data, hermosa location.	
7a5	Footage near facility	6.71E+01	meters	1	6.71E+01	based on largest rupture distance	
<b>Scenario 6b Leak at natural gas pipeline</b>							<b>1.19E-04</b>
<b>Scenario 6b Leak at natural gas pipeline : near facility</b>							<b>3.70E-05</b>
7b1	Full bore pipe rupture	1.76E-07	/m.yr	805	1.42E-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	9.86E-06	/valve.yr	3	2.96E-05	Rijnmond 1981,	

Ref	Event	Failure rate or probability	Units	Number	Event rate or probability	Reference	Total rate
<b>Scenario 7 Loss of Containment from odorant storage/transfer</b>							<b>6.92E-02</b>
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-03	/yr	1	1.70E-03	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	
<b>Scenario 8 Release of Crude Oil and Subsequent Fire</b>							<b>2.73E-04</b>
<b>Scenario 9 Release of Crude Oil Storage/Pumping with subsequent spill outside containment</b>							<b>1.56E-07</b>
9a1	Crude oil tank failure	9.99E-05	/yr	2	2.00E-04	Atmospheric metallic vessel - Catastrophic failure. CCPS, 1989	
9a2	Major earthquake	6.90E-04	/yr	1	6.90E-04	Based on a probability of a 0.5g or greater earthquake. USGS data, hermosa location.	
9a3	Crude oil tank pipe rupture	9.00E-08	/m.yr	50	4.50E-06	length estimated	
9a4	Probability of ignition	1.00E+00	on demand	1	1.00E+00	OPS data for crude releases at pump stations 1986-2000, 5% produce fires. As flare is in the bermed area, would be 100%	
9a5	Probability of earthquake tank failure	1.00E-01	on demand	1	1.00E-01	Estimated at 10%	
9a6	Number of drainings per year	1.0	number	1	1.0	assumed drained once every 1 years	
9a7	Failure to close drain valve after draining	1.90E-03	on demand	1	1.90E-03	Rijnmond, failure to close a valve properly	
9a8	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	
9a9	Frequency of drain valve inspections	4	number	1	4	weekly inspections	
<b>Scenario 10a Rupture at refrigeration system</b>							<b>3.52E-05</b>
10a1	Full bore pipe rupture	9.00E-08	/m.yr	25	2.25E-06		
10a2	Full bore valve rupture	1.10E-06	/valve.yr	8	8.76E-06		
10a3	Heat exchanger failure	1.49E-05	/yr	1	1.49E-05		
10a4	Vessel rupture	1.00E-06	/yr	1	1.00E-06		
10a5	Full bore compressor failure	8.25E-03	/yr	1	8.25E-03		
10a6	Low pressure shut off failure	1.00E-03	on demand	1	1.00E-03		
10a7	Fraction to overpressure/explosion				0.03		
<b>Scenario 10b Leak at refrigeration system</b>							<b>4.04E-04</b>
10b1	Leak in pipe	2.63E-06	/m.yr	25	6.58E-05		
10b2	Leak at valve	9.86E-06	/valve.yr	8	7.88E-05		
10b3	Rupture of small valve	1.10E-06	/valve.yr	16	1.75E-05		
10b4	Leak in vessel	1.00E-05	/yr	1	1.00E-05		
10b5	Leak in heat exchanger	1.49E-04	/yr	1	1.49E-04		
10b6	Compressor leak	8.25E-02	/yr	1	8.25E-02		
10b7	Low pressure shut off failure	1.00E-03	on demand	1	1.00E-03		

**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	4	times/yr based on SCAQMD requirements info
PSV inspection frequency	4	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

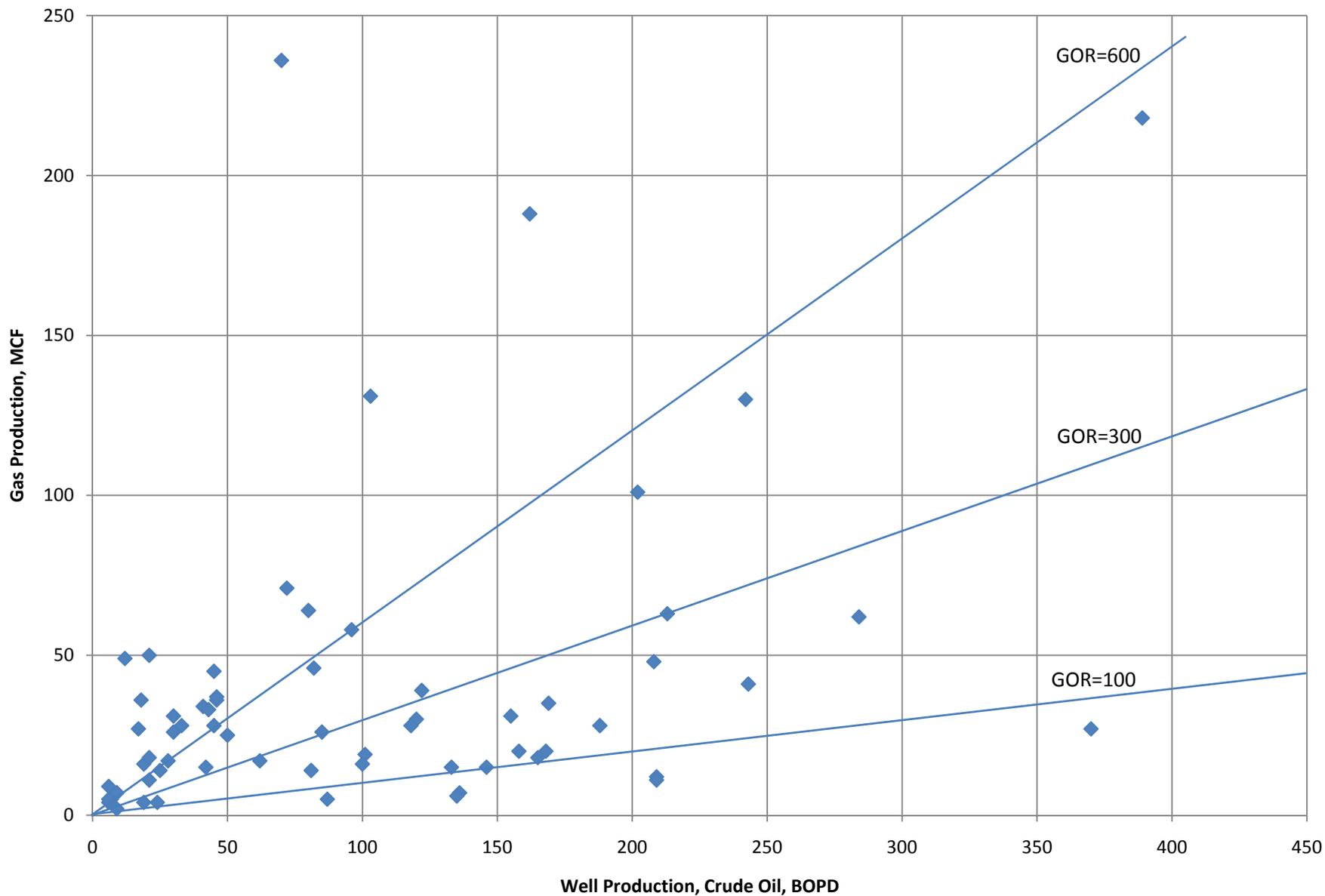
**Hermosa QRA Modeling Results**

Release Source Term	1 - Well Blowouts				2, 5 - Gas Plant high pressure				3 - Gas Plant Low Pressure			
	Gas Rupture - 1000 psi		Gas/Crude Rupture, 1000 psi		Leak		Rupture		Leak		Rupture	
	Before	After			Before	After	Before	After	Before	After	Before	After
Pressure, pa	6,892,857	101,325	6,892,857	101,325	3,446,429	101,325	3,446,429	101,325	172,321	101,325	172,321	101,325
Pressure, psi	1,000	14.7	1,000	14.7	500	14.7	500	14.7	25	14.7	25	14.7
Temperature, K	322	178	320	289	322	191	322	191	322	306	322	319
Temperature, F	120	-139	117	61	120	-116	120	-116	120	91.4	120	115
Diameter, inches	3	10.1	10	20	1	2.5	3	7.6	1	1.0	6	6.0
Diameter, m	0.0762	0.2577	0.254	0.497	0.0254	0.06334	0.0762	0.193	0.0254	0.0254	0.1524	0.1524
Area, m2	0.00456	0.05216	0.05067	0.19400	0.00051	0.00315	0.00456	0.02926	0.00051	0.00051	0.01824	0.01824
Velocity, m/s	420	726	480	547	-	424	-	429	-	-	141	141
Mass Flow, peak, kg/s	42	42	17.8	17.8	2.4	-	22.3	22.3	0.11	0.11	1.6	1.6
Discharge Duration, s					>600	-	34	-	>600	-	>600	-
Crater Area m2 (if applicable)												
Jet Direction		Horz.		Horz.		Horz.		Horz.		Horz.		Horz.
<b>Impacts</b>												
<b>Thermal</b>		<b>Flame Jet</b>		<b>Flame Jet</b>		<b>Flame Jet</b>		<b>Flame Jet</b>		<b>Flame Jet</b>		<b>Flame Jet</b>
10 kw/m2 dist, m		62		47		-		43		-		-
5 kw/m2 dist, m		77		66		-		56		-		-
Other												
<b>Overpressure/BLEVE</b>												
Distance to 1 psi, m		91		91		-		66		-		66
Distance to 0.3 psi, m		231		231		-		167		-		167
Distance to 80 kj/m2-s, m		-		-		-		-		-		-
Distance to 25 kj/m2-s, m		-		-		-		-		-		-
<b>Vapor Cloud and Met Condition</b>		<b>D/4</b>		<b>F/2</b>		<b>D/4</b>		<b>F/2</b>		<b>D/4</b>		<b>F/2</b>
LFL distance, m		41		45		3		3		27		30
LFL width, m		6		7		0.8		0.8		4		5
1/2 LFL distance, m		98		121		9		9		64		81
1/2 LFL width, m		10		12		2		2		8		9
<b>Toxic</b>												
ERPG-3, fatality, m		0.0		0.0		0		0		0		0
ERPG-2, injury, m		6.8		7.5		0.0		0.0		0.0		0.0
Notes	3", to simulate well hole releases. Methane		10" hole, GOR =300		1m piping length to large vessel. No offsite impacts		1m piping length to large vessel		1m piping length to large vessel. No offsite impacts		1m piping length to large vessel	

Hermosa QRA Modeling Result

Release Source Term	4 - Gas Plant Mid pressure				6 - Gas Pipeline				7 - Odorant Release		8 - Crude Spill with Fire
	Leak		Rupture		Leak		Rupture				Crude Dike Fire
Expansion	Before	After	Before	After	Before	After	Before	After			
Pressure, pa	1,137,321	101,325	1,137,321	101,325	3,446,429	101,325	3,446,429	101,325	101,325	101,325	
Pressure, psi	165	14.7	165	14.7	500	14.7	500	14.7			
Temperature, K	322	212	322	195	293	169	293	167	300	300	
Temperature, F	120	-77.8	120	-108	68	-155.2	68	-159			
Diameter, inches	1	1.5	4	6.1	1	2.5	4	8.6	1	-	
Diameter, m	0.0254	0.039	0.1016	0.1545	0.0254	0.0626	0.1016	0.2179	-	-	
Area, m2	0.00051	0.00119	0.00811	0.01875	0.00051	0.00308	0.00811	0.03729	28	1500 m2	
Velocity, m/s				400		400		391	-	-	
Mass Flow, peak, kg/s		0.78		12.8	2.5		30.89		0.008	-	
Discharge Duration, s	>600		70	-	>600		62	-	-	-	
Crater Area m2 (if applicable)									-	-	
Jet Direction		Horz.		Horz.		Horz.		Horz.	-	-	
									-	-	
<b>Impacts</b>									-	-	
<b>Thermal</b>	<b>Flame Jet</b>		<b>Flame Jet</b>		<b>Flame Jet</b>		<b>Flame Jet</b>		-	<b>Thermal</b>	
10 kw/m2 dist, m	-		35		-		54		-	28	
5 kw/m2 dist, m	-		44		-		67		-	43	
Other									-	-	
									-	-	
<b>Overpressure/BLEVE</b>									-	-	
Distance to 1 psi, m	-		79				91		-	-	
Distance to 0.3 psi, m	-		200				231		-	-	
Distance to 80 kj/m2-s, m	-		-						-	-	
Distance to 25 kj/m2-s, m	-		-						-	-	
									-	-	
<b>Vapor Cloud and Met Condition</b>	<b>D/4</b>	<b>F/2</b>	<b>D/4</b>	<b>F/2</b>	<b>D/4</b>	<b>F/2</b>	<b>D/4</b>	<b>F/2</b>	<b>D/4</b>	<b>F/2</b>	
LFL distance, m	3	3	21	22	7	8	35	38			
LFL width, m	1	1	3.5	3.6	1.3	1.4	5.2	5.6			
1/2 LFL distance, m	8	9	49	60	17	20	82.5	101			
1/2 LFL width, m	1	2	6	7	2.8	3.1	8.9	10.6			
<b>Toxic</b>											
ERPG-3, fatality, m	0	0	0	0	0	0	0	0	0	0	
ERPG-2, injury, m	0.5	0.5	3.5	3.7	0.0	0.0	0.0	0.0	5	48	
Notes	1m piping length to large vessel. No offsite impacts		1m piping length to large vessel		Mass flow is 10 second average				Odorant release based on spill to ground producing a pool with a vapor evolution rate of 0.008 kg/s		Crude composition with 1500m2 dike area

# Crude, Gas and GOR, Redondo Wells as per CSLC 1977 Report



**Pipeline Failure Rates: Entire Pipeline**

CSFM rate, per 1000 mile years	5.27
Pipeline length, miles	3.55
Rupture fraction	0.18
Number of years of project	35
Rupture rate, per year	3.37E-03
Return period ruptures, years	297
Probability	10.5%
Leak rate, per year	1.53E-02
Return period leaks, years	65.2
Probability	31.4%
Any size leak or rupture	1.87E-02
Return period leaks, years	53.5
Probability	34.0%

**Pipeline Failure Rates: Segment at Valley/Herondo Only**

CSFM rate, per 1000 mile years	5.27
Pipeline length, miles	0.95 length between site and Prospect Ave
Rupture fraction	0.18
Rupture rate, per year	9.01E-04
Return period ruptures, years	1109.7
Probability	3.1%
Leak rate, per year	4.11E-03
Return period leaks, years	243.6
Probability rupture	12.4%
Any size leak or rupture	5.01E-03
Return period leaks, years	199.7
Probability leak	14.7%

**ERW and FBE+ 3-layer Coating with Cement Covering:**

Causes	Percent	Reduction factor with Mitigation	Reduced Value
Internal Corrosion	32.1	0.25	8.03
External corrosion	25.5	0.03	0.77
Unspecified corrosion	0.3	0.03	0.009
Manufacturing/Constru	9.7	0.25	2.43
Equip malfunction	0.3	1	0.30
Outside force	24.9	0.1	2.49
Incorrect ops	1.6	1	1.60
Weather/natural force	3.1	1	3.10
Cause not specified	2.5	1	2.50
<b>Total</b>	<b>100</b>		<b>21.2</b>

Source: Causes from Keystone EIR Appendix K and DOT, Mainline Pipeline Only- all sizes: Figure 8  
Corrosion rates reduction based on CSFM best pipeline rate reduction of 97%

**Pipeline Failure Rates: Entire Pipeline MITIGATED**

CSFM rate, per 1000 mile years	5.27
Pipeline length, miles	3.55
Rupture fraction	0.18
Number of years of project	35
Rupture rate, per year	7.35E-04
Return period ruptures, years	1360
Probability	2.5%
Leak rate, per year	3.28E-03
Return period leaks, years	305.3
Probability	10.2%
Any size leak or rupture	3.99E-03
Return period leaks, years	250.6
Probability	12.1%

**Probability of Spills to the Ocean**

from Herondo/Valley Segment only

		Rain Event, inches per 24 hours			
		0.01	0.10	0.50	1.00
<b>Annual Average Number of Days</b>	<b>Anytime</b>	<b>34</b>	<b>22</b>	<b>9</b>	<b>4</b>
<i>Annual Frequency</i>					
Rupture	9.0E-04	8.4E-05	5.4E-05	2.2E-05	9.9E-06
Leak	4.1E-03	3.8E-04	2.5E-04	1.0E-04	4.5E-05
<i>Project Life Percentage</i>					
Rupture	3.1%	0.29%	0.19%	0.08%	0.03%
Leak	12.4%	1.32%	0.86%	0.35%	0.16%
Combined Probability (leaks and ruptures)	14.7%	1.61%	1.05%	0.43%	0.19%

CSFM rate, per 1000 mile years 5.27  
 Pipeline length, miles 0.95 length between site and Prospect Ave  
 Rupture fraction 0.18  
 Number of years of project 35

**Probability of Spills to the Ocean: Mitigated**

from Herondo/Valley Segment only

		Rain Event, inches per 24 hours			
		0.01	0.10	0.50	1.00
<b>Annual Average Number of Days</b>	<b>Anytime</b>	<b>34</b>	<b>22</b>	<b>9</b>	<b>4</b>
<i>Annual Frequency</i>					
Rupture	1.8E-04	1.7E-05	1.1E-05	4.5E-06	2.0E-06
Leak	8.3E-04	7.7E-05	5.0E-05	2.0E-05	9.1E-06
<i>Project Life Percentage</i>					
Rupture	0.6%	0.059%	0.038%	0.016%	0.007%
Leak	2.8%	0.270%	0.175%	0.071%	0.032%
Combined Probability (leaks and ruptures)	3.4%	0.329%	0.213%	0.087%	0.039%

ERW and Specialized Coatings/Sleeves Pipe  
 Fraction reduction 0.212  
 Earthquake frequency 2.1E-05  
 Resulting rate 1.1E-03  
 Revised rate, all releases, per 1000 mile yrs 1.06  
 Revised rupture rate, per 1000 mile years 0.19