Appendix H-3: System Safety and Risk of Upset Report

PG&E Line 406/407
Natural Gas Pipeline Project

System Safety and Risk of Upset

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System Safety and Risk of Upset

This appendix H-3D presents the potential risks to the public from the proposed PG&E Line 406/407 Natural Gas Pipeline Project. These risks would primarily result from unintentional releases of natural gas and the possibility of subsequent fires and/or explosions which could cause injuries and fatalities.

The risk assessment included as Appendix H-3 of the Draft and Final EIR included risk measurement terminology which was not defined in the document. This resulted in some confusion. This Appendix has been significantly revised to resolve this confusion. The primary revisions to this document from earlier versions are summarized below:

- Earlier versions of Appendix H-3 included a section entitled "Individual Risks". This section presented the anticipated annual likelihood of fatalities from all of the project components (e.g., pipeline, block valves, pig launchers and receivers, etc). The results represented the annual likelihood of an individual fatality along the entire 42.3 mile pipeline system. This has been confused with a common definition of Individual Risk (IR), which relates to the risk of an individual fatality at a specific location.

- The correct terminology for the risk presented in earlier versions of this Appendix is probable loss of life (PLL), or aggregate risk. (Marszal 2001) There are no known significance thresholds for acceptable levels of PLL or aggregate risk.

- Earlier versions of Appendix H-3 correctly stated that a commonly accepted individual risk threshold is an annual likelihood of fatality of one in one-million (1 : 1,000,000). However, the report incorrectly compared the aggregate, or PLL risk, to this individual risk threshold. This version of Appendix H-3 includes a presentation of the individual risks posed by each of the pipeline segments and compares them to the one in one million individual risk threshold.

RESULTS SUMMARY

The risks to the public posed by each of the pipeline components are presented in this Appendix. The individual risks have been evaluated using two approaches: a simplified and an enhanced approach. The individual risk results are summarized in the table below. These are the maximum individual risk values, which would occur directly over the top of each pipeline. As the distance from each pipeline increases, the individual risk decreases. The individual risk directly over each pipeline segment would be less than the common significance threshold of 1 : 1,000,000. As one moves further from each pipeline, the risk would decrease further below the significance threshold.

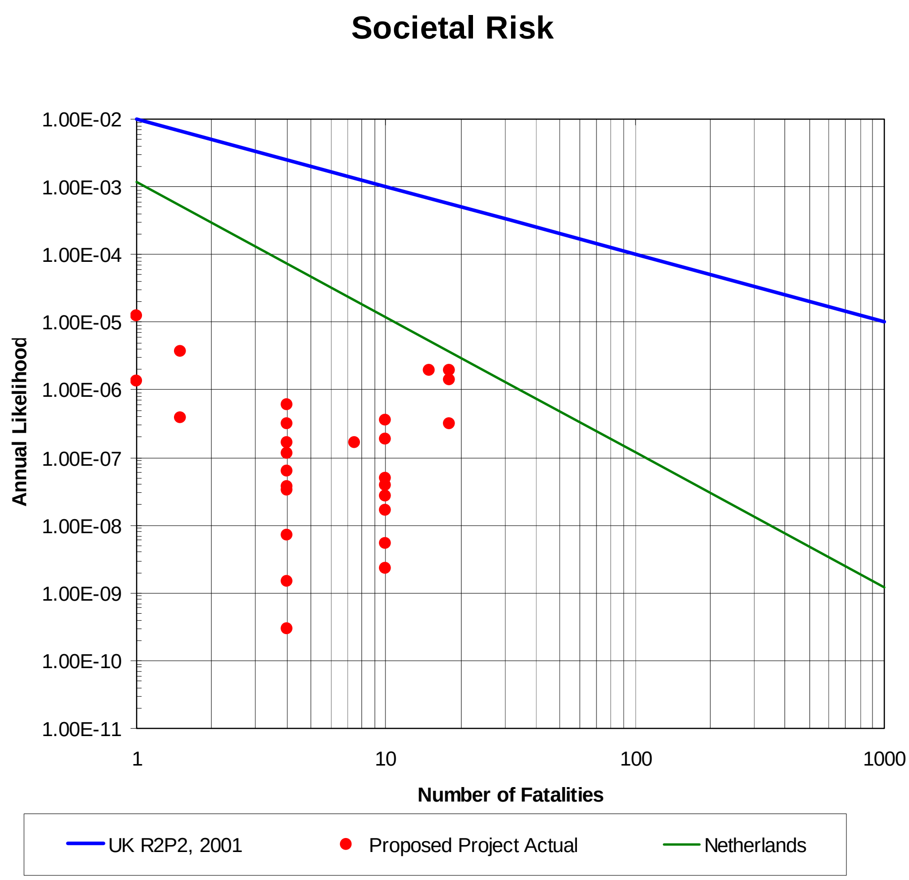
Individual Risk Result Summary

Pipeline Segment	Pre-Mitigation Maximum Annual Risk of Fatality	Pre-Mitigation Maximum Annual Probability of Occurrence	Significance Threshold
Simplified Analysis			
Line 406	3.94×10^{-7}	1 : 2,538,000	1 : 1,000,000 Less Than Significant
Line 407	3.83×10^{-7}	1 : 2,610,000	1 : 1,000,000 Less Than Significant
Line DFM	1.61×10^{-7}	1 : 6,219,000	1 : 1,000,000 Less Than Significant
Enhanced Analysis			
Line 406	4.68×10^{-7}	1 : 2,137,000	1 : 1,000,000 Less Than Significant
Line 407	4.85×10^{-7}	1 : 2,062,000	1 : 1,000,000 Less Than Significant
Line DFM	2.35×10^{-7}	1 : 4,255,000	1 : 1,000,000 Less Than Significant

The proposed mitigation would reduce the individual risk by fifty percent (50%). The post mitigation individual risk results are presented in Table 4.6.2-1.

The societal risks have also been evaluated. Theses risks also fall below the commonly accepted risk threshold, as indicated in the following figure.

Societal Risk Result Summary



1.0 ENVIRONMENTAL SETTING

1.1 NATURAL GAS PUBLIC RISKS

Unintentional releases of natural gas from the proposed pipelines and related facilities could pose risks to human health and safety. For example, natural gas could be released from a leak or rupture in one of the pipe segments. If the natural gas was to reach a combustible mixture and an ignition source was present, a fire and/or explosion could occur, resulting in possible injuries and/or deaths.

1.2 NATURAL GAS CHARACTERISTICS

Natural gas is comprised primarily of methane. It is colorless, odorless, and tasteless. Methane is not toxic, but is classified as a simple asphyxiate, possessing a slight inhalation hazard. If breathed in high concentration, oxygen deficiency can result in serious injury or death.

Methane has an ignition temperature of 1,000°F and is flammable at concentrations between 5 percent and 15 percent in air. Unconfined mixtures of methane in air are not explosive. However, a flammable concentration within an enclosed space in the presence of an ignition source can explode. Methane is buoyant at atmospheric temperatures and disperses rapidly in air.

2.0 REGULATORY SETTING

2.1 FEDERAL

The United States Department of Transportation (USDOT) provides oversight for the nation's natural gas pipeline transportation system. Its responsibilities are promulgated under Title 49, United States Code (USC) Chapter 601. The Pipeline and Hazardous Materials Safety Administration (PHMSA), Office of Pipeline Safety (OPS), administers the national regulatory program to ensure the safe transportation of gas and other hazardous materials by pipeline.

2.1.1 Regulatory Framework

Two statutes provide the framework for the Federal pipeline safety program. The Natural Gas Pipeline Safety Act of 1968 as amended (NGPSA) authorizes the OPS to regulate pipeline transportation of natural (flammable, toxic, or corrosive) gas and other gases as well as the transportation and storage of liquefied natural gas (LNG). Similarly, the Hazardous Liquid Pipeline Safety Act of 1979 as amended (HLPSA) authorizes the OPS to regulate pipeline transportation of hazardous liquids (crude oil, petroleum products, anhydrous ammonia, and carbon dioxide). Both of these Acts have been recodified as 49 USC Chapter 601.

The OPS shares portions of this responsibility with state agency partners and others at the Federal, state, and local level. The State of California is certified under 49 USC Subtitle VIII, Chapter 601, §60105. The State has the authority to regulate intrastate natural and other gas pipeline facilities. The California Public Utilities Commission (CPUC) is the agency authorized to oversee intrastate gas pipeline facilities, including those proposed by the Applicant. (The California State Fire Marshal has jurisdiction for hazardous liquid pipelines.)

2.1.2 Pipeline Regulations

The Federal pipeline regulations are published in Title 49 of the Code of Federal Regulations (CFR), Parts 190 through 199. 49 CFR 192 specifically addresses natural and other gas pipelines. Many of these pipeline regulations are written as performance standards. These regulations set the level of safety to be attained and allow the pipeline operator to use various technologies to achieve the desired result. Other portions of the regulations are prescriptive.

The proposed pipeline segments and ancillary facilities would all be designed, constructed, operated, and maintained in accordance with 49 CFR 192. Since these are intrastate facilities, the CPUC would have the responsibility for enforcing the Federal and State requirements. 49 CFR 192 is comprised of 15 subparts, which are summarized below:

- Subpart A, General – This subpart provides definitions, a description of the class locations used within the regulations, documents incorporated into the regulation by reference, conversion of service requirements, and other items of a general nature.
- Subpart B, Materials – This subpart provides the requirements for the selection and qualification of pipe and other pipeline components. Generally, it covers the manufacture, marking, and transportation of steel, plastic, and copper pipe used in gas pipelines and distribution systems.
- Subpart C, Pipe Design – This subpart covers the design (primarily minimum wall thickness determination) for steel, plastic, and copper pipe.
- Subpart D, Design of Pipeline Components – This subpart provides the minimum requirements for the design and qualification of various components (e.g. valves,

flanges, fittings, passage of internal inspection devices, taps, fabricated components, branch connections, extruded outlets, supports and anchors, compressor stations, vaults, overpressure protection, pressure regulators and relief devices, instrumentation and controls, etc.

- Subpart E, Welding of Steel Pipelines – This subpart provides the minimum requirements for welding procedures, welder qualification, inspection and repair/replacement of welds in steel pipeline systems.
- Subpart F, Joining of Materials Other Than By Welding – This subpart covers the requirements for joining, personnel and procedure qualification, and inspection of cast iron, ductile iron, copper, and plastic pipe joints.
- Subpart G, General Construction Requirements for Transmission Lines and Mains – This subpart provides the minimum construction requirements, including, but not limited to: inspection of materials, pipe repairs, bends and elbows, protection from hazards, installation in the ditch, installation in casings, underground clearances from other substructures, and minimum depth of cover.
- Subpart H, Customer Meters, Service Regulators and Service Lines – This subpart prescribes the minimum requirements for these components.
- Subpart I, Requirements for Corrosion Control – This subpart provides the minimum requirements for cathodic protection systems, required inspections and monitoring, remedial measures, and records maintenance.
- Subpart J, Testing Requirements – This subpart prescribes the minimum leak and strength test requirements.
- Subpart K, Uprating – This subpart provides the minimum requirements for increasing the maximum allowable operating pressure.
- Subpart L, Operations – This subpart prescribes the minimum requirements for pipeline operation, including: procedure manuals, change in class locations, damage prevention programs, emergency plans, public awareness programs, failure investigations, maximum allowable operating pressures, odorization, tapping, and purging.
- Subpart M, Maintenance – This subpart prescribes the minimum requirements for pipeline maintenance, including: line patrols, leakage surveys, line markers, record keeping, repair procedures and testing, compressor station pressure relief device inspection and testing, compressor station storage of combustible materials, compressor station gas detection, inspection and testing of pressure limiting and regulating devices, valve maintenance, prevention of ignition, etc.
- Subpart N, Qualification of Pipeline Personnel – This subpart prescribes the minimum requirements for operator qualification of individuals performing covered tasks on a pipeline facility.

- Subpart O, Pipeline Integrity Management – This subpart was promulgated on December 15, 2003. It requires operators to implement pipeline integrity management programs on the gas pipeline systems.

In general, the requirements of the Federal regulations become more stringent as the human population density increases. To this end, 49 CFR 192 defines area classifications, based on population density in the vicinity of a pipeline and specifies more rigorous safety requirements for more heavily populated areas. The class location is an area that extends 220 yards on either side of the centerline of any continuous 1-mile length of pipeline. The four area classifications are defined as follows:

- Class 1 - Location with 10 or fewer buildings intended for human occupancy.
- Class 2 - Location with more than 10 but less than 46 buildings intended for human occupancy.
- Class 3 - Location with 46 or more buildings intended for human occupancy or where the pipeline lies within 100 yards of a building, or small well-defined outside area pipeline any occupied by 20 or more people on at least 5 days a week for 10 weeks in any 12-month.
- Class 4 - Location where buildings with four or more stories aboveground are prevalent.

Pipeline facilities located within class locations representing more populated areas are required to have a more conservative design. For example, pipelines constructed in Class 1 locations must be installed with a minimum depth of cover of 30 inches in normal soil and 18 inches in consolidated rock. Class 2, 3, and 4 locations, as well as drainage ditches of public roads and railroad crossings, require a minimum cover of 36 inches in normal soil and 24 inches in consolidated rock. All pipelines installed in navigable rivers, streams, and harbors must have a minimum cover of 48 inches in soil or 24 inches in consolidated rock.

Class locations also specify the maximum distance to a sectionalizing block valve (e.g., 10.0 miles in Class 1, 7.5 miles in Class 2, 4.0 miles in Class 3, and 2.5 miles in Class 4 locations). Pipe wall thickness and pipeline design pressures, hydrostatic test pressures, maximum allowable operating pressure, inspection and testing of welds, and the frequency of pipeline patrols and leak surveys must also conform to higher standards in more populated areas.

The proposed pipeline facilities would be constructed within Class 1, 2, and 3 locations. Although some increase in population density adjacent to the right-of-way is anticipated, the Applicant would be required to demonstrate compliance with the more stringent requirements, reduce the maximum allowable operating pressure (MAOP) or replace the segment with pipe of sufficient grade and wall thickness to comply with 49 CFR 192 for the new class location if the population density should increase enough to change the Class location. The Applicant is conservatively designing the project as though it were located within higher area class locations, where future development is anticipated within the foreseeable future.

2.1.3 Pipeline Integrity Management

49 CFR 192 Subpart O, Pipeline Integrity Management grew out of a series of pipeline incidents with severe consequences. This Subpart requires operators of gas pipeline systems in High Consequence Areas (HCA's) to significantly increase their minimum required maintenance and inspection efforts. For example, all lines located within HCA's must be analyzed by conducting a baseline risk assessment. In general, the integrity of the lines must also be evaluated using an internal inspection device or a direct assessment, as prescribed in the regulation. Two incidents in particular, raised public concern regarding pipeline safety and necessitated these relatively new requirements.

Bellingham, Washington, June 10, 1999

According to the National Transportation Safety Board (NTSB) accident report, "about 3:28 p.m., Pacific daylight time, on June 10, 1999, a 16-inch diameter steel pipeline owned by Olympic Pipe Line Company ruptured and released about 237,000 gallons of gasoline into a creek that flowed through Whatcom Falls Park in Bellingham, Washington. About one and one half hours after the rupture, the gasoline ignited and burned approximately and one and one-half miles along the creek. Two 10-year-old boys and an 18-year-old young man died as a result of the accident. Eight additional injuries were documented. A single-family residence and the City of Bellingham's water treatment plant were severely damaged. As of January 2002, Olympic estimated that total property damages were at least $45 million. But the actual total costs were likely much higher; the families of the two children settled with the operator for $75 million less than one month prior to trial.

The following major safety issues were identified as factors during the subsequent investigation:

- excavations performed by IMCO General Construction, Inc., in the vicinity of Olympic's pipeline during a major construction project and the adequacy of Olympic Pipe Line Company's inspections thereof;
- the adequacy of Olympic Pipe Line Company's interpretation of the results of in-line inspections of its pipeline and its evaluation of all pipeline data available to it to effectively manage system integrity;
- the adequacy of Olympic Pipe Line Company's management of the construction and commissioning of the Bayview products terminal;
- the performance and security of Olympic Pipe Line Company's supervisory control and data acquisition system; and
- the adequacy of Federal regulations regarding the testing of relief valves used in the protection of pipeline systems." (NTSB 2002)

Carlsbad, New Mexico, August 19, 2000

Per the NTSB accident report, "At 5:26 a.m., mountain daylight time, on Saturday, August 19, 2000, a 30-inch diameter natural gas transmission pipeline operated by El Paso Natural Gas Company ruptured adjacent to the Pecos River near Carlsbad, New Mexico. The released gas ignited and burned for 55 minutes. 12 persons who were camping under a concrete-decked steel bridge that supported the pipeline across the river were killed and their three vehicles destroyed. Two nearby steel suspension bridges for gas pipelines crossing the river were extensively damaged. According to El Paso Natural Gas Company and the figures included in the USDOT database, property and other damages or losses totaled $998,296. However, this figure significantly understates the financial impact to the operator. Although settlements were reached with all of the victims, the only amount disclosed was a $14 million settlement for one of the victims. (Business Weekly)

The major safety issues identified in the NTSB investigation were as follows:

- the design and construction of the pipeline,
- the adequacy of El Paso Natural Gas Company's internal corrosion control program,
- the adequacy of Federal safety regulations for natural gas pipelines, and
- the adequacy of Federal oversight of the pipeline operator. (NTSB 2003)

Pipeline Integrity Management Regulations

As noted earlier, 49 CFR 192, Subpart O, Pipeline Integrity Management, is relatively new and was developed in response to the two major pipeline incidents discussed above. In 2002, Congress passed an Act to strengthen the pipeline safety laws. The Pipeline Safety Improvement Act of 2002 (HR 3609) was passed by Congress on November 15, 2002, and was signed into law by the President in December 2002. As of December 17, 2004, gas transmission operators of pipelines in high consequence areas (HCA's) were required to develop and follow a written integrity management program that contained all of the elements prescribed in 49 CFR 192.911 and addressed the risks on each covered transmission pipeline segment.

The regulation (68 Federal Register 69778, 69 Federal Register 18228, and 69 Federal Register 29903) defines HCA's as they relate to the different area class locations, potential impact circles, or areas containing an identified site as defined in 49 CFR 192.903. The OPS published a series of rules from August 6, 2002 to May 26, 2004 (69 Federal Register 69817 and 29904) that define HCA's where a gas pipeline accident could do considerable harm to people and their property. This definition satisfies, in part, the Congressional mandate in 49 USC 60109 for the OPS to prescribe standards that establish criteria for identifying each gas pipeline facility in a high-density population area.

The HCA's may be defined in one of two ways. Both methods are prescribed by 49 CFR 192.903. The first includes:

- Current Class 3 and 4 locations;
- Any area in Class 1 or 2 locations where the potential impact radius is greater than 660 feet (200 meters) and the area within a potential impact circle contains 20 or more buildings intended for human occupancy; or
- Any area in Class 1 or 2 locations where the potential impact circle includes an "identified site."

In the second method, an HCA includes any area within a potential impact circle that contains:

- 20 or more buildings intended for human occupancy; or
- an "identified site.

"Identified sites" include areas such as beaches, playgrounds, recreational facilities, camp grounds, outdoor theaters, stadiums, recreational areas, religious facilities, and other areas where high concentrations of the public may gather periodically as defined by 49 CFR 192.903.

The "potential impact radius" is calculated as the product of 0.69 and the square root of the maximum allowable operating pressure of the pipeline in pounds per square inch gauge (psig), multiplied by the pipeline diameter in inches squared. ($R = 0.69*(MAOP*d^2)^{0.5}$)

The potential impact circle is a circle with a radius equal to the potential impact radius.

Once a pipeline operator has identified the HCA's along its pipeline(s), it must apply the elements of its integrity management program to those segments of the pipeline within the HCA's. The pipeline integrity management rule for HCA's requires inspection of the entire pipeline within HCA's every 7 years.

As noted earlier, the proposed pipeline facilities are located within Class 1, 2 and 3 areas. As a result, using the first HCA definition, the portions of the line within Class 3 areas would be within an HCA. The impact radii are 646-feet and 215-feet for the 30-inch and 10-inch line segments respectively. These values are less than the 660-foot impact radius which might add additional portions to an HCA. As a result, certain portions of the Project will be required to be included in the Applicant's Pipeline Integrity Management Plan. Should the population density increase, additional portions of the pipeline may become located within an HCA, requiring the Applicant to include the affected pipe segments in their Pipeline Integrity Management Plan.

2.2 STATE

As noted earlier, these intrastate pipeline facilities would be under the jurisdiction of the CPUC, as a result of their certification by the OPS. (The State of California is certified under 49 USC Subtitle VIII, Chapter 601, §60105.) The State requirements for designing, constructing, testing, operating, and maintaining gas piping systems are stated in CPUC General Order Number 112. These rules incorporate the Federal regulations by reference, but for natural gas pipelines, they do not impose any additional requirements affecting public safety.

3.0 SIGNIFICANCE CRITERIA

3.1 INDIVIDUAL RISK

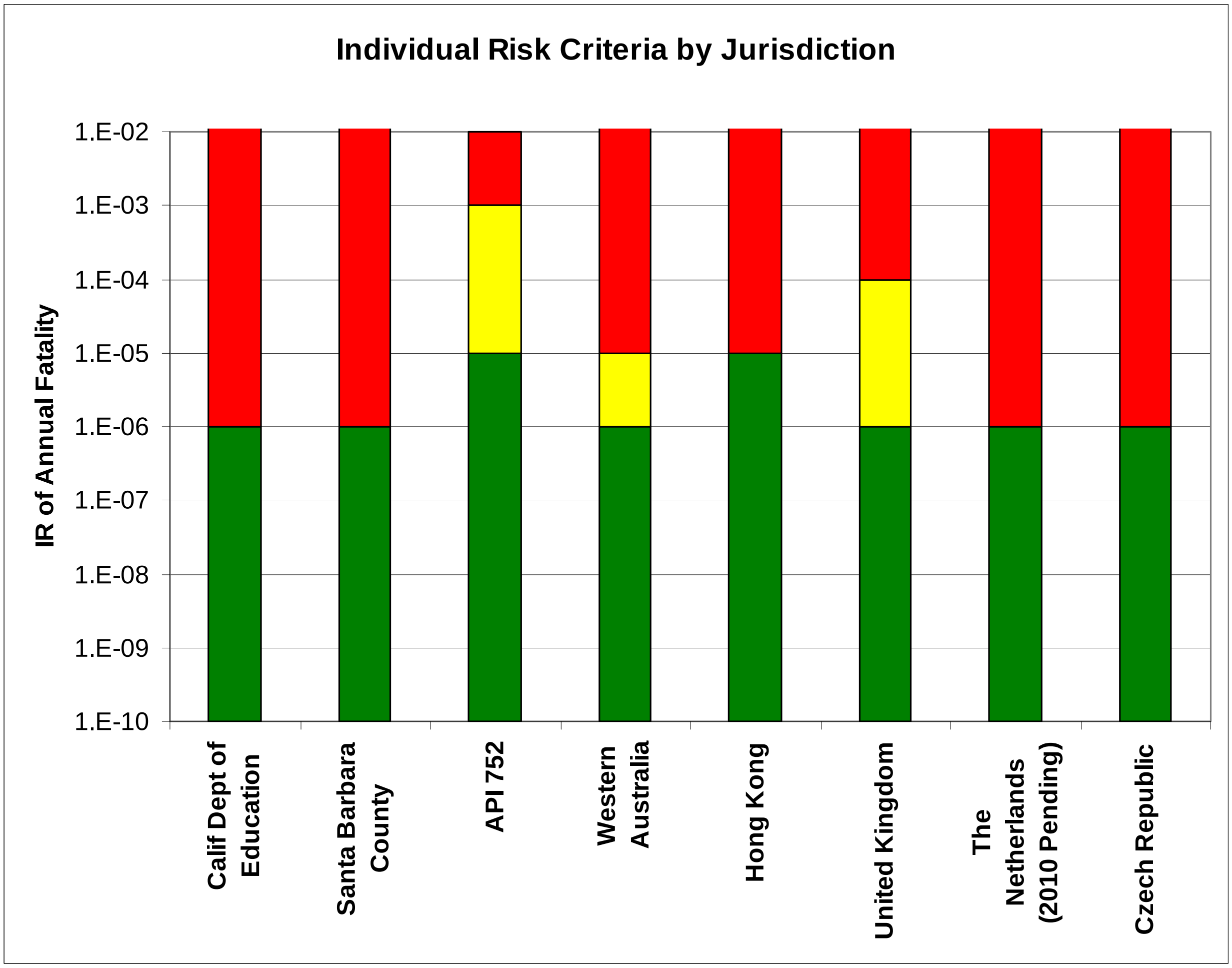
Individual risk (IR) is most commonly defined as the frequency that an individual may be expected to sustain a given level of harm from the realization of specific hazards, at a specific location, within a specified time interval. Individual risk is typically measured as the probability of a fatality per year. The risk level is typically determined for the maximally exposed individual; in other words, it assumes that a person is present continuously – 24 hours per day, 365 days per year. The likelihood is most often expressed numerically, using one of the values shown in Table 2.0-1 below.

Table 3.1-1 Individual Risk Numerical Values

Annual Likelihood of Fatality	Numerical Value	Scientific Notation	Shorthand
1 in 100	1.0×10^{-2}	1.0E-2	10^{-2}
1 in 1,000	1.0×10^{-3}	1.0E-3	10^{-3}
1 in 10,000	1.0×10^{-4}	1.0E-4	10^{-4}
1 in 100,000	1.0×10^{-5}	1.0E-5	10^{-5}
1 in 1,000,000	1.0×10^{-6}	1.0E-6	10^{-6}
1 in 10,000,000	1.0×10^{-7}	1.0E-7	10^{-7}
1 in 100,000,000	1.0×10^{-8}	1.0E-8	10^{-8}
1 in 1,000,000,000	1.0×10^{-9}	1.0E-9	10^{-9}

The California Department of Education (CDE) defines individual risk as the probability of fatality for an individual exposed to the physical impact of a hazard, at a specific location, within a specified period of time. (CDE 2007) As noted in the Final EIR, the individual risk threshold most commonly used, where one has been established, is an annual likelihood of fatality of one in one million (1:1,000,000, 1×10^{-6}, or 1.0E-6 fatalities per year). However, the United States federal and California state governments have not adopted individual risk thresholds; the determination of the acceptable level of risk is left to local decision makers and project proponents. Figure 3.1-1 below presents the individual risk thresholds for a number of jurisdictions, where such thresholds have been adopted.

Figure 3.1-1 Individual Risk Thresholds by Jurisdiction



Sources: (CDE 2007, SBCO 2008, API 1995, Marszal 2001)

The upper end of the green areas represent the *de minimus*[1] risk values for each jurisdiction; IR risk levels within the green range are considered broadly acceptable. Risks within this green region are considered so low that no further consideration is warranted. In addition, risks within the green band are generally considered so low that it is unlikely that any risk reduction would be cost effective, since extraordinary measures would normally be required to further reduce the risk. As a result, a benefit – cost analysis of risk reduction is typically not undertaken.

[1] Latin term for "of minimum importance" or "trifling." Essentially it refers to something or a difference that is so little, small, minuscule, or tiny that the law does not refer to it and will not consider it. In a million dollar deal, a $10 mistake is de minimus.

The lower end of the red areas represent the *de manifestus*[2] risk values; IR risk levels within the red range are considered unacceptable and the risks are not normally justified on any grounds.

Some jurisdictions have adopted a "grey area', where the risk levels may be negotiated or otherwise considered. The United Kingdom developed the ALARP (as low as reasonably practicable) approach. This approach is depicted by the yellow areas in Figure 3.1-1. Generally, risks within the yellow area may be tolerable only if risk reduction is impractical or if its cost is grossly disproportionate to the risk improvement gained. The underlying concept is to maximize the expected utility of an investment, but not expose anyone to an excessive increase in risk.

The United States government has opposed setting tolerable risk guidelines. The 1997 final report of the Presidential/Congressional Commission on Risk Assessment and Risk Management (Commission), entitled Framework for Environmental Health Risk Management, included the following finding, "There is much controversy about bright lines, "cut points," or decision criteria used in setting and evaluating compliance with standards, tolerances, cleanup levels, or other regulatory actions. Risk managers sometimes rely on clearly demarcated bright lines, defining boundaries between unacceptable and negligible upper limits on cancer risk, to guide their decisions. Congress has occasionally sought to include specified bright lines in legislation. A strict "bright line" approach to decision making is vulnerable to misapplications since it cannot explicitly reflect uncertainty about risks, population within, variation in susceptibility, community preferences and values, or economic considerations – all of which are legitimate components of any credible risk management process." The report states further, "Furthermore, use of risk estimates with bright lines, such as one-in-a-million, and single point estimates in general, provide a misleading implication of knowledge and certainty. As a result, reliance on command-and-control regulatory programs and use of strict bright lines in risk estimates to distinguish between safe and unsafe are inconsistent with the Commission's Risk Management Framework and with the inclusion of cost, stakeholder values, and other considerations in decision-making." (Commission 1997)

[2] The Latin term "de manifestus" is often used in the ALARP (as low as reasonably practical) principle. In this context, the term defines a point where the level of risk is intolerable. Above this level, the risks cannot be justified. In Figure 3.1-1, this is the boundary between the red and yellow areas.

The United States is not alone in its opposition to establishing fixed risk thresholds. The vast majority of nations do not have government established risk tolerance criteria. In these cases, risk tolerance is left to individual owners and other decision makers.

Despite the fact that the United States does not have a bright line individual risk threshold, the country has an exemplary safety record. Many believe that this is due to two factors. First, the free market allows the application of capital where it will produce the most risk reduction benefits. And secondly, the tort system provides a mechanism to determine third party liability costs in the event of an injury or fatality. These factors generally result in sound risk reduction decisions which are normally based on a cost-benefit analysis. (Marszal 2001)

~~For individual fatality risks, the generally accepted significance criterion is an annual likelihood of one in one million (1:1,000,000) (CDE 2007, CPUC 2006).~~

3.1.1 California Department of Education

As stated in the California Department of Education's (CDE) Guidance Protocol for School Site Pipeline Risk Analysis, "An IR of 1.0E-06 (one chance in a million each year) has been selected based on regulatory practice for the siting of industrial facilities with hazardous chemicals in the United Kingdom and the Netherlands. In those cases, the IR concept is used as a criterion for determining whether additional mitigation is needed when government authorities are evaluating an industrial asset site. While the situation here is the reverse, siting a school campus site near an existing industrial asset, the risk principles are similar, and CDE concluded that the same criterion is appropriate. If values computed by a standard method described in the Protocol, or similar and well-documented methods, meet the specified criteria, then the proposed school campus site has met the regulatory expectations." (CDE 2007)

3.2 AGGREGATE RISK

Aggregate risk, or *probable loss of life* (PLL), is another risk measure used to evaluate projects. Aggregate risk is the total anticipated frequency of a particular consequence, normally fatalities, that could be anticipated over a given time period, for all project components (e.g., the entire 42.3 mile pipeline system). Aggregate risk is a type of risk integral; it is the summation of risk, as expressed by the product of the anticipated consequences and their respective likelihood. The integral is summed over all of the potential events that might occur for all of the project components, over the entire project length. There are no known codified bright line thresholds for acceptable levels of PLL or aggregate risk. The differences between aggregate risk and individual risk are summarized in the following Table. (Marszal 2001)

Table 3.2-1 Individual Risk (IR) versus Aggregate (PLL) Risk

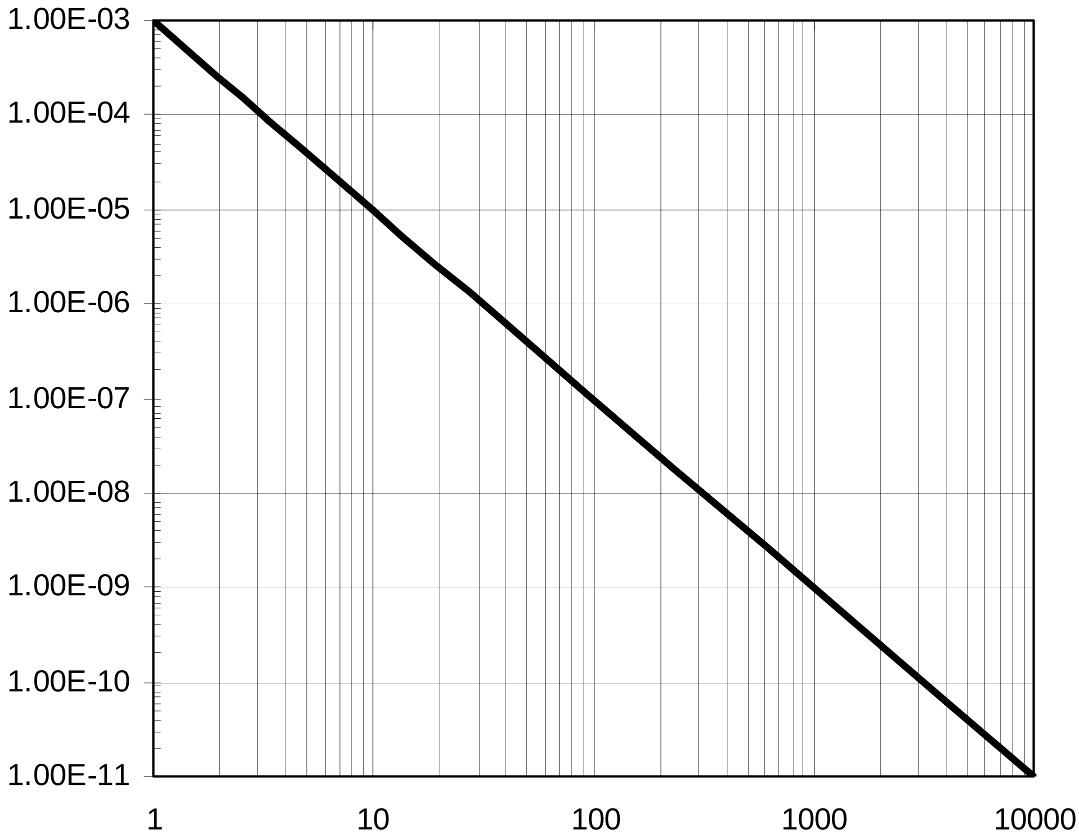
Item	**Individual Risk (IR)**	**Aggregate or PLL Risk**
Exposure Location	Single Specific Location	Cumulative, Along the Length of the Entire Project
Probability of Exposure	100% 24 hours per day, 365 days per year	Actual Value, Normally Less Than 100% Based on Realistic Probability of Exposure to Specific Hazard
Significance Threshold	1 : 1,000,000 Some Jurisdictions Only No Established Threshold in U.S. or California	No Known Established or Codified Threshold

(Marzal 2001)

3.23.3 SOCIETAL RISK

Societal risk is the probability that a specified number of people will be affected by a given event. The accepted number of casualties is relatively high for lower probability events and much lower for more probable events. However, the acceptable values for societal risk vary greatly, depending on the responsible agency or jurisdiction. Unfortunately, there are no prescribed societal risk guidelines for the United States, nor the State of California. The United Kingdom, considers those events which result in 100 fatalities, with an annual probability of 1.0×10^{-5} (1:100,000) or less. The Committee for the Prevention of Disasters, uses the criteria as shown in Figure 3.32-1 below. This data is the same as the criteria used in the Netherlands and is the most conservative of the published data for Western Europe. These criteria have been used to evaluate societal risk in this Appendixdocument.

Figure 3.3~~2~~-1: Societal Risk Criteria



Source: Committee for the Prevention of Disasters, The Hague

3.3.1 California Department of Education

Earlier draft versions of the CDE's Guidance Protocol for School Site Pipeline Risk Analysis (Protocol) included societal risk criteria which were based on the thresholds established by Santa Barbara County. However, the current Protocol uses a simplified approach for evaluating the risk to the student population. As stated in the Protocol, "In addition to IR, some measure of potential impacts based on the population potentially at risk for the school campus site is required. This additional information aids the LEA in their site evaluation. CDE has adopted a simplified approach to evaluating impacts for the campus site in terms of two calculated parameters. The first is the ratio of an average IR across the depth of campus site to the IR at the front property line (or boundary between the usable and unusable portion of the site when the unusable portion faces the pipeline). The second is a site population risk indicator parameter." (CDE 2007)

A complete discussion of these two population risk parameters is beyond the scope of this document. The concepts are described in the cited reference; examples are also provided.

4.0 IMPACT ANALYSIS AND MITIGATION

4.1 POTENTIAL IMPACTS

The proposed Project could pose additional risks to the public. Natural gas could be released from a leak or rupture. If the natural gas reached a combustible mixture and an ignition source was present, a fire and/or explosion could occur, resulting in possible injuries and/or deaths.

Impact HAZ-1: Injuries or Fatalities

An unintentional release from the proposed Project could result in injuries and/or deaths. (Adverse impact that does not meet or exceed the significance criteria. ~~Significant and Unavoidable,~~ Class III~~1~~).

4.1.1 Fire Impact Discussion

~~**Fire**~~

The physiological effect of fire to humans depends on the rate at which heat is transferred from the fire to the person, and the time the person is exposed to the fire. Skin that is in contact with flames can be seriously injured, even if the duration of the exposure is just a few seconds. Thus, a person wearing normal clothing is likely to receive serious burns to unprotected areas of the skin when directly exposed to the flames from a flash fire (vapor cloud fire).

Humans in the vicinity of a fire, but not in contact with the flames, would receive heat from the fire in the form of thermal radiation. Radiant heat flux decreases with increasing distance from a fire. So those close to the fire would receive thermal radiation at a higher rate than those farther away. The ability of a fire to cause skin burns due to radiant heating depends on the radiant heat flux to which the skin is exposed and the duration of the exposure. As a result, short-term exposure to high radiant heat flux levels can be injurious. But if an individual is far enough from the fire, the radiant heat flux would be lower, likely incapable of causing injury, regardless of the duration of the exposure.

An incident heat flux level of 1,600 Btu/hour-square foot (btu/ft^2-hr) is considered by many to be potentially hazardous for people located outdoors and unprotected.

Generally, humans located beyond this heat flux level would not be at risk to injury from thermal radiation resulting from a fire. The radiant heat flux effects to humans are summarized below. The first three endpoints have been used to evaluate the risk of public fatalities from the proposed project.:

- 12,000 btu/ft^2-hr (37.7 kW/m^2) – 100% mortality after 30 second exposure (CDE 2007).
- 8,000 btu/ft^2-hr (25.1 kW/m^2) – 50% mortality after 30 second exposure (CDE 2007).
- 5,000 btu/ft^2-hr (15.7 kW/m^2) – 1% mortality after 30 second exposure (CDE 2007). In many instances, an able bodied person would increase the separation distance or seek cover during this 30 second period.
- 3,500 btu/ft^2-hr (11.0 kW/m^2) - Second degree skin burns after ten seconds of exposure, 15% probability of fatality. This assumes that an individual is unprotected or unable to find shelter soon enough to avoid excessive exposure (Quest 2003). Other data sources indicate that a 45 second exposure would result in a 1% chance of mortality (Hynes 1983).
- 1,600 btu/ft^2-hr (5.0 kW/m^2) - Second degree skin burns after thirty seconds of exposure.
- 440 btu/ft^2-hr (1.4 kW/m^2) - Prolonged skin exposure causes no detrimental effect (CDE 2007, Quest 2003).

4.1.2 Explosion Impact Discussion

As noted earlier, natural gas does not explode unless it is confined sufficiently within a specific range of mixtures with air and is ignited. However, if an explosion does occur, the physiological effects of overpressures depend on the peak overpressure that reaches a person. Exposure to overpressure levels can be fatal. People located outside the flammable cloud when a combustible mixture ignites would be exposed to lower overpressure levels than those inside the flammable cloud. If a person is far enough from the source of overpressure, the explosion overpressure level would be incapable of causing injuries. The generally accepted hazard level for those inside buildings exposed to an explosion is an overpressure of 1.0 psig. This level of overpressure can result in injuries to humans inside buildings, primarily from flying glass and debris. The consequences of various levels of overpressure are outlined in the table below.

Table 4.1.21-1 Explosion Over-Pressure Damage Thresholds

Side-On Over-Pressure	Damage Description
0.02 psig	Annoying Noise
0.03 psig	Occasional Breaking of Large Window Panes Under Strain
0.04 psig	Loud Noise; Sonic Boom Glass Failure
0.10 psig	Breakage of Small Windows Under Strain
0.20 psig	Glass Breakage - No Injury to Building Occupants
0.30 psig	Some Damage to House Ceilings, 10% Window Glass Broken
0.50 to 1.00 psig	Large and Small Windows Usually Shattered, Occasional Damage to Window Frames
0.70 psig	Minor Damage to House Structures, Injury, but Very Unlikely to Be Serious
1.00 psig	1% Probability of a Serious Injury or Fatality for Occupants in a Reinforced Concrete or Reinforced Masonry Building from Flying Glass and Debris 10% Probability of a Serious Injury or Fatality for Occupants in a Simple Frame, Unreinforced Building
2.30 psig	0% Mortality to Persons Inside Buildings or Persons Outdoors (CDE 2007)
3.10 psig	10% Mortality to Persons Inside Buildings (CDE 2007)
3.20 psig	<10% Mortality to Persons Outdoors (CDE 2007)
14.5 psig	1% Mortality to Those Outdoors (LEES)

Sources: LEES, CDE 2007, Quest 2003

For outdoor explosions, the following endpoints have been used to evaluate potential explosion impacts to the public from the proposed project.

Table 4.1.2-2 Explosion Overpressure Levels

Mortality Rate	Outdoor Exposure (psig)	Indoor Exposure (psig)
99% Mortality	29	13
50% Mortality	13	5.7
1% Mortality	2.3	2.3

(CDE 2007)

4.1.24.2 BASELINE DATA

In the following paragraphs, the anticipated frequency of unintentional releases and impacts to humans will be estimated using data from the following sources:

- United States Natural Gas Transmission and Gathering Lines (U.S. Department of Transportation [USDOT]) – 1970 through 2007.
- United States Interstate Hazardous Liquid Pipelines (USDOT) - 1984 through 1998.
- California Regulated Interstate and Intrastate Hazardous Liquid Pipelines (Payne, 1993) - 1981 through 1990.

Each of these data sets provides pipeline incident data for reportable incidents. However, the criteria for reporting incidents differ for each source. This makes direct comparison of the individual results difficult. On the other hand, it provides a methodology for estimating incident rates for a variety of consequences.

4.2.1 U.S. Natural Gas Transmission Lines - 1970 to June 1984

Since the USDOT natural gas pipeline reporting criteria changed in June 1984, the incident reports beginning in July 1984 have been summarized separately, in the next section of this document. The criteria for natural gas releases to be reported to the USDOT from 1970 through June 1984 were as follows:

- Resulted in a death or injury requiring hospitalization;
- Required the removal from service of any segment of a transmission pipeline;
- Resulted in gas ignition;
- Caused an estimated damage to the property owner, or of others, or both, of $5,000 or more;
- Involved a leak requiring immediate repair;
- Involved a test failure that occurred while testing either with gas or another test medium; or
- In the judgment of the operator, was significant even though it did not meet any of the above criteria.

The frequencies of the various consequences reported during this period are summarized below.

- Reportable Unintentional Releases - 1.3 incidents per 1,000 mile-years.

- Reportable Injuries - 0.096 injuries per 1,000 mile-years (0.007 public injuries per 1,000 mile-years).
- Fatalities - 0.016 fatalities per 1,000 mile-years (0.008 public fatalities per 1,000 mile-years).

It should be noted that during this 14½-year period, 36 (50%) of the total 72 fatalities and 161 (59%) of the total 274 of those injured were employees of the operating company.

4.2.2 U.S. Natural Gas Transmission Lines - July 1984 through 2007

In June 1984, the USDOT changed the criteria for reporting natural gas releases. The most significant change was that in general, leaks causing less than $50,000 property damage no longer required reporting to the USDOT. The criteria for natural gas releases to be reported to the USDOT from July 1984 through the present include:

- Events which involved a release of gas from a pipeline, or of liquefied natural gas (LNG) or gas from an LNG facility, which caused: (a) a fatality, or personal injury necessitating inpatient hospitalization; or (b) estimated property damage, including costs of gas lost by the operator, or others, or both, of $50,000 or more.
- An event which resulted in an emergency shut-down of an LNG facility.
- An event that was significant, in the judgment of the operator, even though it did not meet the criteria above.

Since the reporting threshold is now significantly greater than the prior $5,000 reporting criteria, a significant decrease in the resulting reportable incident rate resulted. However, the frequency of reportable injuries and fatalities also decreased, indicating improvements in pipeline safety.

The USDOT also filters the reported incidents and provides reports for “significant” pipeline incidents. These incidents include those which result in:

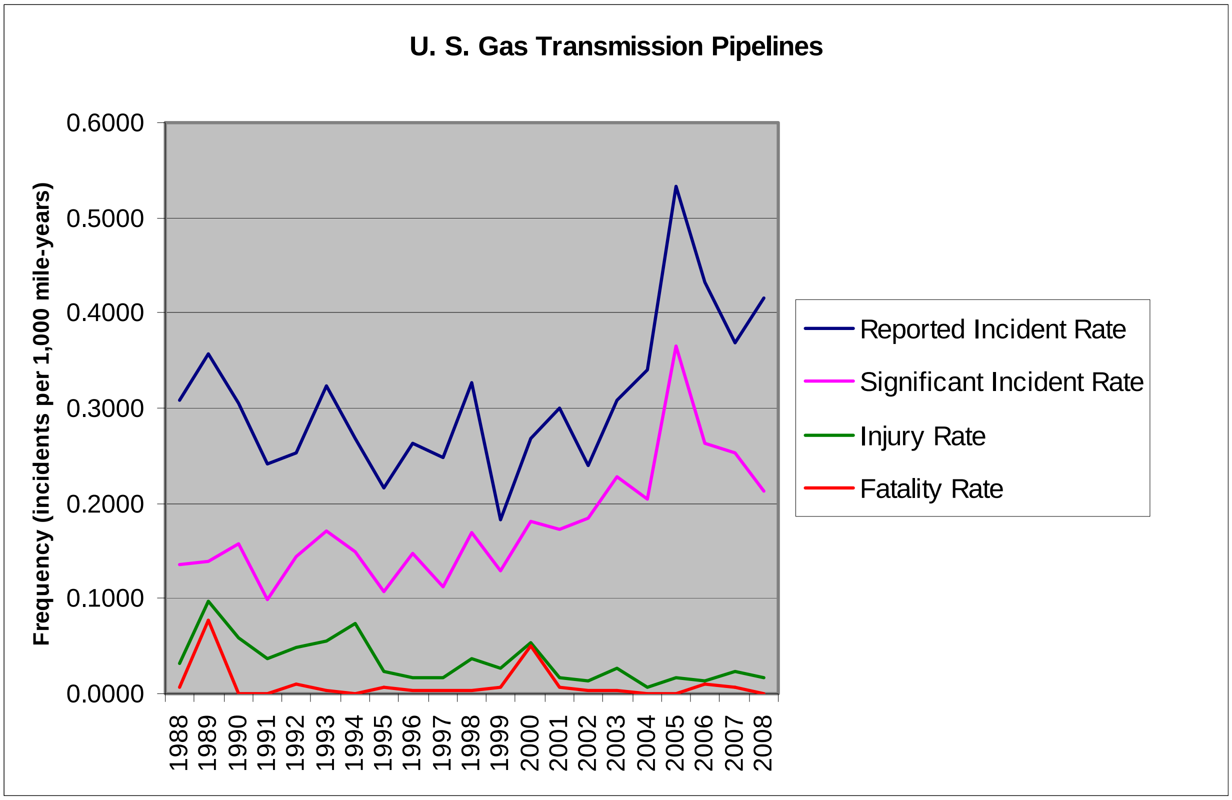
- Fatality or injury requiring in-patient hospitalization,
- $50,000 or more in total costs (measured in 1984 dollars),
- Highly volatile liquid releases of 5 barrels or more or other liquid releases of 50 barrels or more, or
- Liquid releases resulting in an unintentional fire or explosion.

These data are summarized below for the 21~~2~~-year period from January 1, 1988~~6~~ through December 31, 2008~~7.~~ for gas transmission pipelines (including both onshore and offshore segments, but excluding gathering lines).

- Reportable Unintentional Releases - 0.31 incidents per 1,000 mile-years
- Significant Incidents – 0.18 incidents per 1,000 mile-years
- Reportable Injuries - 0.034040 injuries per 1,000 mile-years
- Fatalities - 0.010 fatalities per 1,000 mile-years

In 2002, the USDOT changed their reporting forms. At this time, operators were required to begin reporting additional data for each reportable release. These changes were significant. Some of the additional reporting fields included the reporting of fires and explosions, which were not required to be identified previously.

For the most recent sevensix year period, since the change in the USDOT reporting form (January 2002 through December 20087), there were a total of 795761 reported incidents from natural gas transmission pipelines included in the database, including 516 "significant" incidents, 35 reported injuries, and 7 fatalities. The average reported property damage from the 516 "significant" releases was over $1,200,000was nearly $820,000 per incident. (However, the actual value is likely higher, due to the lag in the settlement of law suits, extended duration of some clean-up and repair efforts, etc. As noted earlier, the actual cost to the operator can be significantly higher than that initially reported to the USDOT.) _The average annual transmission pipeline mileage was 301,625373 miles for this sevensix year period. Using these data, the frequency of reportable incidents during this most recent sevensix year period was up nearly 70over 50% when compared to the 1422-year period presented above - 0.3842 incidents per 1,000 mile-years for 2002 through 20087 versus 0.287 incidents per 1,000 mile-years for 19886 through 20012. The frequency of "significant" incidents increased similarly, from 0.14 (1988 through 2001) to 0.24 (2002 through 2008). The injury and fatality rates for the most recent sevensix year period were 0.0179 and 0.00334 incidents per 1,000 mile-years respectively, down significantly. These data are summarized in the following figure by year.



Source: USDOT, Incident Summary Statistics by Year and Natural Gas Transmission Pipeline Annual Mileage

Figure 4.21.2-1 U.S. Natural Gas Onshore and Offshore Transmission Pipeline Incident Rate History[3]

It should be noted that the above data, as included on the USDOT Incident Summary Statistics by Year, includes 92 incidents which occurred on lines identified as "Gathering" in the USDOT gas transmission incident database (USDOT). An audit of the USDOT database is beyond the scope of this work. As a result, the reason that these data have been included in the USDOT incident databasesummary statistics is unknown. There are several possible reasons. The operator may have indicated the classification of the line as "Gathering" in error. The USDOT may have inadvertently included the incident data in the wrong databasereport.

[3] This figure depicts the data included in the raw USDOT gas transmission pipeline database. The raw database includes incidents which were identified as having occurred on "gathering" lines.

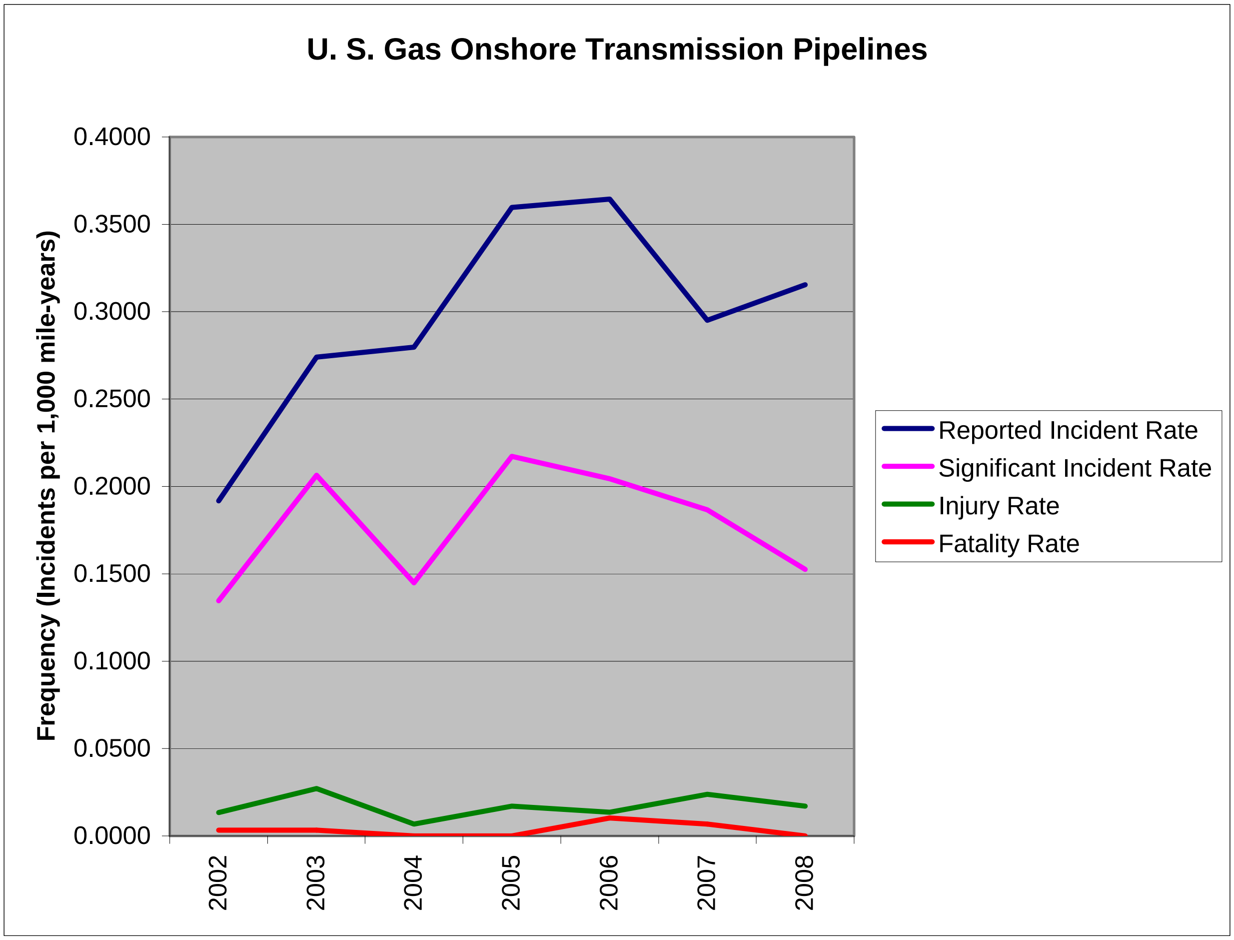
The database also includes incidents which occurred on offshore segments of pipelines. However, making the maximum correction for these incidents does not significantly affect the results. The 2002 through 2008~~7~~ data would be affected as follows, if the ~~92~~ incidents which occurred on lines identified as "Gathering" and those which occurred on "offshore" segments were deleted:

- Reportable Unintentional Releases – This figure would be reduced from 0.38~~42~~ to 0.29~~37~~ incidents per 1,000 mile-years
- Significant Incidents – This figure would be reduced from 0.24 to 0.18 incidents per 1,000 mile-years
- Reportable Injuries - This figure would remain unchanged at ~~be reduced from 0.019 to~~ 0.017 injuries per 1,000 mile-years
- Fatalities – This figure would increase slightly from 0.0033 to 0.0034~~be unchanged at 0.004~~ fatalities per 1,000 mile-years

~~The database also includes incidents which occurred on offshore segments of pipeline. During the six year period between January 2002 and December 2007, there were 216 such incidents. 67 of these occurred on lines identified as "Gathering", while 149 occurred on segments identified as "Transmission". If these offshore releases are also removed from the database, and the mileage is adjusted to only include the onshore mileage, the following incident rates result:~~

- ~~Reportable Unintentional Releases – 0.29 incidents per 1,000 mile-years~~
- ~~Reportable Injuries - 0.017 injuries per 1,000 mile-years~~
- ~~Fatalities – 0.004 fatalities per 1,000 mile-years~~
- ~~Average Property Damage - $520,000~~

The data for onshore gas transmission pipelines only are presented in the following figure.



Source: USDOT

Figure 4.2.2-2 U.S. ~~Natural~~ Gas Onshore Transmission Pipeline Incident Rate History

4.2.3 U.S. Hazardous Liquid Pipelines - 1984 through 1998

The criteria for hazardous liquid pipeline incidents to be reported to the USDOT for inclusion in this data set were as follows:

- Explosion or fire not intentionally set by the operator;
- Loss of more than 50 barrels (2,100 gallons) of liquid or carbon dioxide;
- Escape to the atmosphere of more than five barrels per day of highly volatile liquid;
- Death of any person;

- Bodily harm to any person resulting in loss of consciousness, necessity to carry the person from the scene, or disability which prevents the discharge of normal duties or the pursuit of normal activities beyond the day of the accident; and/or
- Estimated property damage to the property of the operator, or others, or both, exceeding $5,000, prior to June 1994. After June 1994, this criteria was changed to $50,000, including the cost of clean-up, recovery, and the value of any lost product.

The data for this period are summarized below:

- Reportable Unintentional Releases - 1.29 incidents per 1,000 mile-years
- Reportable Injuries - 0.076 injuries per 1,000 mile-years
- Fatalities - 0.015 fatalities per 1,000 mile-years

It should be noted that the 1994 Annual Report on Pipeline Safety excluded 1,851 individuals who were injured with minor burns and vapor inhalation from the failure and ignition of seven hazardous liquid pipelines during the San Jacinto River floods in mid-October, 1994, near Houston, Texas. These incidents were caused by severe flooding in the area. These injuries are not included in the injury rate shown above.

It is interesting to note that the incident rate for hazardous liquid pipeline releases (prior to 1994) was essentially the same as those for reportable U.S. natural gas transmission and gathering lines from 1970 through June 1984, which had a similar $5,000 property damage reporting requirement.

4.2.4 Regulated California Hazardous Liquid Pipelines - 1981 through 1990

This study, undertaken by the California State Fire Marshal, Pipeline Safety Division, included all regulated California interstate and intrastate hazardous liquid pipelines (Payne 1993). It included approximately 7,800 miles of pipeline data, over a ten year period (1981 through 1990). The systems included in this study had complete release records. The major difference for this study, as compared to ones discussed previously, is that all releases, regardless of size, cause, extent of property damage, or extent of injury were included in the study. Also, a complete audit of the pipeline inventory and release data was conducted. As a result, the incident rates resulting from this study were higher than presented in other studies, which only included reported releases fitting a relatively narrow set of criteria. A summary of these results is included below.

- Unintentional Releases - 7.08 incidents per 1,000 mile-years
- Injuries - 0.685 injuries per 1,000 mile-years

- Fatalities - 0.042 fatalities per 1,000 mile-years

4.2.5 Summary of Historical Pipeline Consequence Data

In the following table, the available pipeline release data have been summarized.

Table 4.2.51.2-1 Pipeline Release Consequences by Data Source

Consequence	U.S. Natural Gas Transmission 1970 to June 1984	U.S. Natural Gas Transmission 1988 thru 2008 July 1984 thru 2007 (As Reported by USDOT)	U.S. Natural Gas Onshore Transmission 2002 thru 20087	U.S. Hazardous Liquid - 1984 thru 1998	California Hazardous Liquid - 1981 thru 1990
	Incidents per 1,000 mile-years				
Reportable Incidents	1.30 ($5,000 criteria)	0.31 ($50,000 criteria)	0.2929 ($50,000 criteria)	1.29 ($5,000 criteria)	7.08 (all incidents, regardless of size and value of property damage)
Significant Incidents	N/A	0.18	0.18	N/A	N/A
Injuries regardless of severity	N/A	N/A	N/A	N/A	0.685
Injury requiring hospitalization	0.096	0.0340.040	0.017	N/A	N/A
Injuries requiring hospitalization, causing loss of consciousness, or preventing discharge of normal duties day following the incident	N/A	N/A	N/A	0.076	N/A
Fatalities	0.016	0.010	0.0034004	0.015	0.042

4.3 BASELINE INCIDENT FREQUENCY~~CONSEQUENCE DATA~~ USED IN ANALYSIS

The USDOT database of natural gas transmission pipeline releases from January 2002 through December 2008~~7~~ has been analyzed. These data will be used to develop the baseline frequency of unintentional releases from the proposed facilities. After deleting all releases noted from "Gathering" lines and "Offshore" lines, there were 614~~520~~ releases remaining from onshore transmission pipelines. Of these, the two major causes of releases were excavation damage and external corrosion. 131~~113~~ (21~~22~~%) of the releases were caused by excavation damage from a third party and the pipeline operator. 83~~71~~ (14%) of the releases were caused by external corrosion. The remaining 400~~336~~ (65~~64~~%) of the releases were caused by a variety of factors, listed in descending order of frequency:

- miscellaneous or unknown – 12%
- malfunction of control or relief equipment – 8~~7~~%
- vehicles not related to excavation – 6%
- internal corrosion – 5%
- butt weld failure – 4~~5~~%
- rain and flooding – 4%
- body of pipe failure – 4%
- incorrect operation – 3%
- pipe weld seam failure – 3%
- ~~earth movement – 2%~~
- component failure – 3~~2~~%
- earth movement – 2%
- joint failure – 2%
- threaded fitting or coupling failure – 2%
- lightning – 1%
- fire and explosions – 1%
- fillet weld failure – 1%
- temperature - <1%
- wind - <1%

- rupture of previously damaged pipe - <1%
- vandalism - <1%

4.3.1 Third Party Damage Incident Rate

As noted above, third party damage caused 2122% of the accidental pipeline releases. The Applicant will be required to implement the following mitigation measures to reduce the frequency of third party caused releases in accordance with applicable laws, ordinances, regulations and standards (LORS):

- One-Call System – The Applicant will subscribe to the USA North underground service alert "one-call" system. A toll free number is available for contractors and others to use before they begin excavations. Once a contractor calls and identifies its proposed excavation location, the organization will notify the Applicant and other underground facility owners in the vicinity. The owners respond to these calls with personal communications with the excavator. If their facilities are nearby, they mark the location of their facilities on the ground, so third party intrusions can be avoided. Participation in a one-call system if required as part of an operator's damage prevention program, per 49 CFR 192.614.
- Line Marking – The Applicant is required by federal regulation (49 CFR 192.707) to install line marker posts such that the pipeline is readily identifiable. In addition, they are required to have warning signs installed at each side of road, railroad, and waterway crossings, and at fence lines across open or agricultural property, crossings of other lines (e.g., irrigation, oil, gas, telephone, utilities) where practical, and where the line is above ground in areas accessible to the public.
- Right-of-Way Patrolling - 49 CFR 192.705 requires each operator to have a patrol program to monitor for indications of leaks, nearby construction activity, and any other factors that could affect safety and operation. The frequency of these inspections is based on a number of factors. For the proposed line, in class 1 and 2 area classifications these patrols must be conducted at least twice each calendar year for road crossings and once each calendar year in other locations; in class 3 locations these patrols must be conducted at least four times each calendar year for road crossings and at least twice each calendar year in other locations
- Leakage Surveys – A leakage survey must be conducted at least once each calendar year for class 1 and 2 locations and at least twice per year for class 3 locations.
- Public Education - 49 CFR 192.616 requires pipeline operators to develop and implement a written continuing public education program that follows the guidance provided in the American Petroleum Institute's (API's) Recommended

Practice 1162 Public Awareness Programs for Pipeline Operators as their public education procedure.

The California study found that the overall frequency of third party damage caused unintentional releases was 1.46 unintentional releases per 1,000 mile-years. For pipelines constructed in the 1950's, the frequency was only 0.88 unintentional releases per 1,000 mile-years; it was even lower for newer lines. These lower values were primarily due to the increased awareness of the threat from third party damage to pipeline facilities; newer lines have benefited from improved line marking, one-call dig alert systems, avoidance of high risk areas, improved documentation, increased depth of cover, and public awareness programs. (Payne 1993)

The Applicant's proposed mitigation to increase the depth of cover to a minimum of five -feet will provide increased protection from third party damage. A European Study found that increasing the pipe depth of cover beyond four feet decreased the risk of third party incidents by about 30% versus the depth of cover required by the 49 CFR 192. (HSE 2001)

Using these data and the baseline frequency of 0.29 reportable unintentional releases per 1,000 mile-years from the U. S. natural gas onshore transmission pipelines (2002 through 2007), the anticipated frequency of third party damage caused USDOT reportable releases is 0.043~~5~~ incidents per 1.000 mile-years (0.29 per 1,000 mile-years baseline x 21~~22~~% caused by third party damage x 70% = 0.043~~5~~ incidents per 1,000 mile-years).

4.3.2 External Corrosion Incident Rate

External corrosion of a buried pipe is an electro-chemical reaction, which can occur when bare (un-coated) steel is in contact with the earth. The moist soil surrounding a pipeline can serve as an electrolyte. When this occurs, the pipe can become an anode. The current then flows through the electrolyte, from the anode (pipe) to the cathode (soil). In this instance, the anode (pipe) loses material (corrodes) as this process occurs.

The intent of an effective external corrosion prevention program is twofold. First, the pipe is protected from corrosion by insulating it from contact with the electrolyte (moist soil) using an external coating. Second, in the event that the coating should fail, the pipe is prevented from becoming the anode by introducing some other material into the electrochemical chain that is more anodic than the pipe, or appears to be because of an impressed current. An impressed current or sacrificial anode cathodic protection system makes the current flow through the soil, toward the pipe, instead of away from it; thus, external corrosion is eliminated.

An impressed current system takes alternating current electrical power from a utility source or solar panels. A transformer is used to reduce the voltage. A rectifier then converts the alternating current to a direct current. The direct current flows to and through anodes (graphite, steel, or other material) and into the surrounding earth. At locations where there may be a break in the external pipe coating (holiday), the current will reach the pipeline. It will then flow along the line to the rectifier, completing the circuit, preventing external corrosion at the external pipe coating holiday.

External corrosion typically causes a relatively large percentage of unintentional releases. Often, these releases are relatively small in volume, with low release rates. However, they often can go unnoticed for long periods of time.

The California study found that the frequency of unintentional releases (of all volumes) caused by external corrosion varied significantly by decade of pipe construction and pipeline operating temperature.

During the 1940's and 1950's, significant improvements were made in pipeline construction techniques and materials. Relative to external corrosion, the primary improvements included advances in external coatings and more widespread use of these coatings and cathodic protection systems. These items account for the significant reduction in external corrosion incident rates for modern pipelines, versus pipelines constructed prior to the 1940's. For newer pipelines, it is impossible to isolate the individual affects of pipe age and other improvements (e.g. technology, construction techniques, the more widespread use of high quality external coatings and cathodic protection systems). The table below presents the California data by decade of pipeline construction by incident cause.

Table 4.3~~1~~.2-1~~2~~ Incident Rates by Decade of Construction

Incident Cause	Pre-1940	1940-49	1950-59	1960-69	1970-79	1980-89
External Corrosion	14.12	4.24	2.47	1.47	1.24	0.00
Internal Corrosion	0.38	0.27	0.10	0.16	0.00	0.28
3rd Party - Construction	1.96	1.06	0.68	0.66	0.25	0.28
3rd Party - Farm Equipment	0.53	1.33	0.05	0.00	0.00	0.00
3rd Party - Train Derailment	0.00	0.00	0.00	0.05	0.25	0.00
3rd Party - External Corrosion	0.45	0.00	0.10	0.33	0.00	0.00
3rd Party - Other	0.30	0.13	0.05	0.05	0.00	0.00
Human Operating Error	0.30	0.13	0.00	0.11	0.25	0.00
Design Flaw	0.08	0.00	0.00	0.00	0.00	0.14
Equipment Malfunction	0.38	0.53	0.10	0.60	1.24	0.00
Maintenance	0.00	0.00	0.24	0.00	0.00	0.00
Weld Failure	0.38	0.27	0.15	0.44	0.25	0.00
Other	0.83	0.13	0.24	0.27	0.25	0.28
Total	19.71	8.09	4.18	4.14	3.73	0.98

Source: Payne, 1993

The statistical analyses performed in the California study indicated that operating temperature directly affected the frequency of unintentional releases caused by external corrosion. Considering all pipelines, regardless of decade of construction, those that were operated near ambient temperatures had an external corrosion caused incident rate of 1.33 unintentional releases per 1,000 mile-years. The incident rate rose dramatically as the operating temperature was increased.

The proposed pipeline segment will be operated at ambient temperatures. The table below indicates that the external corrosion incident rates for the California lines operated at various temperatures ranged from 0.48 to 11.36 unintentional releases per 1,000 mile-years. However, the lines operated between 130°F and 159°F had a 1947 mean year of pipeline construction; as discussed earlier, pipe age also significantly affected the incident rate. This effect is also reflected in these data.

Table 4.31.2-23 Incident Rates by Design Operating Temperature

Incident Cause	0-69°F	70-99°F	100-129°F	130-159°F	160°F+
External Corrosion	0.48	1.33	7.11	11.36	11.31
Internal Corrosion	0.00	0.21	0.32	0.57	0.08
3rd Party - Construction	1.91	0.94	0.95	0.57	0.60
3rd Party - Farm Equipment	0.00	0.30	0.47	0.00	0.08
3rd Party - Train Derailment	0.00	0.04	0.00	0.00	0.00
3rd Party - External Corrosion	0.00	0.06	0.16	0.00	0.15
3rd Party - Other	0.00	0.24	0.16	0.00	0.15
Human Operating Error	0.00	0.11	0.00	0.00	0.23
Design Flaw	0.00	0.04	0.00	0.00	0.00
Equipment Malfunction	0.00	0.24	0.16	0.57	0.98
Maintenance	0.00	0.09	0.16	0.00	0.00
Weld Failure	0.00	0.19	0.32	0.00	0.60
Other	0.00	0.21	1.11	1.14	0.45
Total	2.39	4.00	10.92	14.21	14.63

Source: Payne, 1993

To reduce the likelihood of releases caused by external corrosion, the following measures would be implemented by the Applicant in compliance with applicable LORS:

- Modern External Pipe Coating - The proposed pipeline segments will be externally coated with 14 mils of fusion bonded epoxy (FBE). In addition, pipe that will be installed using the horizontal directional drilling (HDD) or hammer bore technique, will have an additional outer abrasion resistant top coating (e.g., 3M 6352, DuPont NapRock, or Powercrete®).
- Impressed Current Protection System - The proposed pipeline will be protected from external corrosion by an impressed current cathodic protection system.
- Monitoring - At least once each calendar year, at intervals not exceeding 15 months, the Applicant will be required to test their cathodic protection system in accordance with 49 CFR 192.465.
- Visual Inspections - Each time buried pipe is exposed for any reason, the Applicant will be required to examine the pipe for evidence of external corrosion in accordance with 49 CFR 192.459. If active corrosion is found, the operator is required to investigate and determine the extent. Pipeline operators are required to maintain records of these USDOT required inspections. They are routinely reviewed by USDOT staff during their inspections.

Using the data presented in the Tables above, an opinion of the anticipated frequency of USDOT reportable unintentional releases due to external corrosion from the proposed pipe segments has been developed. These segments will normally be operated at ambient temperatures, using externally coated pipe, with an impressed current cathodic protection system. The anticipated frequency of third party damage caused USDOT reportable releases is 0.027 incidents per 1.000 mile-years (0.29 per 1,000 mile-years baseline x 14% caused by third party damage x 2/3% = 0.027 incidents per 1,000 mile-years). This frequency is intended to reflect the average value over a 40-year project life. During the early years of operation, the frequency of externally corrosion caused incidents will likely approach zero. It should also be noted that the statistical impact of the new USDOT pipeline integrity regulations are unknown at this time. But they will likely reduce the frequency of releases from the proposed pipeline components located within an HCA which will be included in a Pipeline Integrity Management Plan.

4.3.3 Miscellaneous Causes Incident Rate

As noted above, the remaining 654% of the incidents not caused by third party damage or external corrosion are caused by a number of factors. Since each of these causes is a relatively small percentage of the total, adjustments were not made to these frequencies individually. A one-third reduction has been made to account for the remaining Applicant proposed mitigation measures and the fact that these facilities will be modern, new systems. A larger adjustment could have been made. However, the resulting frequency is intended to reflect the average value over a 40-year project life. The anticipated frequency of non-third party damage or external corrosion caused USDOT reportable releases is 0.12624 incidents per 1.000 mile-years (0.29 per 1,000 mile-years baseline x 654% x 2/3 = 0.12624 incidents per 1,000 mile-years).

4.3.4 Overall Pipeline Facility Incident Rate

The anticipated frequency of USDOT reportable releases from the proposed facilities is 0.196 incidents per 1.000 mile-years (0.0435 from third party damage, 0.027 from external corrosion, and 0.1264 from other causes).

4.1.34.4 QUALITATIVE AGGREGATE RISK ASSESSMENT

In this section, the anticipated frequency of unintentional releases, injuries and fatalities will be developed using the historical baseline data presented above for the following project components:

- 14-mile long, 30-inch diameter Line 406, including the regulating and metering facilities at Capay Station and Yolo Junction;
- 13.5-mile long, 30-inch diameter Line 407W, including the Power Line Road main line vale site;
- 12-mile long, 30-inch diameter Line 407E, including the Baseline/Brewer main line valve and the Baseline Road Pressure Regulating Station; and the
- 2.5–mile long, 10-inch diameter, DFM, including the Power Line Road regulating station.

4.4.1 Anticipated Frequency of Unintentional Releases

Using the baseline data compiled in the previous section, the anticipated frequencies of unintentional releases have been estimated. These data, for the proposed pipeline segments, are shown in Table 4.1.3-1 below. These data also include anticipated releases from the meter stations and other appurtenances, which are also under USDOT jurisdiction and are subject to the pipeline incident reporting requirements. As a result, releases from these facilities have been included in the previously presented baseline data.

Table 4.4.11.3-1 Anticipated Frequency of Unintentional Releases

Incident Cause	Incident Rate	Anticipated Number of Incidents Per Year	Likelihood of Annual Occurrence
Total, All Releases, Regardless of Spill Volume	3.00 per 1,000 mile-years	0.126	1 in 7.9
USDOT Reportable Gas Releases - 1970 thru June 1984 criteria (>$5,000 damage)	1.30 per 1,000 mile-years	0.055	1 in 18
USDOT Reportable Gas Releases - Current Criteria (>$50,000 damage)	0.196 per 1,000 mile-years	0.008	1 in 120

4.4.2 Anticipated Frequency of Injuries and Fatalities

Most unintentional natural gas releases are relatively small and do not cause personal injuries or death. In this section, the likelihood of human injuries and deaths will be estimated using historical baseline data. Later in this document, the human life impacts will be evaluated using a probabilistic approach.

As noted earlier, the primary natural gas component is methane, which is not toxic. Although methane presents a slight inhalation hazard, the primary risk to humans is posed by exposures to fire or explosion. A fire could result from a natural gas release with two conditions present. First, a volume of natural gas must be present within the combustible mixture range (5% to 15% methane in air). Second, a source of ignition must be present with sufficient heat to ignite the air/natural gas mixture (1,000°F). In order for an explosion to occur, a third condition must be present - the natural gas vapor cloud must be confined, to a sufficient degree.

It is difficult to estimate the potential extent of human injury because there are so many variables affecting the size of a fire or explosion: rate of vapor cloud formation (controlled primarily by the release rate), size of the vapor cloud within the combustible range (controlled by weather, including wind and temperature, release rate, etc.), concentration of vapors (varying with wind and topographic conditions), degree of vapor cloud confinement, etc. (These actual conditions will be evaluated later, in Section 4.4.3~~1.4~~ of this Appendix.)

Based on the historical data presented earlier, the following frequencies for human life consequences are anticipated from the pipeline components and associated metering stations, regulating stations, and appurtenances:

Table 4.4.2-1~~1.3-2~~ Human Life Impacts Based on Historical Data

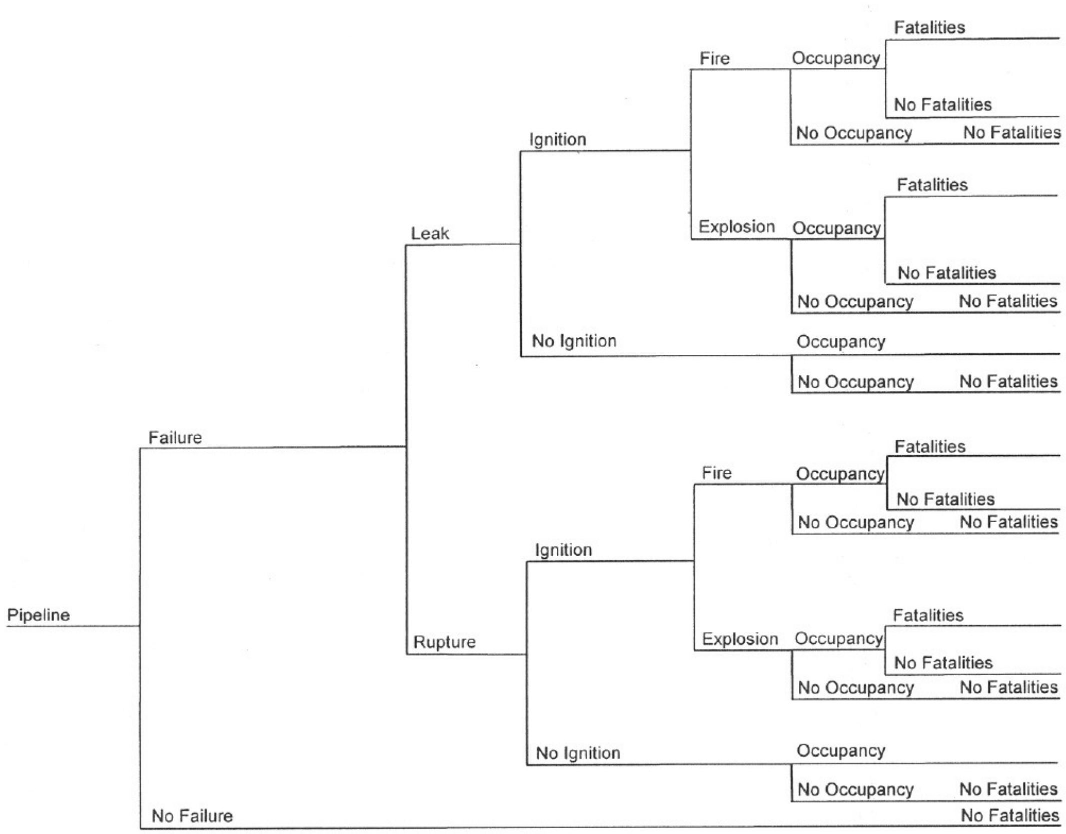
Consequence	Frequency	Annual Number of Events	Return Interval (Years)
Injuries regardless of severity	0.700 incidents per 1,000 mile-years	2.9×10^{-2}	34
Injuries requiring hospitalization	0.017 incidents per 1,000 mile-years	7.1×10^{-4}	1,400
Fatalities	0.004 fatalities per 1,000 mile-years	1.7×10^{-4}	6,000

As indicated in the table above, the annual aggregate probability of a fatality is 1:6,000, based on the qualitative risk assessment. This is the qualitative aggregate risk, as defined earlier in Section 3.2 of this Appendix. This is the estimated likelihood of a fatality along the entire project, considering all of the project components. This aggregate risk should not be confused with individual risk, nor the individual risk thresholds presented earlier in Section 3.1. The individual risk of fatality is the probability of a fatality at a single specific location, whereas the aggregate risk is the probability of a fatality along the entire pipeline. (Reference Table 3.2-1 for a summary of the differences between individual and aggregate risk.) This is significantly higher than the generally accepted significance criterion of one in one million (1:1,000,000) (CDE 2007, CPUC 2006). As a result, this level of risk would generally be considered significant.

The anticipated frequencies of injuries and fatalities presented above are useful references. However, they do not facilitate an accurate evaluation of the specific parameters for the proposed pipeline facilities. For example, these summary data do not differentiate between the risks of a relatively benign natural gas pipeline and a liquefied petroleum gas (LPG) pipeline transporting chlorine in a gaseous state, which is much more likely to result in serious impacts due to toxic impactsfires and explosions. These historical data also do not differentiate between various population densities. For example, a release in an urban area is likely to cause more significant impacts to humans than a release in a rural, undeveloped area. For the rural portion of the proposed facilities, the values shown above overstate the risk to the public; while in the urban areas they likely understate the risk. In the following section, a probabilistic risk assessment will be presented. This analysis will consider the actual environment, pipe contents, pipe diameter, actual operating conditions and the proximity to the public.

4.1.44.5 QUANTITATIVE RISK ASSESSMENT

In this section, a probabilistic pipeline risk assessment will be presented. This analysis considers the actual site population density, as well as the characteristics of the pipe contents in the event of an unintentional release. This analysis was conducted using the following consequence event tree, with minor modifications to differentiate between flash and torch fires.



4.5.1 Baseline Frequency of Unintentional Releases

For this analysis, a baseline frequency of USDOT reportable unintentional releases of 0.196 incidents per 1,000 mile-years has been used. (This baseline frequency of unintentional releases was developed earlier in Section 4.3 of this Appendix.)

4.5.2 Conditional Consequence Probabilities

In order to conduct a probabilistic analysis, the conditional probabilities of each fault tree branch must be established. For example:

- What percentage of pipe failures are relatively small leaks versus full bore ruptures?
- What percentage of vapor clouds resulting from leaks and ruptures are ignited?
- What percentages of ignited vapor clouds burn versus explode?
- And in the event of a fire or explosion, do any serious injuries or fatalities result?

In order to evaluate these conditional probabilities, the actual unintentional release data reported to the Department of Transportation, Office of Pipeline Safety (USDOT) have been evaluated. Unfortunately, the USDOT incident reports prior to January 1, 2002 did not include fields for reporting fires or explosions; these fields were added in 2002. Between January 1, 2002 and December 31, 2007, there were 520 onshore transmission pipeline incidents reported to the USDOT. The following data are worth noting:

- 91 (17.5%) of the resulting vapor clouds ignited,
- 56 (61.5%) of the vapor clouds simply burned, and
- 35 (38.5%) of the vapor clouds exploded

In other words, 10.8% of the reported onshore natural gas transmission pipeline incidents resulted in fires while 6.7% resulted in explosions. 361 (69.4%) of the incidents were identified as being released directly from the pipeline, as apposed to other appurtenances (e.g., compressors, regulators, etc.). Of these, 109 (30%) of the pipeline releases were identified as ruptures. 26 (7%) of the pipeline release incidents resulted in fires and 20 (6%) resulted in explosions.

It is interesting to note that between January 1, 2002 and December 31, 2007, 55 (10.6%) of the reported 520 natural gas transmission pipeline incidents occurred in compressor stations; –14 (25%) of these incidents resulted in fires and 10 (18%) resulted in explosions. 50 (9.6%) of the reported incidents occurred at meter and/or regulator stations; 10 (20%) of these resulted in fires and 1 (2%) resulted in an explosion. The remaining 54 incidents were not identified as to which part or component of the pipeline system failed.

The conditional probabilities used in the probabilistic risk assessment are summarized in the following tables.

Table 4.5.21.4-1 Conditional Probabilities

Parameter	Conditional Consequence Probability	Value - Source
Leak Size	Probability of Release (1-inch diameter hole)	70% - USDOT
	Probability of Rupture (complete, full diameter pipe severance)	30% - USDOT
Ignition	Probability of No-Ignition	82.5% - USDOT
	Probability of Ignition	17.5% - USDOT
Fire/Explosion	Probability of Fire Upon Ignition	61.5% - USDOT
	Probability of Explosion Upon Ignition	38.5% - USDOT

Table 4.5.21.4-2 Combined Conditional Probabilities, Fires versus Explosions

Consequence	Conditional Release Consequence	Value
Fires	Pipeline Release (1-inch) Resulting in a Fire	0.70 x 0.175 x 0.615 = 7.5%
	Pipeline Rupture Resulting in a Fire	0.30 x 0.175 x 0.615 = 3.2%
Explosions	Pipeline Release (1-inch) Resulting in an Explosion	0.70 x 0.175 x 0.385 = 4.7%
	Pipeline Rupture Resulting in an Explosion	0.30 x 0.175 x 0.385 = 2.0%

Flash Fires versus Torch Fires

The USDOT data does not provide any differentiation regarding the type of fire (torch fire versus flash fire). However, since there are a relatively large number of reported explosions in the USDOT database, it is likely that the number of flash fires is limited. There are also few historical flash fires on record (LEES). The analyses assumed that 10% of the fires would be flash fires and 90% would be torch fires.

Unignited Vapor Clouds, Flash Fires versus Indoor Explosions

Should the combustible portion of a vapor cloud migrate to nearby residences or commercial buildings before ignition, a flash fire would occur if the ignition waswere outdoors, or an explosion would occur indoors. Unfortunately, available references provide little data regarding the likelihood of these two occurrences. The analyses assumed that 90% of the fires would be flash fires and 10% would be explosions within the structures.

Table 4.5.21.4-3 Combined Conditional Probabilities, Torch Fires versus Delayed Ignition of Vapor Clouds

Consequence	Conditional Release Consequence	Value
Torch Fires	Release (1-inch) Resulting in a Torch Fire	7.5% x 0.90 = 6.8%
	Rupture Resulting in a Torch Fire	3.2% x 0.90 = 2.9%
Flash Fires (Vapor Cloud Ignition Outdoors)	Release (1-inch) Resulting in a Flash Fire	7.5% x 0.10 x 0.90 = 0.7%
	Rupture Resulting in a Flash Fire	3.2% x 0.10 x 0.90 = 0.3%
Indoor Explosion (Vapor Cloud Ignition Indoors)	Release (1-inch) Indoor Explosion	7.5% x 0.10 x 0.10 = 0.08%
	Rupture Indoor Explosion	3.2% x 0.10 x 0.10 = 0.03%

4.5.3 Release Modeling Input and Assumptions

In this section, various pipeline release scenarios are presented. The releases were modeled using CANARY, by Quest, version 4.3 software. For vapor cloud explosion modeling, this software uses the Baker-Strehlow model to determine peak side-on over-pressures as a function of distance from a release. CANARY software also uses a torch fire model to determine radiant heat flux as a function of distance from a release. Literally thousands of possible data combinations could be used to evaluate individual releases (e.g., various release angles, various size releases, etc.). However, in order to evaluate the impacts from the proposed facilities using a reasonable amount of resources, the following assumptions were made:. (It should be noted that the applicant has furnished information regarding the natural gas composition and the installation of the pipeline in a dedicated right-of-way. These changes are noted in the following table as changes to the fuel reactivity and obstacle density.)

Table 4.1.4-4 Release Modeling Input

Parameter	Model Input
Operating Pressure	975 psig maximum allowable operating pressure for all line segments
Typical Flow Rate	475 MMSCFD for 30-inch Line 406 180 MMSCFD for 30-inch Line 407W and 407E 17 MMSCFD for 10-inch DFM Line The actual flow rate will vary considerably, depending on natural gas demands, pressures in other system components, etc.
Modeled Releases	1-inch diameter release Full Bore release
Contents	Methane
Contents Temperature	70° F
Wind Speed	2 meters per second (4.5 mph) for vapor cloud explosion modeling 20 mph for torch fire modeling Note – See also Section 5.0 of this Appendix which provides an atmospheric condition sensitivity analysis.
Stability Class	D assumed Pasquill-Gifford atmospheric stability is classified by the letters A through F. Stability can be determined by three main factors: wind speed, solar insulation, and general cloudiness. In general, the most unstable (turbulent) atmosphere is characterized by stability class A. Stability A occurs during strong solar radiation and moderate winds. This combination allows for rapid fluctuations in the air and thus greater mixing of the released gas with time. Stability D is characterized by fully overcast or partial cloud cover during daytime or nighttime, and covers all wind speeds. The atmospheric turbulence is not as great during D conditions, so the gas will not mix as quickly with the surrounding atmosphere. Stability F generally occurs during the early morning hours before sunrise (no solar radiation) and under low winds. This combination allows for an atmosphere which appears calm or still and thus restricts the ability to actively mix with the released gas. A stability classification of “D” is generally considered to represent average conditions. Note – See also Section 5.0 of this Appendix which provides an atmospheric condition sensitivity analysis.
Relative Humidity	70%
Air and Surface Temperature	72° F
Continuous Release Duration	Two (2) hours, or until the pipe segment has been depressurized

Parameter	Model Input
Duration of Normal Flow after Leak Initiation	Two (2) hours for 1-inch diameter release Fifteen (15) minutes for full bore rupture The applicant has indicated that a severe pipeline rupture would be identified within 10 to 15 minutes. Line 406 could be shut-in remotely between Capay and Yolo Stations. The other line segments would require a physical response. The response could take from 15 minutes to 2 hours, depending on the location of employees and the time of occurrence. It should be noted that the applicant has agreed to install automatically actuated block valves at all locations along the line. As a result, the duration of normal flow assumed for ruptures is likely conservative.
Pipe Length Upstream and Downstream of Break	~~3-miles assumed for 30-inch diameter line segments~~ ~~1.25-miles assumed for 10-inch diameter line segment.~~ The actual pipe segment length has been used in the analysis. All releases were assumed to occur at the mid-point of each line segment.
Release Angle	Simplified Analysis - 45° above horizontal, downwind (100% of releases) Enhanced Analysis: 15° above horizontal, downwind (20% of releases) 45° above horizontal, downwind (20% of releases) Vertical (20% of releases) 45° above horizontal, upwind (20% of releases) 15° above horizontal, upwind (20% of releases)
Fuel Reactivity	Medium~~Low~~ Most hydrocarbons have medium reactivity, as defined by the Baker-Strehlow method. Low reactivity fluids include methane, natural gas (98+% methane), and carbon monoxide. The natural gas being transported is likely around 95% methane, which results in medium fuel reactivity. High reactivity fluids include hydrogen, acetylene, ethylene oxide, and propylene oxide.
Obstacle Density	Low assumed for rural, residential, commercial, and agricultural areas due to the dedicated right-of-way planned for this installation and relatively low building density around the pipeline. The low obstacle density is also appropriate because the five release angles result in an unconfined, overhead vapor cloud, except for very near the release (low obstacle density). Where the vapor cloud is located at ground level, near the release, the surroundings are relatively open along the entire pipeline alignment (low obstacle density) due to the dedicated right-of-way which will prohibit building construction very near the pipeline. Medium would normally be assumed for residential and commercial developed areas where buildings surround the pipeline, providing a reasonable degree of vapor cloud confinement. This parameter describes the general level of obstruction in the area including and surrounding the confined (or semi-confined) volume. Low density occurs in open areas or in areas containing widely spaced obstacles. High density occurs in areas of many obstacles, such as tightly-packed process areas or multi-layered pipe racks.

Parameter	Model Input
Flame Expansion	3 D assumed This parameter defines the number of dimensions available for flame expansion. Open areas are 3-D, and produce the smallest levels of overpressure. 2.5-D expansions are used to describe areas that quickly transition from 2-D to 3-D. Examples include compressor sheds and the volume under elevated fan-type heat exchangers. 2-D expansions occur within areas bounded on top and bottom, such as pipe racks, offshore platforms, and some process units. 1-D expansion may occur within long confined volumes such as hallways or drainage pipes, and produce the highest overpressures.
Reflection Factor	2 assumed This factor is used to include the effects of ground reflection when an explosion is located near grade. A value of 2 is recommended for ground level explosions.

4.5.4 Explosion Modeling Results

As discussed previously, natural gas generally does not explode, unless the vapor cloud is confined in some manner. The eastern portion of the 30-inch Line 407E and the 10-inch DFM are surrounded by residential and commercial land uses and open space. The otherremainder of the pipeline segments are surrounded by open, rural land with some road crossings. There is insufficient confinement to cause a significant vapor cloud explosion within the atmosphere in the rural, residential and agricultural areas. Should natural gas migrate into residences or other structures, the overpressures from an explosion within the confined space would be life threatening.

For an outdoor explosion resulting from a release from each of the line segments, Outdoors, the peak overpressure would bewas only 0.381.5 psig for the residential areas(medium fuel reactivity and low obstacle density), due to the relatively open development immediately around the pipeline. This overpressure level is would not be high enough to pose potentially fatal risks to the public.have a 1% probability of serious injury or fatality to occupants of reinforced concrete or reinforced masonry buildings due to flying glass and debris. There is a 10% probability of serious injuries to occupants of simple frame, unreinforced buildings. This over pressure level would generally not be great enough to cause injuries to those outdoors. For indoor explosions, the peak overpressure level would be 5.9 psig (medium fuel reactivity and high obstacle density).

~~The peak overpressure was only 0.02 psig for the rural and agricultural line segments, due to the very open surroundings and lack of confinement. This level results in an annoying noise.~~

A typical pipeline release is depicted in the figure below. This figure shows an elevation view of a downwind release from a rupture of the 30-inch Line 406, operating at 975 psig at a flow rate of 475 MMSCFD, with the release oriented at 45° above the horizon. The combustible portion of the vapor cloud is between the 5 and 15 mole percent contours. As depicted in this figure, the combustible portion of the vapor cloud is well overhead, where there would not be any confinement to cause an explosion.

Figure 4.5.4-2 Line 406, Rupture Explosion, Elevation

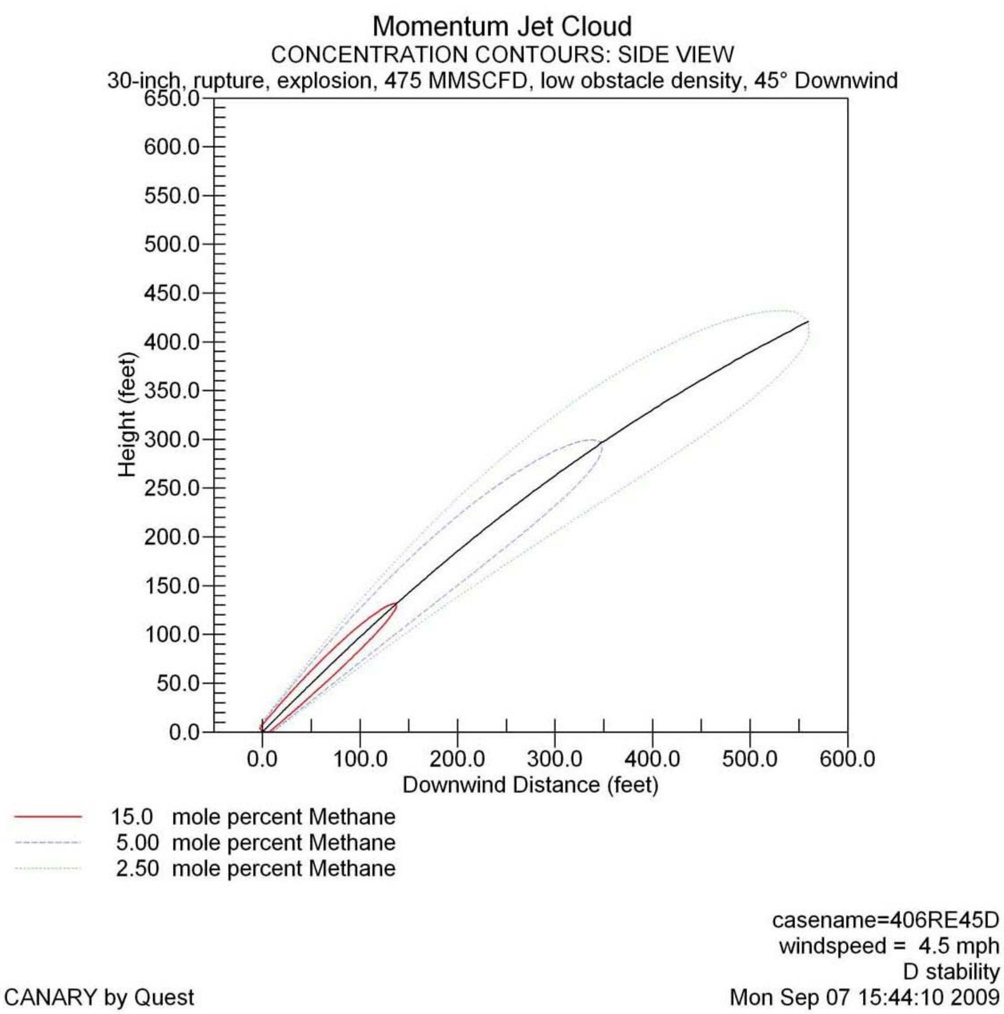


Figure 4.1.4-2 Line 406, Rupture Explosion, Elevation

The distances to various levels of peak side-on overpressures for each of the pipe segments are summarized in the table below. It is interesting to note that the results for Lines 406 and 407, which are similar except for the flow rate, are essentially the same. Also, the data for the 1-inch diameter releases are the same for all line segments, since the MAOP is the same for each segment. These explosion over-pressure levels are applicable in residential areas only. The overpressure levels are too low to result in injuries or fatalities in rural and agricultural areas.

Table 4.1.4-5 Vapor Cloud Explosion Modeling Results in Residential Areas

Release	Operating Pressure	Maximum Width of Combustible Portion of Vapor Cloud (feet)	Distance from Unintentional Release (feet) Measured Perpendicular to Pipeline		
			1.00 psig Overpressure	0.70 psig Overpressure	0.10 psig Overpressure
Line 406 475 MMSCFD Full Bore Release @ 45° above horizon	975 psig	107	381	544	3,807
Line 406 475 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	10	35	50	352
Line 407 E & W 180 MMSCFD Full Bore Release @ 45° above horizon	975 psig	105	377	538	3,771
Line 407 E & W 180 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	10	35	50	352
DFM 17 MMSCFD Full Bore Release @ 45° above horizon	975 psig	31	114	162	1,137
DFM 17 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	10	35	50	252

4.5.5 Torch Fire Modeling Results

~~Torch Fires~~

The torch fire modeling results are presented in the following tables.

Table 4.5.5-1~~1.4-6~~ Line 406 Torch Fire Modeling Results

Release Angle	Maximum Operating Pressure	Size of Release	Horizontal Distance from Unintentional Release to Endpoint Measured Perpendicular to Pipeline (feet) / Width of Exposure Measured Parallel to Pipeline (feet)		
			12,000 btu/hr-ft^2	8,000 btu/hr-ft^2	5,000 btu/hr-ft^2
15° Downwind	975 psig	Rupture	626	657	725
			500	620	850
45° Downwind	975 psig	Rupture	413	505	611
			380	560	800
Vertical	975 psig	Rupture	149	237	374
			250	420	650
45° Upwind	975 psig	Rupture	63	97	165
			240	400	620
15° Upwind	975 psig	Rupture	35	48	72
			190	320	550
15° Downwind	975 psig	1-inch	63	66	72
			54	72	92
45° Downwind	975 psig	1-inch	40	48	58
			34	50	72
Vertical	975 psig	1-inch	62	67	73
			54	70	92
45° Upwind	975 psig	1-inch	62	67	73
			56	66	92
15° Upwind	975 psig	1-inch	63	67	73
			54	70	92

Note – Radiant heat flux values shown are measured at 6-feet above ground surface.

Release	Maximum Operating Pressure	Width of 8,000 btu/hr-ft² Isopleth (feet)	Flame Length (feet)	Horizontal Distance from Unintentional Release (feet)		
				8,000 btu/hr-ft²	3,500 btu/hr-ft²	1,600 btu/hr-ft²
Line 406 475 MMSCFD Full Bore Release @ 45° above horizon	975 psig	300	527	523	734	946
Line 406 475 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	25	52	48	66	87
Line 407 E & W 180 MMSCFD Full Bore Release @ 45° above horizon	975 psig	300	523	519	728	938
Line 407 E & W 180 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	25	52	48	66	87
DFM 17 MMSCFD Full Bore Release @ 45° above horizon	975 psig	90	158	161	217	286
DFM 17 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	25	52	48	66	87

Table 4.5.5-2 Line 407 (Station 1107+00 to 1361+00) Torch Fire Modeling Results

Release Angle	**Maximum Operating Pressure**	**Size of Release**	**Horizontal Distance from Unintentional Release to Endpoint Measured Perpendicular to Pipeline (feet)** / **Width of Exposure Measured Parallel to Pipeline (feet)**		
			12,000 btu/hr-ft^2	**8,000 btu/hr-ft^2**	**5,000 btu/hr-ft^2**
15° Downwind	975 psig	Rupture	643	673	746
			520	630	880
45° Downwind	975 psig	Rupture	422	517	626
			400	580	820
Vertical	975 psig	Rupture	152	241	382
			250	420	660
45° Upwind	975 psig	Rupture	64	99	168
			260	400	660
15° Upwind	975 psig	Rupture	36	49	74
			200	320	560
15° Downwind	975 psig	1-inch	63	66	72
			54	72	92
45° Downwind	975 psig	1-inch	40	48	58
			34	50	72
Vertical	975 psig	1-inch	62	67	73
			54	70	92
45° Upwind	975 psig	1-inch	62	67	73
			56	66	92
15° Upwind	975 psig	1-inch	63	67	73
			54	70	92

Note – Radiant heat flux values shown are measured at 6-feet above ground surface.

Table 4.5.5-3 Line DFM Torch Fire Modeling Results

Release Angle	Maximum Operating Pressure	Size of Release	Horizontal Distance from Unintentional Release to Endpoint Measured Perpendicular to Pipeline (feet) / Width of Exposure Measured Parallel to Pipeline (feet)		
			12,000 btu/hr-ft^2	8,000 btu/hr-ft^2	5,000 btu/hr-ft^2
15° Downwind	975 psig	Rupture	101	205	220
			150	200	260
45° Downwind	975 psig	Rupture	135	161	195
			120	180	250
Vertical	975 psig	Rupture	51	82	121
			80	130	200
45° Upwind	975 psig	Rupture	22	34	57
			80	120	200
15° Upwind	975 psig	Rupture	25	25	25
			60	100	170
15° Downwind	975 psig	1-inch	63	66	72
			54	72	92
45° Downwind	975 psig	1-inch	40	48	58
			34	50	72
Vertical	975 psig	1-inch	62	67	73
			54	70	92
45° Upwind	975 psig	1-inch	62	67	73
			56	66	92
15° Upwind	975 psig	1-inch	63	67	73
			54	70	92

Note – Radiant heat flux values shown are measured at 6-feet above ground surface.

The results for a torch fire resulting from a full bore rupture of the 30-inch Line 406 are depicted in the figure below for a vertical release.

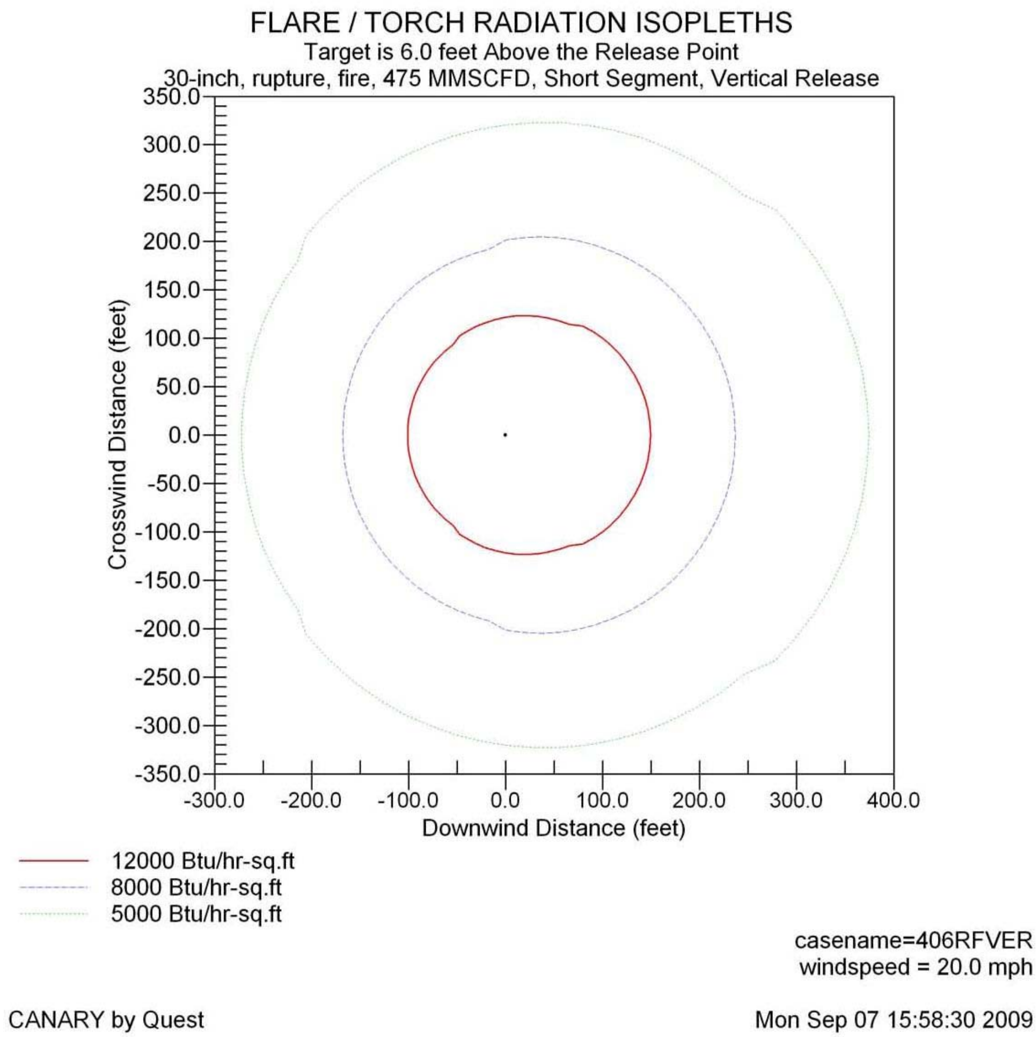


Figure 4.5.5-1 Line 406, Rupture Torch Fire, Plan

4.5.6 Flash Fire Modeling Results

As discussed previously, flash fires can occur when a vapor cloud is formed, with some portion of the vapor cloud within the combustible range, and the ignition is delayed. (If the ignition is immediate, a torch fire results.) In a flash fire, the portion of the vapor cloud within the combustible range burns quickly. It is assumed that those within the combustible portion of the vapor cloud would likely be seriously injured or killed. Those outside the combustible portion of the vapor cloud would likely be uninjured. In other words, the public would generally be safe if they were too close to the release (over rich mixture, above the upper flammable limit) or beyond the portion of the vapor cloud with concentrations below the lower flammability limit. The results of the flash fire modeling are shown in the tables which follow.below:

Table 4.5.6-11.4-7 Line 406 Flash Fire Modeling Results

Release Angle	Maximum Operating Pressure	Size of Release	Horizontal Distance from Unintentional Release to Lower Flammability Limit (feet) Measured Perpendicular to Pipeline	Width of Exposure (feet) Measured Parallel to Pipeline
15° Downwind	975 psig	Rupture	520	57
45° Downwind	975 psig	Rupture	347	56
Vertical	975 psig	Rupture	236	56
45° Upwind	975 psig	Rupture	0	0
15° Upwind	975 psig	Rupture	0	0
15° Downwind	975 psig	1-inch	49	8
45° Downwind	975 psig	1-inch	32	5
Vertical	975 psig	1-inch	4	5
45° Upwind	975 psig	1-inch	0	0
15° Upwind	975 psig	1-inch	0	0

Release	Operating Pressure	Distance from Unintentional Release (feet) Measured Perpendicular to Pipeline	
		Upper Flammability Limit (UFL)	Lower Flammability Limit (LFL)
Line 406 475 MMSCFD Full Bore Release @ 45° above horizon	975 psig	143	362
Line 406 475 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	12	32
Line 407 E & W 180 MMSCFD Full Bore Release @ 45° above horizon	975 psig	141	358
Line 407 E & W 180 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	12	32
DFM 17 MMSCFD Full Bore Release @ 45° above horizon	975 psig	41	109
DFM 17 MMSCFD 1-inch Diameter Release @ 45° above horizon	975 psig	12	32

Table 4.5.6-2 Line 407 (Station 1107+00 to 1361+00) Flash Fire Modeling Results

Release Angle	Maximum Operating Pressure	Size of Release	Horizontal Distance from Unintentional Release to Lower Flammability Limit (feet) Measured Perpendicular to Pipeline	Width of Exposure (feet) Measured Parallel to Pipeline
15° Downwind	975 psig	Rupture	534	59
45° Downwind	975 psig	Rupture	357	58
Vertical	975 psig	Rupture	141	58
45° Upwind	975 psig	Rupture	0	0
15° Upwind	975 psig	Rupture	0	0
15° Downwind	975 psig	1-inch	49	8
45° Downwind	975 psig	1-inch	32	5
Vertical	975 psig	1-inch	4	5
45° Upwind	975 psig	1-inch	0	0
15° Upwind	975 psig	1-inch	0	0

Table 4.5.6-3 Line DFM Flash Fire Modeling Results

Release Angle	Maximum Operating Pressure	Size of Release	Horizontal Distance from Unintentional Release to Lower Flammability Limit (feet) Measured Perpendicular to Pipeline	Width of Exposure (feet) Measured Parallel to Pipeline
15° Downwind	975 psig	Rupture	164	31
45° Downwind	975 psig	Rupture	108	17
Vertical	975 psig	Rupture	21	31
45° Upwind	975 psig	Rupture	0	0
15° Upwind	975 psig	Rupture	0	0
15° Dowwind	975 psig	1-inch	49	8
45° Downwind	975 psig	1-inch	32	5
Vertical	975 psig	1-inch	4	5
45° Upwind	975 psig	1-inch	0	0
15° Upwind	975 psig	1-inch	0	0

4.5.7 Risk~~s~~ Analysis Exposure Assumptions and Methodology~~to Humans~~

In order to quantify the potential risk to humans, a number of assumptions must be made; otherwise, the effort required to perform the risk analysis can become unreasonably complex. The following paragraphs outline the assumptions made in estimating the frequency and severity of the potential hazards.

Exposure Probability

In cases where the exposure to impacts only occurred on one side of the pipeline, the probability was reduced by one-half. For example, where future commercial and industrial structures are proposed on only one side of the pipeline, the probability of exposure was reduced 50%.

Proximity to Residences and Commercial Buildings

In determining the distances from the pipe segments to existing residences and commercial buildings, the nearest distance from the pipeline to each structure was used. For individuals outside the structures, the analysis assumed that they would be located near the primary building.

Exposures to Occupants of Residences and Commercial Buildings

Flash Fires and Indoor Explosions

Residential Occupants

Should the combustible portion of a vapor cloud migrate to nearby residences before ignition, a flash fire would occur if the ignition occurredwere outdoors, or an explosion would occur indoors.

The analyses assumed a 100% probability of serious injury or fatality to those exposed to a flash fire. However, those housed within their residences were assumed to be sufficiently protected from an outdoor flash fire to prevent serious injury or fatality. The analyses assumed that those protected inside a residence would be able to evacuate safely should the structure catch fire, after the flash fire subsided. The analyses assumed that occupants of these residences would be outside their homes, exposed to outdoor flash fire effects, an average of 10% of the time (roughly 17 hours per week).

In the event that natural gas were to migrate inside the structure before ignition, the analysis assumed a 100% probability of serious injury or fatality. The analyses assumed a 75% probability that occupants would be evacuated by emergency responders, or evacuate the structure on their own once they identified the gas odorant, before the gas reached a combustible mixture and ignited. The analysis assumed that occupants of these residences would be inside their homes, exposed to potential indoor explosions, an average of 70% of the time (16.8 hours per day). This results in a 17.5% probability of exposure (25% not evacuated x 70% = 17.5%).

Commercial Building Occupants

This analysis is similar to that described above for residential structures, except for the exposure duration. For a 1-inch diameter release, where the exposure width is relatively small, the analyses assumed that occupants of the commercial buildings would be outside the buildings, exposed to flash fire effects, an average of 6% of the time (roughly 10 hours per week, 2 hours per work day). For a flash fire resulting from a rupture, the width of the impact area is much larger and the likelihood of an individual being exposed is much higher. For these cases, the individual risk assessment analyses assumed an outdoor exposure of 50 hours per week (30% of the time); the societal risk assessment assumed an exposure of 6%, as this type of analysis considers the estimated number of people exposed to the hazard~~.~~; in other words, it is less likely that the maximum number of exposed individuals versus a single person would be present at a given location in the event of a rupture.

In the event that natural gas were to migrate inside the structure, the analyses assumed a 100% probability of serious injury or fatality to building occupants. The analyses assumed that occupants would be within the building 50 hours per week (30% of the time), with a 75% probability that occupants would be evacuated by emergency responders, or evacuate the structure on their own once they identified the gas odorant, before the gas reached a combustible mixture. This results in a 7.5% probability of exposure (25% not evacuated x 30% = 7.5%).

Torch Fires

Residential Occupants

The simplified individual risk analyses assumed that residents within the 8,000 btu/hr-ft^2 heat flux isopleth[4] ~~contour~~ would be exposed to a 50% probability of fatality while they are outside their homes (30 second exposure assumed). The enhanced individual risk analyses assumed that 100% of the residents exposed to 12,000 btu/hr-ft^2 heat flux would be fatally injured; 50% of those exposed to 8,000 btu/hr-ft^2 would be fatally injured, and 1% of those exposed to 5,000 btu/hr-ft^2 would be fatally injured while they are outside their homes (30 second exposure assumed). As depicted in Figure 6.0-1,

[4] An isopleth is a line on a chart or map which connects points at which a given variable has a specified constant value, in this case radiant heat flux.

presented later in this Appendix, 75% mortality was assumed between the 12,000 btu/hr-ft^2 and 8,000 btu/hr-ft^2 heat flux isopleth (average of 100% and 50% mortality); 25% mortality was assumed between the 8,000 btu/hr-ft^2. and 5,000 btu/hr-ft^2 heat flux contour (average of 50% and 1% mortality). The societal risk analyses assumed that residents within the 12,000 btu/hr-ft^2 heat flux isopleth would be exposed to a 75% probability of fatality; 25% of the residents were assumed to move away from the hazard or find protection within 30 seconds; the remaining 75% were assumed to be fatally injured.

The analyses assumed that individuals would be sheltered from injurious radiant heat impacts while inside their homes. The analyses also assumed that those protected inside their residence would be able to evacuate safely should the structure catch fire. For 1-inch diameter releases, where the exposure width is relatively small, the analyses assumed that occupants of these residences would be outside their homes, exposed to torch fire effects, an average of 10% of the time (roughly 17 hours per week). For a torch fire resulting from a rupture, the width of the impact area is much larger and the likelihood of an individual being exposed is much higher. For these cases, the individual risk assessment analyses assumed an outdoor exposure of 50 hours per week (30% of the time); the societal risk assessment assumed an exposure of 6%, as this type of analysis includes the estimated number of people exposed to the hazard; in other words, it is less likely that the maximum number of exposed individuals versus a single person would be present at a given location in the event of a rupture.

Commercial Building Occupants

This analysis is similar to that discussed above for residences. However, the analysis assumed that occupants of these buildings would be outside, exposed to torch fire effects from a 1-inch diameter release, an average of 10 hours per week (6% of the time). The individual risk analyses assumed an exposure of 30% (50 hours per week) for torch fires resulting from full bore ruptures, due to the much larger width of exposure. For the societal risk assessment, an exposure of 6% was used for both 1-inch diameter and full bore releases.

Explosions

The analysis assumed a 10% probability of a serious injury or fatality to building occupants exposed to an over-pressure level of 1.00 psig due to flying glass and debris. As described above, residential buildings were assumed to be occupied 70% of the time

(16.8 hours per day) and commercial buildings were assumed to be occupied 30% of the time (50 hours per week). However, as noted earlier, the peak overpressure levels from this project are anticipated to be only 0.38 psig, due to the lack of confinement. As a result, fatalities resulting from explosions are not anticipated from the proposed project. The overpressure levels are expected to be well below the threshold required to cause serious injuries or fatalities to those outdoors.

Exposures to Vehicle Occupants

Flash Fires

There is little actual or experimental data available for natural gas flash fires. Based on a full bore release at 45° above the horizon at the modeled conditions, the flammable concentration of the vapor cloud would be less than 100-feet wide in all of the modeled scenarios (measured perpendicular to the release). A vehicle traveling at 40 miles per hour perpendicular to the release would only be within the flammable portion of the vapor cloud for about two seconds, unless the vehicle were stopped (e.g., red light, traffic jam, etc.).

Considering the variety of possible release angles, the likely short duration of exposure, and the protection afforded by the vehicle, these analyses assumed that 10% of the occupants of vehicles exposed to the modeled maximum horizontal projection of a flash fire resulting from a pipeline release would be seriously injured or killed.

It should be noted that 100% casualties are assumed for similar analyses used in the United Kingdom. However, there is evidence that those exposed to flash fires can survive. Although natural gas flash fires are rare, an event occurred on October 1982 which is noteworthy. This event is noted in the Report on a Study of International Pipeline Accidents (HSE 2000). In this case an end cap blew off the end of a natural gas pipeline in Pine Bluff, Arkansas. The ignition of the resulting gas cloud was delayed, until the flammable portion of the cloud reached a nearby welding machine. As stated in the report, “All seven persons at the accident site were engulfed in the flash-fire. The two welder-helpers, who were wearing goggles but not welding helmets, and the two company employees standing atop the ditch at the east and south end were placed in intensive care at a local hospital. Another worker on top of the ditch was admitted to the hospital in a serious but stable condition. The two welders, who were under the pipe when the fire erupted and were more sheltered from the fire, were treated and released from the hospital… While none of the workmen were killed, they were not representative of the population as a whole; they were relatively young, fit and wearing working clothes. Children or the elderly (perhaps 50% of the population), or those wearing less protective clothing in a similar fire would probably not have survived."

Torch Fires

Because the exposure time to passing vehicles would be limited, the analyses assumed that occupants in passing vehicles would be somewhat protected from the radiant heat due to torch fires. The societal risk analyses assumed that serious injuries and fatalities would only occur to those exposed directly to the flame or those within the 128,000 btu/hr-ft^2 isopleth. ~~For a full bore rupture, this extends about 520 feet for the 30-inch line segments and 160 feet for the 10-inch line segment. For a 1-inch diameter release, it extends about 50 feet. It should be noted that the flame lengths and distances to the 8,000 btu/hr-ft^2 are essentially the same.~~ Due to the variation in the possible release angles (e.g., the flame may be vertical, or pass above the vehicle) and the possibility for vehicle occupants to pass through the hazard area relatively quickly, the societal risk analyses assumed a 1025% probability of serious injury or fatality ~~was assumed~~.

Explosions

The peak overpressures resulting from atmospheric explosions are not anticipated to be sufficient to cause serious injuries or fatalities in areas where residential and commercial development have occurred. However, traffic can create some degree of confinement. The societal risk assessment conservatively assumed a ~~A~~ 10% probability of fatality to those exposed to an explosion.~~rate has been assumed.~~

Number of Vehicle Occupants Exposed to Release

The analysis estimated the number of individuals exposed as follows:

- The traffic counts were obtained from Section 4.13X of the Final EIRis document. For roadways where traffic counts were not available, they were assumed as follows: For un-named county roads along each segment, 200 trips per day average was assumed. For roads along Line DFM, 500 trips per day average were assumed. For roads along Phase I of Line 407, 1,000 trips per day average were assumed. For rural highways along Phase II of Line 407, 1,000 trips per day average were assumed.
- An average traffic speed of 40 miles per hour was used, except for I-5 and Highway 505, which assume 70 miles per hour.

- The length of hazard, measured along the roadway, was determined individually for each type of release by modeling.
- The normal stopping distance was determined using a one second reaction time and 15 feet per second rate of deceleration.
- An average vehicle occupancy of 1 was assumed for individual risk and 2 for societal risk.

~~For the individual risk analysis, if the above calculation yielded a number greater than unity, the number exposed was reduced to one individual, consistent with the definition of the individual risk analysis.~~

~~4.5.7 Individual Risks~~

~~Exposures to Occupants of Residences and Commercial Buildings~~

~~In the following paragraphs, the impacts (e.g., serious injuries and fatalities) have been evaluated for individuals exposed to a fire or explosion. For Line 406, the impacts were assessed considering the existing buildings only; future land development was not considered in the analysis. For Line 407 and Line DFM, the existing conditions, plus the impacts of the following proposed land development projects were considered: Sutter Pointe, Placer Vineyard, Sierra Vista, and Curry Creek. The lengths of pipeline that could result in serious impacts the public are summarized in the table below, for each of the identified conditions.~~

~~Table 4.1.4-8 Length of Pipeline Posing Risks to Building Occupants~~

~~Release Description~~	~~Significant Impact Distance from Release (feet)~~	~~Line 406 (feet)~~	~~Line 407 Phase I (feet)~~	~~Line 407 Phase II (Feet)~~	~~Line DFM (feet)~~
	~~Lines 406/407~~				
	~~Line DFM~~				
~~Explosion Full Bore Rupture~~	~~380~~	~~3,650~~	~~58,455~~	~~15,655~~	~~5,100~~
	~~115~~				
~~Explosion 1-inch Release~~	~~35~~	~~60~~	~~47,910~~	~~0~~	~~5,100~~
	~~35~~				

Torch Fire Full Bore Rupture	520 160	4,930	59,350	21,545	5,100
Torch Fire 1-inch Release	50 50	120	48,270	800	5,100
Flash Fire Full Bore Rupture	360 110	3,435	58,455	15,565	5,100
Flash Fire 1-inch Release	35 35	60	47,910	0	5,100

Note: For Line 407, Phase I, the distribution was assumed to be roughly 50% residential

As noted above, only a relatively short distance of Line 406 would pose a risk to occupants of existing residences. However, for the eastern portion of the project (Line 407 Phase I), much more of the line would pose a risk to occupants of existing and proposed residences and commercial properties. The resulting frequencies of anticipated serious injuries and fatalities to occupants of residential, commercial, and industrial buildings are summarized in the table below.

Table 4.1.4-9 Frequency of Serious Injury or Fatality to Building Occupants

Release Description	Line 406	Line 407 Phase I	Line 407 Phase II	Line DFM	Total
Explosion Full Bore Rupture	1.9×10^{-7}	2.2×10^{-6}	8.2×10^{-7}	5.7×10^{-8}	3.3×10^{-6}
Explosion 1-inch Release	7.4×10^{-9}	4.2×10^{-6}	0	1.3×10^{-7}	4.3×10^{-6}
Torch Fire Full Bore Rupture	8.0×10^{-7}	9.6×10^{-6}	3.5×10^{-6}	4.1×10^{-7}	1.4×10^{-5}

~~Torch Fire 1-inch Release~~	~~4.5×10^{-9}~~	~~1.5×10^{-6}~~	~~3.0×10^{-8}~~	~~5.8×10^{-8}~~	~~1.6×10^{-6}~~
~~Flash Fire Full Bore Rupture~~	~~4.4×10^{-8}~~	~~1.4×10^{-6}~~	~~2.0×10^{-7}~~	~~8.5×10^{-8}~~	~~1.7×10^{-6}~~
~~Flash Fire 1-inch Release~~	~~1.8×10^{-9}~~	~~1.1×10^{-6}~~	~~0~~	~~4.4×10^{-8}~~	~~1.1×10^{-6}~~
~~Total Probability Serious Injury or Fatality~~	~~1.05×10^{-6}~~	~~1.99×10^{-5}~~	~~4.54×10^{-6}~~	~~7.00×10^{-7}~~	~~2.62×10^{-5}~~
~~Annual Likelihood of Serious Injury or Fatality~~	~~1 : 950,000~~	~~1 : 50,000~~	~~1 : 220,000~~	~~1 : 1,400,000~~	~~1 : 26,000~~
~~Percentage of Total Risk to Building Occupants~~	~~4.0 %~~	~~76.0 %~~	~~17.3 %~~	~~2.7 %~~	~~100.0 %~~

~~As noted a above, the frequency of serious injuries and fatalities caused by explosion for Lines 406, 407 (Phase II), and DFM are extremely low, due to the rural areas where the majority of these lines are being installed. Line 407 (Phase I) poses 76% of the total project risk to occupants of residential, commercial, and industrial buildings, due to the density of existing and planned land development.~~

~~Exposure to Vehicle Occupants~~

~~The risks posed to vehicle occupants are summarized in the table below, for each of the line segments.~~

~~Table 4.1.4-10 Frequency of Serious Injury or Fatality to Vehicle Occupants~~

~~Description~~	~~Line 406~~	~~Line 407 Phase I~~	~~Line 407 Phase II~~	~~Line DFM~~	~~Total~~

Total Probability of Serious Injury or Fatality	1.84×10^{-6}	2.94×10^{-5}	3.21×10^{-6}	2.06×10^{-7}	3.46×10^{-5}
Annual Likelihood of Serious Injury or Fatality	1 : 540,000	1 : 34,000	1 : 310,000	1: 4,900,000	1 : 29,000
Percentage of Total Risk to Building Occupants	5.3 %	84.9 %	9.2 %	0.6 %	100.0 %

It should be noted that the figures presented in the above table somewhat understate the likelihood of risks posed to vehicle occupants. As noted earlier, the length of hazard, measured along the roadway, was determined individually for each type of release; the exposures were calculated using the traffic speed, stopping distance, traffic volume, and the length of actual exposure to the hazard. For example, for a rural county road with an assumed traffic count of 200 trips per day, 40 miles per hour average traffic speed, 232-foot stopping distance, and a potentially hazardous cloud distance of 520-feet, the individual exposure was determined to be 0.03. In other words, given these parameters, the likelihood of an individual vehicle occupant being exposed to the hazard was 3%. However, for unignited vapor clouds, a passing vehicle is often the source of ignition. In these cases, the actual exposure to vehicle occupants would be 100%. Unfortunately, data is not available to support an accurate determination of the frequency in which motorists are the source of ignition. For scenarios with higher traffic counts, greater average traffic speed, etc., the error induced by this methodology is reduced or is eliminated altogether; for example, the likelihood of exposure along many of the heavily traveled roadways (e.g., Baseline Road, Interstate 5, etc.) was 1.00 (100%) for many of the release scenarios. In these cases, the results would not be affected whether the vehicle was the source of ignition, or not.

4.5.8 Individual Risk Results Simplified Methodology

The individual risk for each of the three project components has been determined using the same methodology that was used to determine the aggregate risk presented in Section 4.1.4 of Appendix H-3 of the Final EIR. (It should be noted that this aggregate risk was incorrectly identified as individual risk in the Final EIR.) The Final EIR analysis was simplified by making the following assumptions:

- A single release angle at 45° above the horizon was used.
- All releases were assumed to be oriented downwind, which resulted in the worst case impact footprint (e.g., greatest length of exposure measured perpendicular to the pipeline).
- For flash fire impacts which were located overhead, the horizontal extent of the hazard was projected to grade level. This results in some overstatement of the impact since an overhead flash fire would not normally impact those on the ground. However, if the release angle were lower that the single 45° release angle assumed, the flash fire could impact those at ground level.

These simplifying assumptions greatly reduced the amount of release modeling required to perform the analysis. As discussed in the following section of this Appendix, the individual risk is slightly lower using this simplified approach very close to the pipeline and at large distances from the pipeline. This is due to the fact that the releases posing 100% mortality near the pipeline and 1% mortality at some distance from the pipeline were not included in the simplified analysis. However, the risk using the simplified methodology is higher between these values, because all of the releases were assumed to result in 50% mortality. Although these differences are noteworthy, they do not appreciably affect the results.

The individual risks posed by Lines 406, 407 and DFM are shown in the following figures. These figures present risk transects which show the annual risk of fatality resulting from a pipeline release as a function of the downwind distance from the pipeline, measured perpendicular to the pipeline. (The upwind distances would be much less.) The results are shown for the pipe segments both before and after mitigation. It should be noted that these data are based on the continuous presence of a person at a specific location (24 hours per day, 365 days per year), consistent with the definition of individual risk presented in the Section 3.1 of this Appendix. It should also be noted that the highest risks are posed directly over the pipelines, as shown in Figures 4.5.8-1, 4.5.8-2 and 4.5.8-3. These maximum annual individual risks of fatality are summarized below:

- Line 406 Annual Maximum Individual Risk of Fatality (Directly Over Pipeline)

  Pre Mitigation - 3.94×10^{-7} (1 : 2,538,000)

  Post Mitigation - 1.97×10^{-7} (1 : 5,076,000)

- Line 407 Annual Maximum Individual Risk of Fatality (Directly Over Pipeline)

  Pre Mitigation - 3.83x10^{-7} (1 : 2,610,000)

  Post Mitigation - 1.92x10^{-7} (1 : 5,220,000)

- Line DFM Annual Maximum Individual Risk of Fatality (Directly Over Pipeline)

  Pre Mitigation - 1.61x10^{-7} (1 : 6,219,000)

  Post Mitigation - 8.04x10^{-8} (1 : 12,440,000)

Figure 4.5.8-1 Line 406 Individual Risk

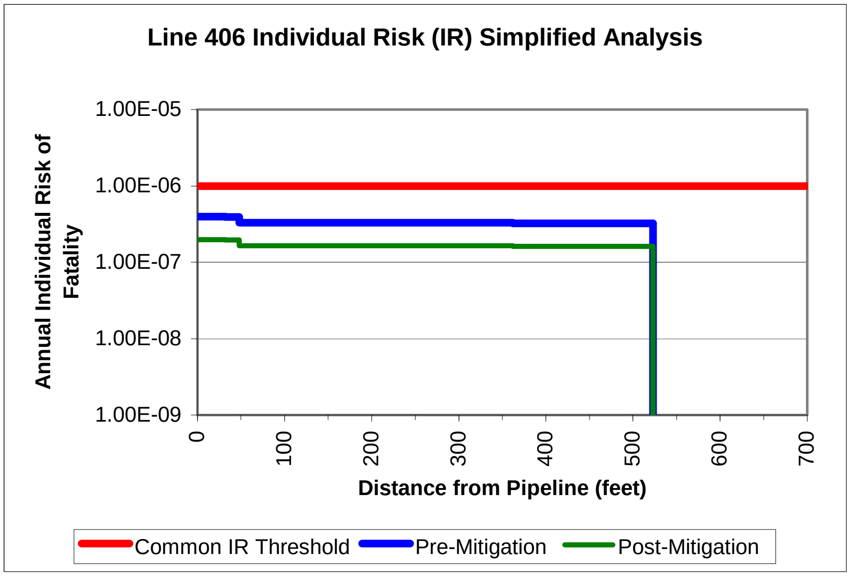
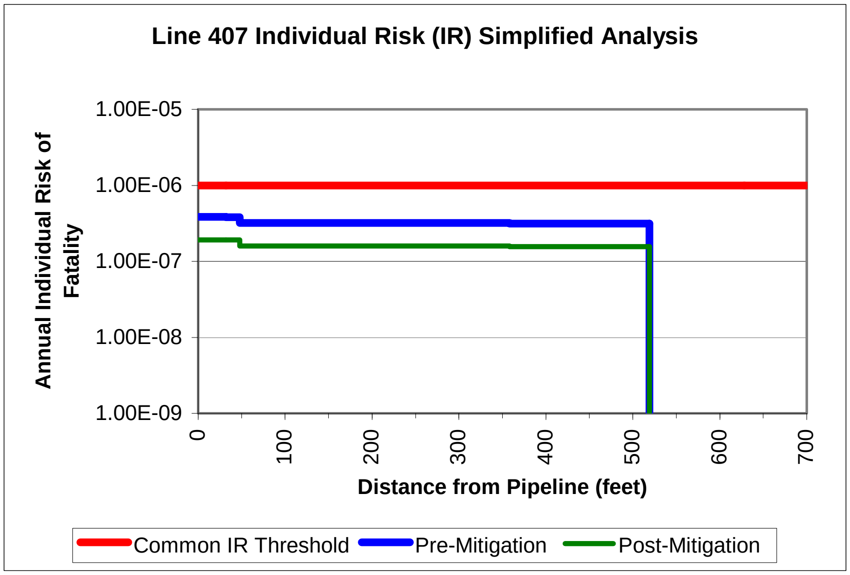
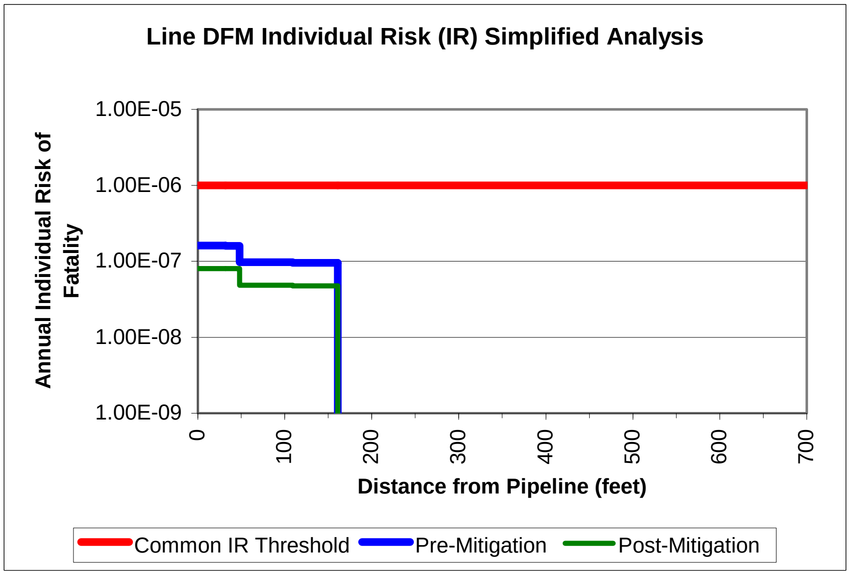


Figure 4.5.8-2 Line 407 Individual Risk



Note – The analysis results depicted above assumed a typical segment of Line 407. The line segment was six (6) miles in length, with a block valve located three (3) miles on either side of the release.

Figure 4.5.8-3 Line DFM Individual Risk



As indicated in the figures above, the individual risks for each of the three pipe segments fall below the individual risk threshold of 1 : 1,000,000. The highest values are experienced directly over the pipe. The risk levels decrease as the distance from the pipeline increases. The risk level for the Line 406 and 407 segments are essentially the same; they differ only slightly, due to the differing flow rates and segment lengths (475,000,000 standard cubic feet per day for Line 406 and 180,000,000 standard cubic feet per day for Line 407). The impact distances for Line DFM are much shorter, due to the smaller pipe diameter and the much lower mass flow rate in the event of a rupture. However, the required pipe diameter is a function of the required flow rate and the pressure drop within the line. As a result, simply reducing the pipe diameter to reduce the impact distances is not a feasible alternative.

The flow rate through a pipeline can be evaluated using the Weymouth formula; the flow rate is proportional to the pipe diameter to the 2.667 power ($D^{2.667}$). To achieve the same flow rate as a 30-inch diameter line, nineteen (19) 10-inch diameter lines would be required to flow the same volume of gas under the same operating conditions.

4.5.9 Individual Risk Results Enhanced Methodology

As noted previously, the analysis presented in the Final EIR, and in the prior Section 4.5.8 of this document, used a single release angle at 45° above the horizon for all release scenarios (e.g., vapor cloud explosions, flash fires and torch fires). The 45° release angle was used in the simplified analysis because it represents a reasonable average release. However, it does not create the worst case situation; a horizontal release normally results in the greatest impact distances. Also, the simplified analysis assumed that all releases were oriented downwind, which resulted in the worst case impact footprint (e.g., greatest length of exposure measured perpendicular to the pipeline). Finally, the simplified analysis used only a single endpoint for torch fire modeling, which accounted for roughly ninety-nine percent (99%) of the overall individual risk. The enhanced analyses included the following additional release modeling.

- Five different release angles were considered: 15° above the horizon downwind, 45° above the horizon downwind, vertical, 45° above the horizon upwind, and 15° above the horizon upwind. (Because the pipeline is buried, 15° above the horizon was assumed to be the lowest feasible release angle.) Twenty percent (20%) of the releases were assumed to be directed at each of these angles.

- The Final EIR used a single end point for torch fire impacts, 50% mortality at 8,000 btu/hr-ft^2 for a 30 second exposure. The enhanced analyses included three torch fire end points – 100% mortality at 12,000 btu/hr-ft^2, 50% mortality at

8,000 btu/hr-ft^2, and 1% mortality at 5,000 btu/hr-ft^2 for 30 second exposures. (CDE 2007)

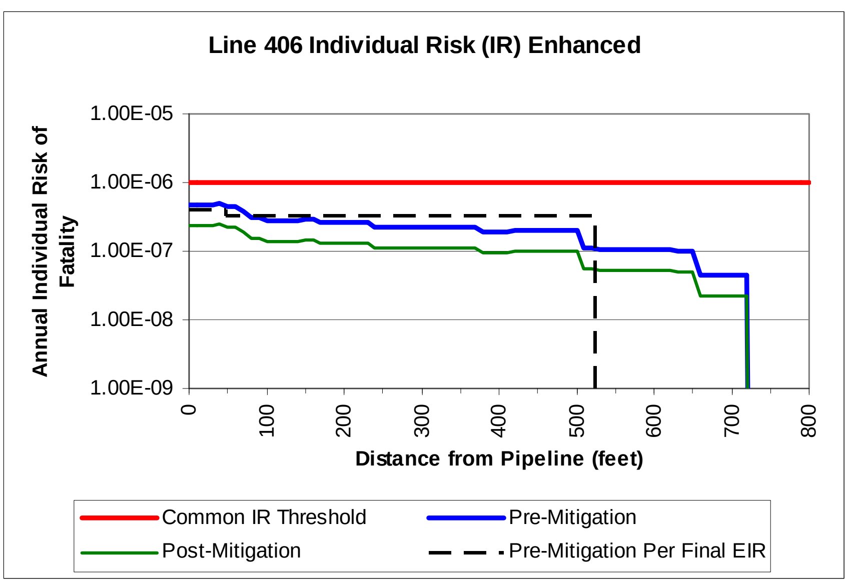
Line 406

Line 406 would be 30-inches in diameter, 13.9 miles long, would operate at 975 psig at a flow rate of 475 million standard cubic feet per day. There would not be any intermediate block valves within this segment; but an automatically actuated valve would be installed at each end (Capay Station and Yolo Junction Station). The maximum individual risk values posed by this line segment are summarized below. These individual risks would be posed to a person located directly over the pipeline. As the distance from the pipeline increases, the individual risk would be reduced.

- Pre Mitigation Annual Maximum Individual Risk of Fatality - 4.68x10^{-7} (1 : 2,137,000)
- Post Mitigation Annual Maximum Individual Risk or Fatality - 2.34x10^{-7} (1 : 4,274,000)

The individual risk for this line segment, using the enhanced methodology is presented in the risk transect depicted in the following figure.

Figure 4.5.9-1 Line 406 Individual Risk, Enhanced Analysis



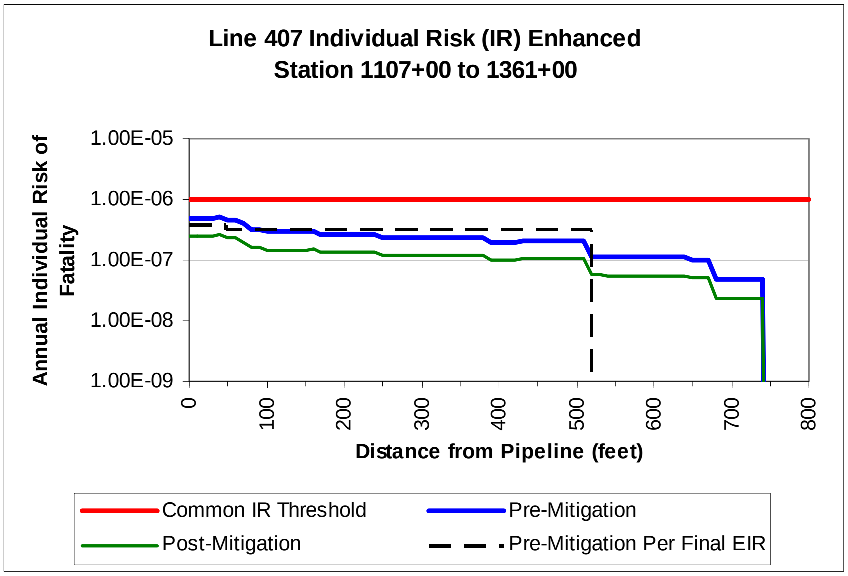
The dashed black line overlays the results using the methodology used in the Final EIR, presented in the preceding section of this Appendix. As indicated, the individual risk is slightly higher using the enhanced approach very close to the pipeline and beyond about 520-feet. This is due to the fact that the releases posing 100% mortality near the pipeline and 1% mortality at some distance from the pipeline were not included in the earlier analysis. However, the risk using the simplified methodology is higher between these values, because all of the releases were assumed to result in 50% mortality. Although these differences are noteworthy, they do not appreciably affect the results.

The annual individual risk of fatality posed by Line 406 is less than the 1 : 1,000,000 threshold used by some jurisdictions.

Line 407

Line 407 would be 30-inches in diameter, 26.0 miles long, would operate at 975 psig at a flow rate of 180 million standard cubic feet per day (mmscfd). There would be three intermediate block valves within this segment, located at Stations 752+00, 1107+00, and 1361+00. These intermediate block valves would be automatically actuated in accordance with the proposed project mitigation. These automatic block valves result in the following segment lengths along Line 407 – 14.2 miles, 6.7 miles, 4.8 miles, and 0.3 mile. The individual risk for the 4.8 mile long segment between Station 1107+00 to 1361+00 is presented in the individual risk transect depicted in the following figure.

Figure 4.5.9-2 Line 407 (Station 1107+00 to 1361+00) Individual Risk, Enhanced Analysis



The maximum individual risk values posed by this line segment for an individual located directly over the pipeline are summarized below:

- Pre Mitigation Annual Maximum Individual Risk of Fatality - 4.85×10^{-7} (1 : 2,062,000)
- Post Mitigation Annual Maximum Individual Risk of Fatality - 2.43×10^{-7} (1 : 4,115,000)

This segment was selected for modeling because it was the shortest (other than the extremely short 0.3 mile segment) and was located in the vicinity of three of the four proposed subdivisions, which are in various stages of planning. For the very short segment of line 407, the risk would be less than shown in Figure 4.5.9-2. For the longer line segments of Line 407, the risk would be in between that shown for this segment of Line 407 and the risk depicted earlier for the longer line Line 406, which are essentially the same.

As indicated above, the individual risk directly over this Line 407 pipeline segment is slightly more than for Line 406 (roughly 4% more). This variation is due to a combination of the lower flow rate (180 mmscfd versus 475 mmscfd) and the shorter length of the line segment (4.8 miles versus 13.9 miles). In this case, the shorter line length, even though it has a lower flow rate, allows the compressed gas to escape faster than it would for the longer line segment, due to the reduced pipe friction losses; this results in a slightly higher mass flow release rate and slightly longer torch fire impact. However, this situation depends on the segment length; if the segment were much shorter, the risk directly over the line would be lower. For example, a one mile line segment would have an individual risk directly over the line roughly twenty percent (20%) lower than that depicted in Figure 4.5.9-2.

Also, the maximum downwind distance to torch fire impacts extend slightly longer for Line 407 than for line 406 (about 746 feet for Line 407 versus about 725 feet for Line 406). This is due primarily to the shorter segment length, which yields a slightly higher mass flow rate in the event of a pipeline rupture.

The annual individual risk of fatality posed by Line 407 is less than the 1 : 1,000,000 threshold used by some jurisdictions.

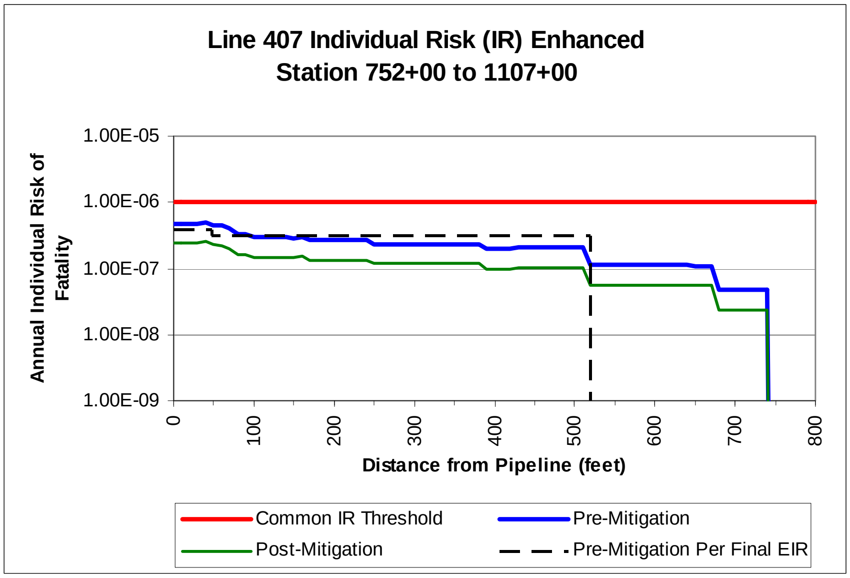
Planned Developments

The individual risks near each of the planned future developments (e.g., Sutter Pointe, Placer Vineyard, Sierra Vista, and Curry Creek) are presented in the following paragraphs. As indicated, The annual individual risk of fatality posed by Line 407 to each of these developments is less than the 1 : 1,000,000 threshold.

Sutter Pointe

The Sutter Pointe development is shown on the Sutter Pointe Specific Plan. The development would be located on the north and south sides of Riego Road, on either side of Highway 99/70. The total frontage along Riego Road would be roughly 4.2 miles. The Sutter Point development is proposed between Stations 752+00 and 1107+00 of Line 407; the individual risk along this segment is presented in the following figure. The pre-mitigation individual risk of fatality is 4.81×10^{-7} per year for this line segment (1 : 2,100,000). This risk is below the significance threshold of 1.0×10^{-6} (1 : 1,000,000) used by some jurisdictions. The post mitigation individual risk of fatality is 2.40x10-7 per year (1 : 4,200,000).

Figure 4.5.9-3 Line 407 (Station 752+00 to 1107+00) Individual Risk, Enhanced



Placer Vineyards, Curry Creek and Sierra Vista

The Placer Vineyards and Curry Creek developments, as well as the majority of the Sierra Vista development, are located between Stations 1107+00 to 1361+00 of Line 407; Figure 4.5.9-2 presents the individual risk along this segment. (Please reference Exhibit 2-7 of the Revised Final EIR which shows the locations of the proposed block valves.)

The Placer Vineyard development is shown on the Placer Vineyards Land Use Specific Plan. The development would be located on the south side of Baseline Road, on either side of Watt Avenue. The total frontage along Baseline Road would be 5.1 miles. It should be noted that there are two horizontal directionally drilled (HDD) crossings planned within this segment. These crossings would place the pipeline well below the depths that would normally be exposed to third party damage. The mitigation proposed in the Final EIR was intended to reduce the likelihood of third party incidents by one-third. The deeper installation depths will undoubtedly further reduce the likelihood of third party incidents; however the extent is largely unknown.

The Curry Creek development is shown on the Regional University Specific Plan. The development would be located on the north side of Baseline Road, between South Brewer Road and Watt Avenue. In the absence of specific identified land uses within the development, 50% residential and 50% commercial development have been assumed.

The Sierra Vista development is shown on the Sierra Vista Land Use Map. The development would be located on the north side of Baseline Road, west of Fiddymont Road. The total frontage along Baseline Road would be roughly 2.4 miles.

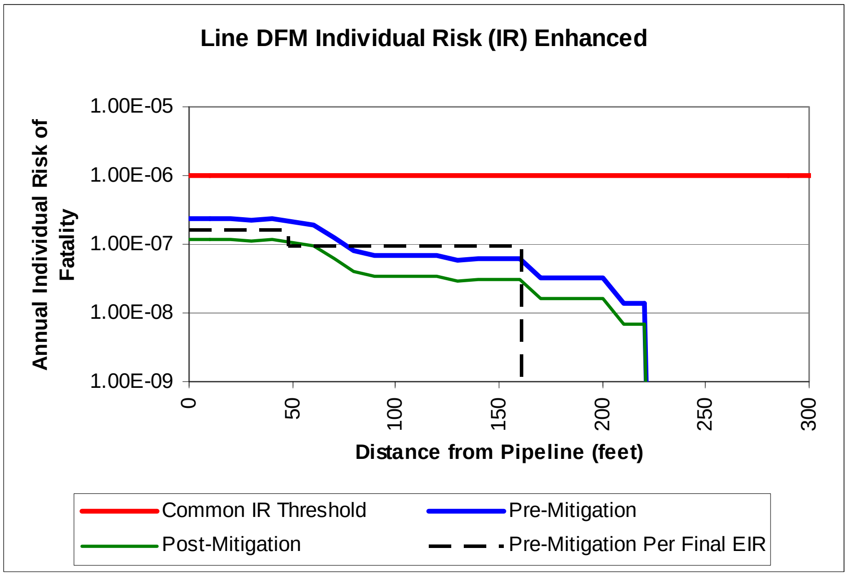
The pre-mitigation individual risk of fatality is $4.85x10^{-7}$ per year for this line segment (1 : 2,060,000). This risk is below the significance threshold of $1.0x10^{-6}$ (1 : 1,000,000) used by some jurisdictions. The post mitigation individual risk of fatality is $2.42x10^{-7}$ per year (1 : 4,120,000).

Line DFM

Line DFM would be 10-inches in diameter, 2.44 miles long, and would operate at 975 psig at a flow rate of 17 million standard cubic feet per day (mmscfd). There would not be any intermediate block valves within this segment. The maximum individual risk values posed by this line segment are summarized below; the individual risk for this line segment is presented in the individual risk transect depicted in the following figure.

- Pre-Mitigation Annual Maximum Individual Risk of Fatality - $2.35x10^{-7}$ (1 : 4,255,000)
- Post Mitigation Annual Maximum Individual Risk of Fatality - $1.18x10^{-7}$ (1 : 8,475,000)

Figure 4.5.9-4 Line DFM Individual Risk, Enhanced Analysis



The risk and impact distances are reduced for this smaller diameter line which has a lower flow rate and much lower stored volume of natural gas. In the event of a rupture, the mass flow rate and resulting size of the flash or torch fires are less than those for the 30-inch segments of Lines 406 and 407.

The annual individual risk of fatality posed by Line DFM is less than the 1 : 1,000,000 threshold used by some jurisdictions.

~~Individual Risk Results~~

~~The total exposure to the public from the various pipe segments is summarized in the table below.~~

~~Table 4.1.4-11 Individual Risk Summary~~

~~Release Description~~	~~Line 406~~	~~Line 407 Phase I~~	~~Line 407 Phase II~~	~~Line DFM~~	~~Total~~
~~Building Occupants~~	~~1.05×10^{-6}~~	~~1.99×10^{-5}~~	~~4.54×10^{-6}~~	~~7.00×10^{-7}~~	~~2.62×10^{-5}~~

Vehicle Occupants	1.84×10^{-6}	2.94×10^{-5}	3.21×10^{-6}	2.06×10^{-7}	3.46×10^{-5}
Total Probability of Serious Injury or Fatality	2.89×10^{-6}	4.93×10^{-5}	7.75×10^{-6}	9.06×10^{-7}	6.08×10^{-5}
Total Annual Likelihood of Serious Injury or Fatality	1 : 350,000	1 : 27,000	1 : 130,000	1: 1,100,000	1 : 16,000
Percentage of Total Risk to Building Occupants	4.8 %	81.1 %	12.7 %	1.4 %	100.0 %

As presented above, the anticipated individual frequency of serious injury or fatality from the proposed project is is approximately 6.1×10^{-5}. This represents a 1:16,000 likelihood of a serious injury or fatality annually. This value is roughly sixty times greater than the generally accepted significance criteria of one in one-million per year (1:1,000,000). As a result, the individual risk posed by the proposed project is considered significant. The individual risks posed by each of the individual line segments are also summarized. As noted, the risk for each of the individual line segments, except Line DFM, exceeds the individual risk significance criteria; and for the Line DFM, the individual risk significance is within the tolerance of the assumptions made in this study and should be considered significant.

It should be noted that this analysis was done based on the existing and stated future level of land development. Should population density or traffic volumes increase over the life of the project beyond these assumptions, the resulting likelihood of serious injuries and fatalities would increase accordingly.

4.5.10 Societal Risks

Societal risk is the probability that a specified number of people will be affected by a given event. The accepted number of casualties is relatively high for lower probability events and much lower for more probable events.

Exposures to Occupants of Residences and Commercial Buildings

The following scenarios were considered:

- Flash Fire or Indoor Explosion, 1-inch Diameter Pipeline Release – These impacts could be significant within about 5035 feet of the proposed line segments. (Reference Tables 4.5.6-1 through 4.5.6-3.) Roughly 4.5 miles of the Line 407, Phase I line segment could pose a hazard to existing or proposed buildings. The width of the vapor cloud within the combustible mixture would be less than roughly 10-feet. As a result, only one structure would likely be exposed. The analysis assumed that one residence or one commercial structure could be affected by a release. A population of up to four per residence and up to ten individuals per commercial building was used.

- Flash Fire or Indoor Explosion, Full Bore Pipeline Release – These impacts could be significant within 164110-feet for Line DFM and 530360-feet for Lines 406 and 407. The width of exposure extends roughly 30-feet for Line DFM and 60100-feet for Lines 406 and 407. (Reference Tables 4.5.6-1 through 4.5.6-3.) Roughly 5.6 miles of the Line 407, Phase I line segment could pose a hazard to existing or proposed buildings. The analyses assumed that one commercial building or one residence could be impacted, with an exposure of up to ten persons (commercial) or four persons (residential).

- Torch Fire, 1-inch Diameter Pipeline Release – These impacts were assumed to could be significant within 6350-feet of the proposed line segments (128,000 btu/hr-ft^2 isopleth). The 12,0003,500 btu/hr-ft^2 isopleth extends about 6365-feet for each of the proposed line segments. The width of the 3,500 btu/hr-ft^2 isopleth is roughly 80-feet, while the width of the 128.000 btu/hr-ft^2 isopleth is roughly 5480-feet. (Reference Tables 4.5.5-1 through 4.5.5-3.) Roughly 4.6 miles of the Line 407, Phase I line segment could pose a hazard to existing or proposed buildings. The analysis assumed that one residence or one commercial structure could be affected by a release. A population of up to four per residence and up to ten individuals per commercial building was used.

- Torch Fire, Full Bore Release – These impacts could be significant within 101160-feet for Line DFM and 643520-feet for Lines 406 and 407. The 3,500 btu/hr-ft^2 isopleth extends about 150-feet and 500-feet on either side of the release, measured perpendicular to the release, for Line DFM and Lines 406 and 407 respectively. The 128,000 btu/hr-ft^2 isopleth extends about 7590-feet and 260300-feet on either side of the release, for Line DFM and Lines 406 and 407 respectively. (Reference Tables 4.5.5-1 through 4.5.5-3.) For Lines 406 and 407, the analysis assumed that up to sixten residences (four occupants each) and up to two commercial buildings (ten occupants each) could be affected. For Line DFM, the analysis assumed that up to two residences and one commercial structure could be affected.

- Explosion, 1-inch Diameter Pipeline Release –– The overpressure level is less than 1.00 psig. As a result, explosion impacts are not expected to result in public fatalities. These impacts could be significant within 35 feet from each of the line segments. The analysis assumed that one residence or one commercial structure could be affected by a release. A population of up to four per residence and up to ten individuals per commercial building was used.

- Explosion, Full Bore Pipeline Release - The overpressure level is less than 1.00 psig. As a result, explosion impacts are not expected to result in public fatalities. These impacts could be significant within 55-feet of Line DFM and 380-feet of Lines 406 and 407. A width of exposure to a 1 psig pressure level of 400-feet was assumed for Lines 406 and 407, resulting in up to four residences, housing four individuals per residence and up to two commercial buildings, with 10 occupants each. A population of one residence (four occupants) or one commercial building (ten occupants) was used for Line DFM.

Exposures to Vehicle Occupants

The societal risk analysis for potential impacts to vehicle occupants used the same methodology as outlined earlierabove for the individual risk. However, an average occupancy of two occupants per vehicle was used, instead of one occupant per vehicle for the individual risk analysis.

Societal Risk Results

Selected results of the societal risk analyses are presented below. The items presented are the cases that resulted in the highest ratio of site casualties to the societal risk criteria. In other words, these cases are those that presented the risks closest to the stated significance criteria. As indicated, the ratio of site casualties to the societal risk criteria is less than 1.0 for each situation. As a result, the societal risk is not considered significant, using the stated societal risk criteria; the number of anticipated site casualties is less than the societal risk criteria corresponding to the exposure probability.

For example, the probability of a rupture torch fire from Line 407 (Phase I) is 9.6e-06 per year. Based on the societal risk criteria (SRC), 23 people would need to be seriously injured or killed before this incident would be considered significant because the likelihood is relatively low. Should this type of incident occur, the analysis indicates that the number of site casualties (SC) would be 182. The resulting SC/SRC ratio is 0.7953. Since this value is less than 1.00, the societal risks posed by this scenario is not considered significant.

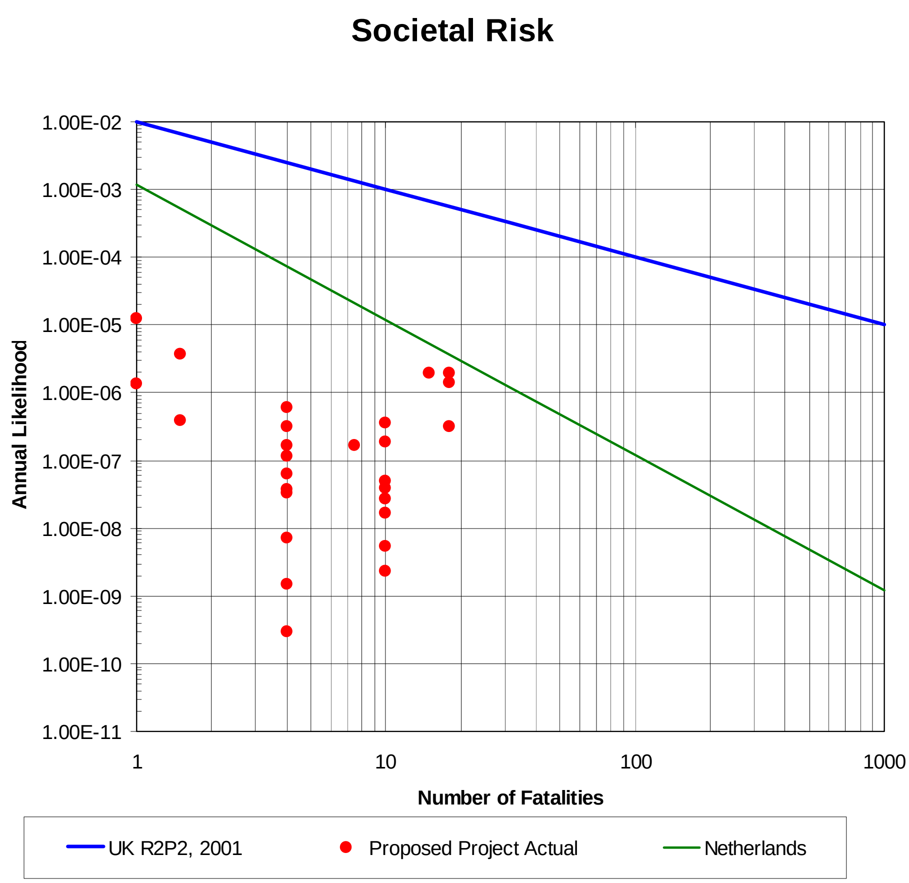
Table 4.5.10~~1.4-12~~ Societal Risk Summary (Highest Risk Scenarios Only)

Release	Exposure Probability	Probability of Serious Injury or Fatality to Exposed Individuals	Population Exposed	Number of Site Casualties (SC)	Societal Risk Criteria (SRC)	SC/SRC
Exposures to Occupants of Residences and Commercial Buildings						
Line 406 Rupture Torch Fire Residences	3.19e-07	0.75~~50~~	24	18~~12~~	56	0.32~~21~~
Line 407, Phase I Rupture Torch Fire Residences	9.6e-06	0.75~~50~~	24	18~~12~~	23	0.79~~53~~
Line 407, Phase I Rupture Torch Fire Commercial	9.6e-06	0.75~~50~~	20	15~~10~~	23	0.66~~44~~
Exposures to Vehicle Occupants						
Line 406 Interstate 5 Rupture Explosion	9.1e-07	0.10	6	0.6	33	0.02
Line 406 Interstate 5 Rupture Torch Fire	1.6e-06	0.10	7	0.7	25	0.03
Line 407 Phase I Baseline Road Rupture Explosion	1.2e-05	0.10	3	0.3	9	0.03
Line 407 Phase I Baseline Road Rupture Torch Fire	1.7e-06	0.10	4	0.4	8	0.05

Line 407 Phase I Baseline Road Rupture Flash Fire	1.9e-06	0.10	3	0.3	23	0.01

These results are presented graphically in the following figure. As indicated, the actual societal risk posed by the proposed project is less than the significance threshold.

Figure 4.5.10-1 Societal Risk Results



There are a few release scenarios that could impact both building occupants and vehicle passengers. For example, an explosion along Baseline Road could impact commercial buildings, the residential neighborhood, and vehicle occupants. However, when these data are combined, the resulting societal risk remains below the stated significance threshold.

4.6 MITIGATION MEASURES

The following mitigation measures are proposed to reduce the ~~significant~~ impacts posed by this project.

HAZ-1a. All pipe to be installed shall meet the following requirements:

- Line pipe shall be manufactured in the year 2000 or later.
- A 6-inch wide polyethylene marker tape shall be installed approximately 12 to 18-inches below the ground surface, above the center of the pipeline. The marking tape shall be brightly colored and shall be marked with an appropriate warning (e.g., Warning – High Pressure Natural Gas Pipeline).
- The pipe wall thickness shall be at least 0.375-inches.
- The depth of cover shall be at least 48-inches.
- 100% of the circumferential welds shall be radiographically inspected in accordance with American Petroleum Institute (API) Standard 1104, Welding of Pipelines and Related Facilities.
- If the in-line inspection required in mitigation measures HAZ-1b below is not implemented because the pipeline is operated below a hoop stress of 40% SMYS, a close interval cathodic protection survey shall be performed at least every seven years on portions of the line not included in the Applicant's Pipeline Integrity Management Program.

HAZ-1b. Prior to placing the pipeline system into service, the Applicant shall:

- Submit to the California State Lands Commission (CSLC) and the California Public Utilities Commission (CPUC) an Operation and Maintenance (O&M) manual, prepared in accordance with 49 CFR 192.605. The O&M manual shall address internal and external maintenance inspections of the completed facility, including but not limited to details of integrity testing methods to be applied, corrosion monitoring and testing of the cathodic protection system, and leak monitoring. In addition, the O&M manual shall also include a preventative mitigation measure analysis for the use of automatic shutdown valves per 49 CFR Part 192.935(c) requirements.
- PG&E shall conduct an in-line inspection of the pipeline if the Maximum Allowable Operating Pressure (MAOP) is raised to a pressure that creates a circumferential stress greater than 40% Specified Minimum Yield Strength (SMYS). The in-line inspection tool shall be capable of identifying pipe

anomalies caused by internal and external corrosion and other causes of metal loss.

- A Pipeline Integrity Management Program for High Consequence Area (HCA) portions of the pipeline shall also be prepared in accordance with 49 CFR 192, Subpart O. The Integrity Management Program shall be submitted to the CSLC and CPUC.

HAZ-1c. The CSLC shall conduct, or cause to be conducted, an independent, third party design review of the Applicant's construction drawings, supporting calculations, and specifications and shall monitor and observe construction to ensure compliance with all applicable LORS, imposed mitigation, and Applicant proposed mitigation. The Applicant shall make payments to the CSLC for these design reviews, plan checks, and construction inspection services. These design review and construction observation services shall not in any way relieve the Applicant of its responsibility and liability for the design, construction, operation, maintenance and emergency response for these facilities.

4.6.1 Rationale for Mitigation

The individual and societal risks are not considered significant. However, there is concern regarding public safety along the pipeline corridor. Measures have been developed which would reduce the likelihood and consequences of unintentional releases. ~~the individual risks identified herein exceed significance thresholds. The significance of these risks is primarily due to the individual risks caused by exposure to possible torch fires and explosions resulting from ruptures within developed areas. The proposed mitigation measures are intended to minimize the likelihood and consequences of pipeline ruptures.~~

The natural gas pipeline incidents, which were identified as "ruptures" in the USDOT database from 2002 through 2006 have been reviewed. The following points are worth noting:

- 46% of the ruptures were considered longitudinal tears or cracks. Of the components where the manufacturing date was provided, the average date of manufacture was 1955 – roughly 50 years old at the time of failure. Roughly three-quarters of these incidents were caused by third party damage and external corrosion, with the remainder being caused by a variety of factors.
- 50% or the ruptures were considered circumferential separation. For these cases, there was not a predominant cause(s).
- 4% or the ruptures were considered "other".

Third Party Damage Mitigation Effectiveness

In western Europe, the effectiveness of various forms of third party damage mitigation has been studied (HSE 2001). The findings are summarized below:

- Increased Wall Thickness – For 24-inch diameter pipe, a wall thickness of 0.375-inches or greater was found to reduce the frequency of third party caused unintentional releases by 80%. In other words, the incident rate was 20% of the norm. (The Applicant has proposed wall thicknesses that are equal to or greater than 0.375-inches for much of the project.)
- Increased Depth of Cover – Pipelines with a depth of cover of 48-inches or greater experienced a 30% reduction in third party caused incidents. (The incident rate was 70% of the norm.)
- Supplemental Third Party Protection – Pipelines protected with some form of third party warning device (e.g., marker tape, concrete cap, steel plates, etc.) experienced a reduction in third party caused incidents of 10%. (The incident rate was 90% of the norm.)

By implementing the above measures, the frequency of third party caused incidents may be reduced by roughly one-third.

External Corrosions Mitigation Effectiveness

Although data is not available to quantify the effectiveness of the external corrosion mitigation measures, the qualitative impacts can be summarized as follows:

- Increased Wall Thickness – Although increased pipe wall thickness does not prevent external corrosion, it allows more time to pass before a leak may result. This increased time period increases the likelihood that the anomaly will be identified by the operator before a release occurs.
- In-Line Inspection – Internal inspections of pipelines using modern techniques can identify external corrosion and other pipe wall anomalies, reducing the likelihood of a release.
- Close Interval Survey – Close interval cathodic protection surveys can identify coating defects and potential metal loss before a release is experienced.

Circumferential Separation

Inspecting 100% of the circumferential welds in accordance with API 1104 will decrease the likelihood of weld defects, which caused a portion of the circumferential separation ruptures noted in the USDOT database.

4.6.2 Residual Impacts

With the proposed mitigation, the individual risk would be reduced by roughly one-half, as summarized in the following table. However, the individual risk would still be approximately 1:30,000 which exceeds individual risk significance thresholds by a factor of thirty.

It should be noted that there are a significant number of similar natural gas pipelines located in similar, and even more heavily urbanized areas. Many of these pipelines pose a greater risk to the public than the proposed line segments. The risks posed by these facilities have been generally accepted as a cost of modern living.

Table 4.6.2-1 Post Mitigation Individual Risk Result Summary

Pipeline Segment	Post Mitigation Maximum Annual Risk of Fatality	Post Mitigation Maximum Annual Probability of Occurrence	Significance Threshold
Simplified Analysis			
Line 406	1.97×10^{-7}	1 : 5,076,000	1 : 1,000,000 Less Than Significant
Line 407	1.92×10^{-7}	1 : 5,220,000	1 : 1,000,000 Less Than Significant
Line DFM	8.04×10^{-8}	1 : 12,440,000	1 : 1,000,000 Less Than Significant
Enhanced Analysis			
Line 406	2.34×10^{-7}	1 : 4,274,000	1 : 1,000,000 Less Than Significant
Line 407	2.43×10^{-7}	1 : 4,115,000	1 : 1,000,000 Less Than Significant
Line DFM	1.18×10^{-7}	1 : 8,475,000	1 : 1,000,000 Less Than Significant

4.1.54.7 IMPACTS OF ALTERNATIVES

A No Project Alternative and twelve options have been proposed for the alignment in order to minimize or eliminate environmental impacts of the proposed project and to respond to comments from nearby landowners. The twelve options, labeled A through L, have been analyzed in comparison to the portion of the proposed route that has been avoided as a result of the option. Descriptions of the options can be found in Section

3.0, Alternatives and Cumulative Projects, and are depicted in Figure 3-2 of the Final EIR.

The identified alternatives have been analyzed in the same manner that was used to analyze the proposed project. From a public risk standpoint, the alternatives present slightly different risks, since each route has slightly different lengths of line which could affect the public in the event of a release and subsequent fire and/or explosion

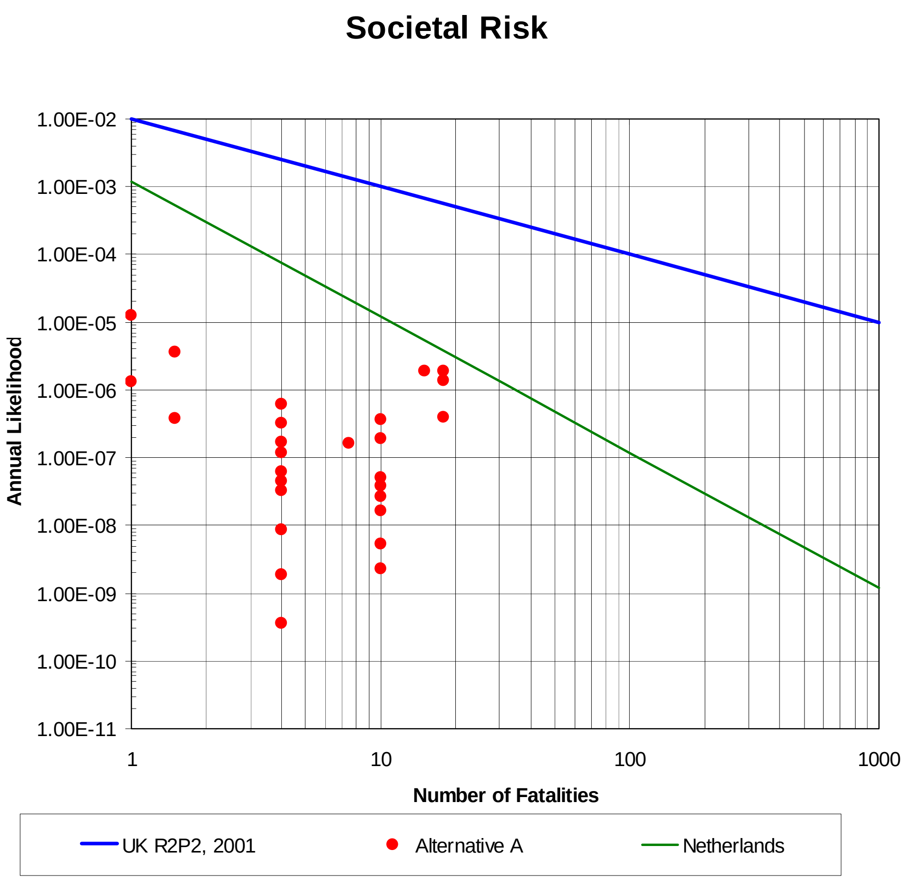
4.7.1 No Project Alternative

The "no project" alternative would eliminate the risks posed by the project, provided the operating pressures, sizes, and other operating parameters of existing natural gas facilities were not changed.

4.7.2 Option A

This option would realign a portion of Line 406 along County Road 16 and 15B. This would increase the length of Line 406 which would pose an impact to existing residences and roadways. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk result would remain below the significance threshold as depicted in the following figure.~~The annual likelihood of serious injury or fatality along Line 406 would increase 22%, from $2.89x10^{-6}$ to $3.52x10^{-6}$. The overall likelihood of serious injury or fatality for all of the proposed line segments would increase 1%, from $6.08x10^{-5}$ to $6.16x10^{-5}$.~~

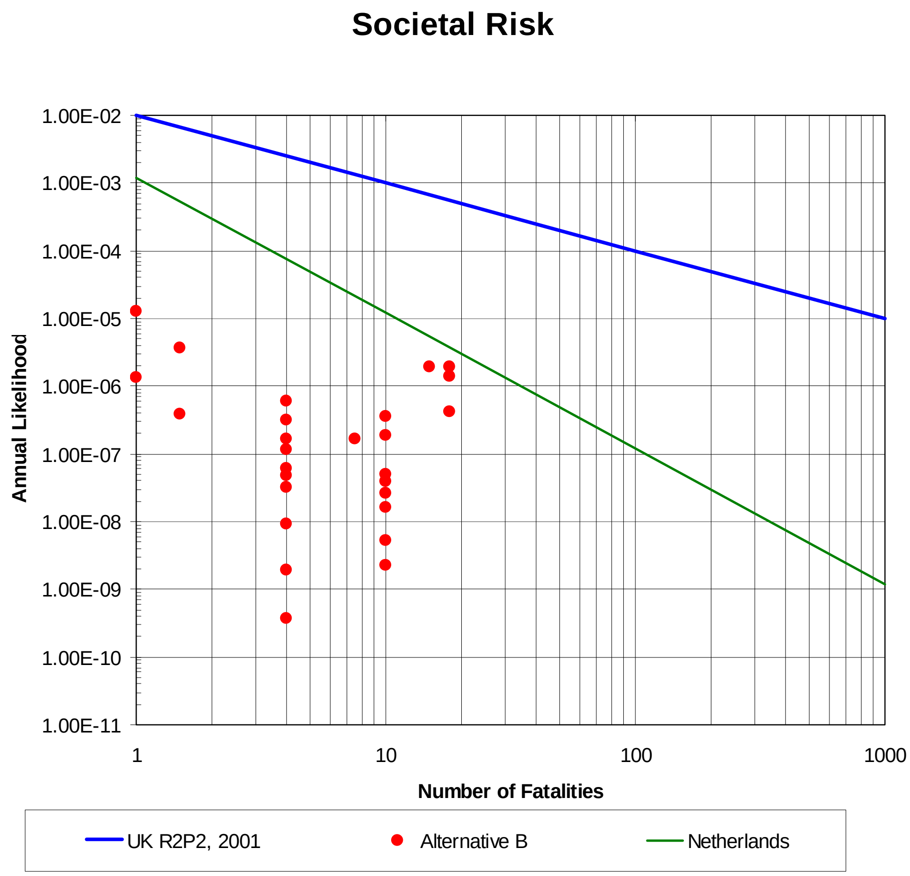
Figure 4.7.2-1 Option A Societal Risk Results



4.7.3 Option B

Similar to option A, this option would realign a portion of Line 406. This would increase the length of Line 406 which would pose an impact to existing residences and roadways. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk result would remain below the significance threshold as depicted in the following figure. The annual likelihood of serious injury or fatality along Line 406 would increase 29%, from 2.89×10^{-6} to 3.72×10^{-6}. The overall likelihood of serious injury or fatality for all of the proposed line segments would increase 2%, from 6.08×10^{-5} to 6.18×10^{-5}.

Figure 4.7.3-1 Option B Societal Risk Results



4.7.4 Option C

The risks posed by this option are essentially the same as the proposed project.

4.7.5 Option D

This option would realign a portion of Line 406. The primary change would be to extend the portion of line along County Road 17. This would increase the length of Line 406 which would pose an impact to existing residences and roadways. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk result would remain below the significance threshold. The societal risk would be essentially the same as for option B, presented in Figure 4.7.3-1. ~~The annual likelihood of serious injury or fatality along Line 406 would increase 30%,~~

from $2.89x10^{-6}$ to $3.75x10^{-6}$. The overall likelihood of serious injury or fatality for all of the proposed line segments would increase 2%, from $6.08x10^{-5}$ to $6.18x10^{-5}$.

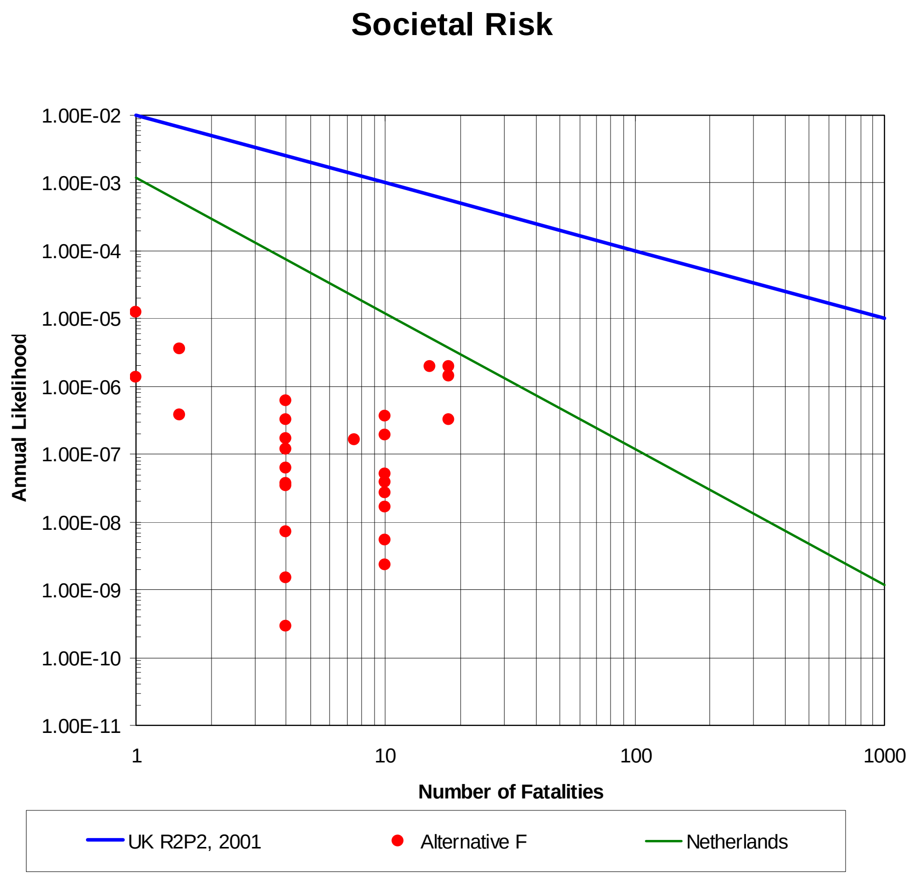
4.7.6 Option E

This option would realign a portion of Line 406. The primary change would be to extend the portion of line along County Road 19. This would increase the length of Line 406 which would pose an impact to existing residences and roadways. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk result would remain below the significance threshold. The societal risk would be in between that presented for options A and B, as depicted in Figures 4.7.2-1 and 4.7.3-1. The annual likelihood of serious injury or fatality along Line 406 would increase 24%, from $2.89x10^{-6}$ to $3.57x10^{-6}$. The overall likelihood of serious injury or fatality for all of the proposed line segments would increase 1%, from $6.08x10^{-5}$ to $6.16x10^{-5}$.

4.7.7 Option F

This option would realign a portion of Line 407, Phase II. The realignment would result in minimal changes to the risks posed to the public. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk result would remain below the significance threshold as depicted in the following figure. The annual likelihood of serious injury or fatality along Line 407, Phase II would increase 3%, from $7.75x10^{-6}$ to $7.99x10^{-6}$. The overall likelihood of serious injury or fatality for all of the proposed line segments would increase less than 1%, from $6.08x10^{-5}$ to $6.12x10^{-5}$.

Figure 4.7.7-1 Option F Societal Risk Results



4.7.8 Option G

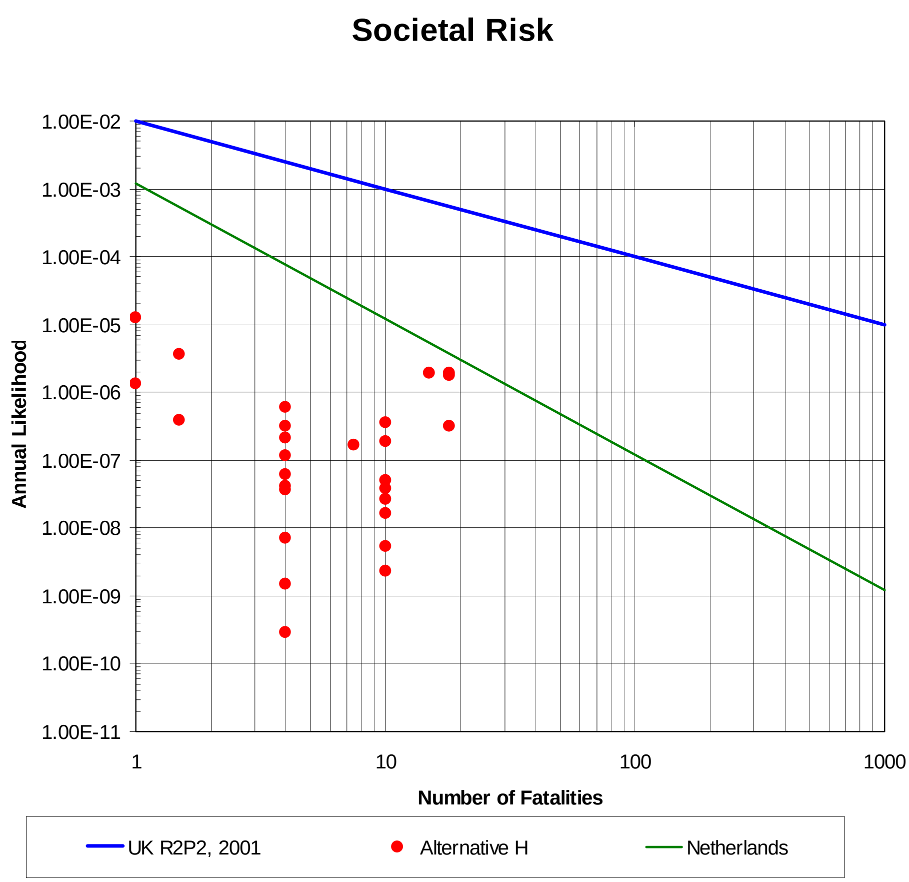
The risks posed by this option are essentially the same as the preferred project.

4.7.9 Option H

This option would realign a portion of Line 407, Phase II, adding to the potential impacts to vehicle occupants along Powerline Road and West Elverta Road. The realignment would result in slight increases to the risks posed to the public. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk result would remain below the significance threshold as depicted in the following figure. ~~The annual likelihood of serious injury or fatality along Line 407, Phase II would increase 28%, from 7.75x10^{-6} to 9.92x10^{-6}. The overall~~

likelihood of serious injury or fatality for all of the proposed line segments would increase less than 4%, from 6.08×10^{-5} to 6.31×10^{-5}.

Figure 4.7.9-1 Option H Societal Risk Results



4.7.10 Option I

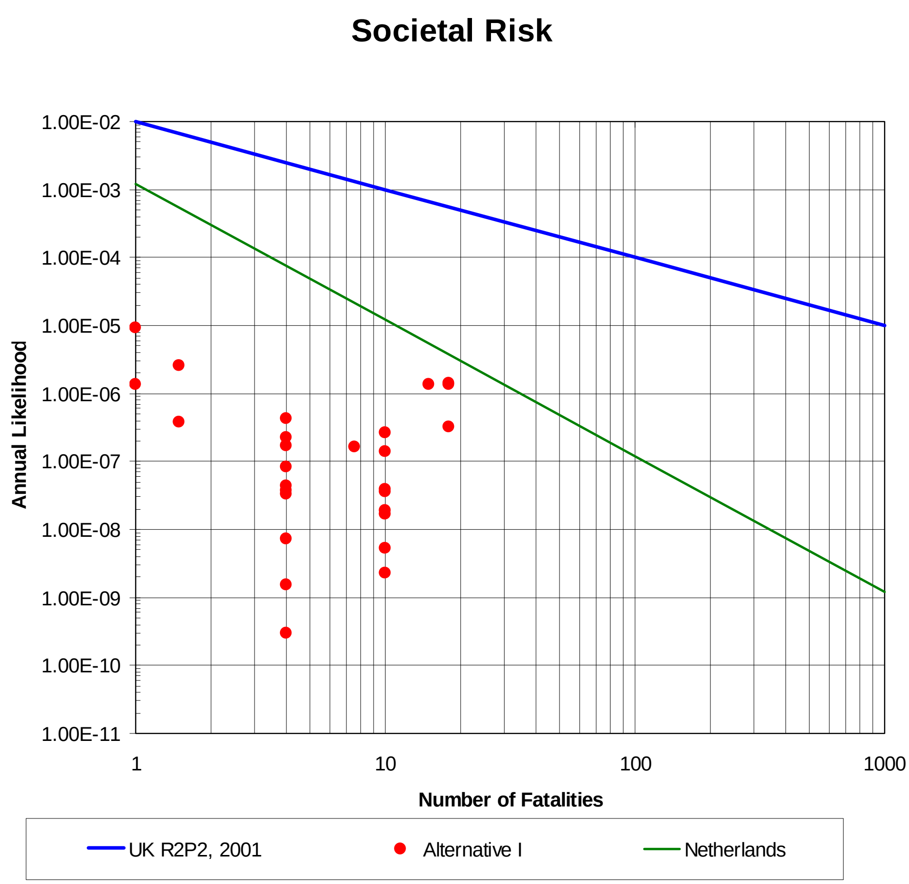
This option would realign a portion of Line 407, Phase I to place the line outside the 1,500-foot buffer zone around a planned high school (PG&E 2009). This alternative would:

- Add approximately 3,000 lineal feet of pipe to the overall pipeline length.
- Remove one mile of line from potential impacts to vehicle occupants and planned commercial development along Baseline Road.
- Add 1,500 lineal feet of potential impacts to vehicle occupants along both South Brewer and Country Acres Roads.

- Add impacts to existing rural residences.

The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk would remain below the significance threshold as depicted in the following figure. ~~The annual likelihood of serious injury or fatality along Line 407, Phase I would decrease 14%, from 1.99×10^{-5} to 1.71×10^{-5}. The overall likelihood of serious injury or fatality for all of the proposed line segments would decrease 5%, from 6.08×10^{-5} to 5.80×10^{-5}.~~

Figure 4.7.10-1 Option H Societal Risk Results



The California Education Code, Section 17213 specifies that a school district may not approve a project involving the acquisition of a school site unless it determines that the property to be purchased or built upon does not contain a pipeline situated underground or aboveground that carries hazardous substances, acutely hazardous materials, or hazardous wastes, unless the pipeline is a natural gas line used only to supply that school or neighborhood. The California Code of Regulation, Title 5, Section 14010(h) states that, "the site shall not be located near an above-ground water or fuel storage tank or within 1,500 feet of the easement of an above ground or underground pipeline that can pose a safety hazard as determined by a risk analysis study, conducted by a competent professional." This realignment would place the proposed natural gas line beyond the specified 1,500-foot school buffer.

4.7.11 Option J

This option J is very similar to Option I discussed above. It would realign a portion of Line 407, Phase I to place the line outside the 1,500-foot buffer zone around a planned high school (PG&E 2009). This alternative would:

- Add approximately 5,200 lineal feet of pipe to the overall pipeline length.
- Remove one mile of line from potential impacts to vehicle occupants and planned commercial development along Baseline Road.
- Add 2,600 lineal feet of potential impacts to vehicle occupants along South Brewer Road.
- Add roughly 2,000 lineal feet of potential impacts to vehicle occupants along Country Acres Road.
- Add impacts to existing rural residences.

The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk would remain below the significance threshold. The societal risk would be very similar to that posed for Option I, presented in Figure 4.7.10-1. ~~The annual likelihood of serious injury or fatality along Line 407, Phase I would decrease 10%, from 1.99×10^{-5} to 1.80×10^{-5}. The overall likelihood of serious injury or fatality for all of the proposed line segments would decrease 3%, from 6.08×10^{-5} to 5.89×10^{-5}. This realignment would place the proposed natural gas line beyond the specified 1,500-foot school buffer.~~

4.7.12 Option K

This alternative would realign a portion of Line 407, Phase I approximately 150-feet further to the north, just beyond the 1,500-foot buffer of a planned elementary school. This alternative would reduce the length of line affecting vehicle occupants from the impacts of 1-inch diameter releases along Baseline Road. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk would remain below the significance threshold. The annual likelihood of serious injury or fatality along Line 407, Phase I would decrease less than 2%, from 1.99×10^{-5} to 1.96×10^{-5}. The overall likelihood of serious injury or fatality for all of the proposed line segments would decrease less than 1%, from 6.08×10^{-5} to 6.05×10^{-5}.

Although this realignment would not place the proposed natural gas line outside the 1,500-foot buffer, it is unlikely that serious risks would be posed to the student body from the applicant proposed pipeline location, which is approximately 1,4001,350 feet from the school boundary. The distances to various impacts from the proposed pipeline are summarized below. As noted, the impacts are very minor at distances greater than 800 to 1,000 feet.

Table 4.7.125.1.5-1 Consequence versus Distance Summary

Distance to Impact (feet)	Description of Potential Consequence
35 feet	1.0 psig overpressure from 1-inch diameter release explosion, release 45° above horizon. Windows usually shattered and occasional damage to window frames. 1% probability of serious injury or fatality to occupants in reinforced concrete or reinforced masonry building from flying glass and debris
50 feet	0.7 psig overpressure from 1-inch diameter release explosion, release 45° above horizon. Minor damage to residential structures. Some injuries to those indoors due to flying debris, but very unlikely to be serious.
4850 feet	8,000 btu/hr-ft^2 heat flux from 1-inch diameter release torch fire, downwind release 45° above horizon. 50% mortality anticipated to those exposed after 30 second exposure.
66 feet	8,000 btu/hr-ft^2 heat flux from 1-inch diameter release torch fire, downwind release 15° above horizon. 50% mortality anticipated to those exposed after 30 second exposure.
70 feet	3,500 btu/hr-ft^2 heat flux from 1-inch diameter release torch fire, downwind release 45° above horizon. Second degree skin burns after ten seconds of exposure.
90 feet	1,600 btu/hr-ft^2 heat flux from 1-inch diameter release torch fire, downwind release 45° above horizon. Second degree skin burns after thirty seconds of exposure.
35760 feet	Distance to lower flammability limit (flash fire boundary) from full bore downwind release at 45° above horizon for flash fire. This would likely result in serious injury or death to those exposed to the ignited vapor cloud under typical conditions.
380 feet	1.0 psig overpressure from full bore release explosion, release 45° above horizon. Windows usually shattered and occasional damage to window frames. 1% probability of serious injury or fatality to occupants in reinforced concrete or reinforced masonry building from flying glass and debris.

~~420 feet~~	~~1.0 psig overpressure from full bore release explosion, horizontal release. Windows usually shattered and occasional damage to window frames. 1% probability of serious injury or fatality to occupants in reinforced concrete or reinforced masonry building from flying glass and debris.~~
422 feet	12,000 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 45° above horizon. 100% mortality after 30 second exposure.
517~~520~~ feet	8,000 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 45° above horizon. 50% mortality anticipated to those exposed after 30 second exposure.
534 feet	Distance to lower flammability limit (flash fire boundary) from full bore downwind release at 15° above horizon for flash fire. This would likely result in serious injury or death to those exposed to the ignited vapor cloud under typical conditions.
~~540 feet~~	~~0.7 psig overpressure from full bore release explosion, release 45° above horizon. Minor damage to residential structures. Some injuries to those indoors due to flying debris, but very unlikely to be serious.~~
~~600 feet~~	~~0.7 psig overpressure from full bore release explosion, horizontal release. Minor damage to residential structures. Some injuries to those indoors due to flying debris, but very unlikely to be serious.~~
600 feet	5,000 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 45° above horizon. California Department of Education uses 1% mortality to those exposed for 30 second exposure.
640 feet	Distance to lower flammability limit (flash fire boundary) from full bore release at horizontal for flash fire. This would likely result in serious injury or death to those exposed to the ignited vapor cloud under typical conditions.
643 feet	12,000 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 15° above horizon. 100% mortality after 30 second exposure.
673 feet	8,000 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 15° above horizon. 50% mortality after 30 second exposure.
730 feet	3,500 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 45° above horizon. Second degree skin burns after ten seconds of exposure.
~~800 feet~~	~~8,000 btu/hr-ft^2 heat flux from full bore release torch fire, horizontal release. 50% mortality anticipated to those exposed.~~
746~~820~~ feet	5,000 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 15° above horizon.~~horizontal release.~~ ~~California Department of Education uses~~ 1% mortality after 30 second exposure~~to those exposed~~.
Boundary of Serious Harm	
820 feet	Distance to lower flammability limit (flash fire boundary) from full bore downwind release at horizontal for flash fire. This would likely result in serious injury or death to those exposed to the ignited vapor cloud. This result is for the worst case modeling inputs, as defined by the United States Environmental Protection Agency.
Worst Case Boundary of Serious Harm	
940 feet	1,600 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 45° above horizon. Second degree skin burns after thirty seconds of exposure. No fatalities anticipated for reasonable exposure duration.
980 feet	1,600 btu/hr-ft^2 heat flux from full bore release torch fire, downwind horizontal release. Second degree skin burns after thirty seconds of exposure. No fatalities anticipated for reasonable exposure duration.

~~1,260 feet~~	~~0.3 psig overpressure from full bore release explosion, release 45° above horizon. 10% window glass breakage. No injuries.~~
1,370 feet	440 btu/hr-ft^2 heat flux from full bore release torch fire, downwind horizontal release. Prolonged skin exposure causes no detrimental effect.
1,540 feet	440 btu/hr-ft^2 heat flux from full bore release torch fire, downwind release 45° above horizon. Prolonged skin exposure causes no detrimental effect.
~~1,890 feet~~	~~0.2 psig overpressure from full bore release explosion, release 45° above horizon. Some window glass breakage, no injuries to building occupants.~~

It should be noted that the California Department of Education (CDE), Guidance Document for School Site Pipeline Risk Analysis (Guidance Document) considers 1% mortality (fatality probability of 1%) to be the reasonable estimate of the boundary of serious harm. It is considered the demarcation between threat (1% mortality) and no-threat (0% mortality). Using this criterion, the following boundary distances could be established from the proposed Line 407, Phase I, to proposed school sites:

- Explosion – The peak overpressure level of an outdoor explosion from any of the three pipeline segments is 0.38 psig (medium fuel reactivity and low obstacle density. This overpressure is less than the level required to cause fatalities. ~~420 feet. This is the distance to the 1.0 psig overpressure level from a full bore, horizontal release. This level of overpressure is considered by some sources to result in a 1% probability of serious injury or fatality to occupants in reinforced concrete or reinforced masonry building from flying glass and debris. It should be noted that this is a conservative result. For reference, the CDE Guidance Document indicates that an overpressure level of up to 2.3 psig will not result in any fatalities to persons inside buildings or outdoors; the maximum anticipated peak overpressure level from the proposed pipeline is 1.5 psig at distances less than 420 feet from the source.~~
- Flash Fire – 534~~640~~ feet. This is the downwind distance to the lower flammability limit of an unignited vapor cloud from a full bore ~~horizontal~~ release at 15° above the horizon, under the typical conditions outlined in Table 4.1.4-4. It should be noted that the size of the combustible vapor cloud can vary significantly depending on atmospheric and other conditions. For example, if the wind speed was decreased from 2.0 to 1.5 meters per second and the stability class was changed from D to F, the downwind distance to the lower flammability limit of the unignited vapor cloud would increase to 820 feet; these conditions are considered the worst case for off-site consequence modeling from stationary sources by the United States Environmental Protection Agency. (See also Section 5.0, Atmospheric Condition Sensitivity Analysis.)
- Torch Fire – 746~~820~~ feet. This is the distance to the 5,000 btu/hr-ft^2 heat flux which is considered by the CDE to be the level of exposure resulting in 1% mortality after a 30 second exposure. For reference, the CDE Guidance

Document provides charts for determining radiant heat from torch fires. Although these charts were developed using a different modeling software, they show a distance of 975 feet from the release to the 5,000 btu/hr-ft^2 heat flux. (CDE 2007)

4.7.13 Option L

Option L would involve installing the portion of Line 407, Phase I which is within the 1,500 foot buffer of a planned elementary school, using horizontal directional drilling techniques. This would significantly reduce or eliminate the likelihood of the line being damaged by third parties, since the line would be installed well below normal excavation depths. The estimated baseline risk of unintentional release would be reduced roughly one-third, from 1.96x 10^{-4} to 1.2x10^{-4}. The individual risk would not be affected by this change, since the individual risk is the likelihood of fatality at a specific point along the pipeline; it does not take into account the length of the line segment. The societal risk probability of exposure along Line 407 Phase I would be decreased less than 3%, remaining below the significance threshold. The annual likelihood of serious injury or fatality along Line 407, Phase I would decrease less than 3%, from 1.99x10^{-5} to 1.94x10^{-5}. The overall likelihood of serious injury or fatality for all of the proposed line segments would decrease less than 1%, from 6.08x10^{-5} to 6.03x10^{-5}.

Summary of Alternatives

Although most of the alternatives pose slightly higher risks than the proposed project, the various project alternatives pose very minor changes to the overall project risk.

Table 4.1.5-1 Summary of Alternatives Risk

Project Alternative	Annual Risk of Serious Injury or Fatality	Annual Likelihood of Serious Risk or Fatality
Proposed Project	6.08e-05	1 : 16,000
Option A	6.16e-05	1 : 16,000
Option B	6.18e-05	1 : 16,000
Option C	6.08e-05	1 : 16,000
Option D	6.18e-05	1 : 16,000
Option E	6.16e-05	1 : 16,000
Option F	6.12e-05	1 : 16,000

Option G	6.08e-05	1 : 16,000
Option H	6.31e-05	1 : 16,000
Option I	5.80e-05	1 : 17,000
Option J	5.89e-05	1 : 17,000
Option K	6.05e-05	1 : 17,000
Option L	6.03e-05	1 : 17,000

4.1.64.8 CUMULATIVE PROJECTS IMPACT ANALYSIS

From a system safety perspective, the proposed project has not been considered as to cumulative impacts.

5.0 ATMOSPHERIC CONDITION SENSITIVITY ANALYSIS

The release modeling presented herein and in the Final EIR assumed a single combination of wind and stability for flash fires and vapor cloud explosions and a single wind speed for evaluating torch fire impacts. The intent was to select the parameters which depict a conservative average release. While some releases may result in impacts at greater distances from the pipeline, the probability of these events would be relatively small. In most instances, the distances to impacts would be less than those incorporated into the analysis. The following paragraphs present the modeling results for a variety of atmospheric conditions and compare them to those used in the analysis.

5.1 FLASH FIRES

The downwind distances to the lower flammability limit (LFL), which would be the maximum downwind distances to the flash fire boundaries are shown in Table 5.1-1 and 5.1-2 below. It should be noted that these are the maximum downwind distances only; they do not take into account the fact that the vapor cloud may be located overhead. For example, for the releases at 45° above grade, the vast majority of the vapor cloud is located well above grade. Specifically, for a rupture release at 45° above the horizon from Line 406, the bottom of the combustible portion of the vapor cloud would be 230-feet above grade at 300-feet from the release. As a result, one would not be exposed to flash fire impacts at this location; the flash fire would be located overhead. The analysis conservatively used the horizontal projection of the overhead vapor cloud in establishing flash impact distances. However, for the pipe segments associated with this project, in both the simplified and enhanced analysis, the risk posed by flash fires is only about one percent (1%) of the total. As a result, although this approach is conservative, it does not appreciably affect the results.

Table 5.1-1 Line 406, Flash Fire Impact Distances, Rupture, Release 45° Above Horizon, Downwind

Atmospheric Stability[5]	Wind Speed					
	0 mps 0 mph	2 mps 4.5 mph	4 mps 8.9 mph	6 mps 13.4 mph	8 mps 17.9 mph	10 mps 22.4 mph
A	571	172	123	100	86	77
B	571	224	167	139	123	111
C	571	278	217	186	166	153
D	571	**347**	288	255	234	219
E	N/A	430	336	N/A	N/A	N/A
F	571	528	N/A	N/A	N/A	N/A

Notes: 1. The above horizontal downwind distances are to the lower flammability limit, in feet.
2. mps = meters per second.
3. mph = miles per hour.
4. Shaded cell reflects impact distance used in the Final EIR analysis.
5. N/A indicates wind and stability combinations that do not normally occur.

[5] Pasquill-Gifford atmospheric stability is classified by the letters A through F. Stability can be determined by three main factors: wind speed, solar insulation, and general cloudiness. In general, the most unstable (turbulent) atmosphere is characterized by stability class A. Stability A occurs during strong solar radiation and moderate winds. This combination allows for rapid fluctuations in the air and thus greater mixing of the released gas with time. Stability D is characterized by fully overcast or partial cloud cover during daytime or nighttime, and covers all wind speeds. The atmospheric turbulence is not as great during D conditions, so the gas will not mix as quickly with the surrounding atmosphere. Stability F generally occurs during the early morning hours before sunrise (no solar radiation) and under low winds. This combination allows for an atmosphere which appears calm or still and thus restricts the ability to actively mix with the released gas. A stability classification of "D" is generally considered to represent average conditions.

Table 5.1-2 Line 406, Flash Fire Impact Distances, 1-inch Diameter, Release 45° Above Horizon, Downwind

Atmospheric Stability[4]	Wind Speed					
	0 mps 0 mph	**2 mps 4.5 mph**	**4 mps 8.9 mph**	**6 mps 13.4 mph**	**8 mps 17.9 mph**	**10 mps 22.4 mph**
A	48	17	12	10	8	7
B	48	22	16	13	11	10
C	48	25	21	17	15	14
D	48	**32**	27	23	21	20
E	N/A	36	31	N/A	N/A	N/A
F	48	39	N/A	N/A	N/A	N/A

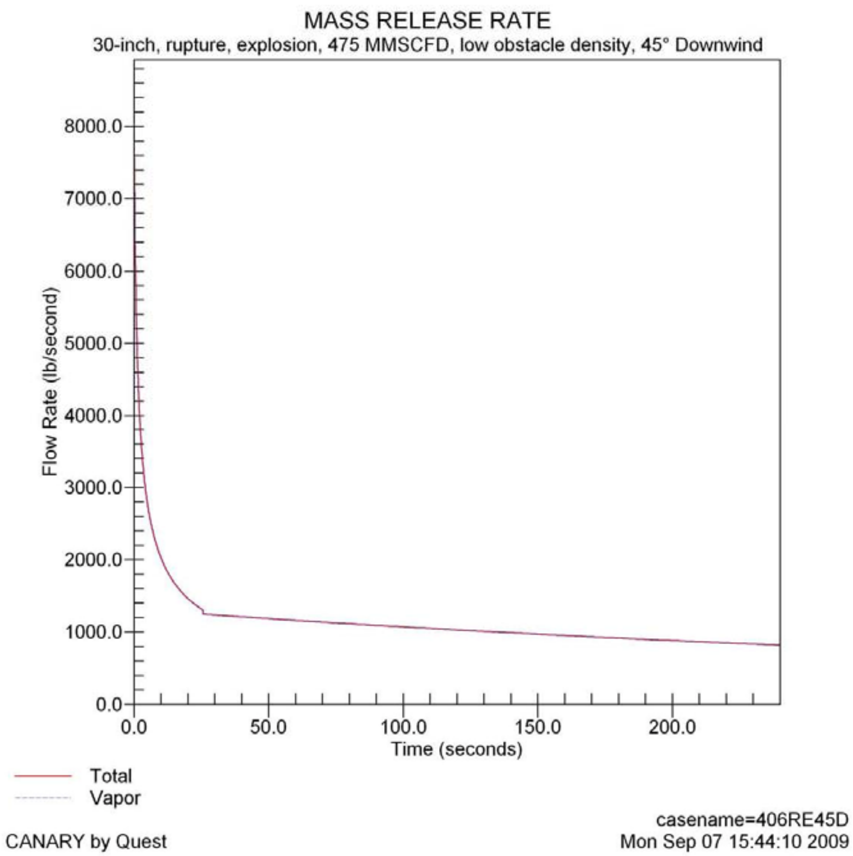
Notes: 1. The above horizontal downwind distances are to the lower flammability limit, in feet.
2. mps = meters per second.
3. mph = miles per hour.
4. Shaded cell reflects impact distance used in the Final EIR analysis.
5. N/A indicates wind and stability combinations that do not normally occur.

5.2 TORCH FIRES

In the event that an individual were exposed to radiant heat flux as a result of a continuous fire (e.g., torch fire), the natural reaction would be to increase the distance from the exposure to prevent harmful impacts. In other words, an able bodied individual would be expected to move away from and/or find protection to avoid injury. The analyses presented in the Final EIR and herein assumed a thirty (30) second exposure time in evaluating torch fire impacts; it assumed that those exposed to torch fire impacts would be exposed for thirty (30) seconds and that they would not seek shelter or move further from the hazard. Fatalities could occur from a shorter exposure; but the required radiant heat flux levels would be much higher and the impact distances would be shorter. This method, used herein and in the Final EIR, is consistent with that used by the California Department of Education and others. (CDE 2007)

The analyses presented in the Final EIR and herein conservatively assumed that ignition occurred immediately after the initiation of a release. This results in the longest torch fire impact distances for pipeline ruptures. As shown in Figure 5.2-1 below, the mass flow rate from a given pipeline release decays rapidly after a pipeline rupture, as the pipeline depressurizes. As the mass flow rate decays, the resulting torch flame length becomes shorter and smaller, resulting in shorter distances to a given radiant heat flux level. As a result, when the ignition is delayed, the distances to significant levels of radiant heat flux are reduced. The torch fire impact distances for 1-inch releases are not normally affected by the time between release and ignition, since the mass flow rate is essentially constant, due to the relatively large volume of gas stored within the pipeline.

Figure 5.2-1 Typical Pipeline Rupture Mass Release Flow Rate



The downwind torch fire impact distances for pipeline ruptures and 1-inch diameter release are presented in the tables which follow.

Table 5.2-1 Line 406, Torch Fire Impact Distances, Rupture, Release 45° Above Horizon, Downwind

Radiant Heat Flux Endpoint 30 Second Exposure	Wind Speed								
	0 mps 0.0 mph	2 mps 4.5 mph	4 mps 8.9 mph	6 mps 13.4 mph	8 mps 17.9 mph	10 mps 22.4 mph	12 mps 26.9 mph	14 mps 31.4 mph	16 mps 35.8 mph
100% Mortality 12,000 btu/hr-ft^2	235	297	376	397	409	416	424	445	453
50% Mortality 8,000 btu/hr-ft^2	409	459	487	496	502	507	512	534	540
1% Mortality 5,000 btu/hr-ft^2	585	602	606	607	609	612	615	617	619

Notes: 1. The above horizontal distances are in feet.
2. mps = meters per second.
3. mph = miles per hour.
4. The Final EIR and the analyses presented herein used a wind speed of 20 mph.

Table 5.2-2 Line 406, Torch Fire Impact Distances, 1-inch Diameter, Release 45° Above Horizon, Downwind

Radiant Heat Flux Endpoint 30 Second Exposure	Wind Speed								
	0 mps 0.0 mph	2 mps 4.5 mph	4 mps 8.9 mph	6 mps 13.4 mph	8 mps 17.9 mph	10 mps 22.4 mph	12 mps 26.9 mph	14 mps 31.4 mph	16 mps 35.8 mph
100% Mortality 12,000 btu/hr-ft^2	20	38	53	60	62	63	65	64	64
50% Mortality 8,000 btu/hr-ft^2	29	49	61	65	67	66	66	66	65
1% Mortality 5,000 btu/hr-ft^2	42	61	70	73	73	72	71	71	70

Notes: 1. The above horizontal distances are to the lower flammability limit, in feet.
2. mps = meters per second.
3. mph = miles per hour.
4. The Final EIR and the analyses presented herein used a wind speed of 20 mph.

5.3 VAPOR CLOUD EXPLOSIONS

As noted in the Final EIR, the maximum anticipated peak overpressure level was only 0.38 psig. This value is not sufficient to result in fatalities to those located outdoors. In the rural areas and relatively open residential and commercial areas along the pipeline corridor, the peak overpressure levels will range from 0.02 to 0.38 psig, due to the lack of confinement. These overpressure levels will not result in fatalities. The anticipated frequencies of fatalities resulting from explosions are presented in Table 5.3-1 below.

Table 5.3-1 Explosion Overpressure Levels

Mortality Rate	Outdoor Exposure (psig)	Indoor Exposure (psig)
99% Mortality	29	13
50% Mortality	13	5.7
1% Mortality	2.3	2.3

(CDE 2007)

6.0 MODELING ASSUMPTIONS

A number of assumptions have been made in order to conduct the risk analyses presented herein. For the most part, these assumptions are conservative and tend to result in an overstatement of risk. The major assumptions and methodology which affect the results presented herein are summarized below:

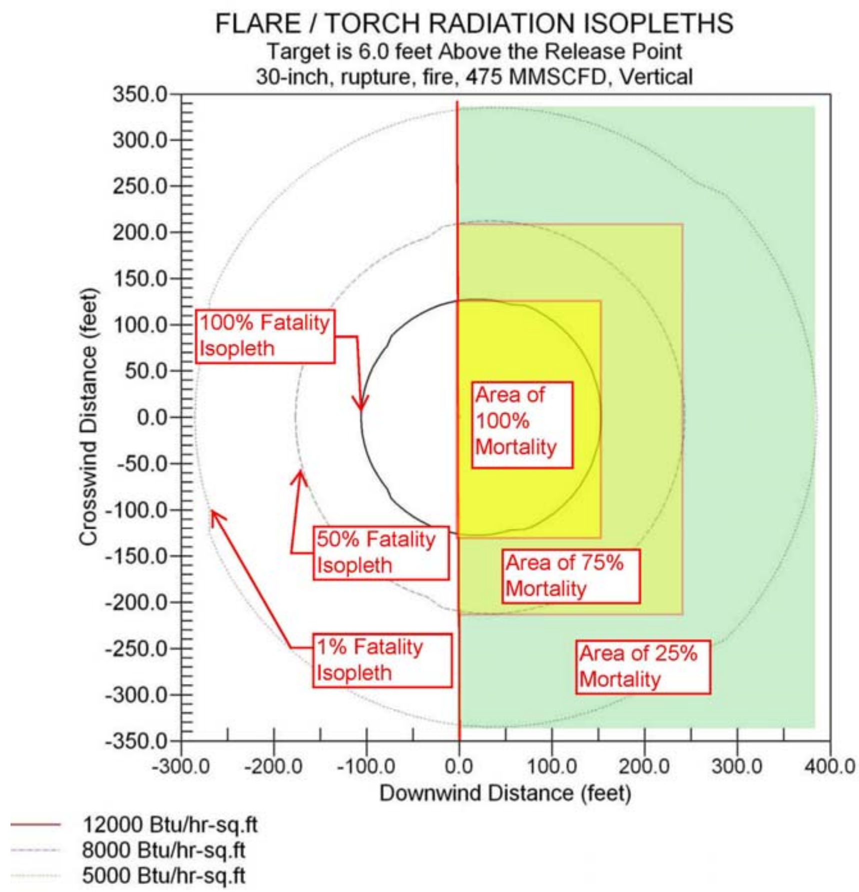
- Wind Direction – For all releases, the wind was assumed to blow perpendicular to the pipeline. This results in the greatest distance to the various impact levels for downwind situations.

- Torch Fire Immediate Ignition – The torch fire analyses assumed that the ignition was immediate after the initiation of a release; in other words, all releases where an ignition source was present that resulted in a torch fire were assumed to result from immediate ignition. This approach results in the longest torch fire impact distances for pipeline ruptures. As shown in Figure 5.2-1 previously, the mass flow rate from a given pipeline release decays rapidly after a pipeline rupture, as the pipeline depressurizes. As the mass flow rate decays, the resulting torch fire flame length becomes shorter and smaller, resulting in shorter distances to a given radiant heat flux level. As a result, when the ignition is delayed, the distances to significant levels of radiant heat flux are reduced. The average mass flow rate for the first sixty seconds of the release was used to determine the mass flow rate for all torch fires. The torch fire impact distances for 1-inch diameter releases are not affected by the time between release and ignition, since the mass flow rate is essentially constant, due to the relatively large volume of gas stored within the pipeline.

- Flash Fires – For flash fire impacts which were located overhead, the horizontal extent of the hazard was projected to grade level. This results in some overstatement of the impact since an overhead flash fire would not normally impact those on the ground. For example, for the releases at 45° above grade, the vast majority of the vapor cloud is located well above grade. Specifically, for a rupture release at 45° above the horizon from Line 406, the bottom of the combustible portion of the vapor cloud would be 230-feet above grade at 300-feet from the release. As a result, one would not be exposed to flash fire impacts at this location; the flash fire would be located overhead. The analyses conservatively used the horizontal projection of the overhead vapor cloud in establishing flash fire impact distances. However, for these pipe segments, the risk posed by flash fires is only a small portion of the total. As a result, although this approach is conservative, it does not appreciably affect the results.

- Quantification of Results – Most of the impact isopleths from a release are in the general shape of an ellipse. For example, the figure below presents the torch fire isopleths for various mortality levels for a vertical release. These isopleths are elliptical. However, in performing the analyses, the areas of mortality were assumed to be rectangular, as shown in the figure. This results in some conservatism, since the area outside the ellipse but inside the rectangle is subject to less risk than assumed in the analyses.

Figure 6.0-1 Typical Pipeline Rupture Mass Release Flow Rate



- Torch Fire Exposure - A thirty (30) second exposure was assumed for all individuals exposed to radiant heat flux levels resulting from torch fires. This conservatively assumes that able bodied persons would not take efforts to find shelter or distance themselves from the hazard for the entire duration of the exposure; if they did, the risk would be reduced.

7.0 REFERENCES:

American Petroleum Institute (API 1995). 1995. Management of Hazards Associated with Location of Process Plant Buildings.

California Department of Education (CDE 2007). February 2007. Guidance Protocol for School Site Pipeline Risk Analysis.

California Public Utilities Commission (CPUC 2006). Mitigated Negative Declaration for the Kirby Hills Natural Gas Storage Facility (A. 05-07-018).

Health and Safety Executive (HSE 2000). Report on a Study of International Pipeline Accidents, Contract Research Report 294/2000. United Kingdom.

Heath and Safety Executive (HSE 2001). An Assessment of Measures in Use for Gas Pipelines to Mitigate Against Damage Caused by Third Party Activity. Contract Research Report 372/2001. United Kingdom. Mannan, Dr. Sam.

Lee's Loss Prevention in the Process Industries. (LEES) Third Edition.

Marszal, Edward M. (Marszal 2001). 2001. Tolerable Risk Guidelines.

National Transportation Safety Board (NTSB 2002). Pipeline Rupture and Subsequent Fire in Bellingham, Washington, June 10, 1999. Pipeline Accident Report NTSB/PAR-02/02. Washington, DC.

National Transportation Safety Board (NTSB 2003). Natural Gas Pipeline Rupture and Fire Near Carlsbad, New Mexico, August 19, 2000. Pipeline Accident Report NTSB/PAR-03/01. Washington, DC.

New Mexico Business Weekly (Business Weekly). 2002. El Paso Corporation Settles with Victims' Families, September.

Payne, Brian L. et al. EDM Services, Inc. 1993. California Hazardous Liquid Pipeline Risk Assessment, Prepared for California State Fire Marshal, March.

Pacific Gas and Electric Company (PG&E 2007). 2007. Pipeline Extension L-108 Drawing 7051645, Revision 01, sheets 1 through 31.

Pacific Gas and Electric Company (PG&E 2009). 2009. Line 407 Alternative Route Analysis.

Presidential/Congressional Commission on Risk Assessment and Risk Management (Commission 1997). 1997. Framework for Environmental Health Risk Management.

Quest Consultants, CANARY. (QUEST 2003) CANARY by Quest User's Manual. 2003.

Santa Barbara County Planning and Development (SBCO 2008). October 2008. Environmental Thresholds and Guidelines Manual.

United States Department of Transportation (USDOT), Bureau of Transportation Statistics. Various Years. National Transportation Statistics. Accessed data at http://ops.dot.gov/stats/IA98.htm in September and October 2008.