Quantitative Risk Analysis for Amerigas Butane Storage Facility

Prepared in Consideration of:

Amerigas Propane L. P.

2110 North Gaffey Street
San Pedro, CA 90731

Prepared By:

Cornerstone Technologies, Inc.
Environmental Engineering & Construction

1650 Ximeno Avenue, Suite 210
Long Beach, CA 90804
Tel: (562) 494-9465
Fax: (562) 494-5296

September 2010

TABLE OF CONTENTS

SECTION

1.0 Introduction

2.0 Objective, Scope, and Methodology of Study

3.0 Facility Location and Site Description

4.0 Quantitative Risk Analysis Methodology

5.0 Hazards Posed by Amerigas Butane Storage Facility

6.0 Results of Quantitative Risk Analysis

7.0 Conclusions of the Study

APPENDICES

Appendix 1: Release Scenario #1 – Vapor Cloud Explosion (Distance <0.1 miles)

Appendix 2: Release Scenario #2 – Vapor Cloud Explosion (Distance <0.1 miles)

Appendix 3: Release Scenario #3 – Pool Fire (Distance 0.4 miles)

Appendix 4: Release Scenario #4 – Pool Fire (Distance 1.7 miles)

Appendix 5: Release Scenario #5 – Vapor Cloud Explosion (Distance 3.2 miles)

Appendix 6: Release Scenario #6 – Vapor Cloud Explosion (Distance 4.0 miles)

Appendix 7: Release Scenario #7 – BLEVE (Distance 5.2 miles)

Appendix 8: Release Scenario #8 – BLEVE (Distance 6.8 miles)

Quantitative Risk Analysis for Amerigas Butane Storage Facility

Prepared in Consideration of:

Amerigas Propane L. P.

2110 North Gaffey Street
San Pedro, CA 90731

Prepared By:

Cornerstone Technologies, Inc.
Environmental Engineering & Construction

1650 Ximeno Avenue, Suite 210
Long Beach, CA 90804
Tel: (562) 494-9465
Fax: (562) 494-5296

September 2010

NOTICE

TABLE OF CONTENTS

SECTION

1.0 Introduction

2.0 Objective, Scope, and Methodology of Study

3.0 Facility Location and Site Description

4.0 Quantitative Risk Analysis Methodology

5.0 Hazards Posed by Amerigas Butane Storage Facility

6.0 Results of Quantitative Risk Analysis

7.0 Conclusions of the Study

APPENDICES

Appendix 1: Release Scenario #1 – Vapor Cloud Explosion (Distance <0.1 miles)

Appendix 2: Release Scenario #2 – Vapor Cloud Explosion (Distance <0.1 miles)

Appendix 3: Release Scenario #3 – Pool Fire (Distance 0.4 miles)

Appendix 4: Release Scenario #4 – Pool Fire (Distance 1.7 miles)

Appendix 5: Release Scenario #5 – Vapor Cloud Explosion (Distance 3.2 miles)

Appendix 6: Release Scenario #6 – Vapor Cloud Explosion (Distance 4.0 miles)

Appendix 7: Release Scenario #7 – BLEVE (Distance 5.2 miles)

Appendix 8: Release Scenario #8 – BLEVE (Distance 6.8 miles)

1.0 Introduction

This report is intended to provide a quantitative risk analysis associated with butane at the Amerigas facility located at 2110 North Gaffey Street, San Pedro, California. The purpose is to provide the surrounding community with an informed evaluation of the potential health and safety risks that are inherent in this type of industrial setting.

Amerigas handles a number of industrial chemicals at this address. This report will focus exclusively on the butane storage and transport activities associated with the facility. Butane is usually received and/or distributed through a pipeline, railcar, or transport trucks. Based on the facility's Regulated Substances Registration, two refrigerated storage tanks located on the western border of the facility are designated for butane storage, each with a capacity of 12.6 million gallons. Butane can additionally be stored in two smaller horizontal vessels, each with a capacity of 60,000 gallons. When considering all storage activities involving butane, this location can store approximately 25.32 million gallons of butane.

2.0 Objective, Scope, and Methodology of Study

The aim of the analysis is to assess the risk to safety of people living and working in the adjacent neighborhoods surrounding the Amerigas facility. The specific objectives of this analysis include:

- Identification of the typical hazardous incidents that relate to the operation of the facility;
- Assessing the significance of each incident that could occur in terms of its potential off-site impact;
- Assessing and quantifying the off-site levels of risk to people, property and the environment due to the proposed facility operations, using a quantitative risk analysis method; and
- Providing a clear, concise report of the analysis to determine the health risk associated with the operation of the facility.

In order to meet the necessary objectives of this study, the following items are included for consideration:

- Identification of the typical hazards present on the site and development of incident scenarios;
- Assessment of the consequences of the identified potential risk events;
- An assessment of the risk in relation to established risk guidelines.

The Quantitative Risk Analysis includes a systematic approach to the analysis of what potential hazards can occur within the storage facility. The normal conditions of operation of the system are defined and the following questions are provided best-approximation answers:

(1) What accidental events can occur within the storage system?
(2) What are the consequences of each accidental event?
(3) What is the significance of the calculated risk levels?

By objectively quantifying the potential risks from each part of the system, a quantitative risk analysis enables identification of more effective measures to reduce such risks. The methodology begins by defining the system through compiling and assimilating the facility information that is readily available to the public domain. Following the characterization of the facility, common hazards are recognized, in which internal and external events are identified which may cause the release of hazardous materials. The consequence and frequency of such events is modeled based on available information. A risk assessment is conducted, which calculates the potential facility-wide risk and compares the result to other accidental health risk hazards.

In this way, the facility is objectively defined, analyzed, and quantified in order to provide a more accurate evaluation of its safety risk potential for the facility operators and the general public.

3.0 Facility Location and Site Description

Location

The Amerigas facility located on Gaffey Street encompasses approximately 20 acres of land and was previously owned and operated by Petrolane prior to Amerigas' purchase of the facility in 1993. The facility is connected via pipeline to a berth in the Port of Los Angeles which has been used in the past to load ships with butane for export. The facility provides access for vehicles and rail lines as alternative means of shipping or receiving butane and other LPGs.

While the facility is predominantly surrounded by other industrial operations on the north, south, and east sides, to the west across North Gaffey are very dense residential areas and commercial buildings. Based on a survey of the available aerial maps for this region, it is estimated that the nearest commercial receptor is roughly 0.13 miles (~675 feet) from the largest butane storage tanks. The nearest residential receptor is approximately 0.24 miles (1,290 feet) from the largest butane storage tanks. The relatively short distance between the largest butane storage tanks and areas where civilians live and work has generated cause for alarm for the residents near the Amerigas facility.

Geological Description

The facility is relatively level, and records indicate the land was used as a dump and fill area in the past. Numerous chunks of asphalt and concrete were present in the foundation, and the subsurface conditions are known to be relatively uniform for at least a depth of 35 feet. The fill materials that had been previously dumped in the subsurface varied between five and ten feet in thickness and had consistencies ranging from loose to medium-soft. After a depth of about 60 feet, it is postulated that the underlying geological materials consist of medium-firm clays and medium-firm to firm silts. Below this depth, it is estimated that the ground materials are dense deposits of sands and silts.

H. M. Scott and Associates of Rosemead, California, developed the site and excavated unsightly and problematic dump materials from the subsurface, consequently recompacting the area with earth excavated from a bluff at the back of the site. Grading work commenced in October 1972 and completed in December 1972.

The site was originally developed by Petrolane because of the geology of the subject site. It was determined that the large refrigerated tanks could be developed and installed on sand deposits by cutting into an existing slope. This would allow for the tanks to be stored on sturdy, natural foundations. Before development of the site, test borings and an earthquake engineering study were performed by Converse, Davis, and Associates of Pasadena, California. The evaluation included analysis of past statistical data and acceleration level-return period relationship, probability distribution of accelerations and earthquake magnitude, nature and activity of faults in the area of the site, and response spectra of various ground motions.

Facility Description

The facility is divided into two different parts. One portion is a storage facility on Gaffey Street, which includes two 12.6 million gallon butane tanks, transportation vehicles and pipeline and rail shipping capabilities. The second portion of the facility is a berth in the Port of Los Angeles which is used for the export of butane and other LPG products. A 16" pipeline, buried 10 feet below ground, connects the storage tanks to the export operations. At the time of preparing this report, it is our understanding that while the berth is not currently in use, Amerigas is negotiating with the Port for a new berth and renewed use of the pipeline from the tanks to the Port.

While most of the storage, transport, and rail car delivery is located farthest from Gaffey Street, the two largest butane storage tanks are located closest to the western boundary of the facility, which is closest to the nearest residential and commercial areas.

4.0 Quantitative Risk Analysis Methodology

By understanding the configuration of the facility and by describing the storage configuration of the liquid butane, a quantitative risk analysis can provide three primary conclusions:

(1) Determination of potential releases that could result in significant hazardous conditions outside the boundaries of the facility.
(2) For each potential release that is identified, the potentially lethal hazard zones can be defined.
(3) And using a consistent, accepted methodology, a measure of the "risk" posed to the public can be calculated.

It is assumed that a release of butane from the Amerigas storage facility could potentially result in one or more of the following health hazards:

(1) Exposure to thermal radiation, which is heat radiated by combustion of materials.
(2) Exposure to a blast wave from explosion of storage tanks from over-pressure or ignition of materials.

These possible health hazards can be divided more specifically to include pool, torch, and flash fires, vapor cloud explosions, and physical tank explosions. A more thorough description of these potential outcomes is discussed.

Release Risks and Modeling Assumptions

The physical consequences of a butane release are dependent on the quantity released, the rate of release, and for fire and explosion events, when ignition occurs. The quantity of the release will depend on the size of the release (equivalent hole diameter) and duration of release (how soon can the release be detected and isolated). The release rate from a hole will be assumed to be from a circular orifice and estimation is based on the maximum flow-rate from a given hole area.

As butane liquid may be released, it may pool and generate vapors. Ignition of the vapors arising from the butane pool could result in a flash back or a pool fire, both of which may cause intense thermal radiation around the burning pool. If the evaporating pool does not ignite immediately, then the evaporated vapor may form dispersions within the ambient air. These dispersions are affected by the atmospheric conditions, weather, and wind speed during the occurrence. Vapor will remain close to the pool at first, since the vapor is heavier than ambient air, but as time progresses and mixing occurs, the vapor is assumed to more readily disperse. Ignition of such a dispersion could create a flash fire or a vapor cloud explosion. Areas of confinement or congestion are most vulnerable to the impact caused by a vapor cloud explosion.

Most of the representative release scenarios are summations of many individual events (e.g. a tank rupture can occur at various locations, and have varied release outcomes). The frequency of each possible outcome is normally derived using event tree analysis. Starting with an initial butane release, the event tree follows various possible outcomes such as ignition, exposure of persons within the impact radius, and types of injury. Probability of such occurrences are further defined and quantified by considering the detection and mitigating protocols which may decrease or prevent exposure to such incidents. Other factors, such as ambient air conditions, wind flow rates, puncture location, etc., can alter the release scenarios either beneficially or detrimentally.

The prediction modeling thus makes some assumptions to evaluate generalized occurrences and outcomes, since specific modeling data and outcomes are difficult to quantify. The failure modeling assumptions are as follows:

(1) All releases are assumed to be oriented horizontally (parallel to the ground) in the direction that the wind is blowing. All other release orientations would result in smaller hazard zones. Thus, this assumption would allow for a conservative prediction of hazards and their associated risks.
(2) If a release does not immediately ignite upon release, it is assumed to grow to its full extent before ignition. This conservative estimation of the risk would not consider intermediate, smaller ignitions which would create smaller hazard zones.
(3) A very conservative estimate is provided in consideration of tank rupture due to earthquakes, since detailed knowledge of the seismic reinforcements of these tanks is not available. Furthermore, there are limited studies and historical data on how refrigerated butane tanks respond to catastrophic earthquake events. Thus, the analysis provides a very conservative tank failure rate in light of the difficulty in predicting a tank's response to such a geological impact.

Additional assumptions must be made concerning the emergency systems in place at the facility:

(1) It is likely that the facility has installed required mitigation technologies, such as fire control systems, including the fire sprinkler and fire deluge systems. However, the modeling scenarios assume that these mitigation technologies will not immediately reduce the potential of a fire-induced explosion due to catastrophic malfunction, human error, or other worst-case scenario influences.
(2) All significant release events are assumed to occur for at least five minutes before the emergency mitigation and abatement systems are capable of maintaining the situation to full capacity. This considers the probability that some emergency response systems may fail due to unforeseen circumstances associated with accidental releases.

Since the risk analysis also must consider the human factor during evaluation, the following assumptions are made regarding the surrounding population and neighborhoods:

(1) The area surrounding the storage facility is assumed to be occupied by members of the general public at all times. This means that accidental risk hazards could impact the nearby population 365 days a year, 24 hours a day. This is a conservative approach toward the risk analysis, as population density and prevalence will vary considerably based on the time of day and day of the week. However, given the relatively close residential proximity to the facility, the assumption that individuals will be near the release incident at anytime is justifiable.
(2) No external ignition sources (vehicles, spark-ignition equipment, etc.) were assumed to cause any accidental release hazards, given the storage tanks' proximity to nearby receptors and the probability that a release cloud could travel such a distance before combusting.

Influence of the Palos Verdes Fault Zone of Failure Analysis

The potential of a catastrophic earthquake occurring, which would cause rupture of the significant storage tanks at the facility, is estimated based on presently available information on the Palos Verdes fault zone, which is the nearest fault zone to the facility. The fault zone is estimated to extend over 100 km from Lasuen Knoll in the south, across the San Pedro Shelf, along the northeastern base of the onshore Palos Verdes Hills, and cross Santa Monica Bay. The fault zone has been shown to have a maximum exhibited slip rate of about 3.0 mm per year, but has been known to exhibit slip as low as 0.2 mm per year.

The probability of a moderate or major earthquake along the Palos Verdes fault is low when compared to the potential for movements on either the Newport-Inglewood or San Andreas faults. However, this fault is capable of producing strong to intense ground motion and ground surface rupture. The Palos Verdes fault zone has not been designated as an Alquist-Priolo Special Studies Zone by the California Geological Survey; however, the segment of the fault zone that extends through the harbor area has been identified as a Fault Rupture Study Area by the City of Los Angeles General Plan, Safety Element. During a survey conducted in 1996, it was concluded that Los Angeles region of the fault zone could anticipate a >7.0 magnitude earthquake resulting from the fault zone every 400 to 900 years. More recent approximations set the maximum possible magnitude around 7.3.

5.0 Hazards Posed by Amerigas Butane Storage Facility

Hazardous Properties of Butane

Butane inherently presents a human health risk due to its physical properties. Butane vapor is very flammable, and when ignition of vapors occurs, the combustion will flash back to the liquid surface. Butane vapor is colorless and non-toxic, with a potential for asphyxiation at high concentrations due to depletion of ambient oxygen. Asphyxiation is not as common of a health risk, since the risks associated with combustion of the butane are much more likely to occur under normal circumstances.

Heat radiation or direct fire burns occurring from instances of jet fire, pool fire, or flash fire, are also possible during butane leaks. Jet fire occurs when combustion of butane vapor is released from an orifice in the storage tank, which creates a powerful stream of flame as the evacuated butane vapor is rapidly combusted. A pool fire occurs when butane liquid is released and ignited on the surface of the ground or other area. A flash fire occurs when concentrations of released butane vapors mix with ambient air, disperse, and then are later ignited. The ignition can cause the gas cloud to burn back to the source of the spill or leak, and can cause a very rapid, unexpected onset of injury or even death.

Injuries from butane can result from overpressure of the storage tank due to rapid phase transition, resulting in vessel explosion. Overpressure from a vapor cloud explosion or an explosion in a confined space likewise present a risk of severe injuries or death.

Radius of Overpressure Blast Wave

Materials stored at the Amerigas facility may allow overpressure to be generated in two ways. The first type of occurrence is generated as a result of rapid burning (deflagration) of a vapor cloud, which could result in a low overpressure value (~0.15 psig) that could result in windows and glass materials shattering for open, unconfined spaces. Overpressures reaching over 1 psig are commonly associated with the boundary where building structural damage can begin to occur. Overpressure explosions occurring in confined spaces, or in areas where obstructions exist, can achieve such potentially damaging values.

The second type of mechanism by which damaging overpressure can occur results when a blast wave is created by failure of a pressure vessel. When storage tanks fail due to the buildup of vapor pressure from fire or from the absence of the cooling mechanisms, the internal energy of the butane can be converted to a pressure wave. A conservative estimate considers all the internal energy of butane converted to a pressure wave. This is unlikely to ever occur, but provides a worst-case scenario for a blast wave occurrence.

Radius of Fire Radiation Generation

It is assumed that the largest credible hazard that would extend beyond the facility boundaries of the Amerigas facility is the thermal radiation that could be released as a result of the combustion of vapor originating from pooled butane that may have escaped during accidental or catastrophic failure of the storage tank. This calculation considers the worst case scenario whereupon an earthquake could cause catastrophic failure of the largest butane storage tanks simultaneously. Vapor released from such an event would disperse and travel downwind until a combustion source ignited the vapor. It is likely that the flash fire would travel back to the pool source, igniting the dense concentration of vapor within that region and producing a tall column of flames capable of subjecting the immediate vicinity to hazardous amounts of thermal radiation. Other possible fire events are possible, but would result in a potentially smaller hazard zone with decreased exposure of individuals to harmful fire radiation.

6.0 Results of Quantitative Risk Analysis

Eight separate, distinct release scenarios were considered when evaluating the different types of hazards that could occur as a result of a release incident from the butane storage tanks. The scenarios ranged from minor release scenarios where a puncture was made in the walls of the storage tank, to catastrophic release events caused by severe earthquakes, whereupon the entirety of the butane stored in the largest tanks were to release and combust. For purposes of this risk analysis, EPA's RMP*Comp Ver 1.07 was used to calculate the projected release scenarios. A detailed explanation of each release scenario is presented as follows.

Alternative Release – Vapor Cloud Explosion #1

This scenario considers the release incident that may occur from a small puncture in a butane storage tank near the ground level of the tank. Such a puncture could be caused by improper operation of forklifts or other transportation vehicles. In such a situation, the release of butane from the punctured area would be initiated by the pressure of materials above the puncture area. In this model, the puncture area is assumed to be nine (9) square inches, 75 feet below the maximum fill height of the storage tank. The release rate is assumed to be 7,790 pounds per minute based on puncture conditions. Assuming a vapor cloud explosion to be the most likely ignition of the released materials, the impact distance is calculated to be roughly <0.1 miles in radius. In such a scenario, the explosion diameter would reach North Gaffey Street and slightly extend past Westmont Drive to the south. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 1*.

Alternative Release – Vapor Cloud Explosion #2

This scenario considers the incident that may occur from any general release from the storage tank that is caused by the formation of a vapor cloud. The release can occur from the pressure release valve during instances where excess venting may be required due to tank overpressure (due to refrigeration failure, for instance). Other causes may result from improper tank construction and maintenance, which could cause leaks due to material fatigue. In this type of instance, the release rate is lower than an accidental puncture incident. The release rate is assumed to be 1,000 pounds per minute or less. Assuming a vapor cloud explosion to be the most likely ignition of the released materials, the impact distance is calculated to be roughly <0.1 miles in radius. Like the first vapor cloud explosion scenario caused by a puncture, the explosion diameter would reach North Gaffey Street and slightly extend passed Westmont Drive to the south. This indicates that the resulting release incident caused by a puncture or small leak result in equivalent damage scenarios. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 2*.

Alternative Release – Pool Fire #1

This scenario considers a pool fire that may occur when liquid butane is released from a storage tank due to a general release. This may result from improper tank construction and maintenance, which could cause leaks due to material fatigue. The release rate is assumed to be 500 pounds per minute or less. This scenario considers the impact a pool fire would have on the surrounding area. The pool fire would occur once ignition of vapor returned to the dispersed butane liquid collecting near the release point. The consequent ignition of the liquid would result in a large plume of flames fueled by the pooled liquid. The amount of butane present will cause a larger plume of flame, which increases the possibility of exposure to fire radiation. The outer boundary of the projected area of such an event is the furthest area where an individual would suffer second degree burns if exposure to the fire radiation were to exceed thirty seconds.

Assuming a release duration of 360 minutes, occurrence of a pool fire under this scenario would cause an impact radius of 0.4 miles in radius from the source. This release would extend to the west past North Gaffey Street, impacting some residential areas to the west and southwest of the facility. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 3*.

Alternative Release – Pool Fire #2

This scenario considers the incident that may occur when liquid butane is released from a storage tank due to a rupture, similar to an incident postulated in the first vapor cloud explosion scenario. The release rate is expected to be larger than the scenario addressed in “Pool Fire #1” for this study. It is assumed to be 7,790 pounds per minute or less. This scenario considers the impact a pool fire would have on the surrounding area.

Assuming a release duration of 360 minutes, occurrence of a pool fire under this scenario would cause an impact radius of 1.7 miles from the source. This release would extend to the west as far as South Western Ave. (Highway 213), to the north as far as Ken Malloy Harbor Regional Park, and to the south as far as Highway 47 (Vincent Thomas Bridge), causing a devastating impact to residential and commercial centers. To the east, the impact area includes several major container terminals in the port of Los Angeles. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 4*.

Worst-Case Scenario – Vapor Cloud Explosion #1

Worst-case scenario assumes that a catastrophic earthquake would cause complete tank failure and instant release of the stored butane. In this model, only one butane tank is considered to completely fail under such a circumstance. The model assumes instantaneous and rapid release of butane vapor from the collective 63 million pounds that would be present at the time of failure. The scenario considers that the vapor cloud will disperse its maximum distance before ignition by an external, uncontrolled source. The model assumes vapor cloud explosion, whereupon the entirety of the butane is in vapor form and is instantly ignited upon full dispersion.

In this scenario, the impact radius would be 3.2 miles. The impact would cause large scale structural and physical damage due to rapid overpressure caused by the explosion. The explosion is shown to extend east into predominant shipping yards in the Long Beach harbor, to the north towards West Carson, to the south towards the coast of San Pedro, and to the west as far as the boundary of Rancho Palos Verdes. The impact would encompass terminals in Long Beach and includes nearly all the Port of Los Angeles terminals, as well as the visitor serving areas of the new Wilmington Waterfront project, the proposed San Pedro Waterfront project, and the Los Angeles Cruise Terminals. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 5*.

Worst-Case Scenario – Vapor Cloud Explosion #2

Worst-case scenario assumes that a catastrophic earthquake would cause complete tank failure and instant release of the stored butane. In this model, all of the butane tanks on-site are considered to completely fail under such a circumstance. The scenario assumes instantaneous and rapid release of butane vapor from the collective 126.5 million pounds that would be present at the time of failure. The scenario considers that the vapor cloud will disperse its maximum distance before ignition by an external, uncontrolled source. The model assumes vapor cloud explosion, whereupon the entirety of the butane is in vapor form and is instantly ignited upon full dispersion.

In this scenario, the impact radius would be 4.0 miles. The impact would cause large scale structural and physical damage due to rapid overpressure caused by the explosion. The explosion is shown to extend east into predominant shipping yards in the Long

Beach harbor, to the north towards Carson, to the south towards the coast of San Pedro, and to the west as far as the boundary of Rancho Palos Verdes. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 6*.

<u>Alternative Release – BLEVE #1</u>

This model is another worst-case scenario like the previous two scenarios, though the resulting release type is considered alternative to the more common type of release mode vapor cloud explosions. BLEVE (Boiling Liquid Expanding Vapor Explosion) occurs when a sudden drop in pressure inside a container causes violent boiling of the liquid, which rapidly liberates large amounts of vapor. The pressure of this vapor can be extremely high, causing a significant wave of overpressure (explosion) which may completely destroy the storage vessel and project fragments over the surrounding area. The harm involved with such an incident can include injury from shrapnel, explosion, and fire radiation.

The first model assumes catastrophic failure of only one butane storage tank due to an earthquake. Again, this represents roughly 63 million pounds of butane released. If BLEVE were to occur, the projected release radius is approximately 5.2 miles. This would expand to the east towards downtown Long Beach, to the north near the 405 Freeway, to the west into central Rancho Palos Verdes, and to the south past the coastline and over the Pacific Ocean. The projected impact covers nearly half of Palos Verdes Hills. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 7.*

<u>Alternative Release – BLEVE #2</u>

The final BLEVE model assumes catastrophic failure of all the butane storage tanks on-site due to an earthquake. Again, this represents roughly 126.5 million pounds of butane released. If BLEVE were to occur, the projected release radius is approximately 6.8 miles. This would expand to the east past downtown Long Beach, to the north towards Gardena, to the west towards Redondo Beach, and to the south past the coastline and over the Pacific Ocean. A summary of the projected conditions and represented aerial impact map are shown in *Appendix 8.*

Though this is a worst-case scenario projection, it is highly unlikely to occur, and contains some considerations that may not occur in practicality.

First, a large magnitude earthquake from the Palos Verdes fault zone (up to 7.3 magnitude), is only expected to occur once every 400-900 years. Likewise, the probability this would be centered near the Amerigas facility is moderate, since the fault zone extends nearly 100 kilometers. Similarly, it is not confirmed that such a large earthquake would rupture the tanks, since historical and test data is limited for such an occurrence.

Second, it is highly likely that the vapor cloud will distribute and ignite before reaching its maximum radius, so BLEVE may not occur. The numerous electrical sources in the area will likely ignite the vapor cloud before this can occur. When considering an earthquake failure, exposed electrical sources are anticipated to be more abundant and will likely act as instantaneous ignition sources.

Finally, weather conditions along the harbor are anticipated to generate consistent yet variable wind speeds that would disperse the butane vapor more rapidly to prohibit dense, overpressure conditions upon ignition.

7.0 Conclusions of the Study

In the event of unexpected release of butane from the Amerigas storage facility, a variety of accidental risks can occur, which include types of combustion (pool, flash, and jet fires) and types of overpressure explosions (overpressure in storage tank, BLEVE, etc.). The worst case scenario of a large-scale release hazard is projected to occur during the night when population density of the nearest receptors is highest. Low wind velocity is considered, as this would cause a dense vapor cloud of evaporated butane to collect within the facility, producing a powerful blast wave upon ignition. The largest combustion incident is projected to occur, whereupon BLEVE will occur as the result of simultaneous tank failure due to catastrophic earthquake, creating an intense overpressure that would result in a large-scale explosion, projectile shrapnel, and fire radiation exposure.

A summary of the release scenarios and statistics is shown in the following table:

Release Description	Wind Speed (m/s)	Air Temperature (°F)	Release Rate (lb/min.)	Impact Radius (miles)
Vapor Cloud Explosion	3.0	77.0	7,790	<0.1
Vapor Cloud Explosion	3.0	77.0	1,000	<0.1
Pool Fire	3.0	77.0	500	0.4
Pool Fire	3.0	77.0	7,790	1.7
Vapor Cloud Explosion	1.5	77.0	Instantaneous	3.2
Vapor Cloud Explosion	1.5	77.0	Instantaneous	4.0
BLEVE	3.0	77.0	Instantaneous	5.2
BLEVE	3.0	77.0	Instantaneous	6.8

It is important to note that the analysis is conducted based on a number of assumptions. This may result in an over-conservative conclusion in regards to toxic and flammable hazard zones. These assumptions were necessary, however, due to the lack of historical data and lack of access to facility-specific data.

While the probability of larger-scale release scenarios is very low, the smaller incidents that may occur from ruptures or leaks still pose a threat to the local communities surrounding the facility. Thus, while incidents resulting from large magnitude earthquakes are not likely, factors such as accidental release or rupture can still pose an inherent risk to surrounding residential and commercial areas.

Appendix 1

Release Scenario #1 – Vapor Cloud Explosion
(Distance <0.1 Miles Radius)

<u>Appendix 2</u>

Release Scenario #2 – Vapor Cloud Explosion
(Distance <0.1 Miles Radius)

Appendix 3

Release Scenario #3 – Pool Fire
(Distance 0.4 Miles Radius)

Appendix 4

Release Scenario #4 – Pool Fire
(Distance 1.7 Miles Radius)

Appendix 5

Release Scenario #5 – Vapor Cloud Explosion
(Distance 3.2 Miles Radius)

<u>Appendix 6</u>

Release Scenario #6 – Vapor Cloud Explosion
(Distance 4.0 Miles Radius)

Appendix 7

Release Scenario #7 – BLEVE
(Distance 5.2 Miles Radius)

Appendix 8

Release Scenario #8 – BLEVE
(Distance 6.8 Miles Radius)

Appendix 1

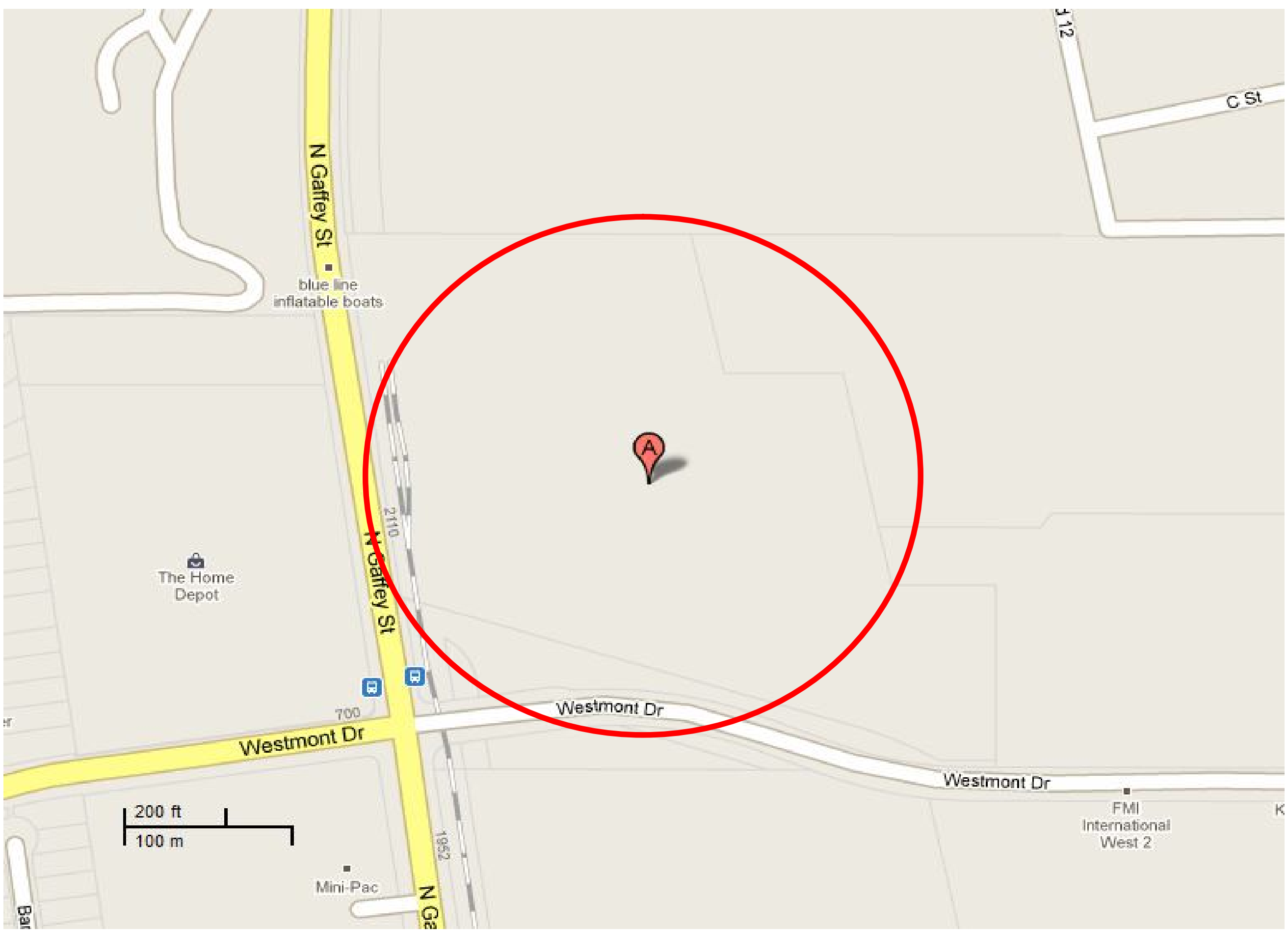
Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas

Scenario:	***Alternative Release***
Storage Parameters:	***Tank Under Atmospheric Pressure***
Hole or Puncture Area:	***9 square inches***
Height of Liquid Column Above Hole:	***75 feet***
Release Rate to Outside Air:	***7790 lbs/min (based on the condition of punctured area)***
Release Type:	***Vapor Cloud Fire***
Release Duration:	***360 Minutes***
Mitigation Measures:	***None***
Lower Flammability Limit:	***36 mg/L***

Assumptions about this scenario

Wind Speed:	3 meters per second (6.7 miles/hour)
Atmospheric Turbulence:	D Class (Neutral)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance to Lower Flammability Limit: < 0.1 miles radius (< 0.16 kilometers)



Appendix 2

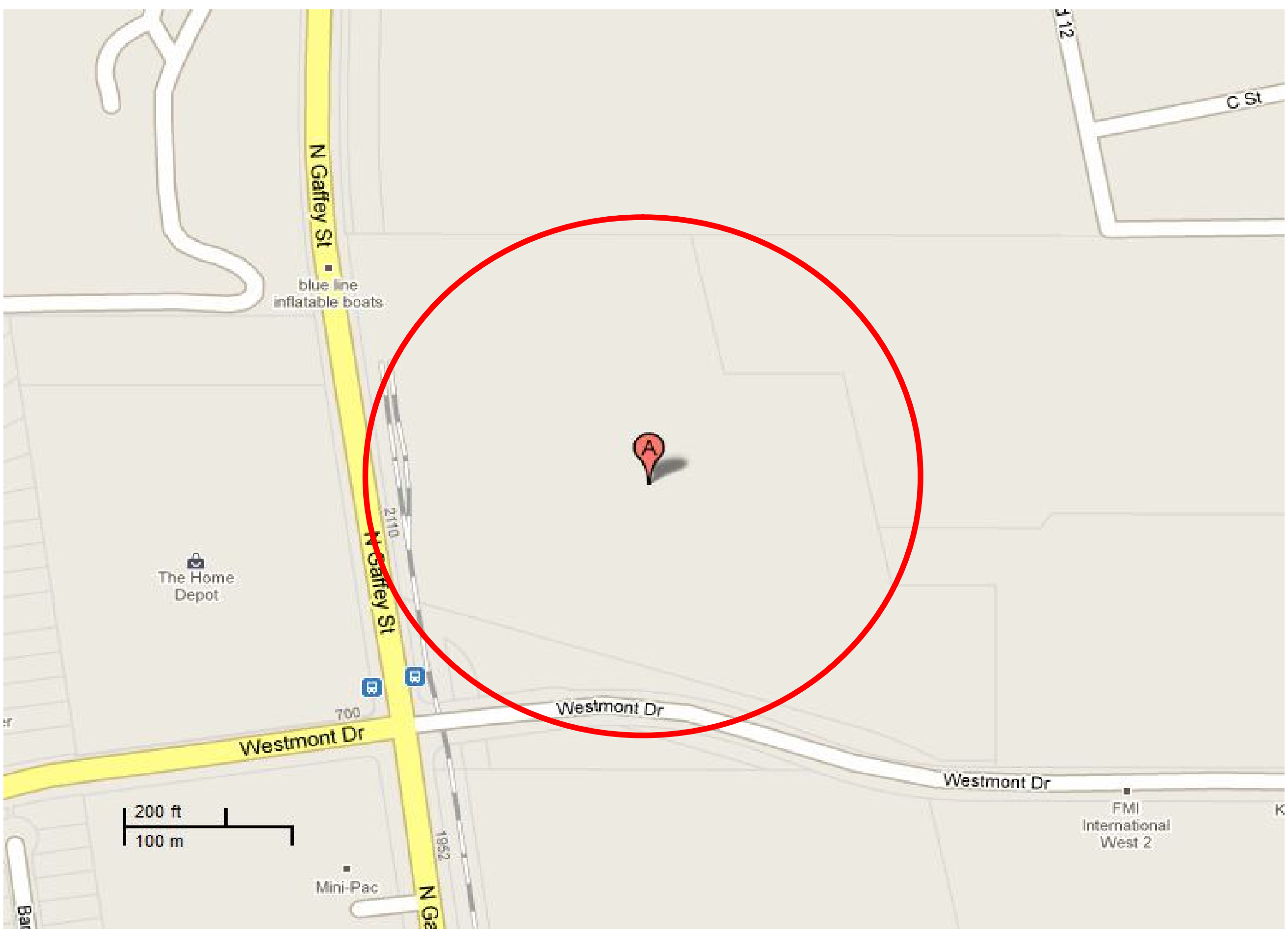
Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas

Scenario:	***Alternative Release***
Storage Parameters:	***Tank Under Atmospheric Pressure***
Release Rate to Outside Air:	***1000 lbs/min***
Release Type:	***Vapor Cloud Fire***
Release Duration:	***360 Minutes***
Mitigation Measures:	***None***
Lower Flammability Limit:	***36 mg/L***

Assumptions about this scenario

Wind Speed:	3 meters per second (6.7 miles/hour)
Atmospheric Turbulence:	D Class (Neutral)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance to Lower Flammability Limit: < 0.1 miles radius (< 0.16 kilometers)



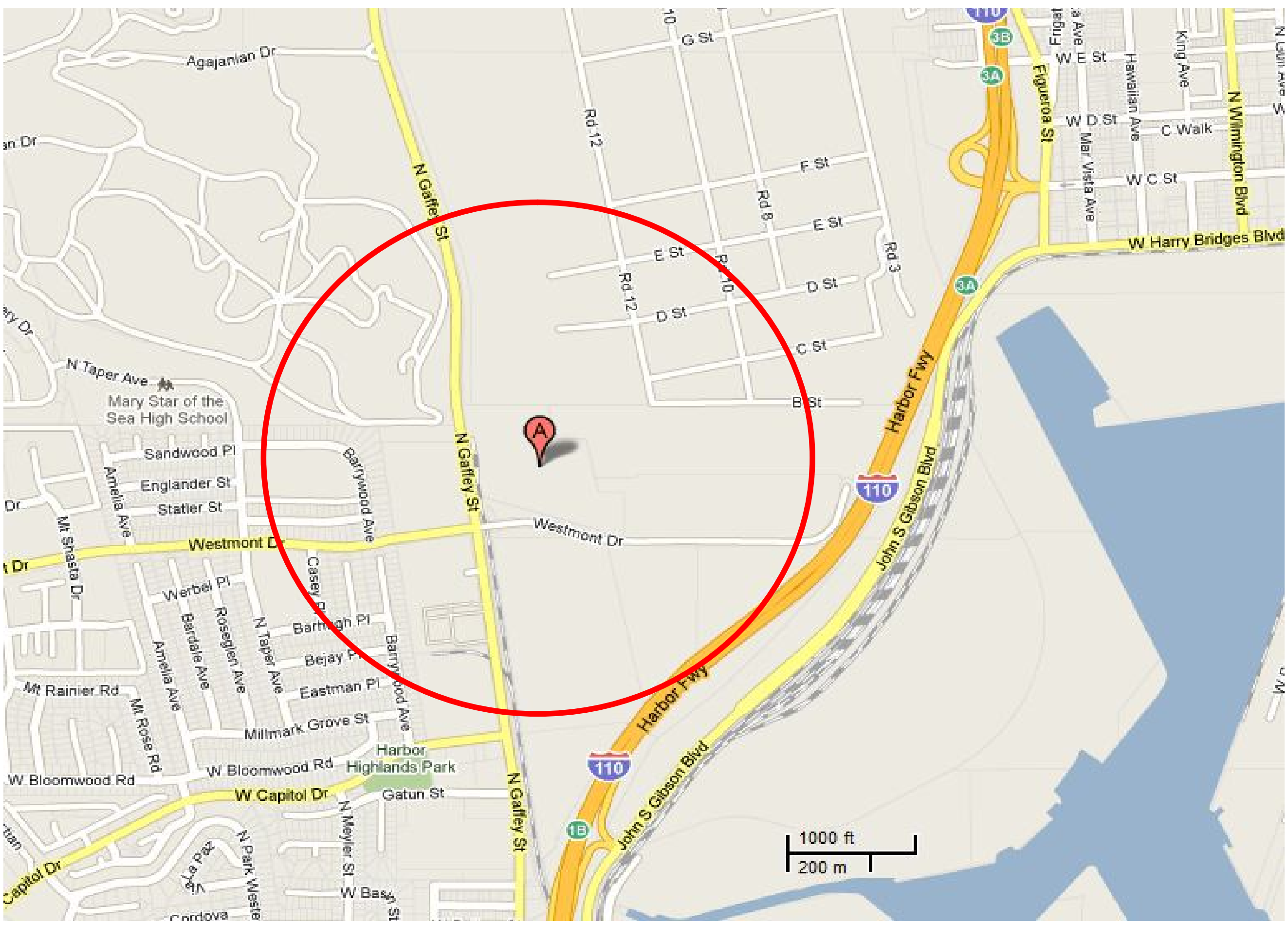
<u>Appendix 3</u>

Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas
Scenario:	***Alternative Release***
Storage Parameters:	***Tank Under Atmospheric Pressure***
Release Rate to Outside Air:	***500 lbs/min***
Release Type:	***Pool Fire***
Release Duration:	***360 Minutes***
Mitigation Measures:	***None***
Topography:	***Urban Surroundings (many obstacles in the immediate area)***

<u>Assumptions about this scenario</u>

Wind Speed:	3 meters per second (6.7 miles/hour)
Atmospheric Turbulence:	D Class (Neutral)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance to Heat Radiation Endpoints (5 kilowatts/square meter): 0.4 miles radius (0.7 kilometers)



Appendix 4

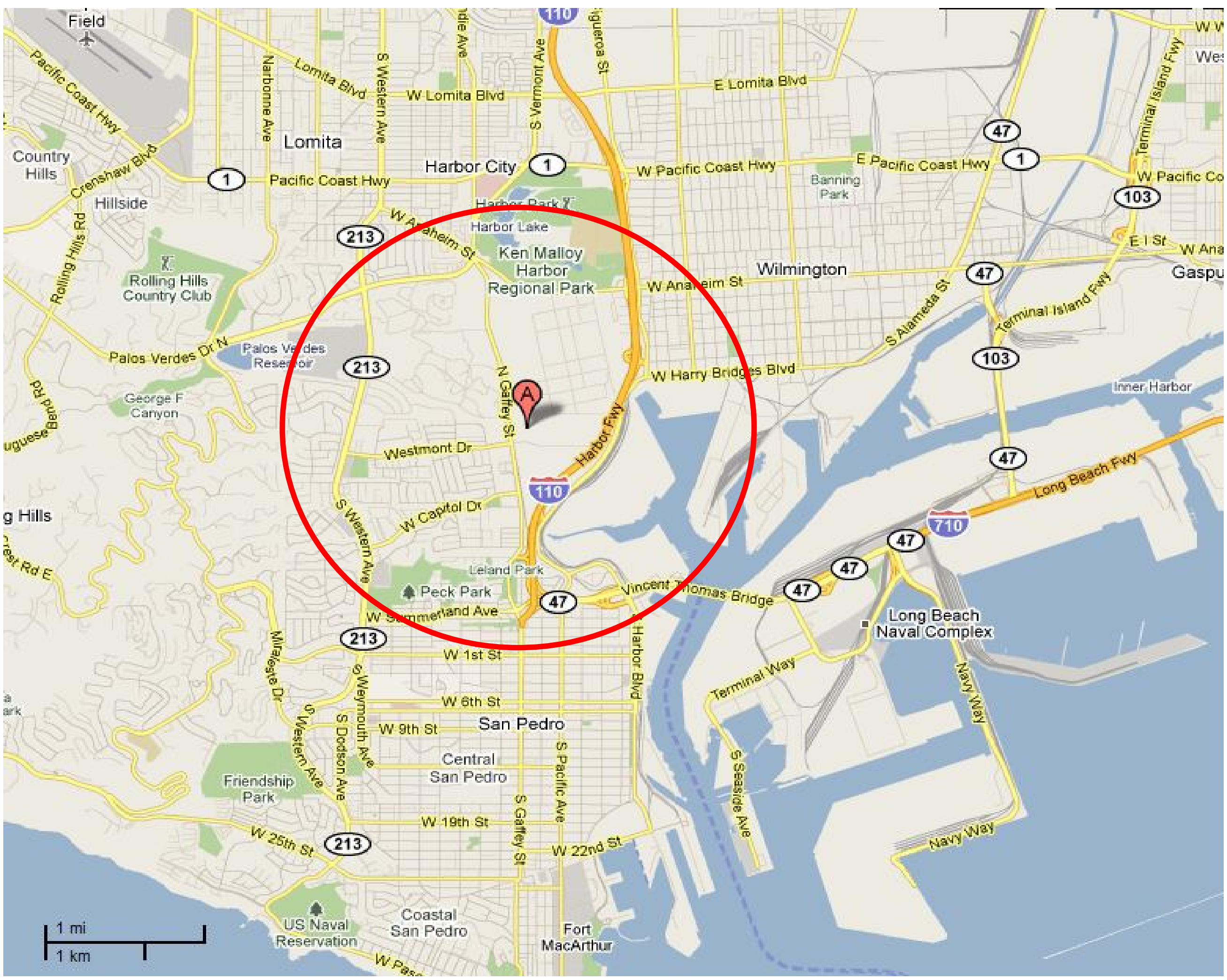
Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas

Scenario:	***Alternative Release***
Storage Parameters:	***Tank Under Atmospheric Pressure***
Hole or Puncture Area:	***9 square inches***
Height of Liquid Column Above Hole:	***75 feet***
Release Rate to Outside Air:	***7790 lbs/min (based on the condition of punctured area)***
Release Type:	***Pool Fire***
Release Duration:	***360 Minutes***
Mitigation Measures:	***None***
Topography:	***Urban Surroundings (many obstacles in the immediate area)***

Assumptions about this scenario

Wind Speed:	3 meters per second (6.7 miles/hour)
Atmospheric Turbulence:	D Class (Neutral)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance to Heat Radiation Endpoints (5 kilowatts/square meter): 1.7 miles radius (2.7 kilometers)



Appendix 5

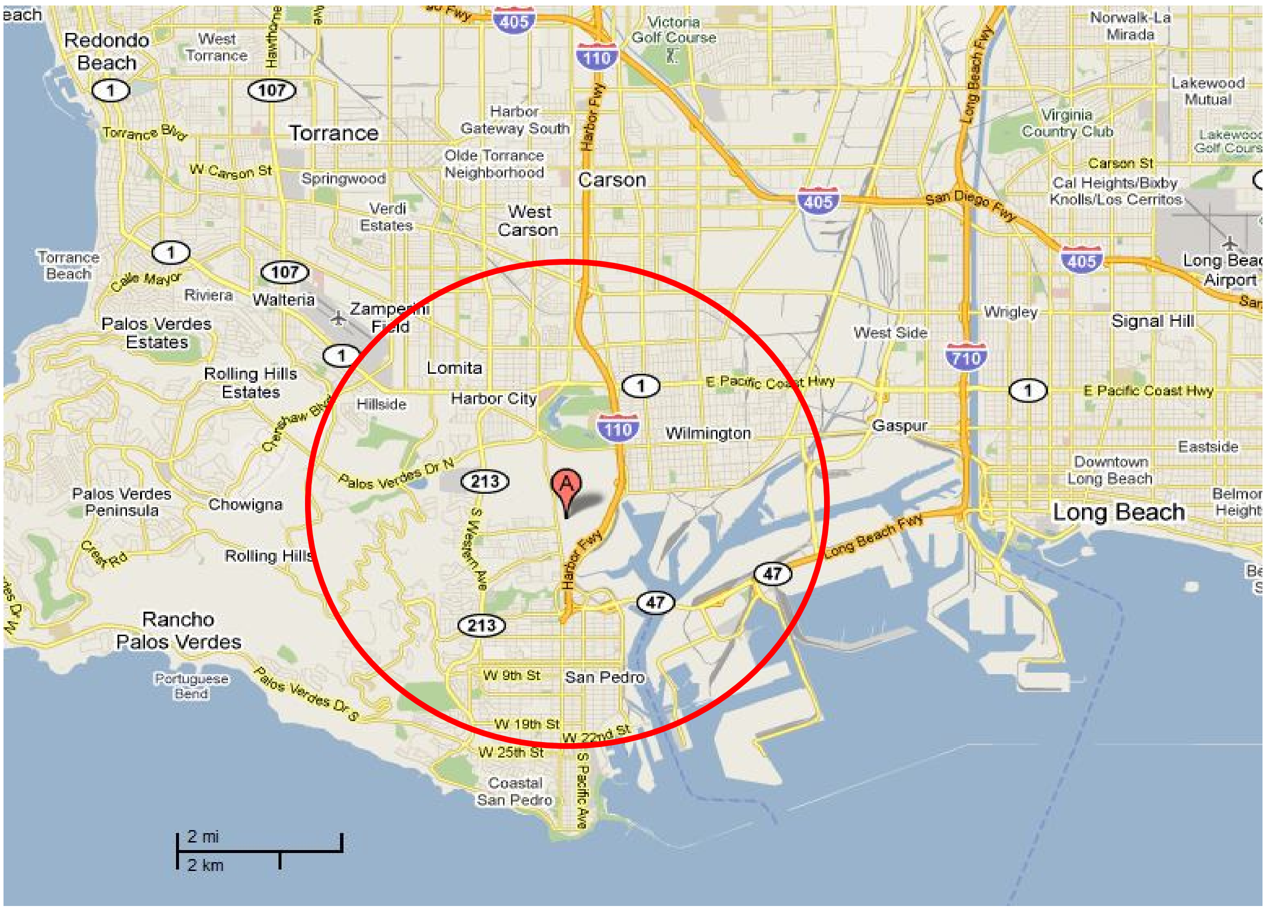
Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas

Scenario:	***Worst-Case***
Quantity Released:	***62,958,773 Pounds***
Release Type:	***Vapor Cloud Explosion***
Mitigation Measures:	***None***

Assumptions about this scenario

Wind Speed:	1.5 meters per second (3.4 miles/hour)
Atmospheric Turbulence:	F Class (Stable)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance to 1 psi overpressure: 3.2 miles radius (5.1 kilometers)



Appendix 6

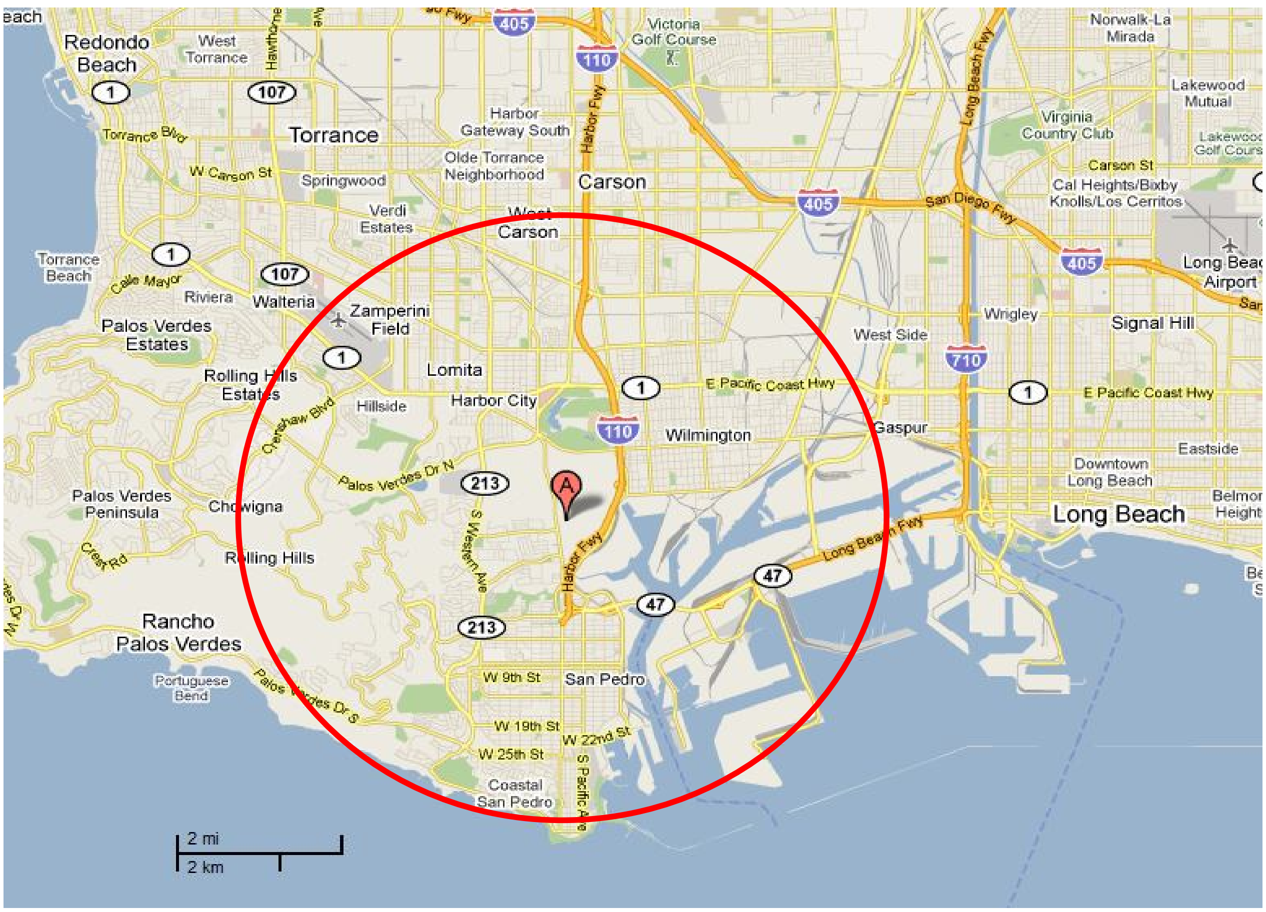
Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas

Scenario: ***Worst-Case***
Quantity Released: ***126,517,153 Pounds***
Release Type: ***Vapor Cloud Explosion***
Mitigation Measures: ***None***

Assumptions about this scenario

Wind Speed:	1.5 meters per second (3.4 miles/hour)
Atmospheric Turbulence:	F Class (Stable)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance to 1 psi overpressure: 4.0 miles radius (6.5 kilometers)



Appendix 7

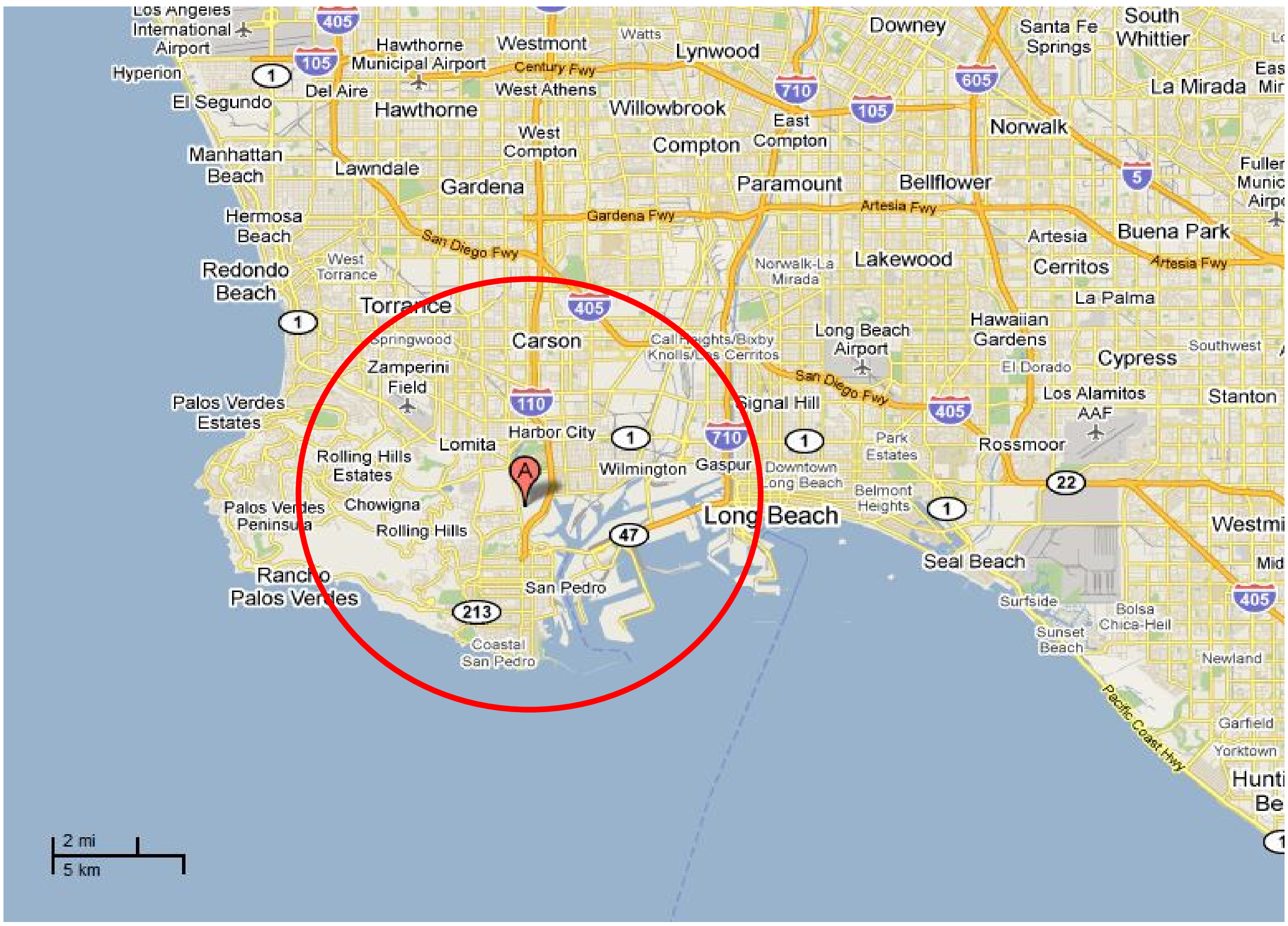
Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas

Scenario: ***Alternative Release***
Quantity Released: ***62,958,773 Pounds***
Release Type: ***BLEVE (boiling liquid expanding vapor explosion)***
Mitigation Measures: ***None***

Assumptions about this scenario

Wind Speed:	3 meters per second (6.7 miles/hour)
Atmospheric Turbulence:	D Class (Neutral)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance at which exposure may cause second-degree burns: 5.2 miles radius (8.4 kilometers)



Appendix 8

Chemical:	Butane
CAS #:	106-97-8
Form:	Liquefied by Refrigeration
Category:	Flammable Gas

Scenario:	***Alternative Release***
Quantity Released:	***126,517,153 Pounds***
Release Type:	***BLEVE (boiling liquid expanding vapor explosion)***
Mitigation Measures:	***None***

Assumptions about this scenario

Wind Speed:	3 meters per second (6.7 miles/hour)
Atmospheric Turbulence:	D Class (Neutral)
Air Temperature:	77 degrees F (25 degrees C)

Estimated Distance at which exposure may cause second-degree burns: 6.8 miles radius (11.0 kilomete