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EGAS

The Egyptian Natural Gas Holding Company "EGAS"

Quantitative Risk *Assessment* "QRA" Study For Aga Pressure Reduction Station

Prepared By
Petroleum Safety and Environmental Services Company
PETROSAFE

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Executive Summary

This report summarizes the Quantitative Risk Assessment (QRA) analysis study undertaken for the New Natural Gas Pressure Reduction & Metering Station "PRMS" with Odorant at Aga – Dakahlia Governorate – Egypt, which owned by Egyptian Natural Gas Holding Company "EGAS" and operated by Egypt Gas Company, in order to identify and evaluate hazards generated from the new PRMS.

The scope of work includes performing frequency assessment, consequence modeling analysis and Quantitative Risk Assessment of Aga PRMS in order to assess its impacts on the surroundings.

The main objective of the Quantitative Risk Assessment (QRA) study is to demonstrate that Individual Risk "IR" for workers and Societal Risk "SR" for public fall within the ALARP region of Risk Acceptance Criteria, and the new Aga PRMS does not lead to any unacceptable risks to the workers or the public.

QRA Study has been undertaken in accordance with the methodology outlined in the UKHSE as well as international regulations and standards.

QRA starts by Hazard Identification (HAZID) study, which determines the Major Accident Hazards (MAH) that requires consequence modelling, frequency analysis, and risk calculation.

In order to perform consequence-modelling analysis of the potential hazardous scenarios resulting from loss of containment, some assumptions and design basis have been proposed. Three scenarios of the release have been proposed:

1. Gas Release from the inlet / outlet pipeline.
2. Gas Release from the off-take point.
3. Leak from odorant tank.

The QRA has been performed using DNV Phast software (Ver. 7.0) for consequence modelling of different types of hazardous consequences.

Weather conditions have been selected based on wind speed and stability class for the area detailed weather statistics.

The worst case weather conditions has been selected represented by wind speed of 3.11 m/s and stability class "D" representing "Neutral" weather conditions, in order to obtain conservative results. The prevailing wind direction is North North West (NNW), North West (NW) & North (N).

As per results from modeling the consequences of each scenario, the following table summarize the study, and as follows:

Event	Scenario	Effects
Pin hole (1") gas release 8" inlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value (4, 9.5, 12.5 & 25 kW/m^2) will be limited inside the PRMS and affecting the facilities.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the overpressure wave of 0.020 bar effects will extend outside the PRMS NE fence with about 3 m downwind and southwest fence with about 5 m crosswind.* *The overpressure waves of 0.137 & 0.206 bar will be limited inside the PRMS fence affecting the facilities.*
Half Rupture (3") gas release 6" inlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud will extend the NE fence downwind reaching the sub-way route outside the PRMS.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that all values will extend outside the NE fence downwind with various distances that reaching the sub-way route (25 & 37.5 kW/m^2), and the main road (9.5 kW/m^2).* *The main gate and security office will reached by the value of 4 & 1.6 kW/m^2.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching the housing area SE downwind and NE crosswind.* *The value of 0.137 bar will be limited inside the PRMS from the NW side and extend the PRMS fences from NE (5m), SE (3m) & SW (5m), and will affect the*

Event	Scenario	Effects
		control room, and heater area. *The value of 0.206 bar will be limited inside the PRMS from three sides and extend from SW (2m), and will affect the control room.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching housing area SE side downwind.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS from the SE side reaching the main road and near to the housing area.*
Full Rupture gas release 6" inlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects (UFL, LFL & 50 % LFL) will extend outside the SE fence covering the sub-way and irrigation canal.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values will extend outside the PRMS SE fence downwind affecting the sub-way and irrigation canal, and near to the main road.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching the housing area SE downwind and NE crosswind.* *The value of 0.137 bar will be limited inside the PRMS from the NW side affecting the control room and extend the PRMS fences from NE (5m), SE (3m) & SW (5m).* *The value of 0.206 bar will be limited inside the PRMS from three sides affecting the control room and extend from SW (2m).*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching housing area SE side downwind.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS from the SE side reaching the housing area downwind.*

Event	Scenario	Effects
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value of 9.5 & 12.5 kW/m^2 will be limited inside PRMS fence and covering the control room NE side crosswind.*
Pin hole (1") gas release 8" outlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRMS boundary downwind.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).* *The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
Half Rupture (4") gas release 8" outlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud (UFL, LFL & 50% LFL) will limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that all radiation values will extend outside the PRMS SE downwind covering the sub-way (25 & 37.5 kW/m^2) and SW crosswind covering the sub-way and near to the main road (9. & 12.5 kW/m^2).*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).* *The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.*

Event	Scenario	Effects
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will be limited inside the PRMS boundary from NE & NW, (reaching the control room and heater) and will extend from SE & SW covering the sub-way.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS SE fence to the sub-way downwind.*
Full Rupture gas release 8" outlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will extend outside the PRMS SE fence to reach the sub-way downwind.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that all values will extend outside the SE fence and cover the sub-way, irrigation canal & main road (25 & 37.5 kW/m^2).* *The value of 12.5 kW/m^2 will be near to the housing building and 9.5 kW/m^2 will reach 2 buildings downwind.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).* *The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will be affect the PRMS facility from SE side; also will extend from SE & SW covering the sub-way and the irrigation canal to reach the main road.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS SE fence to affects the irrigation canal downwind.*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values of 9.5 & 12.5 kW/m^2 will be limited inside the PRMS boundary.*

Event	Scenario	Effects
Odorant tank 1" leak		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the LFL, LFL and 50 % LFL will extend outside the PRMS SE fence to cover the sub-way and the irrigation canal and reach the main road downwind.* *Consideration should be taken when deal with liquid, vapors and smokes according to the MSDS for the material.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation of (9.5, 12.5, 25 & 37.5 kW/m^2) effects will be limited inside the PRMS boundary covering the pressure reduction facilities.* *The value of 9.5 kW/m^2 will be near to the control room at the front side.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of:* *0.020 bar will extend from the SE fence to reach the residential building, covering the sub-way and the main road downwind and crosswind.* *0.137 & 0.206 bar will extend to reach the main road downwind.*
Pin hole (1") gas release 6" off-take pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values of 9.5, 12.5, 25 & 37.5 kW/m^2 will be limited inside the off-take valves room.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*

Event	Scenario	Effects
Half Rupture (3") gas release 6" off-take pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values of 9.5, 12.5, 25 & 37.5 kW/m^2 will be limited inside the off-take valves room.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS and reaching the NE building crosswind and near to the buildings SE downwind.* *The value of 0.137 bar and 0.206 bar will extend outside the PRMS boundary NE &NW sides and affect the firefighting facilities (0.137 and 0.206 bar) SW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
Full Rupture gas release 6" off-take pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will extend to the PRMS facilities SE side downwind.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that:* *The heat radiation of 9.5 & 12.5 kW/m^2 will affect the control room crosswind NE side, near to the firefighting facility upwind NW side and extend to reach the main road downwind SE side.* *The heat radiation of 25 & 37.5 kW/m^2 will affect the heater area and the PRMS facility, and with extension to reach the sub-way outside the site.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS and reaching the NE building crosswind and near to the buildings SE downwind.* *The value of 0.137 bar and 0.206 bar will extend outside the PRMS boundary NE &NW sides and affect the firefighting facilities (0.137 and 0.206 bar) SW side.*

Event	Scenario	Effects
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value of 9.5 & 12.5 kW/m^2 will extend outside the PRMS NW & NE sides with no effects on surroundings, but will affect the firefighting facility.*

The previous table shows that there are some potential hazards with heat radiation resulting from jet fire and fireball, and explosion overpressure waves from early and late explosion events.

These hazards will affect the control room at the site, and some scenarios will extend over the site boundary like heat radiation (12.5 kW/m^2) or explosion overpressure waves (0.137 & 0.206 bar) reaching surrounding public road and buildings downwind.

The major hazards that extend over site boundary and/or effect on workers were used for Risk Calculations.

Event Tree Analysis (ETA) is an analysis technique for identifying and evaluating the sequence of events in a potential accident scenario following the occurrence of an initiating event. ETA utilizes a visual logic tree structure known as an event tree (ET). ETA provides a Probabilistic Risk Assessment (PRA) of the risk associated with each potential outcome. ETA has been used for scenario development.

The following data and assumptions have been considered in the Event tree analysis (ETA):

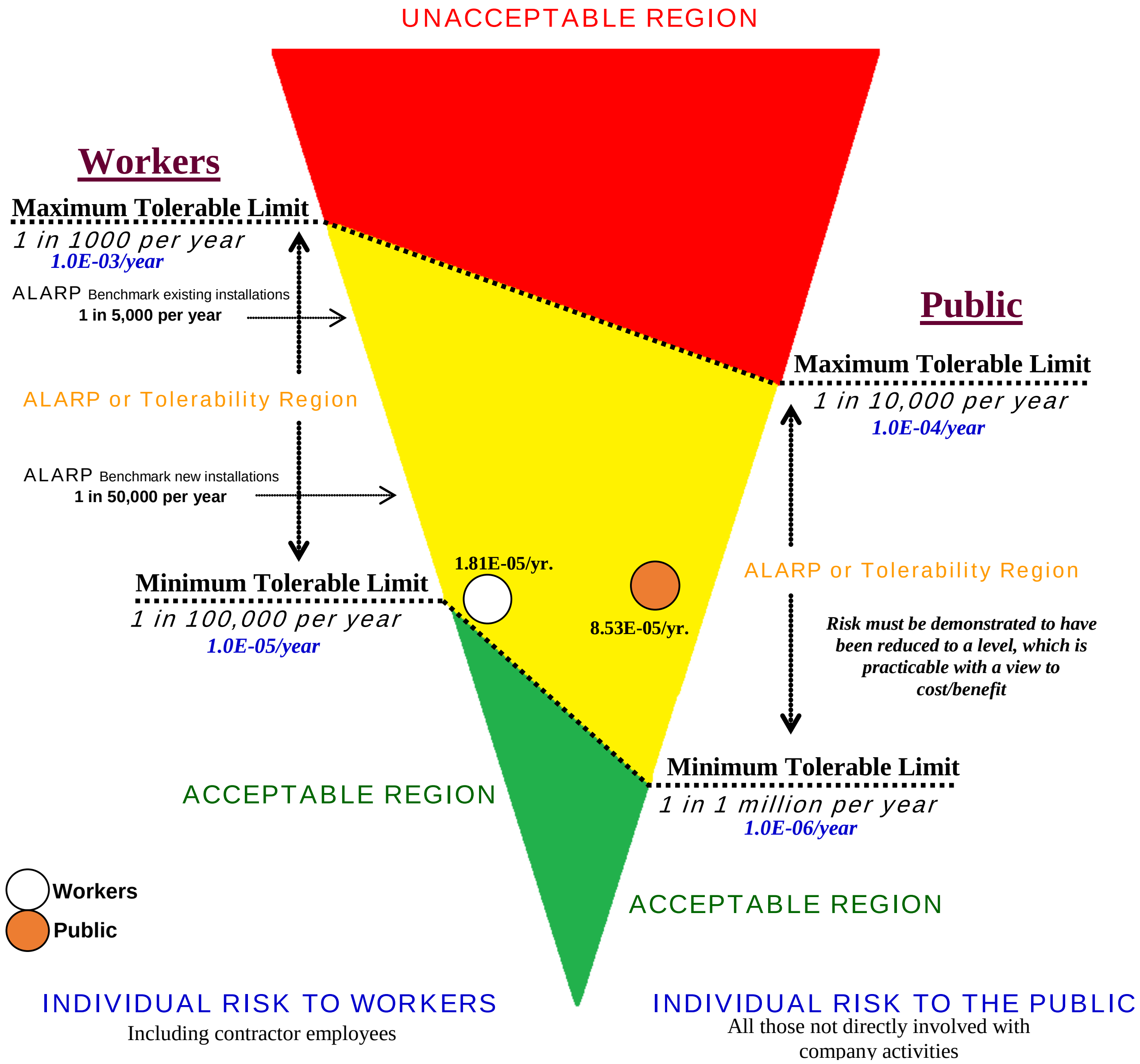
- Failure frequency data (mainly E&P Forum/OGP),
- Risk reduction factors (if available),
- Ignition probabilities (both immediate and delayed),
- Vulnerability data.

Risks have been assessed for workers using International Risk Management Guidelines as a reference.
The resulting risks have been compared with International Risk Acceptance Criteria.
Risk evaluation for Individual Risk "IR" and Societal Risk "SR" for the major hazards presented in the following tables:

Scenario	Event	People	Individual Risk "IR"	Acceptability Criteria
Gas Release from 3"/6" Inlet Pipeline	Explosion	Indoor	***1.73E-05***	ALARP
Gas Release from 6"/6" Inlet Pipeline	Fire Ball	Indoor	***2.58E-07***	Acceptable (√)
	Explosion	Indoor	***3.87E-07***	Acceptable (√)
Gas Release from 6"/6" Off-take Pipeline	Jet Fire	Indoor	***1.29E-07***	Acceptable (√)
TOTAL Risk for Workers			***1.81E-05***	**ALARP**

Scenario	Event	People	Individual Risk "IR"	Acceptability Criteria
Gas Release from 3"/6" Inlet Pipeline	Jet Fire	Outdoor	***2.52E-05***	ALARP
	Explosion	Indoor	***3.46E-05***	ALARP
		Outdoor	***3.60E-06***	ALARP
Gas Release from 8"/8" Outlet Pipeline	Jet Fire	Indoor	***2.58E-07***	Acceptable (√)
		Outdoor	***5.64E-07***	Acceptable (√)
Gas Release from 6"/6" Off-take Pipeline	Jet Fire	Outdoor	***8.06E-08***	Acceptable (√)
Odorant Tank 1" Leak	Jet Fire	Outdoor	***2.10E-05***	ALARP
TOTAL Risk for Workers			***8.53E-05***	**ALARP**

The following figure show the Individual Risk "IR" as well as Societal Risk "SR" for Aga PRMS:



The level of Individual Risk to the exposed worker at Aga PRMS, based on the risk tolerability criterion used is ALARP.

The level of Individual Risk to the exposed Public at Aga PRMS area, based on the risk tolerability criterion used is ALARP.

Introduction

The Egyptian Natural Gas Holding Company "EGAS" has engaged Petroleum Safety and Environmental Services Company "PETROSAFE" to identify and evaluate hazards generated from the "New Natural Gas Pressure Reduction and Odorant Station – PRMS" at Aga – Dakahlia Governorate – Egypt, which operated by Egypt Gas Company in order to advice protective measures for minimizing risk up to acceptable level.

As part of this review, a QRA study conducted for the following objectives:

- Identify hazardous scenarios related to the most critical unexpected event(s).
- Determine the likelihood of the identified scenarios;
- Model the potential consequences of the identified scenarios;
- Determine the Potential risk of fatality resulting from the identified hazardous scenarios.

The proposed study should also identify existing arrangements for the prevention of major accidents and their mitigation. This would involve emergency plan and procedure for dealing with such events.

PETROSAFE selected to carry out this study, as it has the experience in conducting this type of work.

PETROSAFE is also empowered by the Egyptian General Petroleum Corporation "EGPC" to identify and evaluate factors that relate to Occupational Health & Safety and Environmental Protection.

Technical Definitions

ALARP	*Stands for "As Low As Reasonably Practicable", and is a term often used in the milieu of safety-critical and safety-involved systems. The ALARP principle is that the residual risk shall be as low as reasonably practicable.*
API	*American Petroleum Institute.*
Confinement	*A qualitative or quantitative measure of the enclosure or partial enclosure areas where vapors cloud may be contained.*
Congestion	*A qualitative or quantitative measure of the physical layout, spacing, and obstructions within a facility that promote development of a vapor cloud explosion.*
DNV PHAST	*Process Hazard Analysis Software Tool "PHAST" established by Det Norske Veritas "DNV". Phast examines the progress of a potential incident from the initial release to far-field dispersion including modelling of pool spreading and evaporation, and flammable and toxic effects.*
E&P Forum	*Exploration and Production "E&P" Forum is the international association of oil companies and petroleum industry organizations formed in 1974. It was established to represent its members' interests at the specialized agencies of the United Nations, governmental and other international bodies concerned with regulating the exploration and production of oil and gas.*
EGAS	*The Egyptian Natural Gas Holding Company.*
EGPC	*The Egyptian General Petroleum Corporation.*
EX	*Explosion Proof Type Equipment.*
EERA	*Escape, Evacuation and Rescue Assessment.*
ESD	*Emergency Shut Down.*
Explosion	*Explosion is the delayed ignition of gas in a confined or congested area resulting in high overpressure waves.* *Once the explosion occurs, it creates a blast wave that has a very steep pressure rise at the wave front and a blast wind that is a*

	transient flow behind the blast wave. The impact of the blast wave on structure near the explosion known as blast loading. The two important aspects of the blast loading concern are the prediction of the magnitude of the blast and of the pressure loading onto the local structures. Pressure loading predication as result of a blast; resemble a pulse of trapezoidal or triangular shape. They normally have duration of between approximately 40 msec and 400 msec. The time to maximum pressure is typically 20 msec. *Primary damage from an explosion may result from several events:* 1. *Overpressure - the pressure developed between the expanding gas and its surrounding atmosphere.* 2. *Pulse - the differential pressure across a plant as a pressure wave passes might cause collapse or movement, both positive and negative.* 3. *Missiles and Shrapnel - are whole or partial items that are thrown by the blast of expanding gases that might cause damage or event escalation. In general, these "missiles" from atmospheric vapor cloud explosions cause minor impacts to process equipment since insufficient energy is available to lift heavy objects and cause major impacts. Small projectile objects are still a hazard to personnel and may cause injuries and fatalities. Impacts from rupture incidents may produce catastrophic results.*
(ETA) Event Tree Analysis	*Is a forward, bottom up, logical modeling technique for both success and failure that explores responses through a single initiating event and lays a path for assessing probabilities of the outcomes and overall system analysis. This analysis technique used to analyze the effects of functioning or failed systems, given that an event has occurred.*
Failure Rate	*Is the frequency with which an engineered system or component fails, expressed in failures per unit of time. It is highly used in reliability engineering.*
GASCO	*The Egyptian Natural Gas Company.*
Gas Cloud Dispersion	*Gas cloud air dilution naturally reduces the concentration to below the LEL or no longer considered ignitable (typically defined as 50 % of the LEL).*

HSE Policy	*Health, Safety and Environmental Policy.*
Hazard	*An inherent physical or chemical characteristic (flammability, toxicity, corrosively, stored chemical or mechanical energy) or set of conditions that has the potential for causing harm to people, property, or the environment.*
(HAZOP) Hazard And Operability Study	*Is a structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation. The HAZOP technique is qualitative, and aims to stimulate the imagination of participants to identify potential hazards and operability problems; structure and completeness given by using guideword prompts.*
(HAZID) Hazard Identification Study	*Is a tool for hazard identification, used early in a project as soon as process flow diagrams, draft heat and mass balances, and plot layouts are available. Existing site infrastructure, weather, and Geotechnical data also required, these being a source of external hazards.*
(HAC) Hazardous Area Classification	*When electrical equipment is used in, around, or near an atmosphere that has flammable gases or vapors, flammable liquids, combustible dusts, ignitable fibers or flying's, there is always a possibility or risk that a fire or explosion might occur. Those areas where the possibility or risk of fire or explosion might occur due to an explosive atmosphere and/or mixture is often called a hazardous (or classified) location/area.*
(IR) Individual Risk	*The risk to a single person inside a particular building. Maximum individual risk is the risk to the most-exposed person and assumes that the person is exposed.*
Jet Fire	*A jet fire is a pressurized stream of combustible gas or atomized liquid (such as a high-pressure release from a gas pipe or wellhead blowout event) that is burning. If such a release is ignited soon after it occurs, (i.e., within 2 - 3 minutes), the result is an intense jet flame. This jet fire stabilizes to a point that is close to the source of release, until the release stopped. A jet fire is usually a very localized, but very destructive to anything close to it. This is partly because as well as producing thermal radiation, the jet fire causes considerable convective heating in the region*

	beyond the tip of the flame. The high velocity of the escaping gas entrains air into the gas "jet" causing more efficient combustion to occur than in pool fires. *Consequentially, a much higher heat transfer rate occurs to any object immersed in the flame, i.e., over 200 kW/m^2 (62,500 Btdsq. ft) for a jet fire than in a pool fire flame. Typically, the first 10% of a jet fire length is conservatively considered un-ignited gas, as a result of the exit velocity causing the flame to lift off the gas point of release. This effect has been measured on hydrocarbon facility flares at 20% of the jet length, but a value of 10% is used to account for the extra turbulence around the edges of a real release point as compared to the smooth gas release from a flare tip. Jet flames have a relatively cool core near the source. The greatest heat flux usually occurs at impingement distances beyond 40% of the flame length, from its source. The greatest heat flux is not necessarily on the directly impinged side.*
kW/m^2	*Kilowatt per square meter – unit for measuring the heat radiation (or heat flux).*
LFL / LEL	*Lower Flammable Limit / Lower Explosive Limit - The lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source.*
MSDS	*Material Safety Data Sheet.*
mm Hg	*A millimeter of mercury is a manometeric unit of pressure, formerly defined as the extra pressure generated by a column of mercury one millimeter high.*
MEL	*Maximum Exposure Limit.*
NFPA	*National Fire Protection Association.*
N	*North Direction.*
NE	*Northern East Direction.*
NW	*Northern West Direction.*
N/D	*Not Determined.*

N/R	*Not Reached.*
OGP	*Oil and Gas Producers.*
ppm	*Part Per Million.*
PRMS	*Pressure Reduction and Metering Station.*
P&ID's	*Piping and Instrumentation Diagrams.*
PETROSAFE	*Petroleum Safety and Environmental Services Company.*
QRA	*Quantitative Risk Assessment Study is a formal and systematic approach to estimating the likelihood and consequences of hazardous events, and expressing the results quantitatively as risk to people, the environment or your business.*
Risk	*Relates to the probability of exposure to a hazard, which could result in harm to personnel, the environment or public. Risk is a measure of potential for human injury or economic loss in terms of both the incident likelihood and the magnitude of the injury / loss.*
Risk Assessment	*The identification and analysis, either qualitative or quantitative, of the likelihood and outcome of specific events or scenarios with judgments of probability and consequences.*
scm/hr	*Standard Cubic Meter Per Hour.*
SCBA	*Self-Contained Breathing Apparatus.*
SE	*Southern East Direction.*
SW	*Southern West Direction.*
TWA	*Time Weighted Averages.*
UFL/UEL	*Upper flammable limit, the flammability limit describing the richest flammable mixture of a combustible gas.*
V	*Volume.*
Vapor Cloud Explosion (VCE)	*An explosion in air of a flammable material cloud.*

Objectives

The objectives of this QRA for the unit facilities are:

- Identify hazardous scenarios related to the facilities based on historical data recorded;
- Determine the likelihood (frequencies) of the identified scenarios;
- Model the potential consequences of the identified scenarios;
- Determine the Potential risk of fatality resulting from the identified hazardous scenarios;
- Evaluate the risk against the acceptable risk level to ensure that it is within *As Low As Reasonably Practicable "ALARP"*, otherwise additional control measures and recommendations will be provided at this study to reduce the Risk, *(ALARP)*.

Quantitative Risk Assessment Study Scope

The scope of work of this QRA study is limited to the following:

- Identification of the Most Critical Event(s) or scenarios that may lead to fatal accidents as well as to ensure that the expected risk will not exceed the Acceptable Risk Level as per national and international standards.
- To assess and quantify the risks associated with Aga PRMS on the neighboring / surrounding installations.
- The study determines Frequencies, Consequences (Including Associated Effect Contours) and Potential Risk of Fatality for the identified hazardous scenarios.
- Normal operation of the facilities (e.g. Construction and specific maintenance activities are excluded from this analysis);

Quantitative Risk Assessment "QRA" Studies

Method of Assessment

1.0- General Method Used

Attention mainly focussed on those accidents where a gross failure of containment could result in the generation of a large vapour cloud of flammable or toxic material. The approach adopted has involved the following stages:

- Identification of hazardous materials,
- Establishment of maximum total inventories and location.

During the site visit by the study team, the overall functioning of the site discussed in some detail and the Companies asked to provide a complete list of holdings of hazardous materials. A preliminary survey notes was issued by the team, as a private communication to the company concerned, and this formed the basis for subsequent more discussion and analysis.

From the PRMS design model provided by the client, it was impractical to examine in depth all possible failure modes for all parts within the time allowed for this study. Instead, only those potential failures, which might contribute, either directly or indirectly, to off-site risks were examined.

2.0- Risk Assessment

As the PRMS designed and under construction, so it was therefore necessary for the study team to identify and analyse the hazards potential from first principles the routes by which a single or multiple accident could affect the community or neighbouring.

The terms of reference required the team to investigate and determine the overall risk to health and safety both from individual installations and then foreseeable interactions.

The assessment of risk in a complex situation is difficult. No method is perfect as all have advantages and limitations.

It was agreed that the quantitative approach was the most meaningful way of comparing and evaluating different risks. The risk assessment framework shown in Figure (1) used for this study.

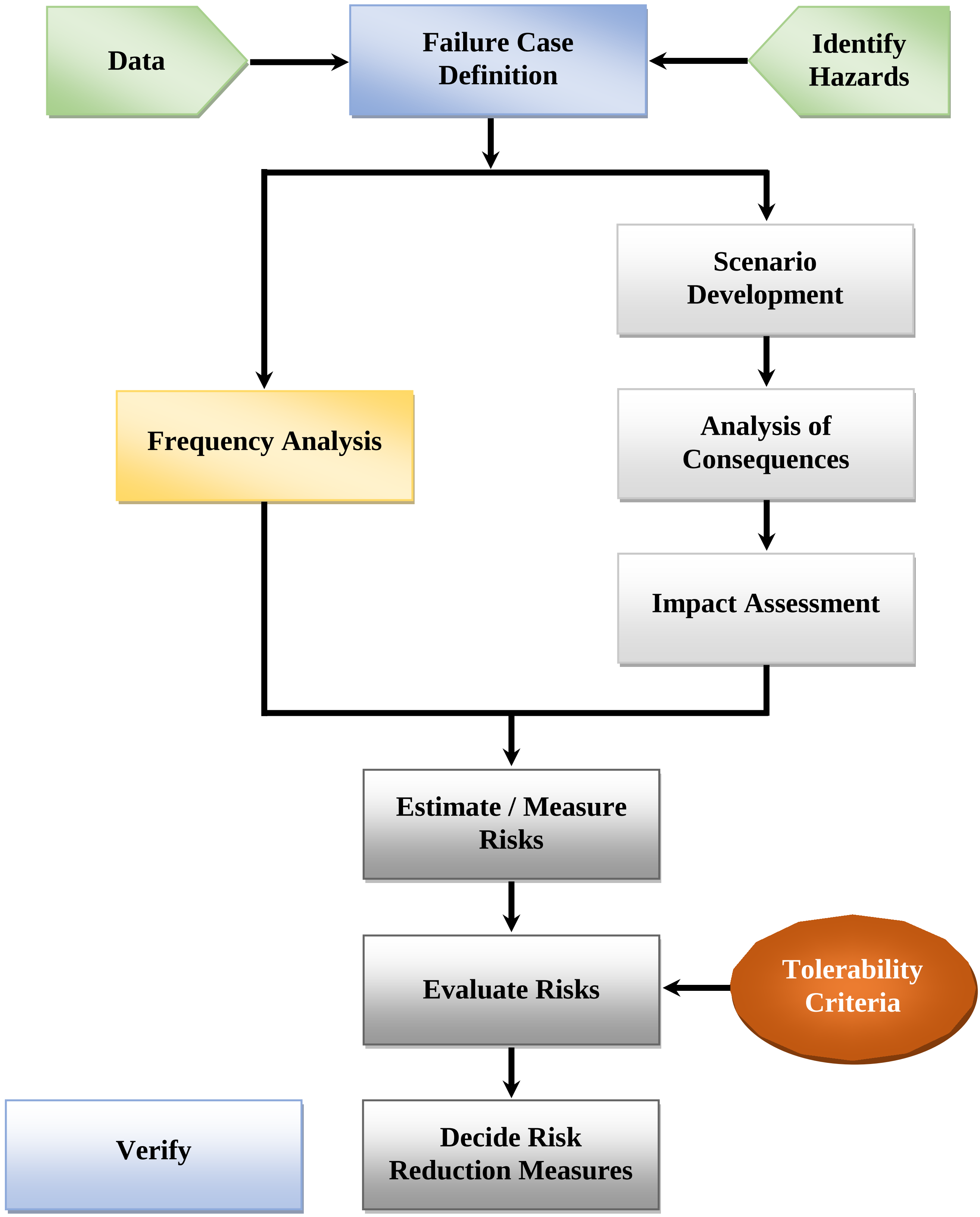


Figure (1) Risk Assessment Framework

Modeling the Consequences

Modeling of the consequences is one of the key steps in Quantitative Risk Assessment "QRA", as it provides the link between hazard identification (in this study Potential Loss of Containment Incidents) and the determination of possible impact of those incidents on People (Worker / Public), Asset and the Environment.

In this study, Natural Gas (Mainly Methane CH_4) was considered. There are several types of consequences to be considered for modelling, these include Gas Dispersion (UFL - LFL - 50 % LFL) / Heat Radiation / Explosion Overpressure modeling, also each of these scenarios described in the following table:

Table (1) Description of Modeling of the Different Scenario

Discharge Modeling	*Modeling of the mass release rate and its variation overtime.*
Radiation Modeling	*Modeling of the Thermal radiation from fires.*
Dispersion Modeling	*Modeling of the Gas and two-phase releases.*
Overpressure	*Associated with explosions or pressure burst.*

Toxic hazards are considered as result of releases / loss of containment for which discharge modeling and gas dispersion modeling are required. The hazard ranges are dependent upon the condition of the release pressure and rate of release.

There are a number of commercial software for modeling gas dispersion, fire, explosion and toxic releases. PETROSAFE select the *DNV PHAST Ver. 7.0 Software package* in modeling scenarios.

The software developed by DNV in order to provide a standard and validated set of consequence models that can be used to predict the effects of a release of hydrocarbon or chemical liquid or vapour. (Results of the modeling presented in pages from 54 to 102)

Criterion for Risk Tolerability

The main function of this phase of the work was to assess the effectiveness of the proposed arrangement for managing risks against performance standards.

In order to do this, we need firstly to define a performance standard and secondly, to be able to analyse the effectiveness of the arrangements in a manner which permits a direct comparison with these standards.

The defining of performance standards undertakes at the following three levels:

- Policy-based
- System
- Technical

Where the present work is mainly concerned with the assessment against the standards associated with the first two levels.

The policy-based performance standard relates to this objective to provide a working environment, where the risk to the individual reduced to a level that is ALARP.

This performance standard is therefore, expressed in the form of individual risk and the arrangements for managing this risk should result in a level of 'Individual Risk', based on a proposed Tolerability Criteria, Figure (2).

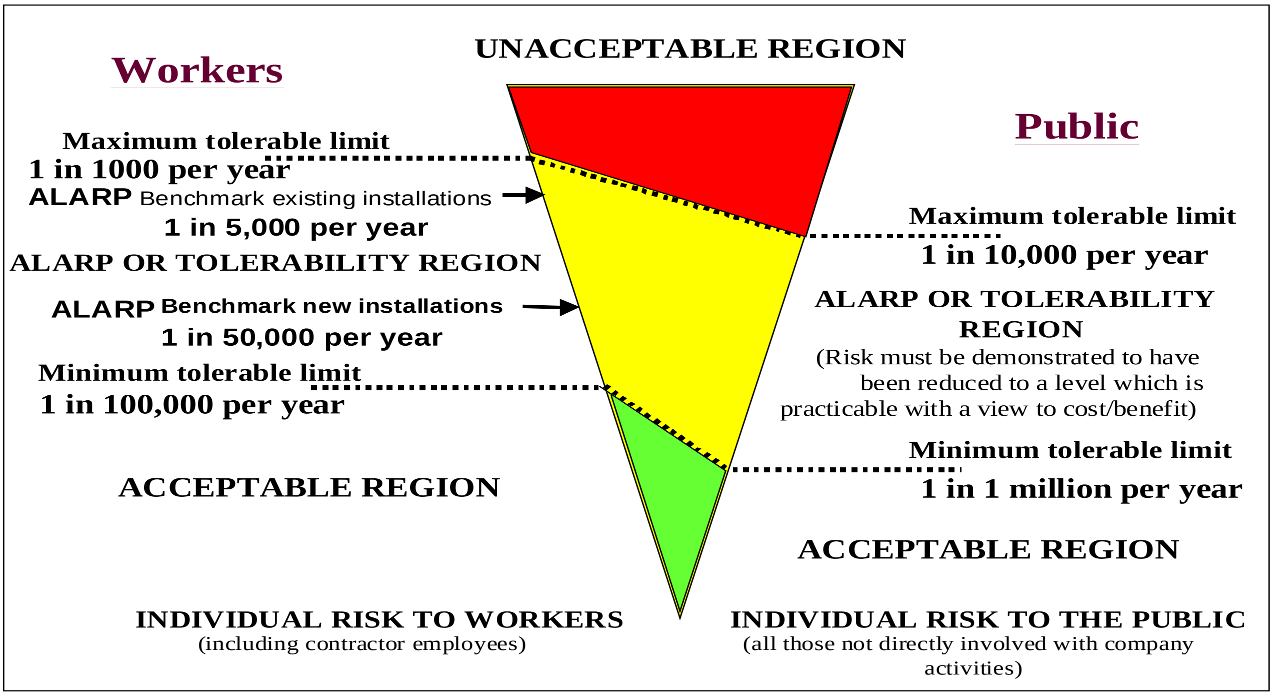


Figure (2) Criteria for Individual Risk Tolerability

The criterion for IR tolerability for workers and to the public outlined in Table (2) and Figure (3).

It should be noted that this criteria proposed only as a guideline. Risk assessment is no substitute to professional judgement.

Table (2) Proposed Individual Risk (IR) Criteria (per person/year)

Risk Level	Workers	Public
Intolerable	*> 10^{-3} per person/yr.*	*> 10^{-4} per person/yr.*
Negligible	*> 10^{-5} per person/yr.*	*> 10^{-6} per person/yr.*

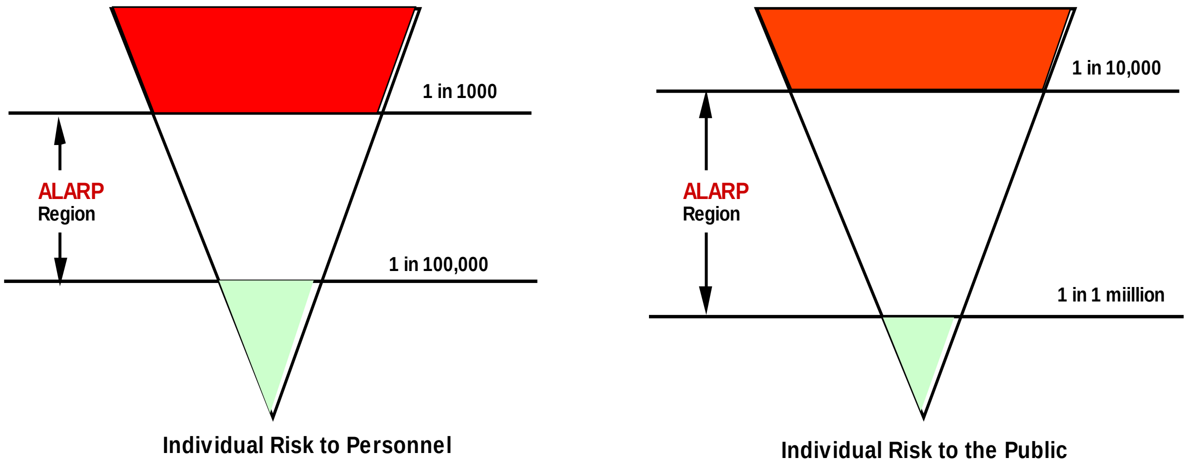


Figure (3) Proposed Individual Risk Criteria

Workers would include the Company employees and contractors. The public includes the public, visitors, and any third party who is not directly involved in the Company work activities.

On this basis, we have chosen to set our level of intolerability at Individual Risk for workers of 1 in 1,000 per year, and we define an individual risk of 1 in 100,000 per year as broadly acceptable. Consequently, our ALARP region is between 1 in 1,000 and 1 in 100,000 per person/year.

It is important to ensure that conflict between these subordinate standards and those stemming from international codes and standards are avoided and that any subordinate standards introduced are at least on a par with or augment those standards, which are associated with compliance with these international requirements. These system level performance standards are included as part of the summaries from the QRA. These used as the basis for assessing the suitability and sufficiency of Egypt Gas Site arrangements for both protecting personnel on site and members of public from major hazards and securing effective response in an emergency. Failure to meet acceptance criteria at this level results in the identification of remedial measures for assessment both qualitatively and quantitatively.

The analytical work use a system analysis approach and divided into a number of distinct phases:

- Data collection, including results from site-based qualitative assessments.
- Definition of arrangements.
- Qualitative evaluation of arrangements against a catalogue of fire and explosion hazards from other major accident hazards.
- Preparing of event tree analysis models.
- Consolidation of list of design events.
- Analysis of the effect of design events on fire, explosion and toxic hazard management and emergency response arrangements.
- Quantification of that impact in terms of individual risk.

The main model would base on a systems approach, and it takes the following form:

- Estimates of incremental individual risk (IIR) per person/yr.
- Is caused-consequences based.
- Uses event tree analysis to calculate the frequency of occurrence.
- Estimates incremental individual risk utilizing event tree analysis, based on modeling the emergency response arrangements from detection through to recovery to a place of safety.

Personnel Vulnerability and Structural Damage

A criterion used in the QRA study for the calculation of personnel vulnerability and structural / asset damage because of fire, explosion and toxic release shown in Table (3).

The criteria shown below provide some assumptions for the impairment effects of hydrocarbon releases on personnel and structures, which based on Health and Safety Executive: Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment)

Table (3) Criteria for Personnel Vulnerability and Structural Damage

Event Type	Threshold of Fatality	Asset/Structural Damage
Jet and Diffusive Fire Impingement	6.3 kW/ m^2 (1) 12.5 kW/m^2 (2)	- Flame impingement 10 minutes. - 300- 500 kW/m^2 Structural Failure within 20 minutes.
Pool Fire Impingement	6.3 kW/ m^2 (1) 12.5 kW/m^2 (2)	- Flame impingement 20 minutes - 100 - 150 kW/m^2 Structural Failure within 30 minutes.
Smoke	2.3% v/v (3) 15% v/v (4)	
Explosion Overpressure	300 mbar	100 mbar

(1) Fatality within 1 - 2 minutes
(2) Fatal < 1 minute
(3) Above 2.3%, escape possible but difficult
(4) No escape possible, fatal in a few seconds

The effects of exposure to fire expressed in terms of heat radiation (kW/m^2) and overpressure waves shown in Tables (4), (5) and (6).

Table (4) Fire Heat Radiation Effects on Structures (World Bank)

Radiation Level kW/m^2	Observed Effect
37.5	Sufficient to cause damage to process equipment.
25	Minimum energy to ignite wood at indefinitely long exposure (non-piloted).
12.5	Minimum energy required to ignite wood, melting of plastic tubing.

Table (5) Heat Radiation Effects on People

Radiation Level kW/m^2	Effects on People
1.2	Equivalent to heat from sun at midday summer.
1.6	Minimum level at which pain can be sensed.
4 - 6	Pain caused in 15 - 20 seconds, Second Degree burns after 30 seconds.
12	20 % chance of fatality for 60 seconds exposure.
25	100 % chance of fatality for continuous exposure. 50 % chance of fatality for 30 seconds exposure.
40	30 % chance of fatality for 15 seconds exposure.
50	100 % chance of fatality for 20 seconds exposure.

Table (6) Effects of Overpressure

Pressure		Effects / Damage
bar	**psig**	
0.002	**0.03**	Occasional breakage of glass windows.
0.006	**0.1**	Breakage of some small windows.
0.021	**0.3**	Probability of serious damage beyond this point = 0.05. 10 % glass broken.
0.027	**0.4**	Minor structural damage of buildings.
0.068	**1.0**	Partial collapse of walls and roofs, possible injuries.
0.137	**2.0**	Some severe injuries, death unlikely.
0.206	**3.0**	Steel frame buildings distorted / pulled from foundation.
0.275	**4.0**	Oil storage tanks ruptured.
0.344	**5.0**	Wooden utilities poles snapped / Fatalities.
0.41	**6.0**	Nearly complete destruction of building.
0.48	**7.0**	Loaded wagon train overturned.
0.689	**10.0**	Total destruction of buildings.

Quantification of the Frequency of Occurrence

The probability of a sequence of events leading to a major hazard is dependent on the probability of each event in a sequence occurring; usually these probabilities may be multiplied together to obtain the end event probability or frequency.

The technique of Quantified Risk Assessment 'QRA' requires data in the form of probability or frequency to be estimated for each input event.

Ideally, data relating to hardware failures and human error that are specific to each plant should be obtained from the company's maintenance and historical records.

Unfortunately, records available were not in the form that allows data relevant to this study to be obtained. Therefore, other sources of data were used as a basis for failure/error scenarios. The sources of information and data are shown in the References section of this report.

Identification of Scenarios Leading to Selected Failures

For each selected failure scenario, the potential contributory factors were examined, taking into account any protective features available. Typically, the factors examined included:

- Operator error
- Metallurgical fatigue or ageing of materials
- Internal or external Corrosion
- Loss of process control, e.g. pressure, temperature or flow, etc.
- Overfilling of vessels
- Introduction of impurities
- Fire and/or explosion
- Missiles
- Flooding

Account was taken at this stage of those limited releases, which, although in themselves did not constitute a significant off-site hazard could, under some circumstances, initiate a sequence leading to a larger release, as a knock-on effect.

It was noted that the proposed criterion for risk tolerability was used in Egypt by the following organizations - British Gas / British Petroleum / Shell / Total.

Relevant Weather Data for the Study

- **Weather Data**

The Weather Data relevant to this study consists of a list of weather conditions in the form of different combinations of wind-speed/direction, temperature, humidity and atmospheric stability. Table (7)

The weather conditions are an important input into the dispersion calculations and results for a single set of conditions could give a misleading picture of the hazard potential.

Met-oceanographic data gathered from Weather base for Dakahlia Governorate over a period of some years.

These data included wind speed, wind direction, air temperature and humidity, as well as current speed, direction and wave height.

Table (7) Annual Average Temperature, Relative Humidity and Wind Speed / Direction

• Air Temperature °C		
	Min. Recorded	**13.1** °C
	Max. Recorded	**26.6** °C
	Annual Average	***20.4 °C***
• Relative Humidity %		
	Average Daily Min.	**58.1 %**
	Average Daily Max.	**70.4 %**
	Annual Average	***66.1 %***
• Wind Speed m/s		
	Annual Average	***3.11 m / sec.***
• Wind Direction		
	Annual Average	***NNW / NW / N***

The general climatic conditions at Dakahlia Governorate are summarized in Tables No. (8, 9 & 10) Below.

Table (8) Mean of Monthly Air Temperature (°C)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp. (c°)	13.1	13.7	15.7	19.4	22.6	25.6	26.6	26.6	25.1	22.7	18.6	14.8

Table (9) Mean of Monthly Wind Speed (m/sec)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed (m/sec)	2.83	3.38	3.69	3.61	3.50	3.30	3	2.69	2.81	2.88	2.69	2.81

Table (10) Mean of Monthly Morning/Evening Relative Humidity

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Relative Humidity (%)	70.2	67.8	65.7	60	58.1	59.7	66.5	69.7	68	67.3	70.4	70.3

Figure (4) shows the maximum temperature diagram for Dakahlia Governorate

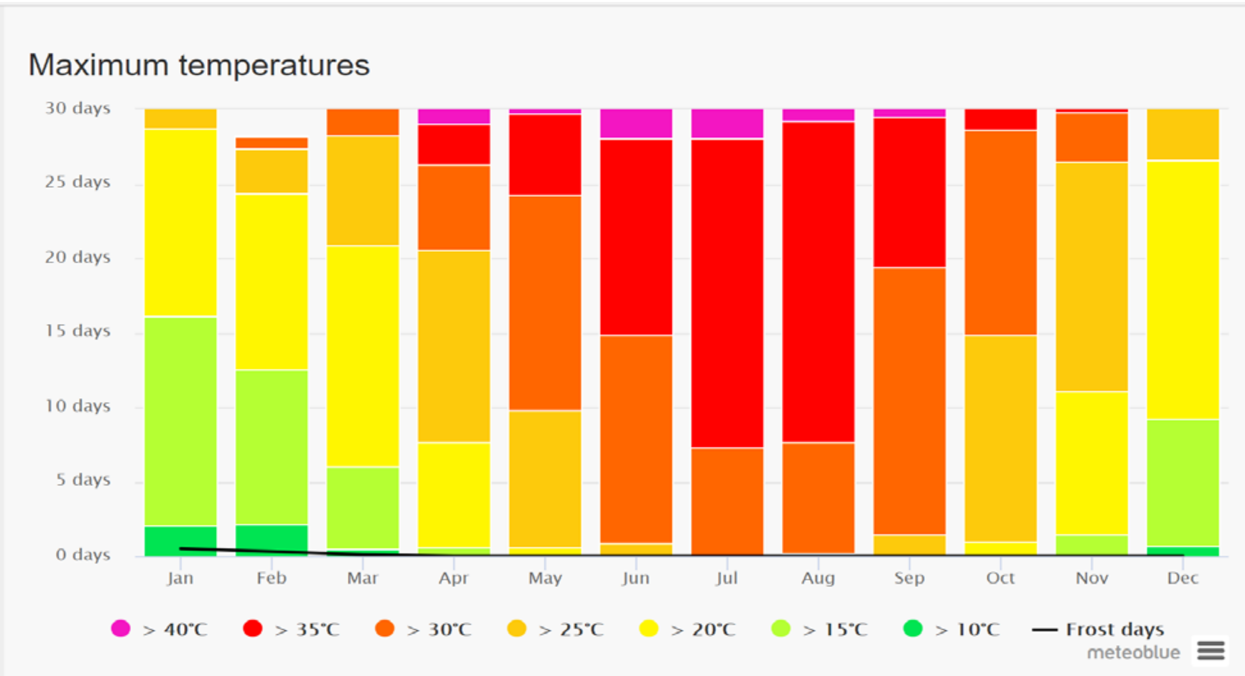


Figure (4) – Monthly Variations of the Maximum Temperature – Dakahlia Governorate

Figures (5 & 6) show the monthly variations of the wind speed as well as wind rose for Dakahlia Governorate respectively.

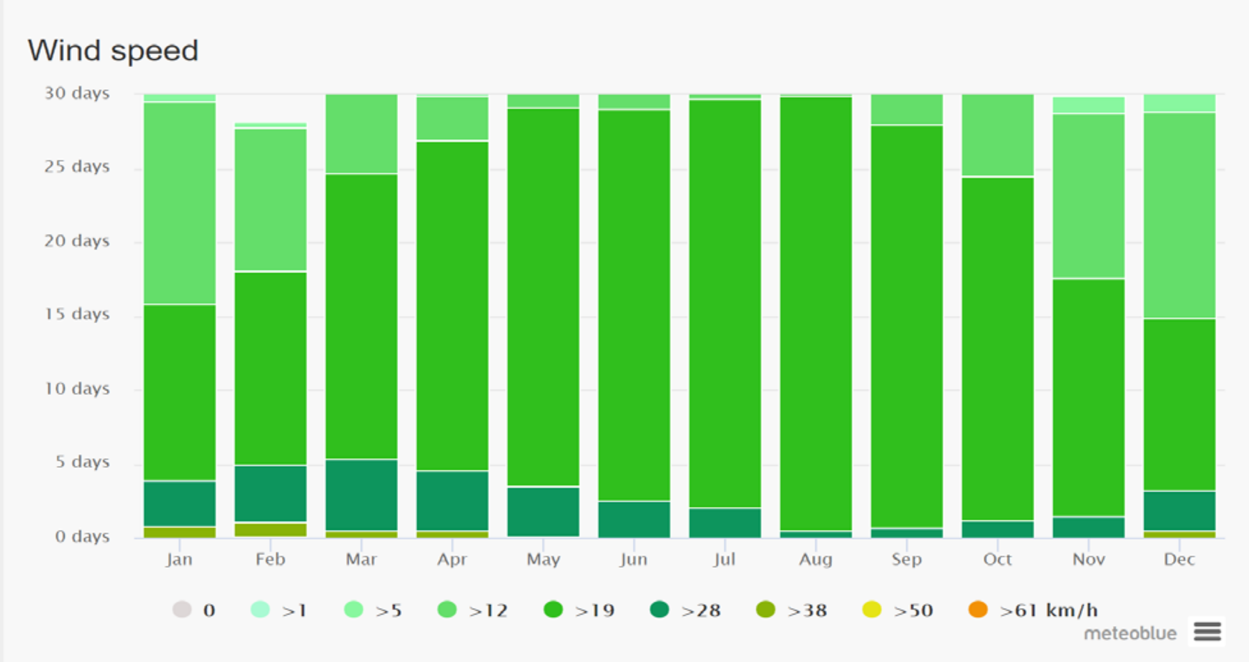


Figure (5) – Monthly Variations of the Wind Speed – Dakahlia Governorate

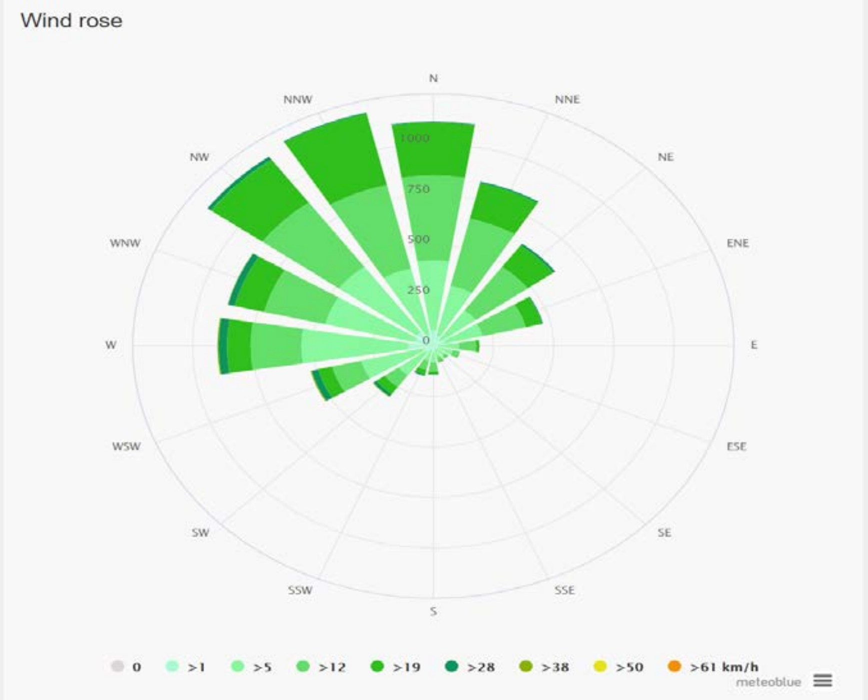


Figure (6) –Wind Rose – Dakahlia Governorate

Figure (7) shows the monthly variations of the sunny, cloudy and precipitation days for Dakahlia Governorate.

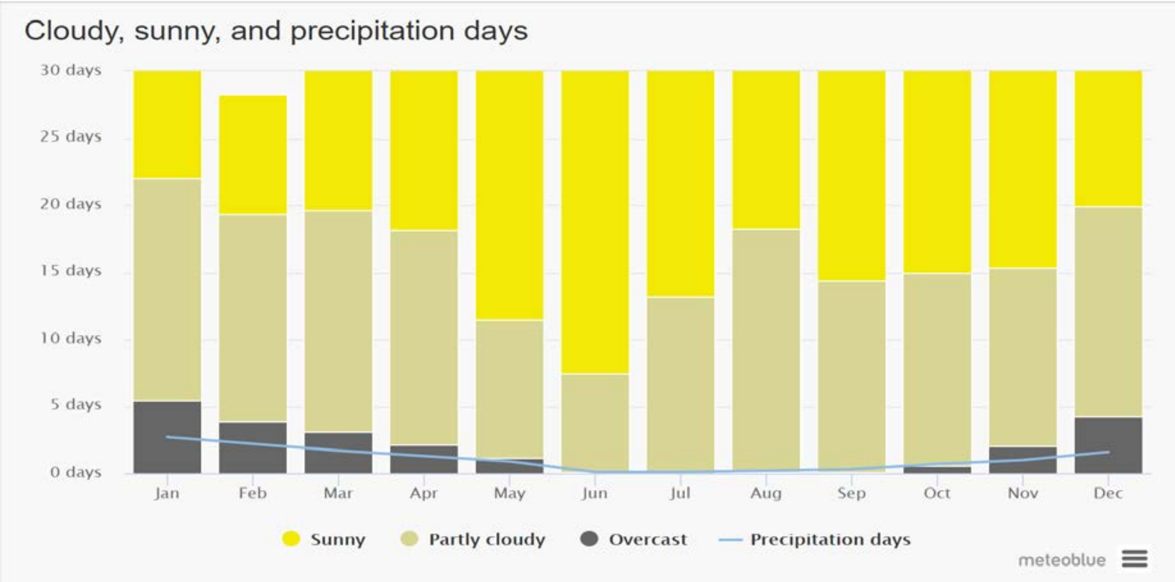


Figure (7) – Monthly Variations of the Sunny, Cloudy and Precipitation days for Dakahlia Governorate

Figure (8) shows the monthly variation of Relative Humidity for Dakahlia Governorate

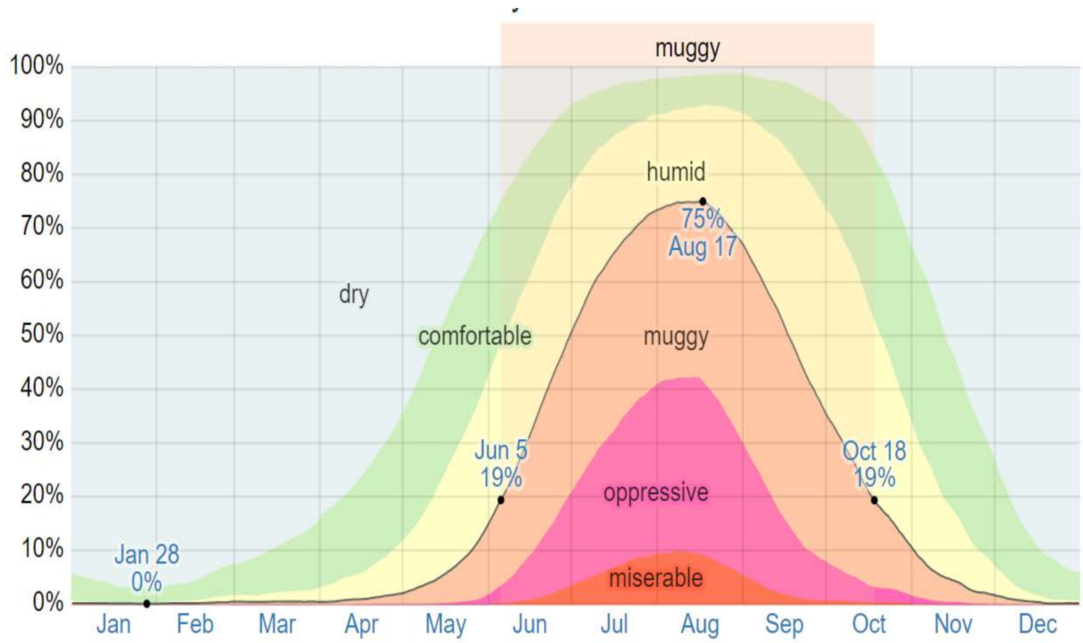


Figure (8) – Monthly Variation of Relative Humidity for Dakahlia Governorate

- **Stability Categories**

The two most significant variables, which would affect the dispersion calculations, are Wind-speed and atmospheric stability. The stability class is a measure of the atmospheric turbulence caused by thermal gradients. Pasqual Stability identifies six main categories, which shown in the Tables (11 & 12) and summarized in Table (13).

Table (11) Pasqual Stability Categories

A	B	C	D	E	F
Very Unstable	Unstable	Moderately Unstable	Neutral	Moderately Stable	Stable

Neutral conditions correspond to a vertical temperature gradient of about 1° C per 100 m.

Table (12) Relationship between Wind Speed and Stability

Wind speed	**Day-time Solar Radiation**			**Night-time Cloud Cover**		
(m/s)	Strong	Medium	Slight	Thin <3/8	Medium >3/8	Overcast >4/5
<2	A	A-B	B	-	-	D
2-3	A-B	B	C	E	F	D
3-5	B	B-C	C	D	E	D
5-6	C	C-D	D	D	D	D
>6	C	D	D	D	D	D

Table (13) Sets of Weather Conditions Initially Selected for this Study

Set for Wind Speed and Stability	
Wind speed	Stability
3.11 m/sec.	D

Aga PRMS Description

Background

Aga Pressure Reduction & Metering Station owned by The Egyptian Natural Gas Holding Company "EGAS" and operated by Egypt Gas Company. It is located about 7.5 km South direction from Mansoura City. The PRSM will provide natural gas to public housing.

The station natural gas feeding will be from the National Gas Pipeline owned by GASCO with pressure from 45 to 70 bar, then reduce the gas pressure to 4 - 7 bar and adding odorant, then connected to the internal distribution network to public housing at Aga area.

PRMS Location Coordinates (Egypt Gas Company Data)

Point	North (N)	East (E)
1	*30° 57' 44.88"*	*31° 21' 28.66"*
2	*30° 57' 45.72"*	*31° 21' 26.08"*
3	*30° 57' 44.59"*	*31° 21'25.59"*
4	*30° 57' 43.98"*	*31° 21' 27.57"*

PRMS Brief Description (Egypt Gas Company Data)

The PRMS will surrounded by 3 m height fence and will mainly consist of the followings: (Ref. Figure 9, 10, 11, 12, 13, 14 and 15)

- Inlet module: contains 6" manual isolation valve.
- Filter module: two identical streams each contain inlet and outlet isolation valves.
- Metering module: two identical.
- Heating system module: two identical.
- Regulating module: two identical regulating lines.
- Outlet module: contains 8" manual outlet isolation valve.
- Odorant module: 600 lit. capacity bulk tank / 50 lit. daily use.
- Inlet 6" from GASCO valves room including automatically controlled isolation valves with GASCO pipeline 8".
- Firewater system: Water tank / Firewater pump / firewater main.
- Security Office (one floor)
- Administration and Control Room Office (one floor)

The following table no. (14) describes the PRMS process units:

Table (14) Aga PRMS Units

No	PRMS Units	Capacity	Size
1	***Inlet unit***		
	Inlet valve	20000 scmh	6"
	Inlet valve bypass (ball + plug)	3000 scmh	2"
2	***Filter units***		
	Line Fl	10000 scmh	4" x 3"
	Line F2	10000 scmh	4" x 3"
	Line F3(only two valves)	10000 scmh	4" x 3"
3	***Meter unit***		
	Line Ml	10000 scmh	3" x 4" x 3"
	Line M2	10000 scmh	3" x 4" x 3"
	Line M3(only two valves)	10000 scmh	3" x 3"
	One extension ball valve on outlet header (future heater)	10000 scmh	4"
	One ball valve full bore for heater bypass	20000 scmh	4"
4	***Regulator unit***		
	Line Rl	10000 scmh	3" x 6"
	Line R2	10000 scmh	3" x 6"
	Line R3(only two valves)	10000 scmh	3" x 6"
	One extension ball valve on inlet header (future heater)	10000 scmh	4"
5	***Odorant unit***		
	Bulk tank	600 lit.	
	Daily use tank	50 lit.	
	Odorant meter		
	Electrical pumps		
	Lapping system		
6	***Outlet unit***		
	Outlet valve	20000 scmh	8"
7	***Monitoring and Control unit***		
8	***Generator (15 KVA)***		
9	***UPS***		

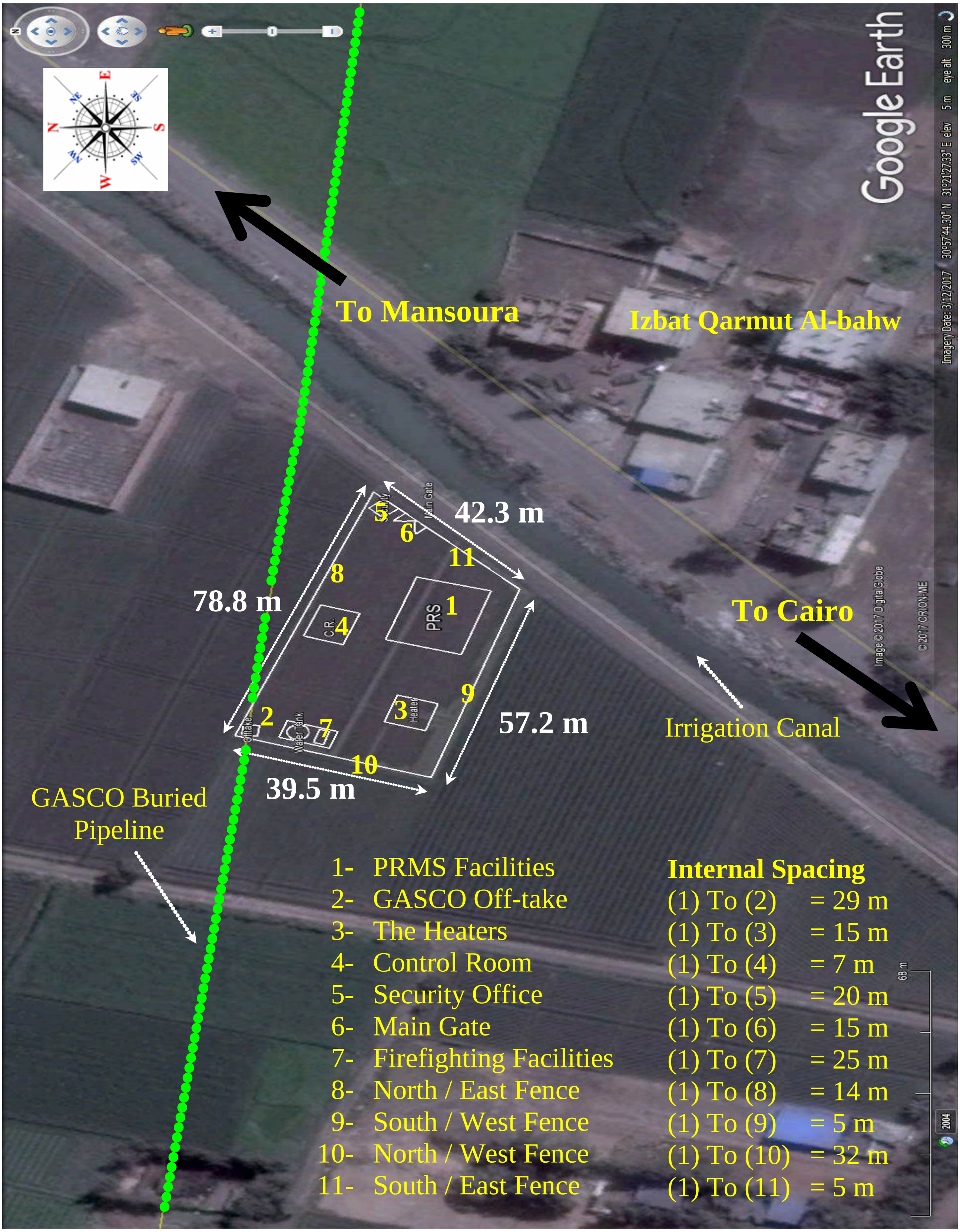


Figure (9) Aga Pressure Reduction Station Plotted on Google Earth Photo

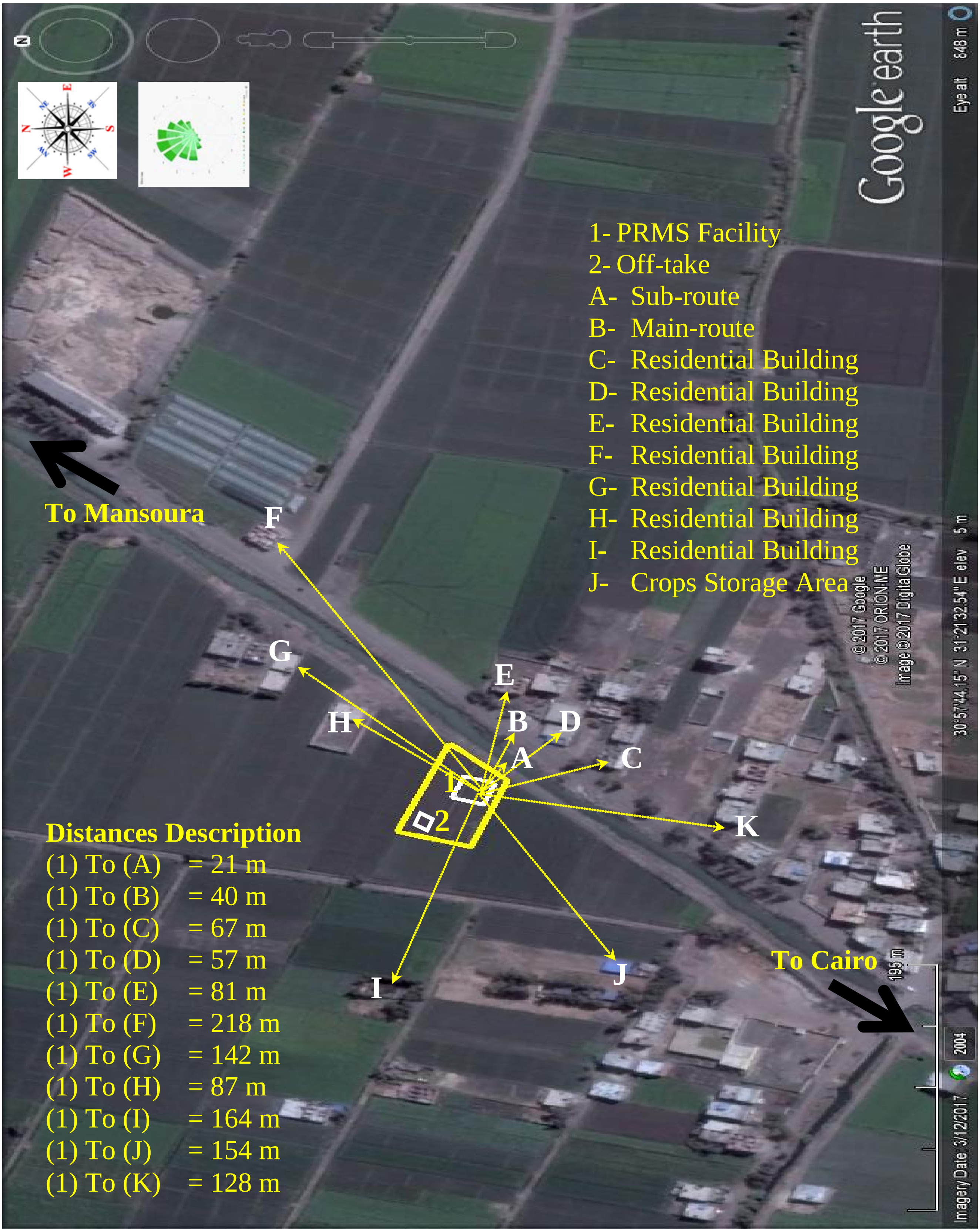


Figure (10) Aga Pressure Reduction Station Plotted on Google Earth Photo and Surroundings

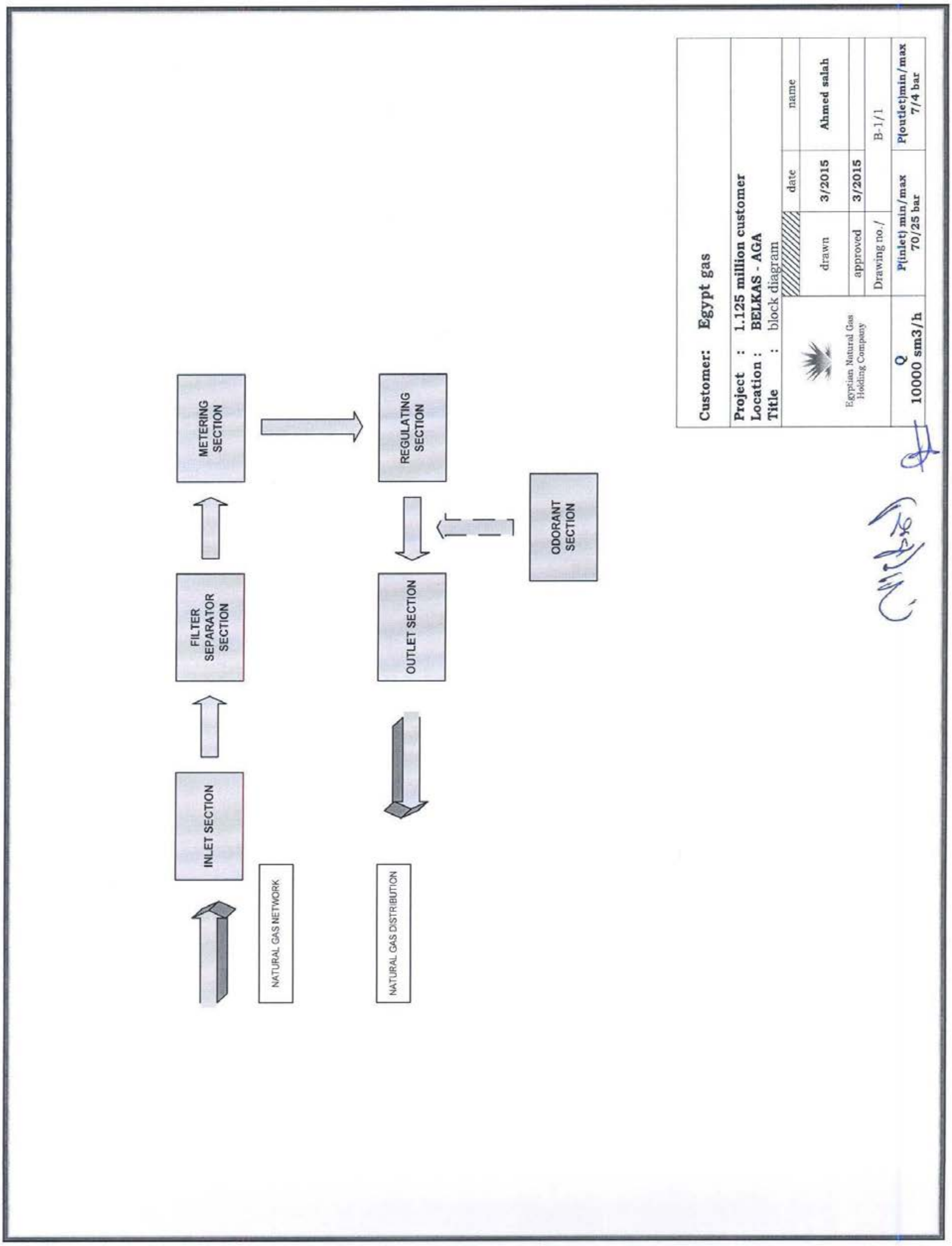


Figure (11) Aga Pressure Reduction Station Block Diagram

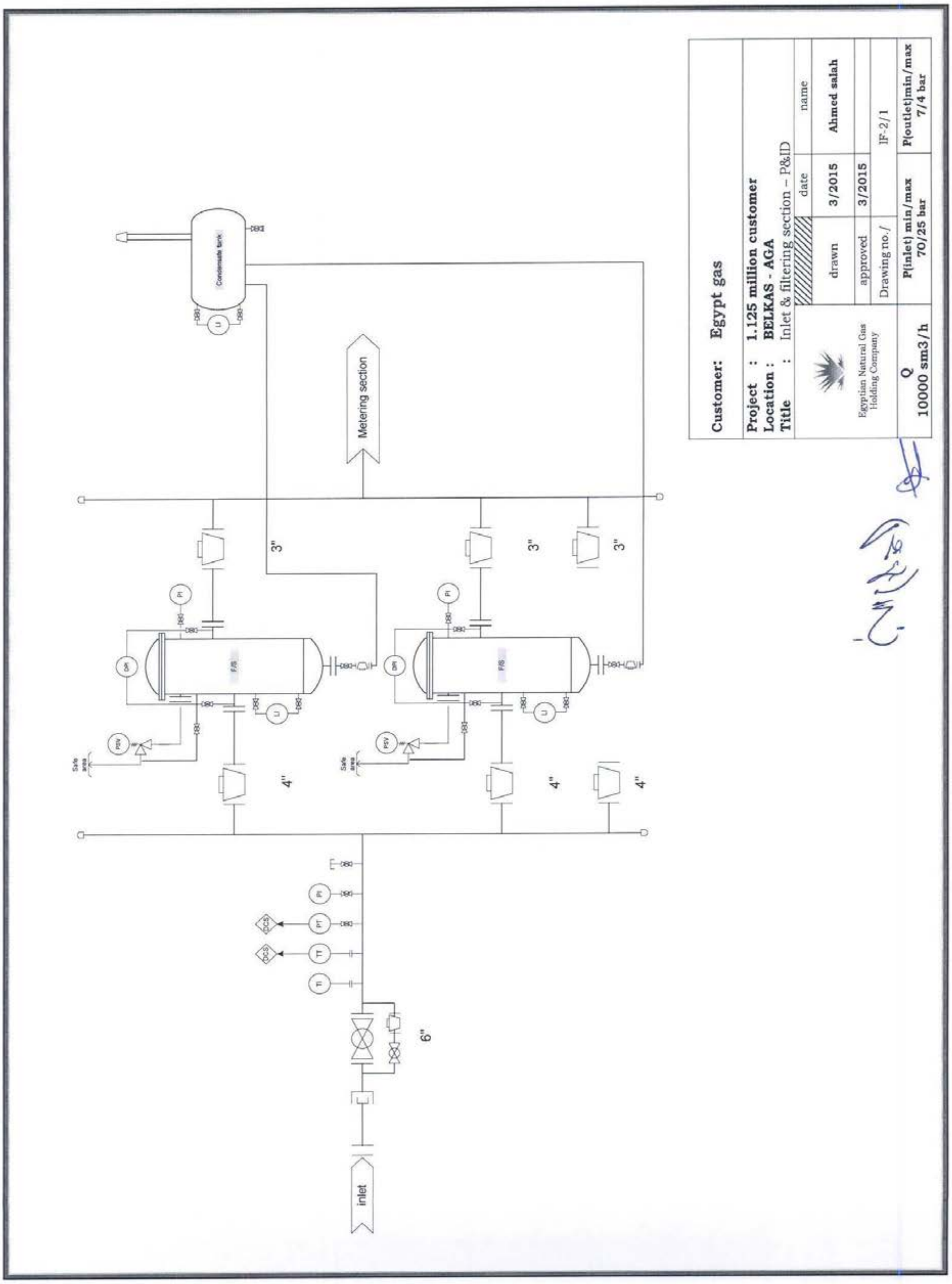


Figure (12) Aga Pressure Reduction Station Piping and Instrumentation Diagram "P&ID" (Inlet & Filtering Section)

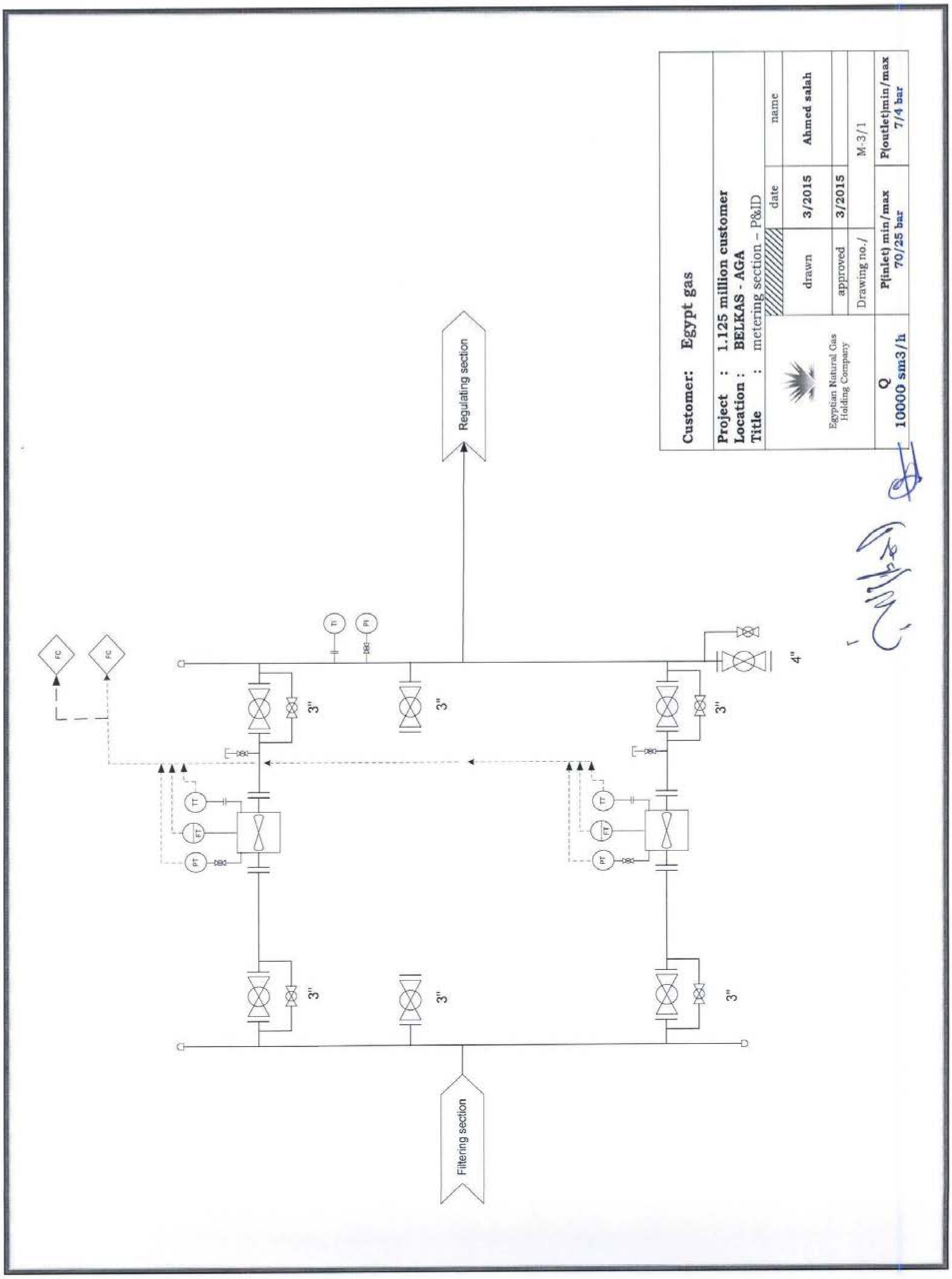


Figure (13) Aga Pressure Reduction Station Piping and Instrumentation Diagram "P&ID" (Metering Section)

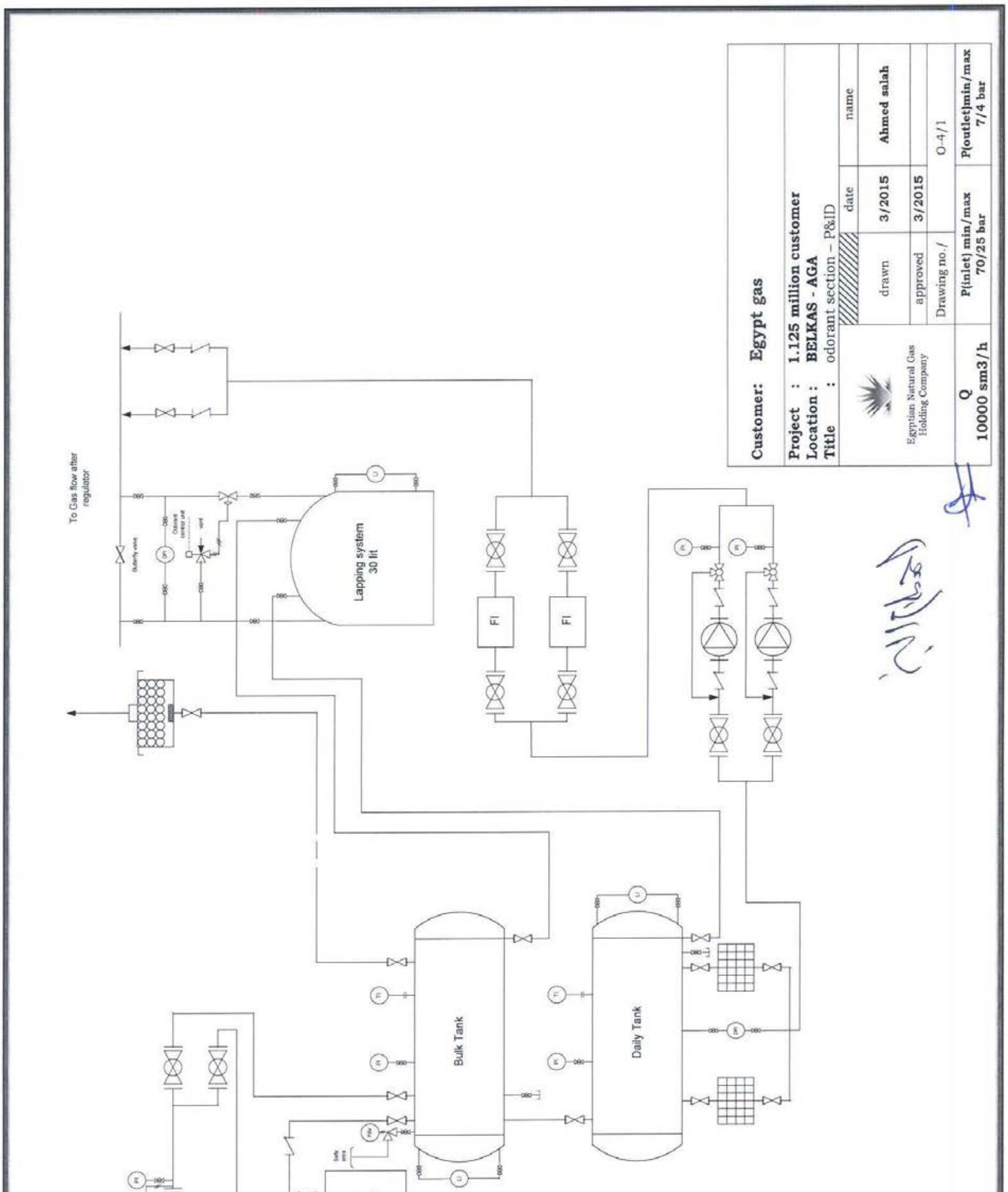


Figure (14) Aga Pressure Reduction Station Piping and Instrumentation Diagram "P&ID" (Odorant Section)

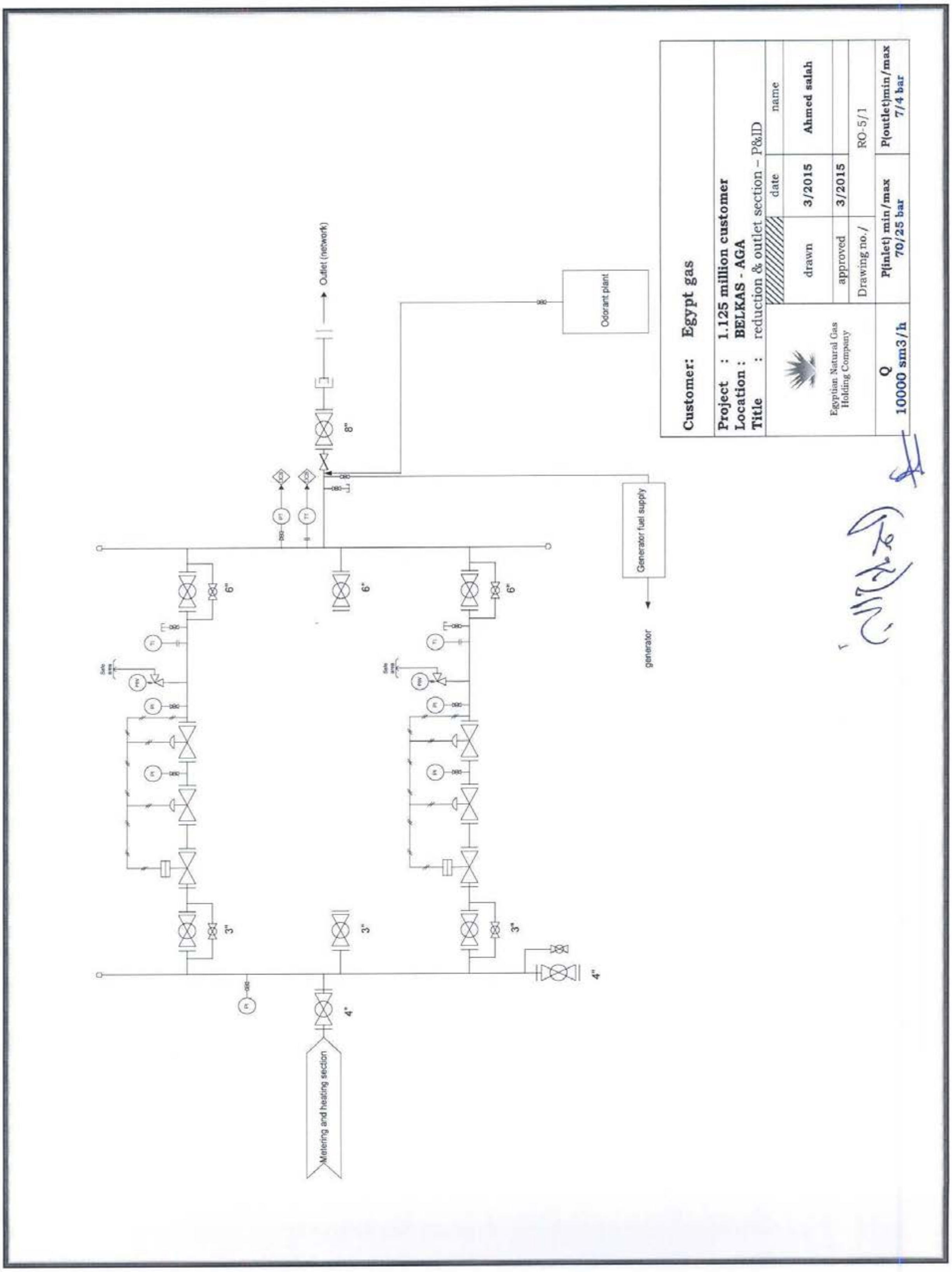


Figure (15) Aga Pressure Reduction Station Piping and Instrumentation Diagram "P&ID" (Reduction & Outlet Section)

Process Condition Data (Egypt Gas Company Data)

The following table no (15) describes the process conditions for Aga PRMS:

Table (15) Process Conditions / Gas Components & Specifications

Process Conditions	
Maximum flow rate scm / hr	5000
future flow rate scm/ hr	10000
Design pressure bar g	70
Min / Max inlet pressure bar g	25 – 70
Min / Max outlet pressure bar g	4 – 7
Min / Max inlet temperature °C	15 – 25
Outlet temperature °C	Not less than 1

Gas Components	
Gas composition % Mol	
Water	0
H_2S	4 ppm
Nitrogen	0.2 - 0.83
Carbon Dioxide	0.07 - 3
Methane	77.73 - 99.82
Ethane	0.03 - 15.68
Propane	0.01 - 4.39
I-Butane	0.0 - 1.14
N-Butane	0.0 - 1.01
I-Pentane	0.0 - 0.19
N-Butane	0.0 - 0.26
C6+	0.0 - 0.25

Gas Specifications	
Specific gravity	0.5 - 0.69 (air = 1 k/m^3)

Gas Odorant Specifications

The odorant supplied with a Hazard Data Sheet and identified as Spotleak 1009. Spotleak is an aliphatic mixture in clear liquid form that is extremely flammable, with the following characteristics:

− Boiling Range	60-70^{o} C
− Flash Point	-17.8^{o} C
− Freezing Point	-45.5^{o} C
− Density (H_2O = 1)	0.812 @ 15.5^{o} C
− Vapor Density	3.0 (air = 1)
− Vapor Pressure (mm Hg)	6.6 @ 37.8^{o} C

Health Hazards

Spotleak is not carcinogenic, but the major health hazards as a result of exposure to Spotleak include the following:

Inhalation

- Short-term exposure: Irritation and central nervous system effects
- Long-term exposure: Irritation

Skin Contact

- Short-term: Irritation
- Long-term: Dermatitis

Eye Contact

- Short-term: Irritation and tearing
- Long-term: Irritation

Ingestion

- Short-term: nausea, vomiting, central nervous system effects
- Long-term: no effects are known

Hygiene Standards and Limits

Occupational Exposure Limit for Spotleak to all components is 45 ppm, and the long-term "MEL" should be below 12 ppm (8 hrs. "TWA").

Fire and Explosion Hazards

Spotleak is a severe fire hazard. Vapor/air mixtures are explosive. Vapor is 3 times heavier than air. Vapor may ignite at distant ignition sources and flash back.

Thermal decomposition products include oxides of sulphur and hydrogen sulphide.

Fire Fighting and Protection Systems and Facilities

As per agreement with EGAS and Civil Defense the PRMS will provided by the following fire protection facilities: (over 100 lit. odorant storage capacity)

- Firewater tank with a capacity of 100 cum.
- Firewater main with a diameter of 6 inch.
- Firewater hydrants 2.5 inch X 1 / each.
- Firewater monitors.
- Smoke detector in all admin rooms.
- Heat detectors in buffet rooms.
- Smoke detectors in control rooms according to the area.
- Different sizes of fire extinguishers will be distributed at PRMS site.

Emergency Response Plan "ERP"

The Emergency Response Plan "ERP" submitted include many items related to operations malfunction scenarios and not include any of the main elements of the ERP items, which need to be established and maintained.

Analytical Results of Consequence Modeling

1.0- Pressure Reduction Station Inlet Pipeline (6 inch)

1/1- Consequence Modeling for 1 inch (Pin Hole) Gas Release

The following table no. (16) Show that:

Table (16) Dispersion Modeling for Inlet - 1" / 6" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	2.20	1.00	0.24 @ 1.30 m
	LFL	8.20	1.02	0.42 @ 5.20 m
	50 % LFL	8.40	0 – 1.84	1.84 @ 8.40 m

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	13.06	1.6	20.89	13.84	0
		4	17.34	8.51	0
		9.5	14.63	4.67	0.72
		12.5	13.50	3.56	20% /60 sec.
		25	11.47	0.96	80.34
		37.5	Not Reached	Not Reached	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	N/D	26.54	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	N/D	14.28	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	N/D	13.31	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

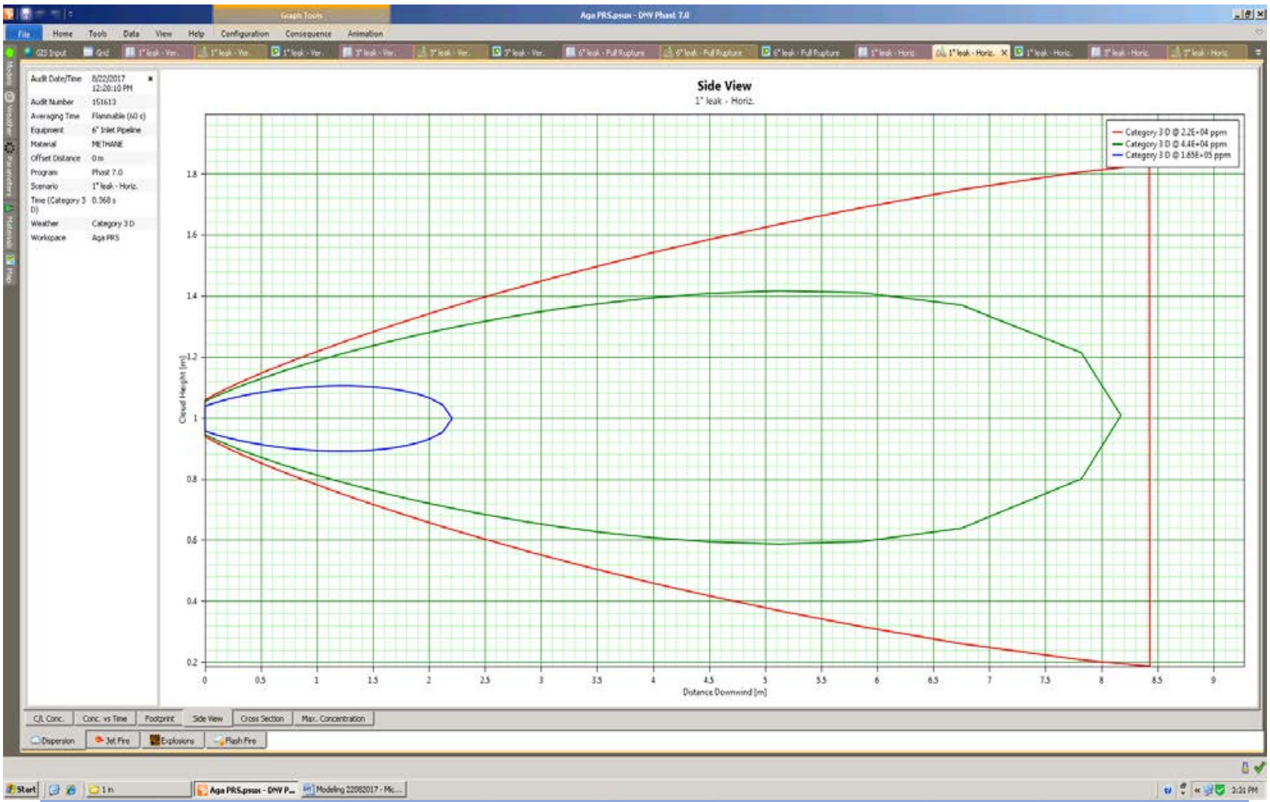


Figure (16) Gas Cloud Side View (UFL/LFL) (1" hole in 6" Inlet Pipeline)

- The previous figure shows that if there is a gas release from 1" hole size without ignition the flammable vapors will reach a distance more than 8 m downwind and from 0 – 1.84 m height.
- The UFL will reach a distance of about 2.20 m downwind with a height of 1 m. The cloud large width will be 0.24 m crosswind at a distance of 1.30 m from the source.
- The LFL will reach a distance of about 8.20 m downwind with a height of 1.02 m. The cloud large width will be 0.42 m crosswind at a distance of 5.20 m from the source.
- The 50 % LFL will reach a distance of about 8.40 m downwind with a height from 0 to 1.84 m. The cloud large width will be 1.84 m crosswind at a distance of 8.40 m from the source.

The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.

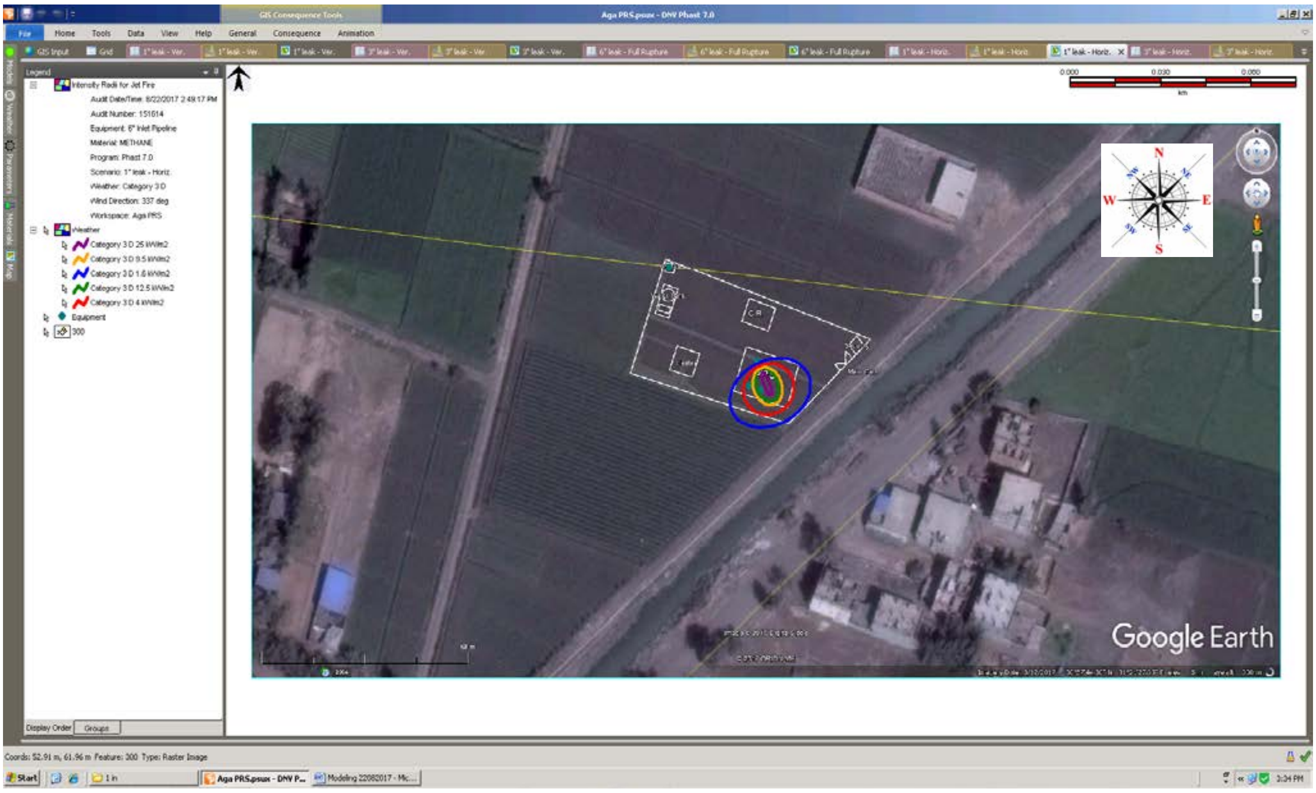


Figure (17) Heat Radiation Contours from Jet Fire (1" hole in 6" Inlet Pipeline)

- The previous figure show that if there is a gas release from 1" hole size and ignited the expected flame length is about 13 meters downwind.
- The 4 kW/m^2 heat radiation contours extend about 17.34 meters downwind and 8.51 meters crosswind.
- The 9.5 kW/m^2 heat radiation contours extend about 14.63 meters downwind and 4.67 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 13.50 meters downwind and 3.56 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 11.47 meters downwind and 0.96 meters crosswind.
- The 37.5 kW/m^2 heat radiation not reached.

The modeling shows that the heat radiation value (4, 9.5, 12.5 & 25 kW/m^2) will be limited inside the PRMS and affecting the facilities.

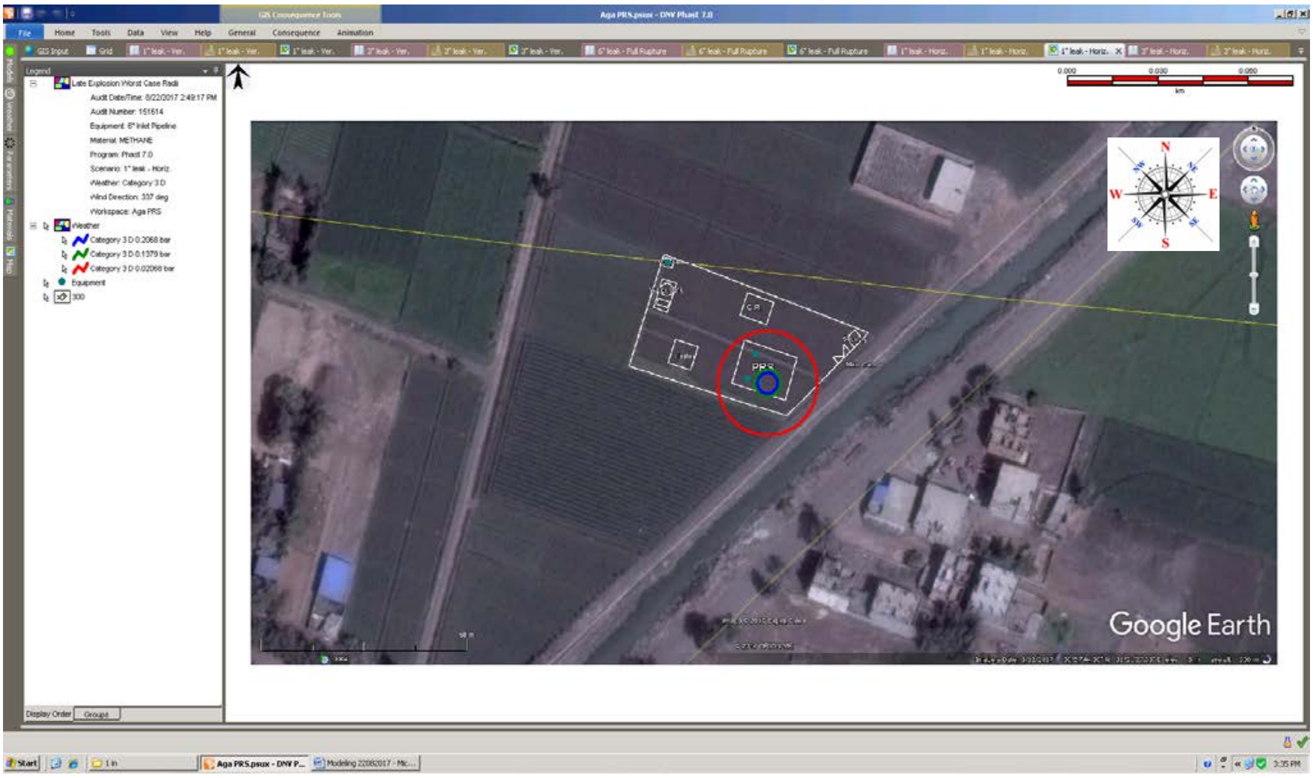


Figure (18) Late Explosion Overpressure Waves (1" hole in 6" Inlet Pipeline)

- The previous figure show that if there is a gas release from 1" hole size and late ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 26.54 meters radius.
- The 0.137 bar overpressure waves will extend about 14.28 meters radius.
- The 0.206 bar overpressure waves will extend about 13.31 meters radius.

The modeling shows that the overpressure wave of 0.020 bar effects will extend outside the PRMS NE fence with about 3 m downwind and southwest fence with about 5 m crosswind.

The overpressure waves of 0.137 & 0.206 bar will be limited inside the PRMS fence affecting the facilities.

1/2- Consequence Modeling for 3 inch (Half Rup.) Gas Release

The following table no. (17) Show that:

Table (17) Dispersion Modeling for Inlet - 3" / 6" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	8.60	1.00	0.80 @ 5.20 m
	LFL	35.25	0 – 3.15	3.25 @ 28.00 m
	50 % LFL	35.30	0 – 5.00	5.00 @ 35.30 m

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	41.68	1.6	74.20	51.40	0
		4	59.46	32.19	0
		9.5	48.86	19.24	0
		12.5	45	15.61	20% /60 sec.
		25	39.67	7.84	80.34
		37.5	31.64	4.48	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	96.98	111.20	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	25.11	67.48	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	19.43	65.79	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

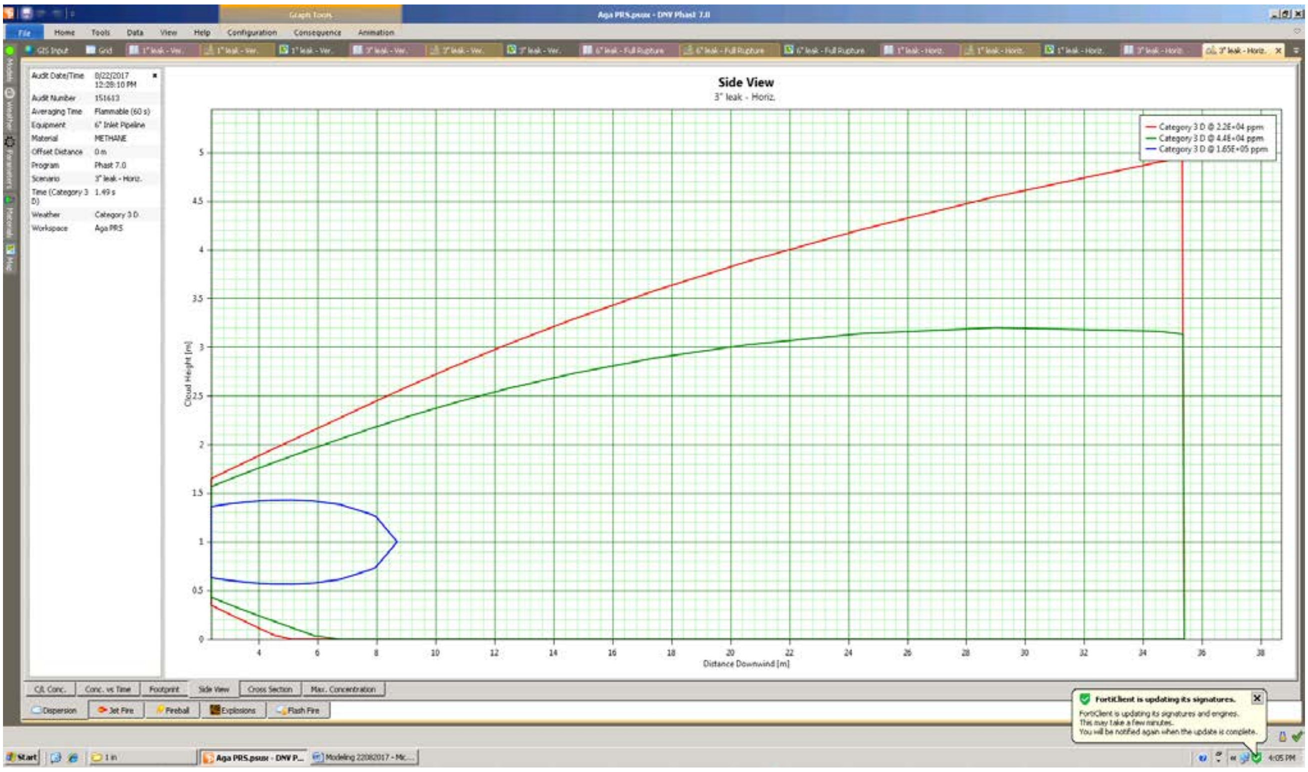


Figure (19) Gas Cloud Side View (UFL/LFL) (3" hole in 6" Inlet Pipeline)

- The previous figure shows that if there is a gas release from 3" hole size without ignition the flammable vapors will reach a distance more than 35 m downwind and from 0 to over 5 m height.
- The UFL will reach a distance of about 8.60 m downwind with a height of 1 m. The cloud large width will be 0.80 m crosswind at a distance of 5.20 m from the source.
- The LFL will reach a distance of about 35.25 m downwind with a height from 0 to 3.15 m. The cloud large width will be 3.25 m crosswind at a distance of 28 m from the source.
- The 50 % LFL will reach a distance of about 35.30 m downwind with a height from 0 to 5 m. The cloud large width will be 5 m crosswind at a distance of 35.30 m from the source.

The modeling shows that the gas cloud will extend the NE fence downwind reaching the sub-way route outside the PRMS.

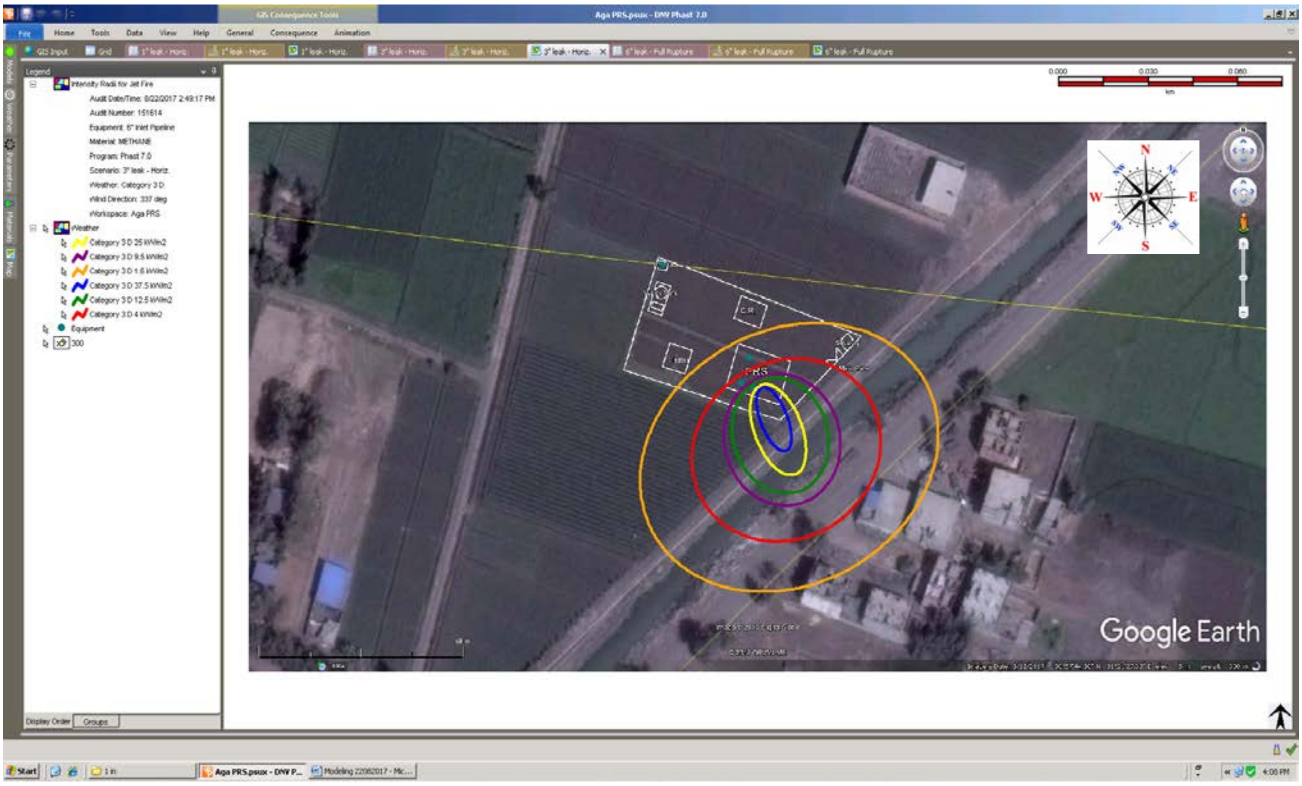


Figure (20) Heat Radiation Contours from Jet Fire (3" hole in 6" Inlet Pipeline)

- The previous figure shows that if there is a gas release from 3" hole size and ignited the expected flame length is about 41 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 48.86 meters downwind and 19.24 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 45 meters downwind and 15.61 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 39.67 meters downwind and 7.84 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 31.64 meters downwind and 4.48 meters crosswind.

The modeling shows that all values will extend outside the NE fence downwind with various distances that reaching the sub-way route (25 & 37.5 kW/m^2), and the main road (9.5 kW/m^2).

The main gate and security office will reached by the value of 4 & 1.6 kW/m^2.

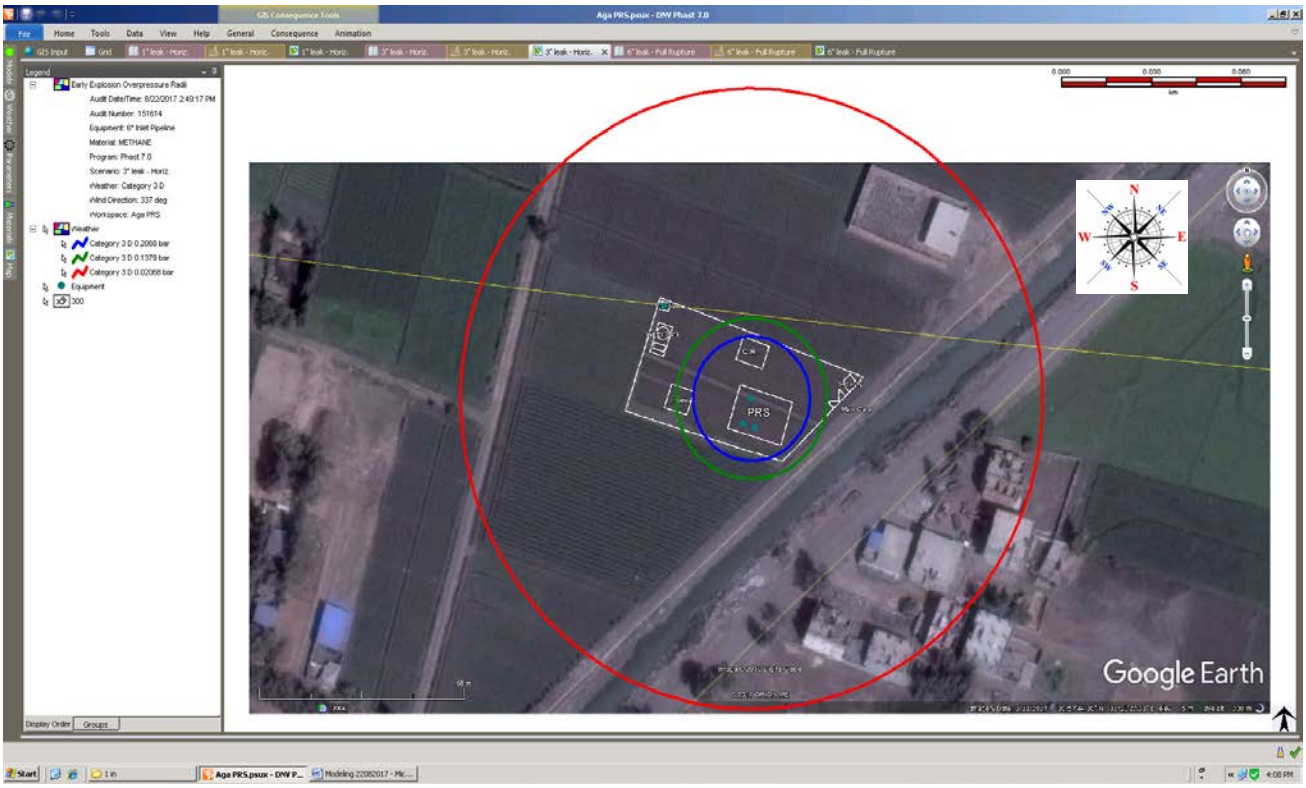


Figure (21) Early Explosion Overpressure Waves (3" hole in 6" Inlet Pipeline)

- The previous figure shows that if there is a gas release from 3" hole size and early ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 97 meters radius.
- The 0.137 bar overpressure waves will extend about 25 meters radius.
- The 0.206 bar overpressure waves will extend about 19 meters radius.

The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching the housing area SE downwind and NE crosswind.

The value of 0.137 bar will be limited inside the PRMS from the NW side and extend the PRMS fences from NE (5m), SE (3m) & SW (5m), and will affect the control room, and heater area.

The value of 0.206 bar will be limited inside the PRMS from three sides and extend from SW (2m), and will affect the control room.

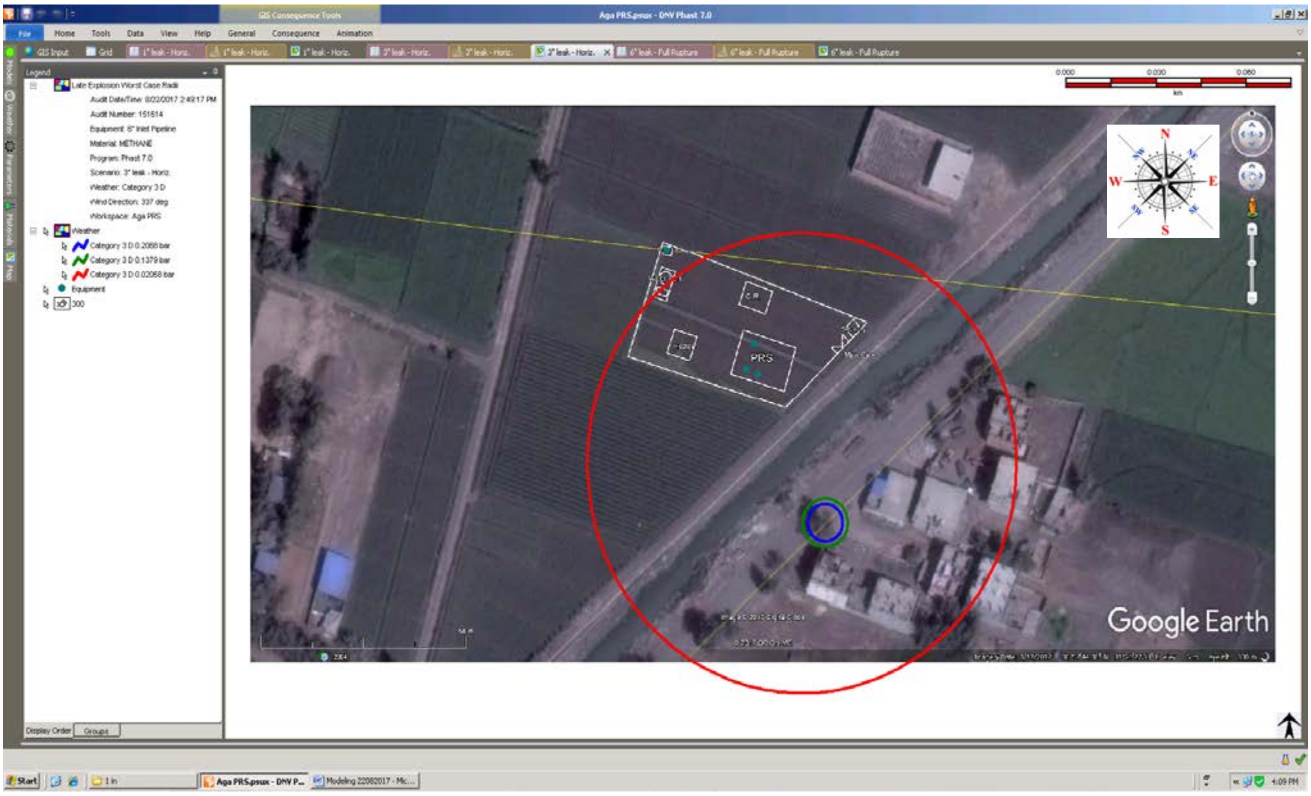


Figure (22) Late Explosion Overpressure Waves (3" hole in 6" Inlet Pipeline)

- The previous figure shows that if there is a gas release from 3" hole size and late ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 111.20 meters downwind.
- The 0.137 bar overpressure waves will extend about 67.48 meters downwind.
- The 0.206 bar overpressure waves will extend about 65.79 meters downwind.

The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching housing area SE side downwind.

The value of 0.137 bar and 0.206 bar will be extend outside the PRMS from the SE side reaching the main road and near to the housing area.

1/3- Consequence Modeling for 6 inch (Full Rupture) Gas Release

The following table no. (18) Show that:

Table (18) Dispersion Modeling for Inlet - 6" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	23.90	1.05	0.80 @ 15.00 m
	LFL	31.80	0 – 5.20	5.20 @ 31.80 m
	50 % LFL	31.90	0 – 6.40	6.40 @ 31.90 m

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	77.80	1.6	148.82	103.54	0
		4	55.55	51.29	0
		9.5	40.92	26.60	0
		12.5	40.34	20.90	20 %/60 sec.
		25	40.34	12.42	80.34
		37.5	40.34	10	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	97	128	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	25	97	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	19	96	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

Fireball			
Wind Category	**Heat Radiation (kW/m^2)**	**Distance (m)**	**Heat Radiation (kW/m^2) Effects on People & Structures**
3.11 D	1.6	59.71	**12.5** *20 % Chance of fatality for 60 sec exposure*
	4	36	**25** *100 % Chance of fatality for continuous exposure* *50 % Chance of fatality for 30 sec exposure*
	9.5	19.71	**37.5** *Sufficient of cause process equipment damage*
	12.5	14.98	
	25	Not Reached	
	37.5	Not Reached	

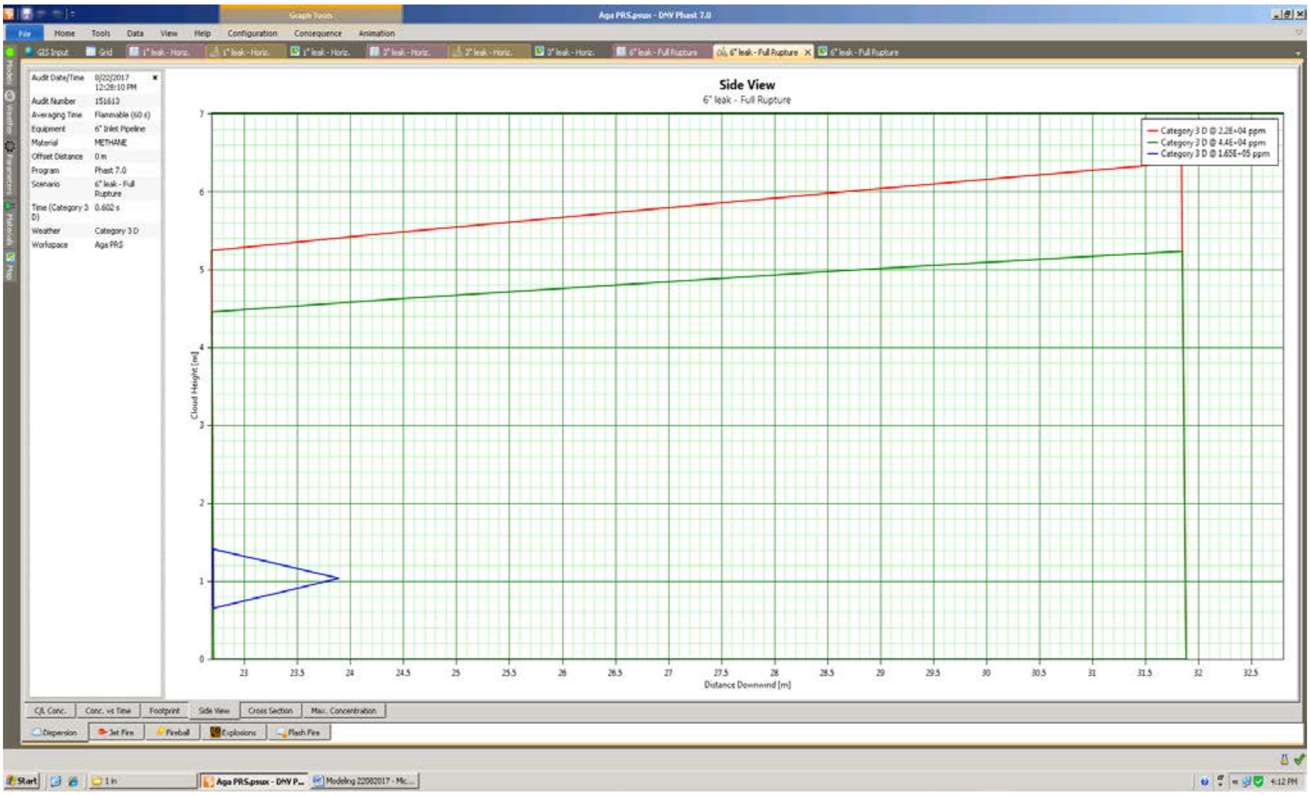


Figure (23) Gas Cloud Side View (UFL/LFL) (6" Inlet Pipeline Full Rupture)

- The previous figure shows that if there is a gas release from 6" pipeline full rupture without ignition, the flammable vapors will reach a distance more than 23 m downwind and over 6 m height.
- The UFL will reach a distance of about 23.90 downwind with a height of 1.05 m. The cloud large width will be 0.80 m crosswind at a distance of 15 m from the source.
- The LFL will reach a distance of about 31.80 m downwind with a height from 0 to 5.20 m. The cloud large width will be 5.20 m crosswind at a distance of 31.80 m from the source.
- The 50 % LFL will reach a distance of about 31.90 m downwind with a height from 0 to 6.40 m. The large width will be 6.40 m crosswind at a distance of 31.90 m from the source.

The modeling shows that the gas cloud effects (UFL, LFL & 50 % LFL) will extend outside the SE fence covering the sub-way and irrigation canal.

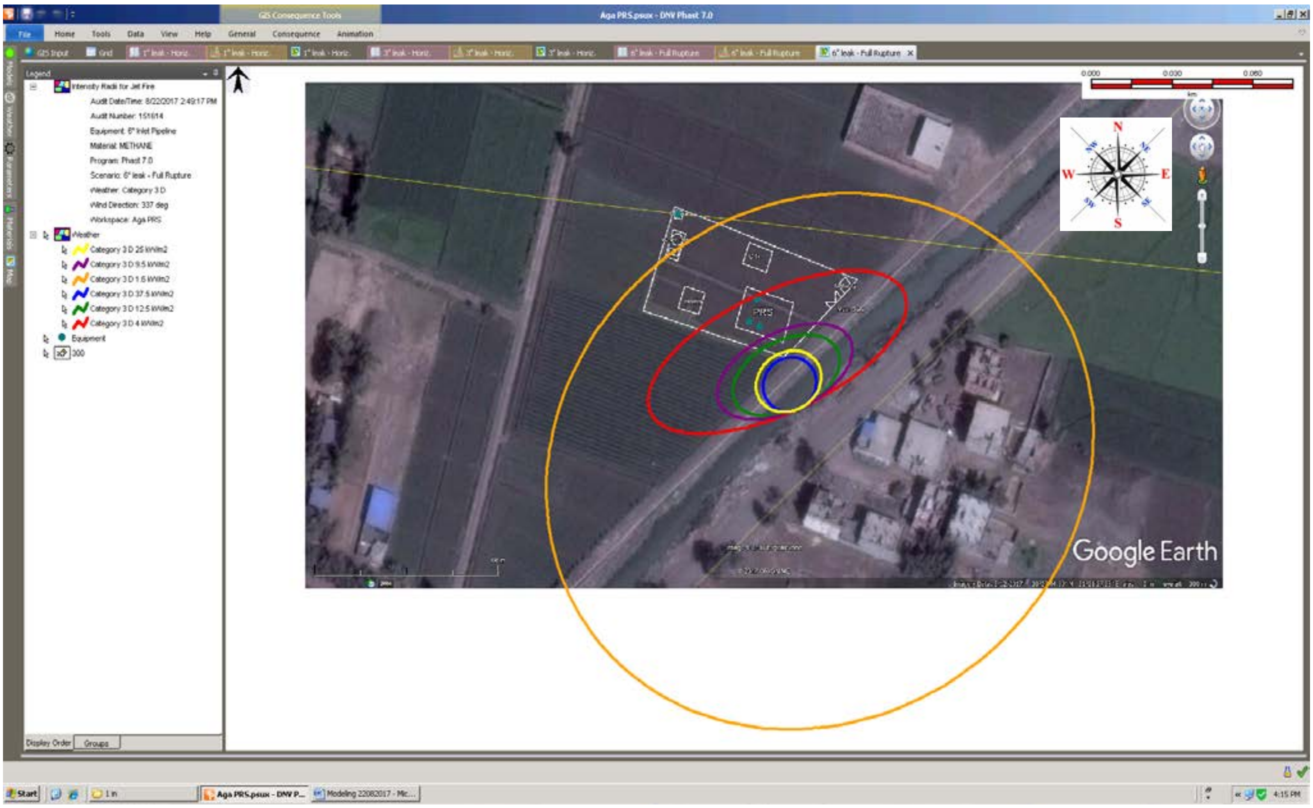


Figure (24) Heat Radiation Contours from Jet Fire (6" Inlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 6" pipeline full rupture and ignited the expected flame length is about 77.80 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 40.92 meters downwind and 26.60 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 40.34 meters downwind and 20.90 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 40.34 meters downwind and 12.42 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 40.34 meters downwind and 10 meters.

The modeling shows that the heat radiation values will extend outside the PRMS SE fence downwind affecting the sub-way and irrigation canal, and near to the main road.

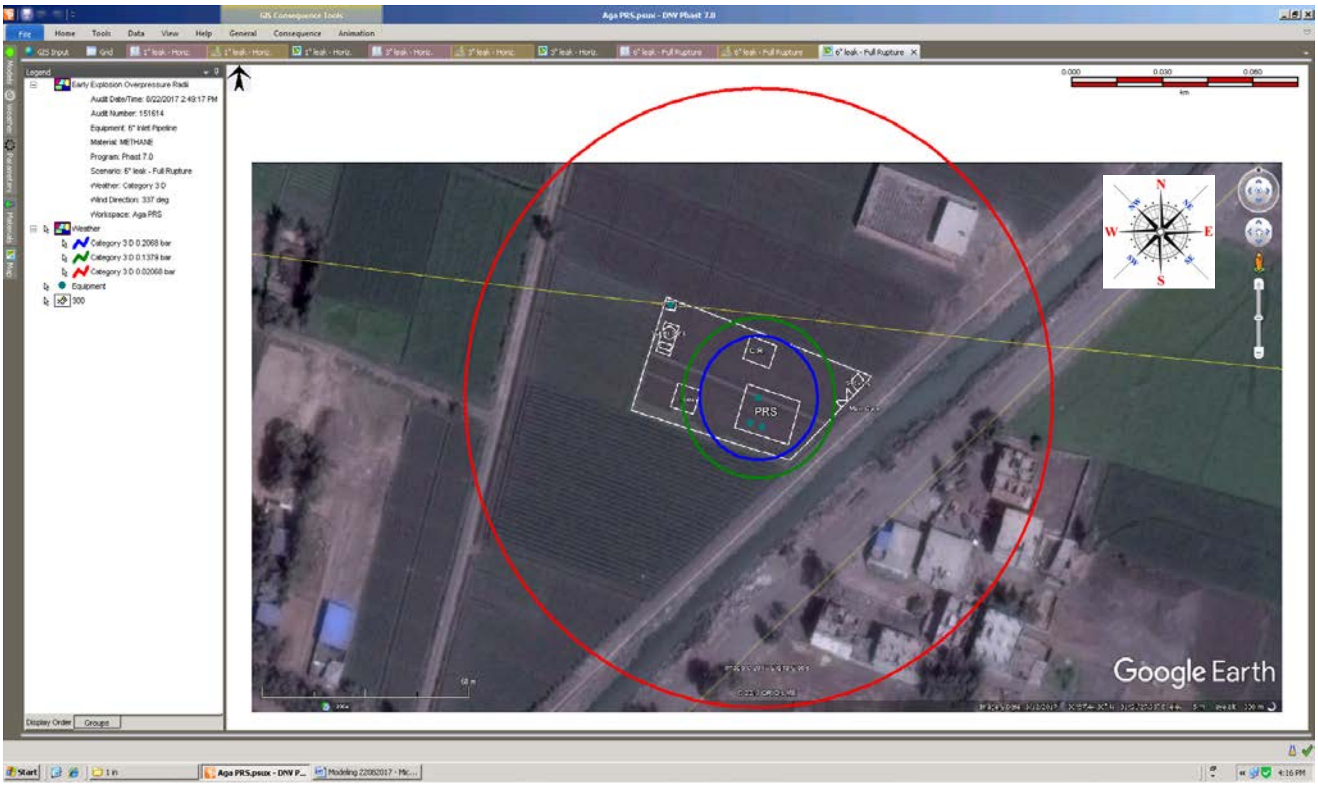


Figure (25) Early Explosion Overpressure Waves (6" Inlet Pipeline Full Rupture)

- The previous figure shows that if there is gas release from 6" pipeline full rupture and early ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 97 meters radius.
- The 0.137 bar overpressure waves will extend about 25 meters radius.
- The 0.206 bar overpressure waves will extend about 19 meters radius.

The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching the housing area SE downwind and NE crosswind.

The value of 0.137 bar will be limited inside the PRMS from the NW side affecting the control room and extend the PRMS fences from NE (5m), SE (3m) & SW (5m).

The value of 0.206 bar will be limited inside the PRMS from three sides affecting the control room and extend from SW (2m).

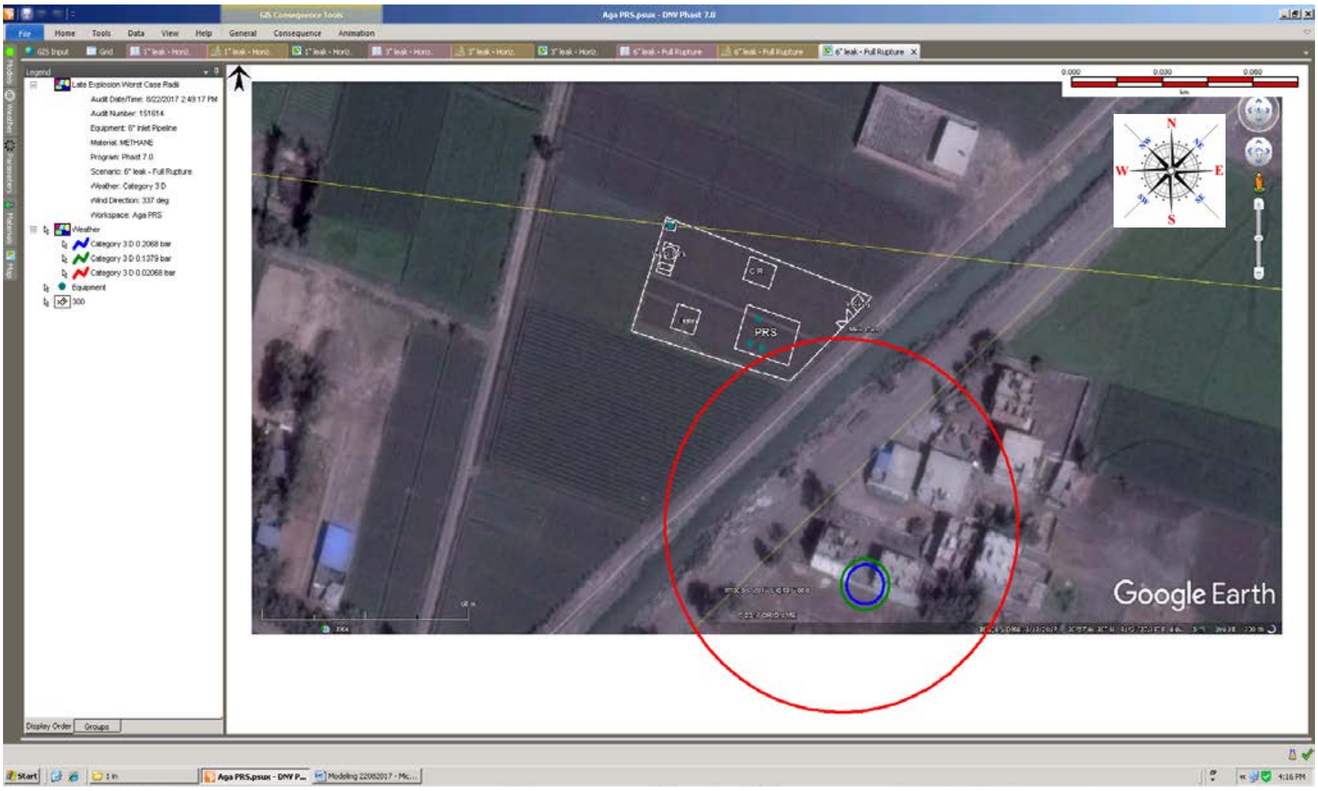


Figure (26) Late Explosion Overpressure Waves (6" Inlet Pipeline Full Rupture)

- The previous figure shows that if there is gas release from 6" pipeline full rupture and late ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 128 meters downwind.
- The 0.137 bar overpressure waves will extend about 97 meters downwind.
- The 0.206 bar overpressure waves will extend about 96 meters downwind.

The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching housing area SE side downwind.

The value of 0.137 bar and 0.206 bar will be extend outside the PRMS from the SE side reaching the housing area downwind.

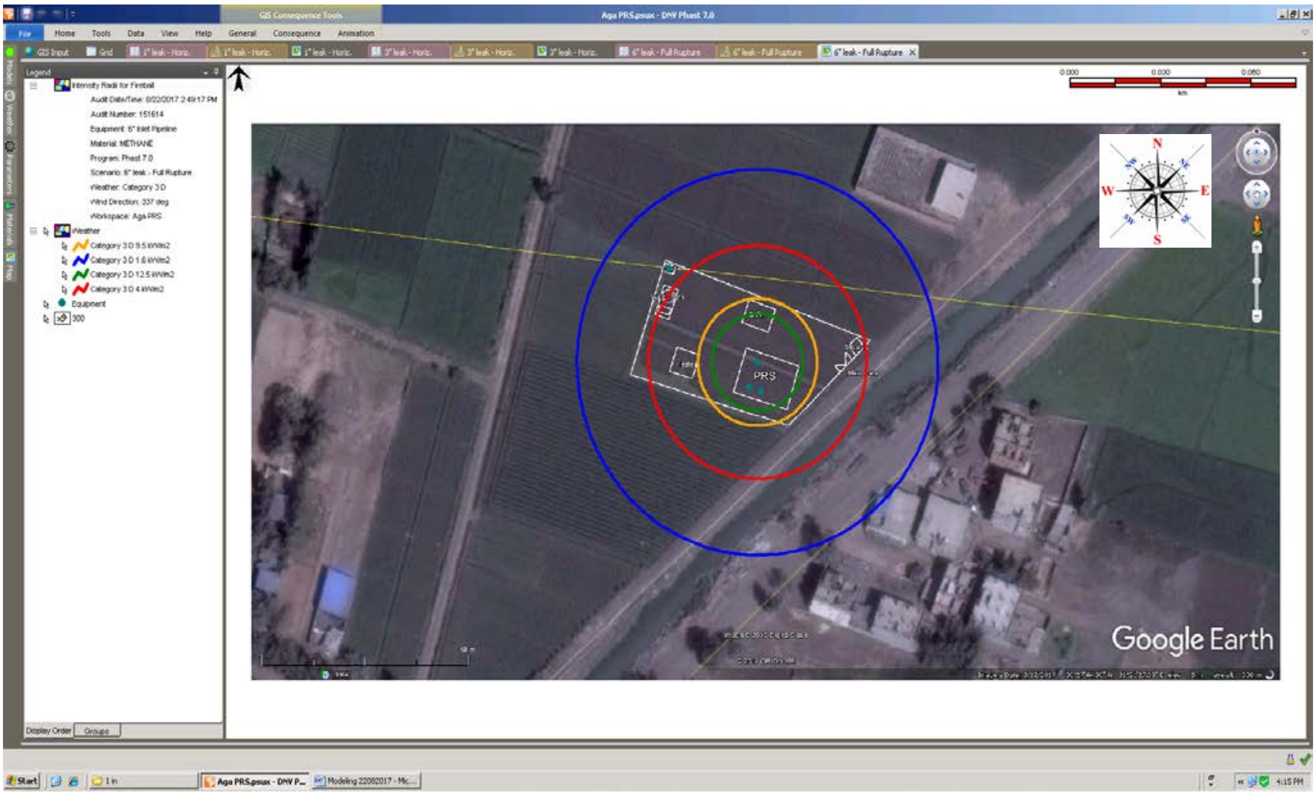


Figure (27) Heat Radiation Contours from Fireball (6" Inlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 6" pipeline full rupture and ignited forming fireball this will gives a heat radiation with different values and contours and will extended in four dimensions.
- The 9.5 kW/m^2 heat radiation contours extend about 19.71 meters radius.
- The 12.5 kW/m^2 heat radiation contours extend about 14.98 meters radius.
- The 25 kW/m^2 heat radiation not reached.
- The 37.5 kW/m^2 heat radiation not reached.

The modeling shows that the heat radiation value of 9.5 & 12.5 kW/m^2 will be limited inside PRMS fence and covering the control room NE side crosswind.

2.0- Pressure Reduction Station Outlet Pipeline (8 inch)

2/1- Consequence Modeling for 1 inch (Pin Hole) Gas Release

The following table no. (19) Show that:

Table (19) Dispersion Modeling for Outlet - 1" / 8" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	1.35	1.00	0.12 @ 0.60 m
	LFL	5.15	1.05	0.56 @ 3.40 m
	50 % LFL	5.90	0 – 1.50	1.50 @ 5.90 m

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	8.46	1.6	12.66	7.79	0
		4	10.58	4.58	0
		9.5	8.63	2.16	0
		12.5	8.23	1.46	20% /60 sec.
		25	Not Reached	Not Reached	80.34
		37.5	Not Reached	Not Reached	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	32.14	N/D	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	8.32	N/D	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	6.43	N/D	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

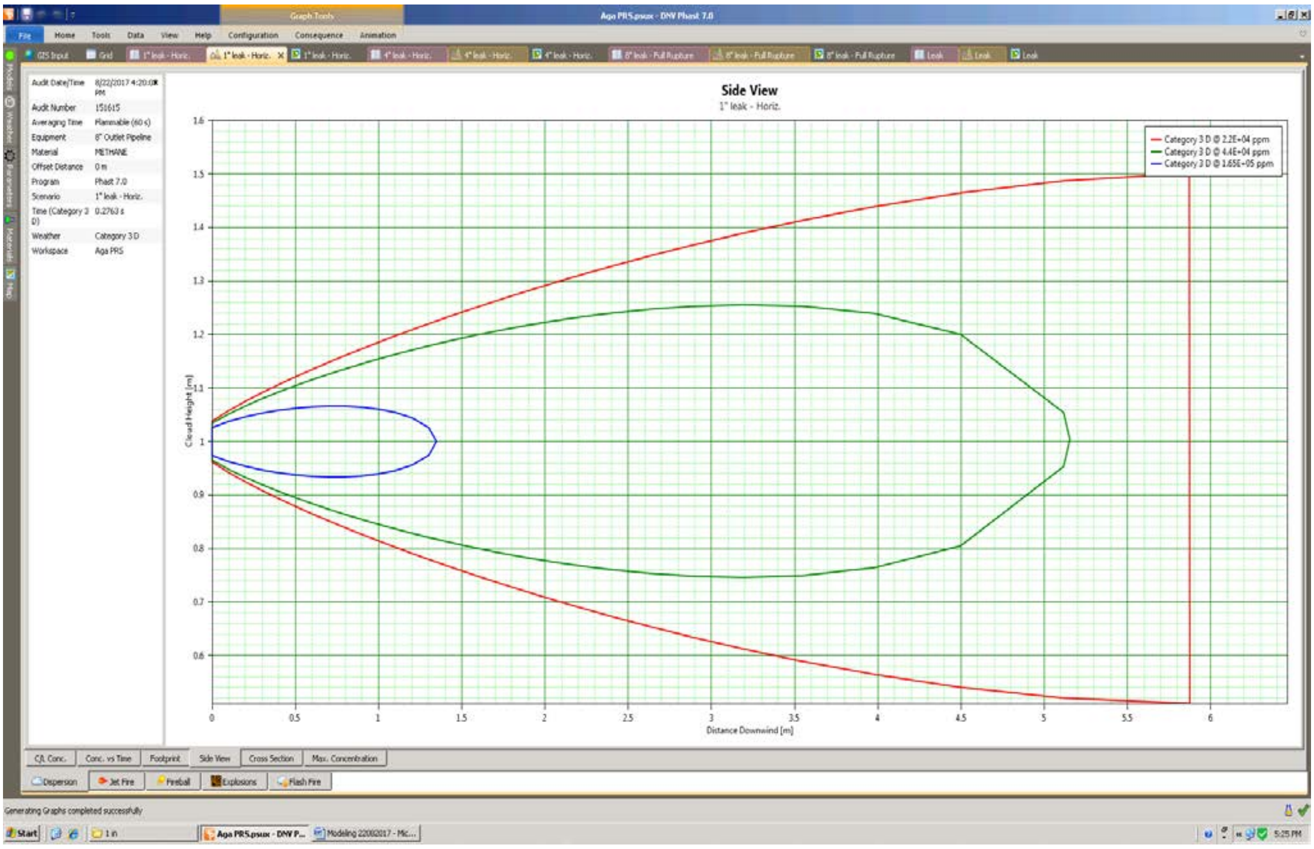


Figure (28) Gas Cloud Side View (UFL/LFL) (1" hole in 8" Outlet Pipeline)

- The previous figure show that if there is a gas release from 1" hole size without ignition the flammable vapors will reach a distance more than 5 m downwind and over 1.50 m height.
- The UFL will reach a distance of about 1.35 m downwind with a height of 1 m. The cloud large width will be 0.24 m crosswind at a distance of 0.60 m from the source.
- The LFL will reach a distance of about 5.15 m downwind with a height of 1.05 m. The cloud large width will be 0.56 m crosswind at a distance of 3.40 m from the source.
- The 50 % LFL will reach a distance of about 5.90 m downwind with a height of from 0 to 1.50 m. The cloud large width will be 3 m crosswind at a distance of 5.90 m from the source.

The modeling shows that the gas cloud will be limited inside the PRMS boundary.

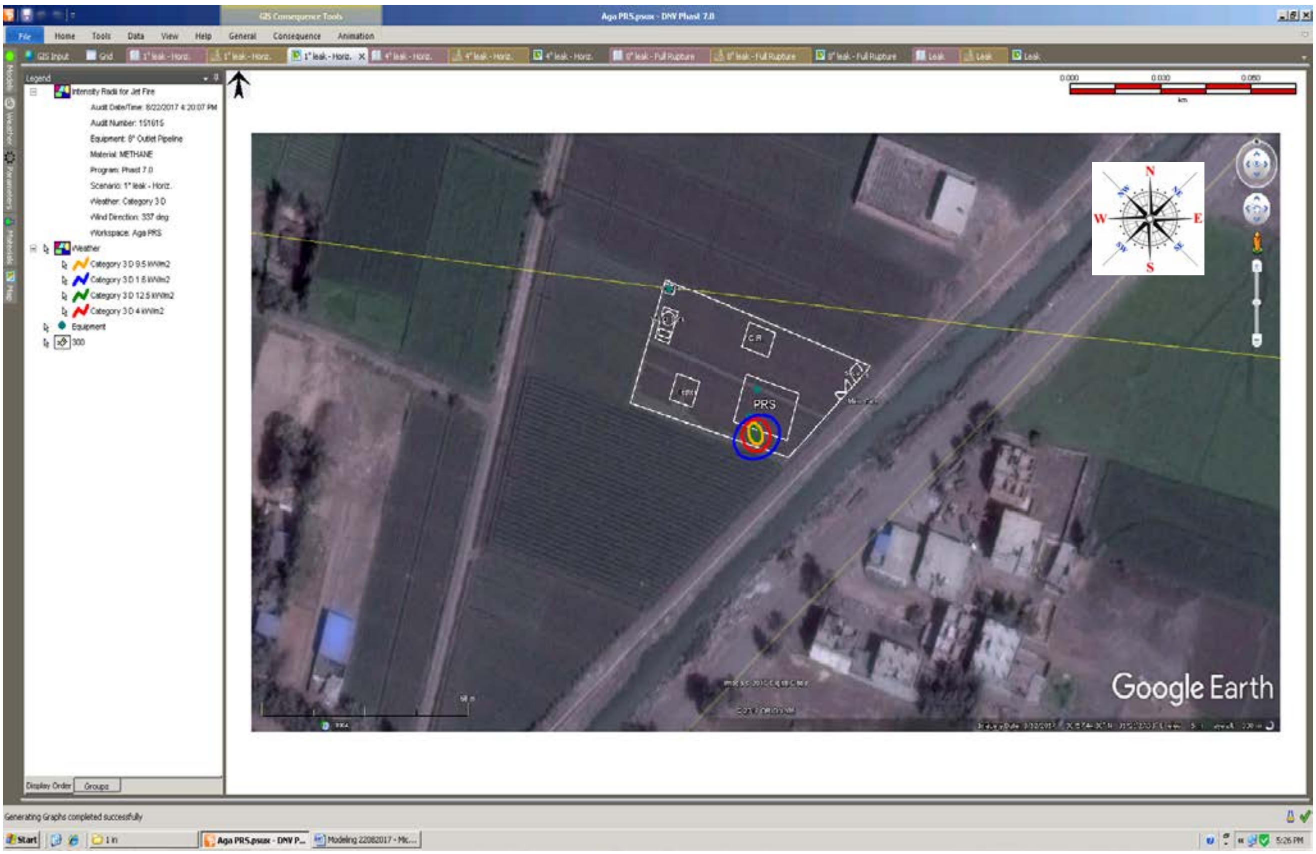


Figure (29) Heat Radiation Contours from Jet Fire (1" hole in 8" Outlet Pipeline)

- The previous figure shows that if there is a gas release from 1" hole size and ignited the expected flame length is about 8.46 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 8.63 meters downwind and 2.16 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 8.23 meters downwind and 1.46 meters crosswind.
- The 25 kW/m^2 heat radiation not reached.
- The 37.5 kW/m^2 heat radiation not reached.

The modeling shows that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRMS boundary downwind.

Figure (30) Early Explosion Overpressure Waves (1" hole in 8" Outlet Pipeline)

- The previous figure show that if there is a gas release from 1" hole size and early ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 32.14 meters radius.
- The 0.137 bar overpressure waves will extend about 8.32 meters radius.
- The 0.206 bar overpressure waves will extend about 6.43 meters radius.

The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).

The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.

2/2- Consequence Modeling for 4 inch (Half Rup.) Gas Release

The following table no. (20) Show that:

Table (20) Dispersion Modeling for Outlet - 4" / 8" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	6.48	1.00	0.20 @ 6.00 m
	LFL	9.50	0 – 2.20	2.20 @ 9.50 m
	50 % LFL	9.60	0 – 2.55	2.55 @ 9.60 m

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	34.33	1.6	59.43	40.70	0
		4	48.18	25.48	0
		9.5	40.13	15.11	0
		12.5	37.32	12.21	20% /60 sec.
		25	32.84	5.91	80.34
		37.5	25.95	3.13	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	32.14	38.74	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	8.32	24.49	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	6.44	23.48	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

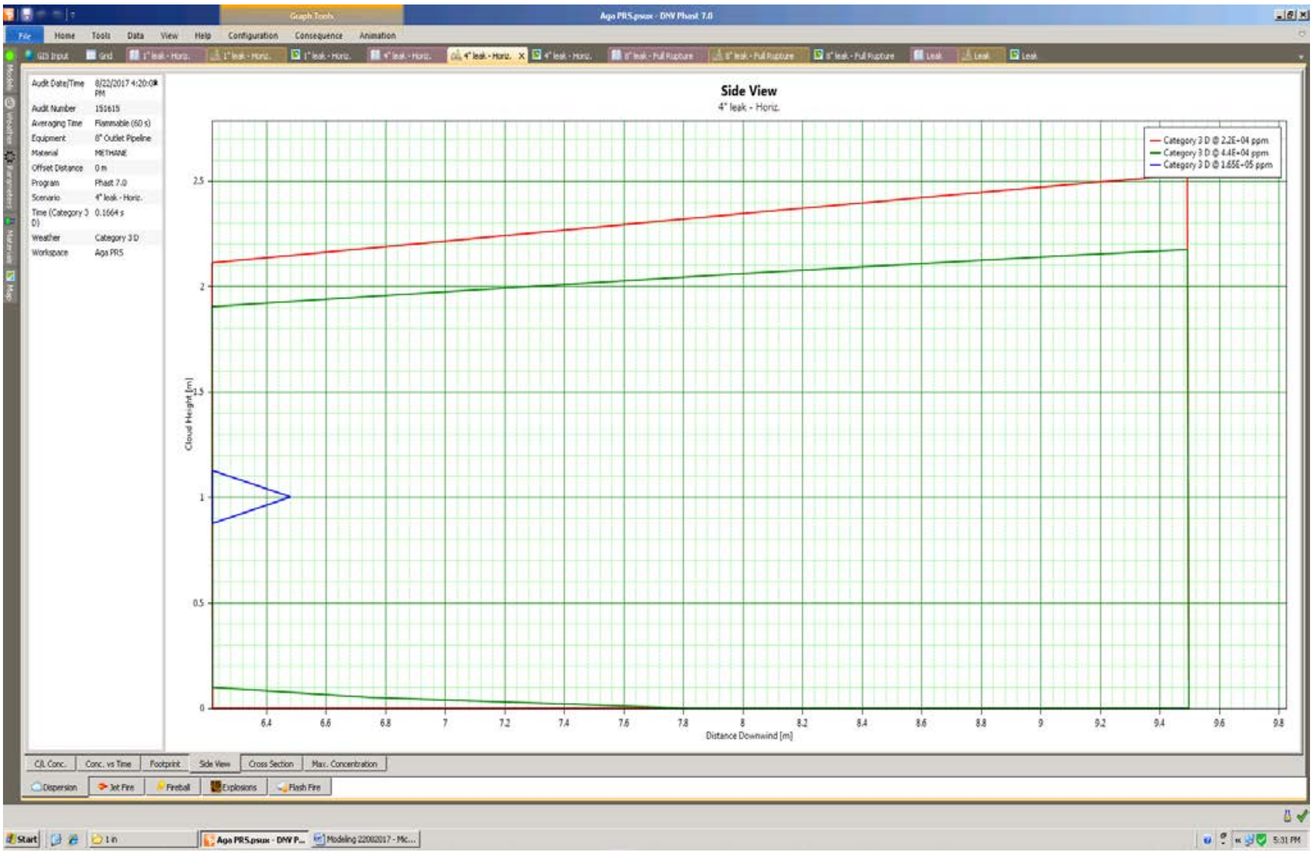


Figure (31) Gas Cloud Side View (UFL/LFL) (4" hole in 8" Outlet Pipeline)

- The previous figure shows that if there is a gas release from 4" hole size without ignition the flammable vapors will reach a distance more than 9 m downwind and over 2 m height.
- The UFL will reach a distance of about 6.48 m downwind with a height of 1 m. The cloud large width will be 0.20 m crosswind at a distance of 6 m from the source.
- The LFL will reach a distance of about 9.50 m downwind with a height from 0 to 2.20 m. The cloud large width will be 2.20 m crosswind at a distance of 9.50 m from the source.
- The 50 % LFL will reach a distance of about 9.60 m downwind with a height from 0 to 2.55 m. The cloud large width will be 2.55 m crosswind at a distance of 9.60 m from the source.

The modeling shows that the gas cloud (UFL, LFL & 50% LFL) will limited inside the PRMS boundary.

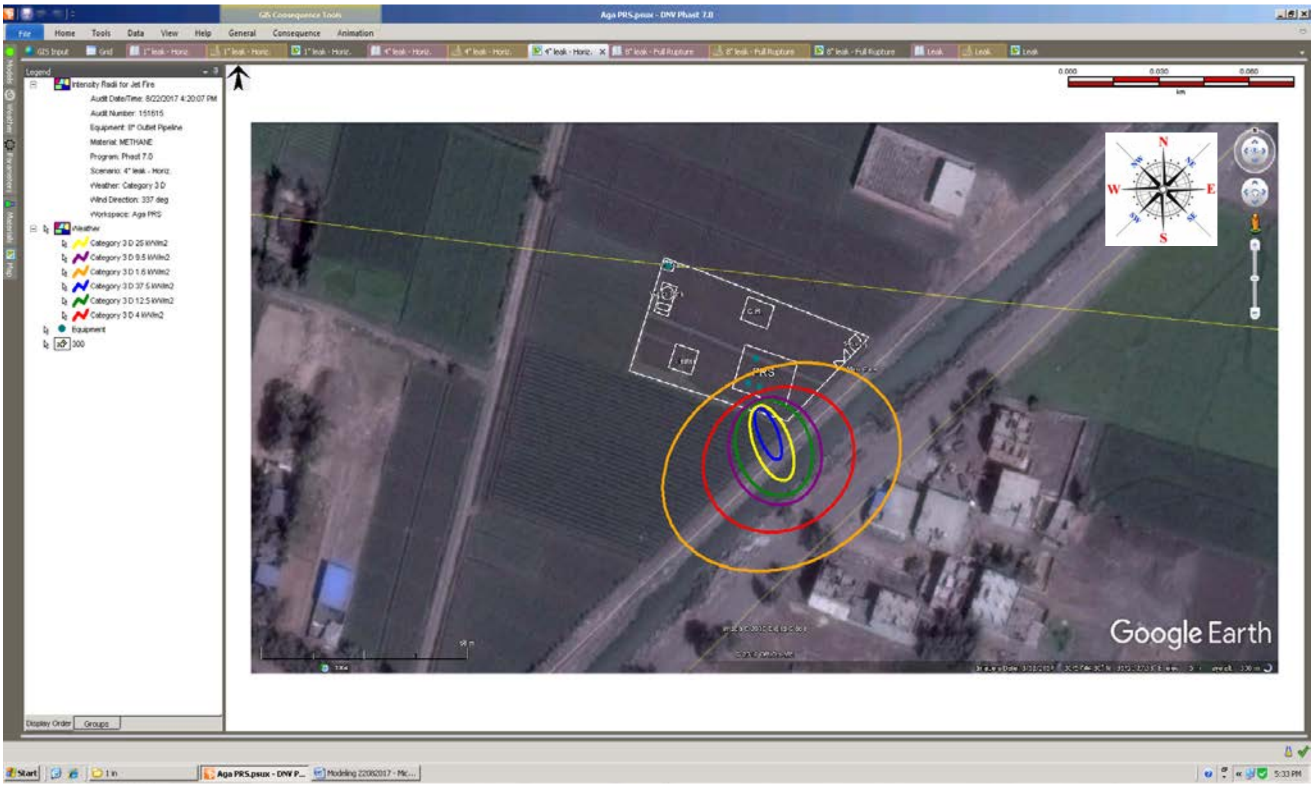


Figure (32) Heat Radiation Contours from Jet Fire (4" hole in 8" Outlet Pipeline)

- The previous figure shows that if there is a gas release from 4" hole size and ignited the expected flame length is about 34.33 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 40.13 meters downwind and 15.11 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 37.32 meters downwind and 12.21 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 32.84 meters downwind and 5.91 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 25.95 meters downwind and 3.13 meters crosswind.

The modeling shows that all radiation values will extend outside the PRMS SE downwind covering the sub-way (25 & 37.5 kW/m^2) and SW crosswind covering the sub-way and near to the main road (9. & 12.5 kW/m^2).

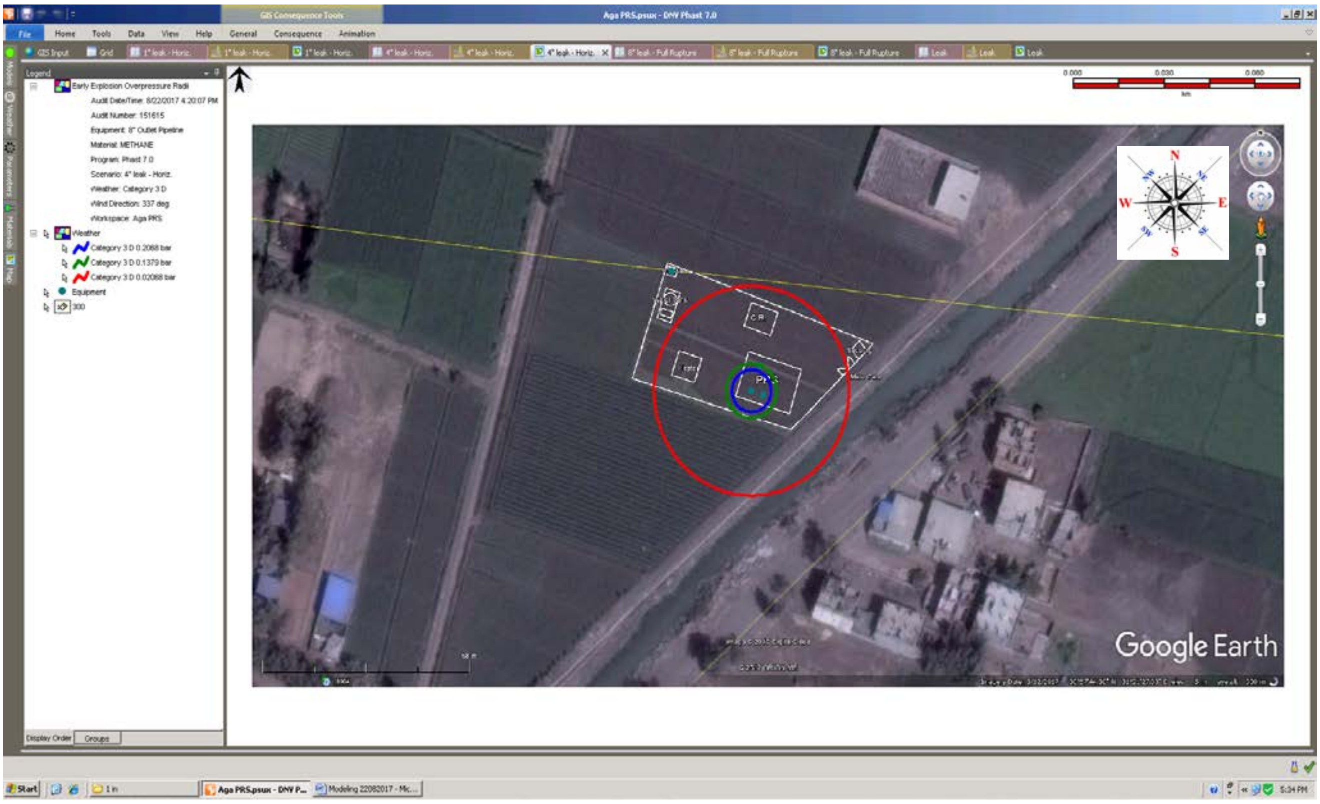


Figure (33) Early Explosion Overpressure Waves (4" hole in 8" Outlet Pipeline)

- The previous figure show that if there is a gas release from 4" hole size and early ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 32.14 meters radius.
- The 0.137 bar overpressure waves will extend about 8.32 meters radius.
- The 0.206 bar overpressure waves will extend about 6.44 meters radius.

The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).

The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.

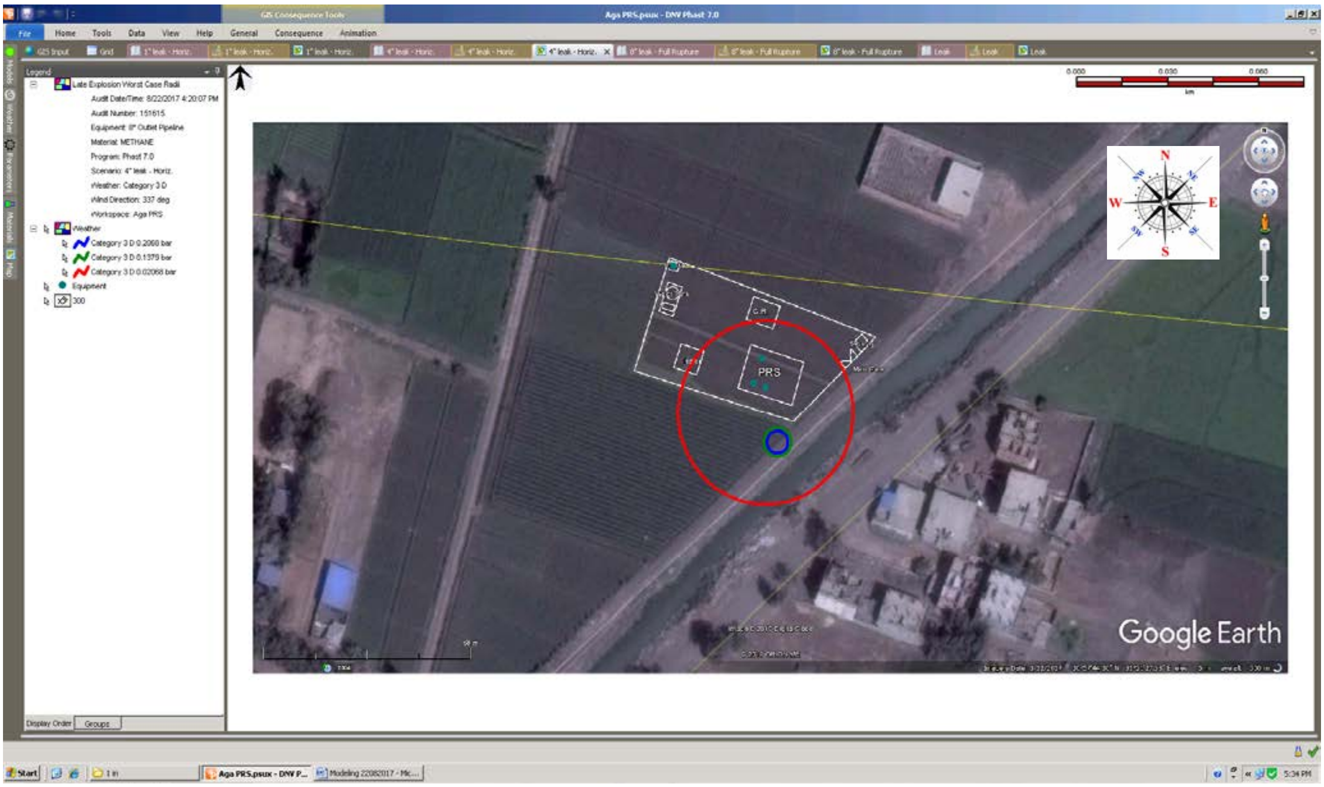


Figure (34) Late Explosion Overpressure Waves (4" hole in 8" Inlet Pipeline)

- The previous figure shows that if there is a gas release from 4" hole size and late ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 38.74 meters downwind.
- The 0.137 bar overpressure waves will extend about 24.49 meters downwind.
- The 0.206 bar overpressure waves will extend about 23.48 meters downwind.

The modeling shows that the value of 0.020 bar will be limited inside the PRMS boundary from NE & NW, (reaching the control room and heater) and will extend from SE & SW covering the sub-way.

The value of 0.137 bar and 0.206 bar will be extend outside the PRMS SE fence to the sub-way downwind.

2/3- Consequence Modeling for 8 inch (Full Rup.) Gas Release

The following table no. (21) Show that:

Table (21) Dispersion Modeling for Outlet - 8" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	11.16	1.30	0.60
	LFL	12.20	0 – 2.35	5.60
	50 % LFL	12.50	0 – 2.65	12.50

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m²)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	57.89	1.6	106.22	73.41	0
		4	83.96	46.10	0
		9.5	67.76	27.80	0
		12.5	62.53	22.79	20% /60 sec.
		25	54.80	12.07	80.34
		37.5	44.72	7.54	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	32.14	42.79	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	8.32	32	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	6.44	31.57	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

Fireball			
Wind Category	**Heat Radiation (kW/m²)**	**Distance (m)**	**Heat Radiation (kW/m²) Effects on People & Structures**
3.11 D	1.6	21.31	**12.5** *20 % Chance of fatality for 60 sec exposure* **25** *100 % Chance of fatality for continuous exposure* *50 % Chance of fatality for 30 sec exposure* **37.5** *Sufficient of cause process equipment damage*
	4	12.89	
	9.5	7.14	
	12.5	5.51	
	25	Not Reached	
	37.5	Not Reached	

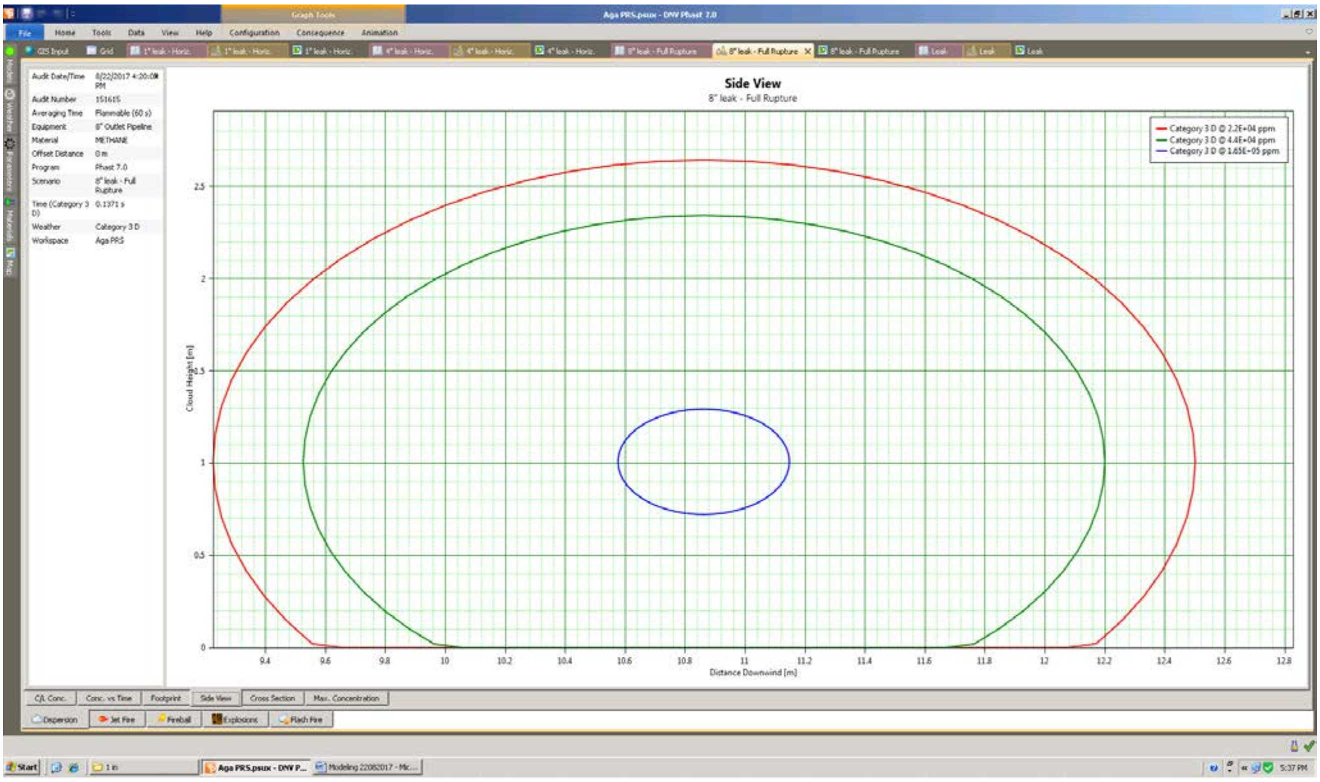


Figure (35) Gas Cloud Side View (UFL/LFL) (8" Outlet Pipeline Full Rupture)

- The previous figure shows that if there is a gas release from 8" pipeline full rupture without ignition the flammable vapors will reach a distance more than 12 m downwind and over 2 m height.
- The UFL will reach a distance of about 11.16 m downwind with a height of 1.30 m. The cloud large width will be 0.60 m crosswind.
- The LFL will reach a distance of about 12.20 m downwind with a height from 0 to 2.35 m. The cloud large width will be 5.60 crosswind.
- The 50 % LFL will reach a distance of about 12.50 m downwind with a height from 0 to 2.65 m. The cloud large width will be 12.50 crosswind.

The modeling shows that the gas cloud effects will extend outside the PRMS SE fence to reach the sub-way downwind.

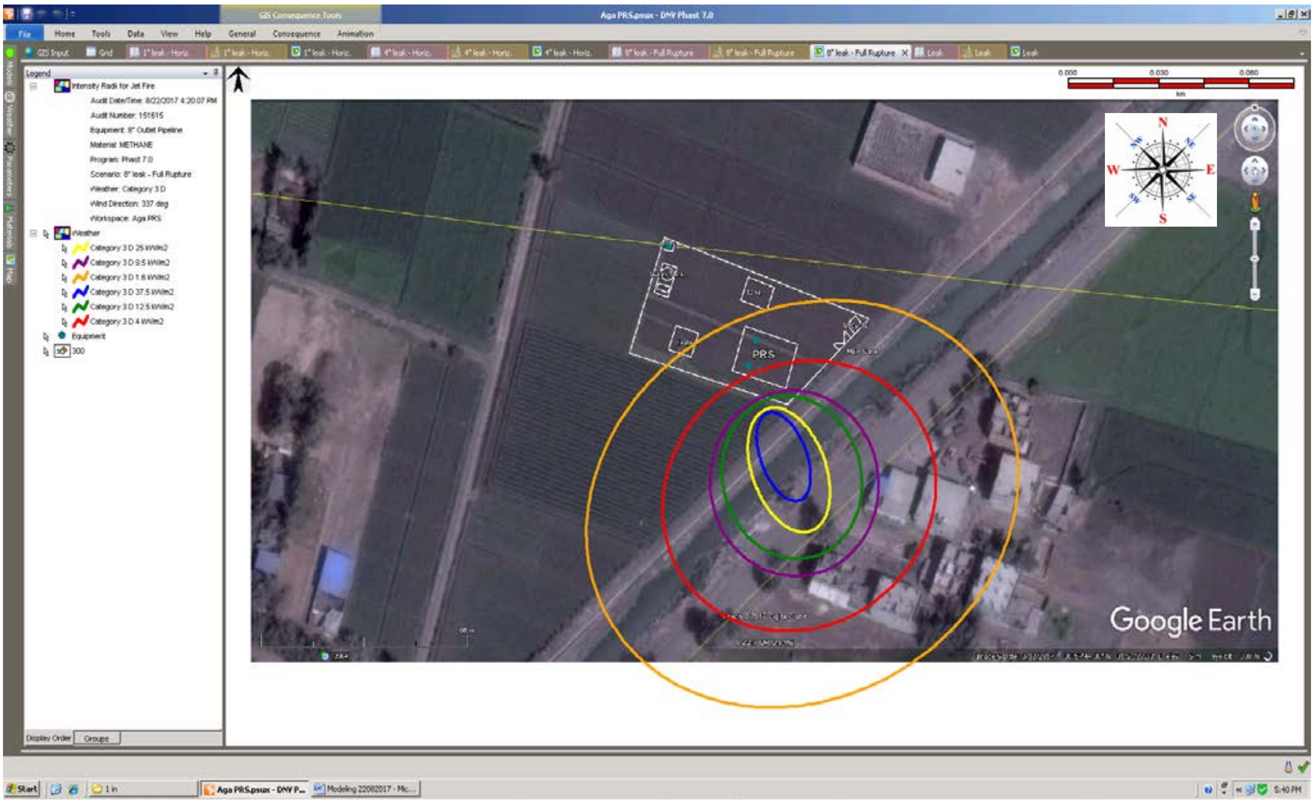


Figure (36) Heat Radiation Contours from Jet Fire (8" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 8" pipeline full rupture and ignited the expected flame length is about 57.89 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 67.76 meters downwind and 27.80 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 62.53 meters downwind and 22.79 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 54.80 meters downwind and 12.07 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 44.72 meters downwind and 7.54 meters crosswind.

The modeling shows that all values will extend outside the SE fence and cover the sub-way, irrigation canal & main road (25 & 37.5 kW/m^2).

The value of 12.5 kW/m^2 will be near to the housing building and 9.5 kW/m^2 will reach 2 buildings downwind.

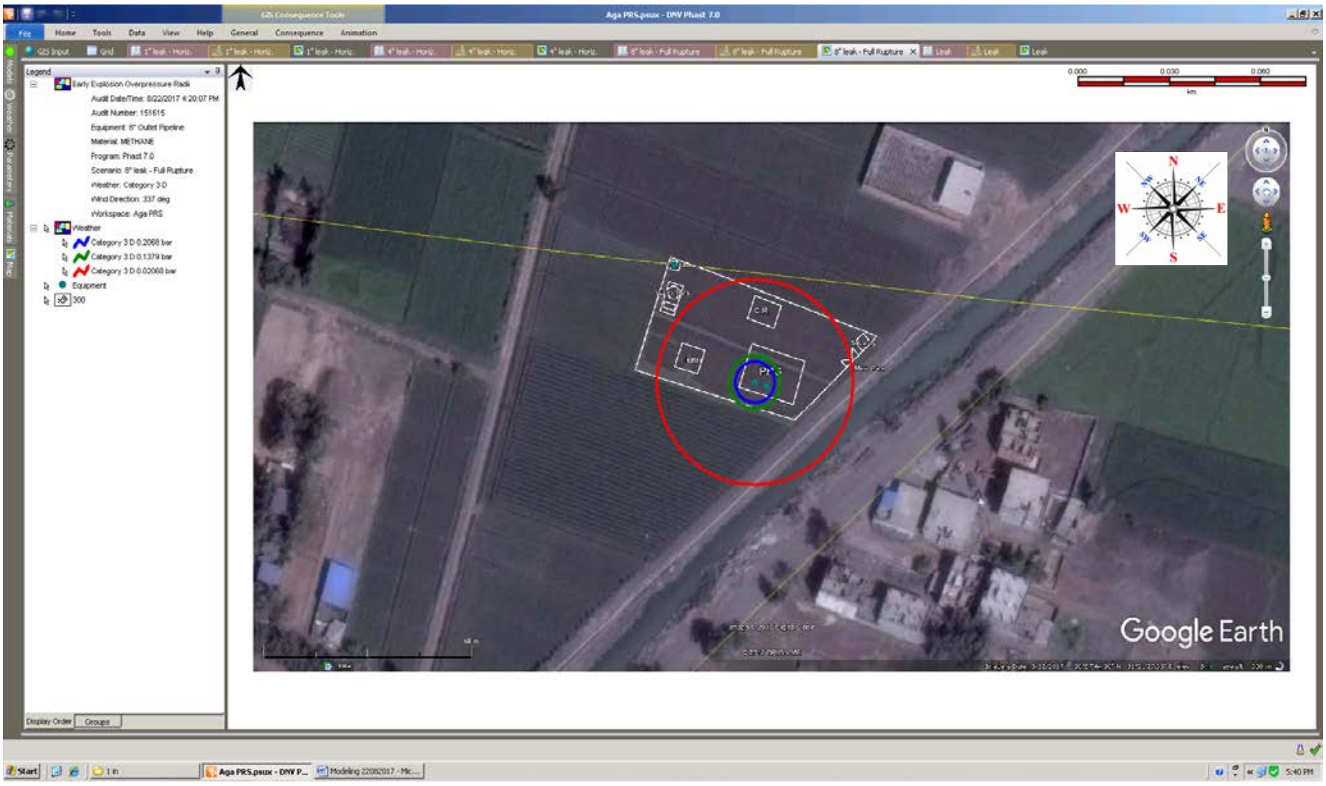


Figure (37) Early Explosion Overpressure Waves (8" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 8" pipeline full rupture and early ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 32.14 meters radius.
- The 0.137 bar overpressure waves will extend about 8.32 meters radius.
- The 0.206 bar overpressure waves will extend about 6.44 meters radius.

The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).

The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.

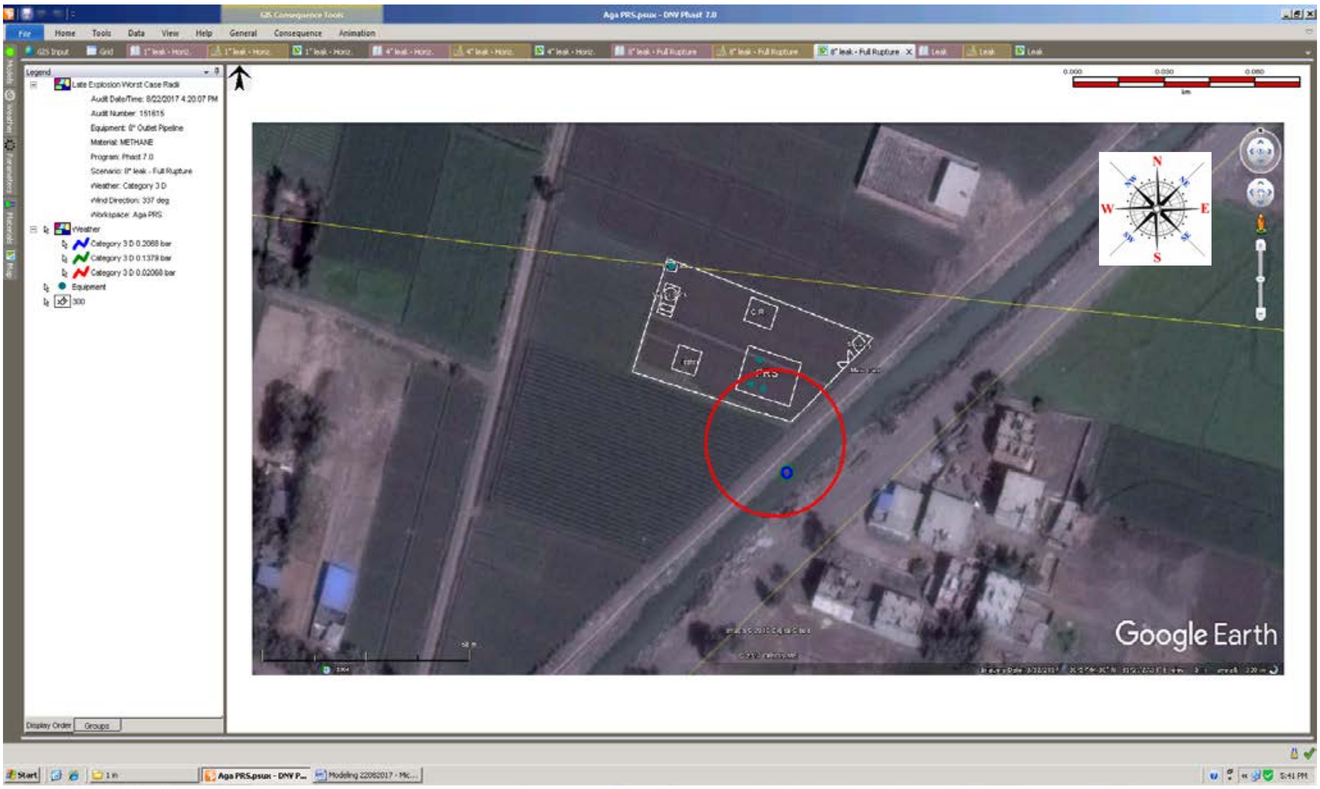


Figure (38) Late Explosion Overpressure Waves (8" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 8" pipeline full rupture and late ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 42.79 meters downwind.
- The 0.137 bar overpressure waves will extend about 32 meters downwind.
- The 0.206 bar overpressure waves will extend about 31.57 meters downwind.

The modeling shows that the value of 0.020 bar will be affect the PRMS facility from SE side; also will extend from SE & SW covering the sub-way and the irrigation canal to reach the main road.

The value of 0.137 bar and 0.206 bar will be extend outside the PRMS SE fence to affects the irrigation canal downwind.

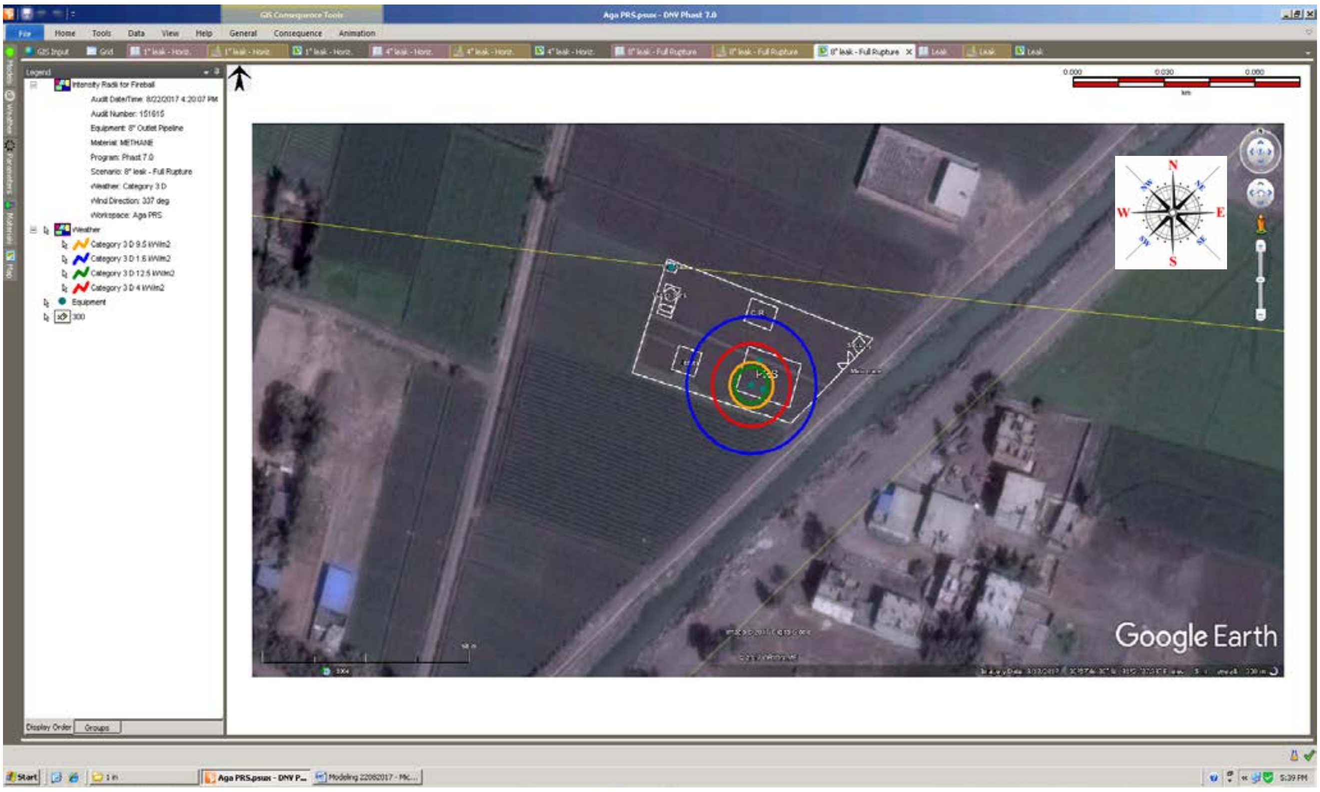


Figure (39) Heat Radiation Contours from Fireball (8" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 8" pipeline full rupture and ignited forming fireball this will gives a heat radiation with different values and contours and will extend in four dimensions.
- The 9.5 kW/m^2 heat radiation contours extend about 7.14 meters radius.
- The 12.5 kW/m^2 heat radiation contours extend about 5.51 meters radius.
- The 25 kW/m^2 heat radiation not reached.
- The 37.5 kW/m^2 heat radiation not reached.

The modeling shows that the heat radiation values of 9.5 & 12.5 kW/m^2 will be limited inside the PRMS boundary.

3.0- Pressure Reduction Station Odorant Tank (Spotleak)

The following table no. (22) Show 1" hole leak form odorant Modeling:

Table (22) Dispersion Modeling for Odorant Tank

Gas Release

Wind Category	Flammability Limits	Distance (m)	Height (m)	Cloud Width (m)
3.11 D	UFL	30.40	0 – 0.30	15.00
	LFL	37.20	0 – 0.42	18.60
	50 % LFL	42.00	0 – 0.90	26.00

Jet Fire

Wind Category	Flame Length (m)	Heat Radiation (kW/m^2)	Distance Downwind (m)	Distance Crosswind (m)	Lethality Level (%)
3.11 D	19.96	1.6	34	34	0
		4	21.64	21.64	0
		9.5	15.86	14.37	0
		12.5	14.64	12.46	20% /60 sec.
		25	12.22	8.12	80.34
		37.5	10.68	5.85	98.74

Explosion Overpressure

Wind Category	Pressure Value (bar)	Over Pressure Radius (m)		Overpressure Waves Effect / Damage	
		Early	Late		
3.11 D	0.020	N/D	88.26	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	N/D	52.50	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	N/D	49.67	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

Figure (40) Vapor Cloud (UFL/LFL) Side View Graph (Odorant leak)

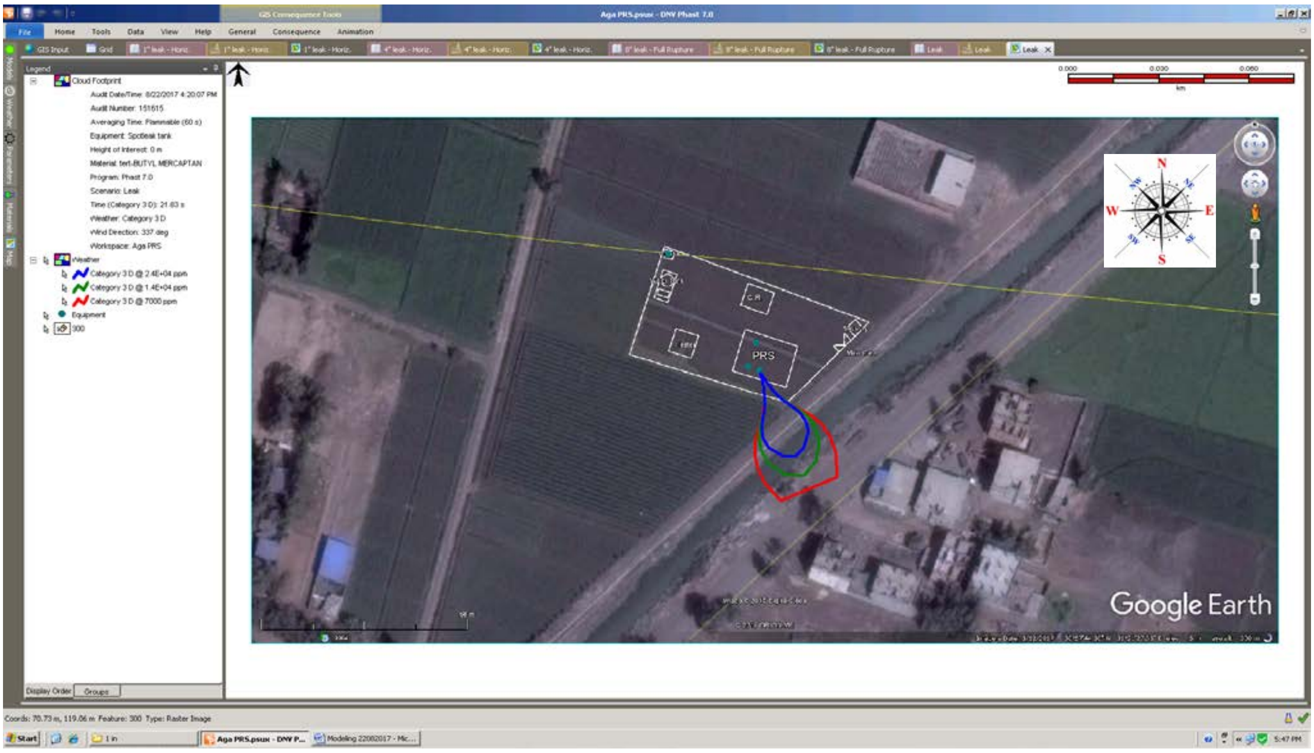


Figure (41) Vapor Cloud (UFL/LFL) Footprint on Site Map (Odorant leak)

- The previous figures show that if there is a leak from odorant tank without ignition the flammable vapors will reach a distance more than 42 m downwind and from 0 to 0.90 m height (the vapors heavier than air).

- The UFL (2.1E+04 ppm) will reach a distance of about 30.40 m downwind with a height from 0 to 0.30 m. The cloud large width will be 15 m crosswind.

- The LFL (1.4E+04 ppm) will reach a distance of about 37.20 m downwind with a height from 0 to 0.42 m. The cloud large width will be 18.60 m crosswind.

- The 50 % LFL (7000 ppm) will reach a distance of about 42 m downwind with a height from 0 to 0.90 m. The cloud large width will be 26 m crosswind.

The modeling shows that the LFL, LFL and 50 % LFL will extend outside the PRMS SE fence to cover the sub-way and the irrigation canal and reach the main road downwind.

Consideration should be taken when deal with liquid, vapors and smokes according to the MSDS for the material.

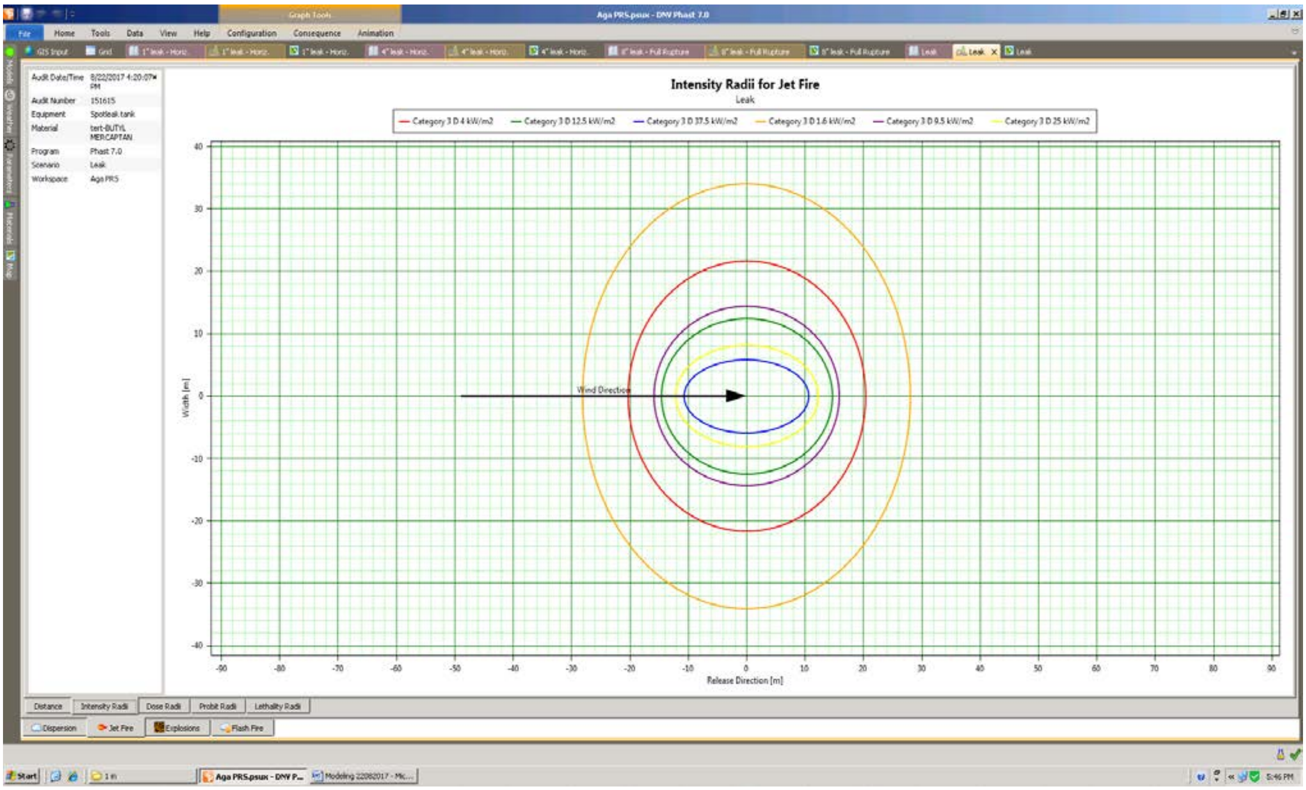


Figure (42) Heat Radiation Contours - Jet Fire Graph (Odorant Leak)

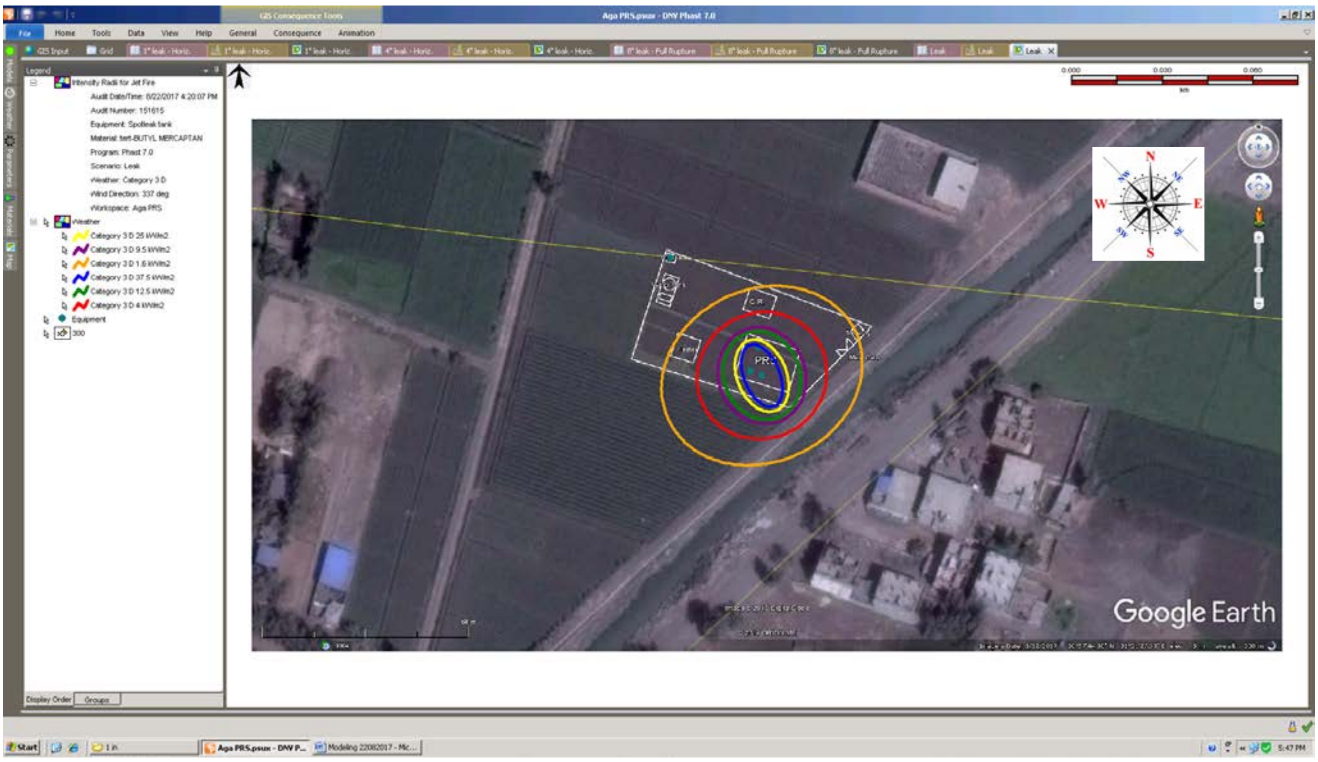


Figure (43) Heat Radiation Contours - Jet Fire on Site (Odorant Leak)

- The previous figure show that if there is a leak from the odorant tank and ignited the expected flame length is about 19.96 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 15.86 meters downwind and 14.37 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 14.64 meters downwind and 12.46 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 12.22 meters downwind and 8.12 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 10.68 meters downwind and 5.85 meters crosswind.

The modeling shows that the heat radiation of (9.5, 12.5, 25 & 37.5 kW/m^2) effects will be limited inside the PRMS boundary covering the pressure reduction facilities.

The value of 9.5 kW/m^2 will be near to the control room at the front side.

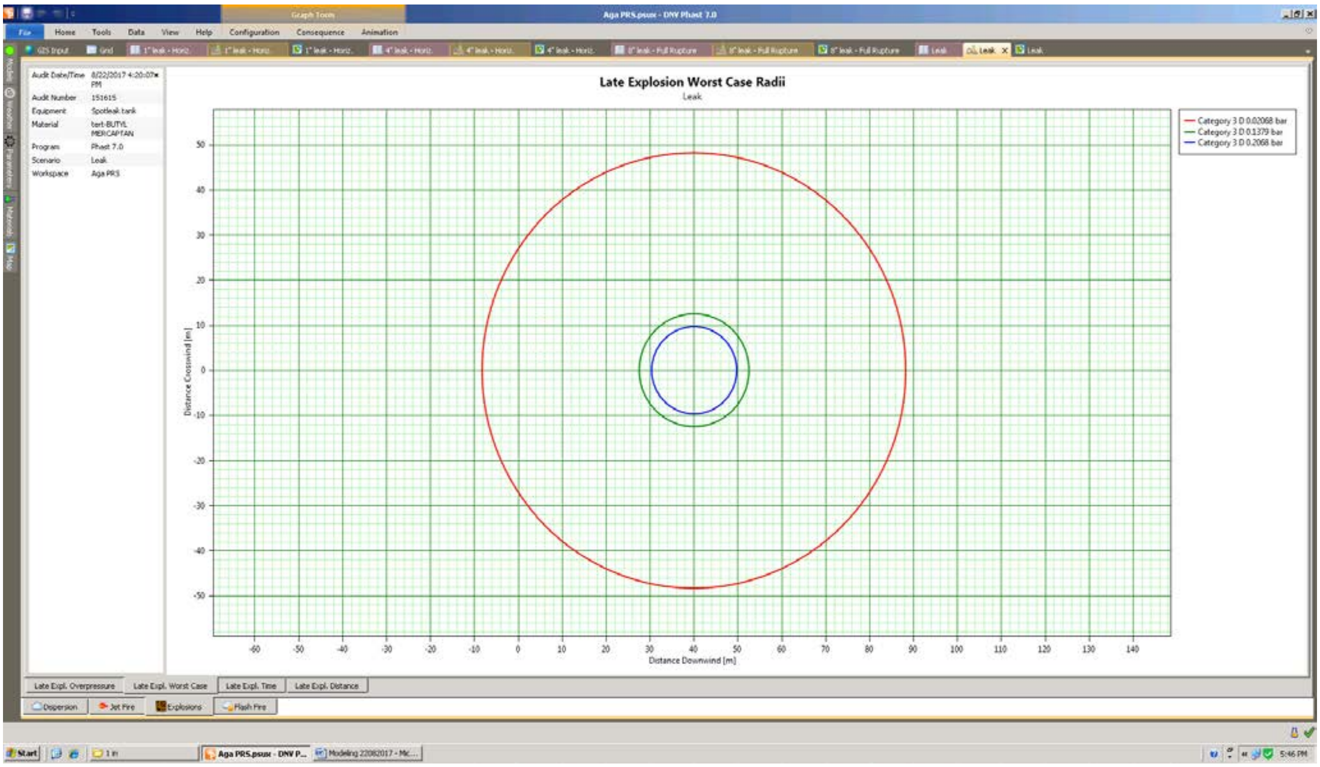


Figure (44) Late Explosion Overpressure Waves Graph (Odorant Leak)

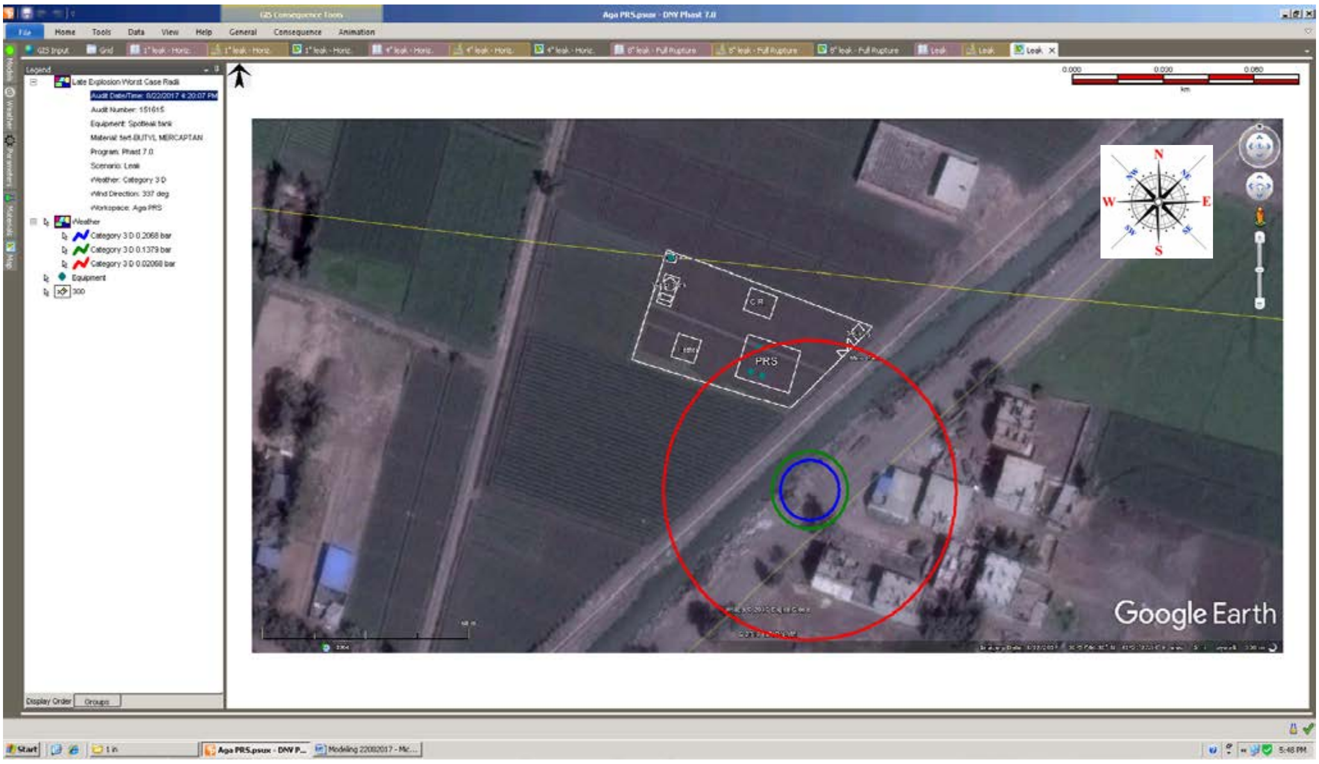


Figure (45) Late Explosion Overpressure Waves on Site (Odorant Leak)

- The previous figure show that if there is a leak from the odorant tank and late ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 88.26 meters downwind.
- The 0.137 bar overpressure waves will extend about 52.50 meters downwind.
- The 0.206 bar overpressure waves will extend about 49.67 meters downwind.

The modeling shows that the value of:

0.020 bar will extend from the SE fence to reach the residential building, covering the sub-way and the main road downwind and crosswind.

0.137 & 0.206 bar will extend to reach the main road downwind.

4.0- Pressure Reduction Station Off-Take Pipeline (6 inch)

4/1- Consequence Modeling for 1 inch (Pin Hole) Gas Release

The following table no. (23) Show that:

Table (23) Dispersion Modeling for Off-take - 1" / 6" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	0.12	- 0.80	0.20
	LFL	0.72	- 5.15	0.80
	50 % LFL	1.48	- 6.00	1.60

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	10.06	1.6	16.11	14.47	0
		4	8.49	6.54	0
		9.5	Not Reached	Not Reached	0.72
		12.5	Not Reached	Not Reached	20% /60 sec.
		25	Not Reached	Not Reached	80.34
		37.5	Not Reached	Not Reached	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	N/D	N/D	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	N/D	N/D	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	N/D	N/D	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

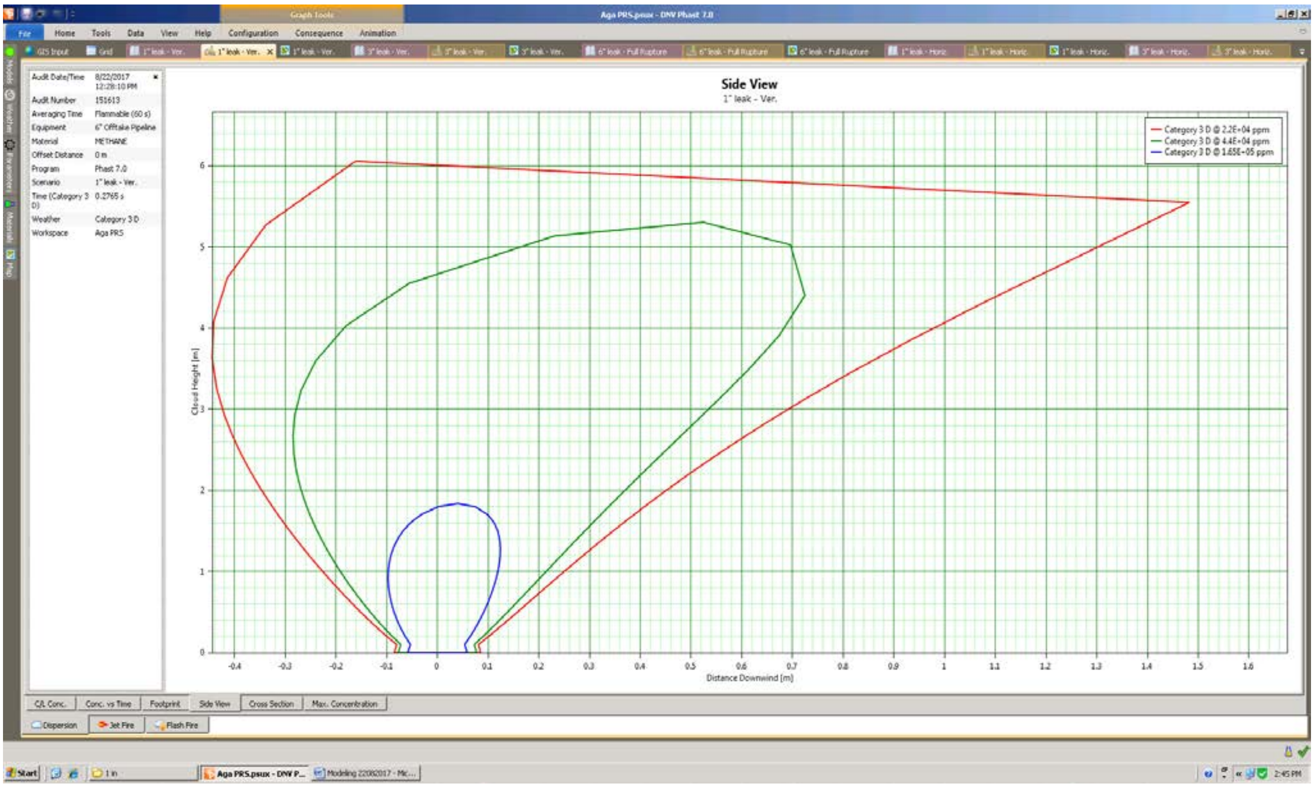


Figure (46) Gas Cloud Side View (UFL/LFL) (1" hole in 6" off-take Pipeline)

- The previous figure shows that if there is a gas release from 1" hole size without ignition the flammable vapors will reach a distance more than 12 m downwind and - 0.80 m height (underground valves room)
- The UFL will reach a distance of about 0.12 m downwind with a height of - 0.80 m. and 0.20 m crosswind.
- The LFL will reach a distance of about 0.72 m downwind with a height of - 5.15 m. and 0.80 m crosswind.
- The 50 % LFL will reach a distance of about 1.48 m downwind with a height - 6 m. and 1.60 crosswind.

The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.

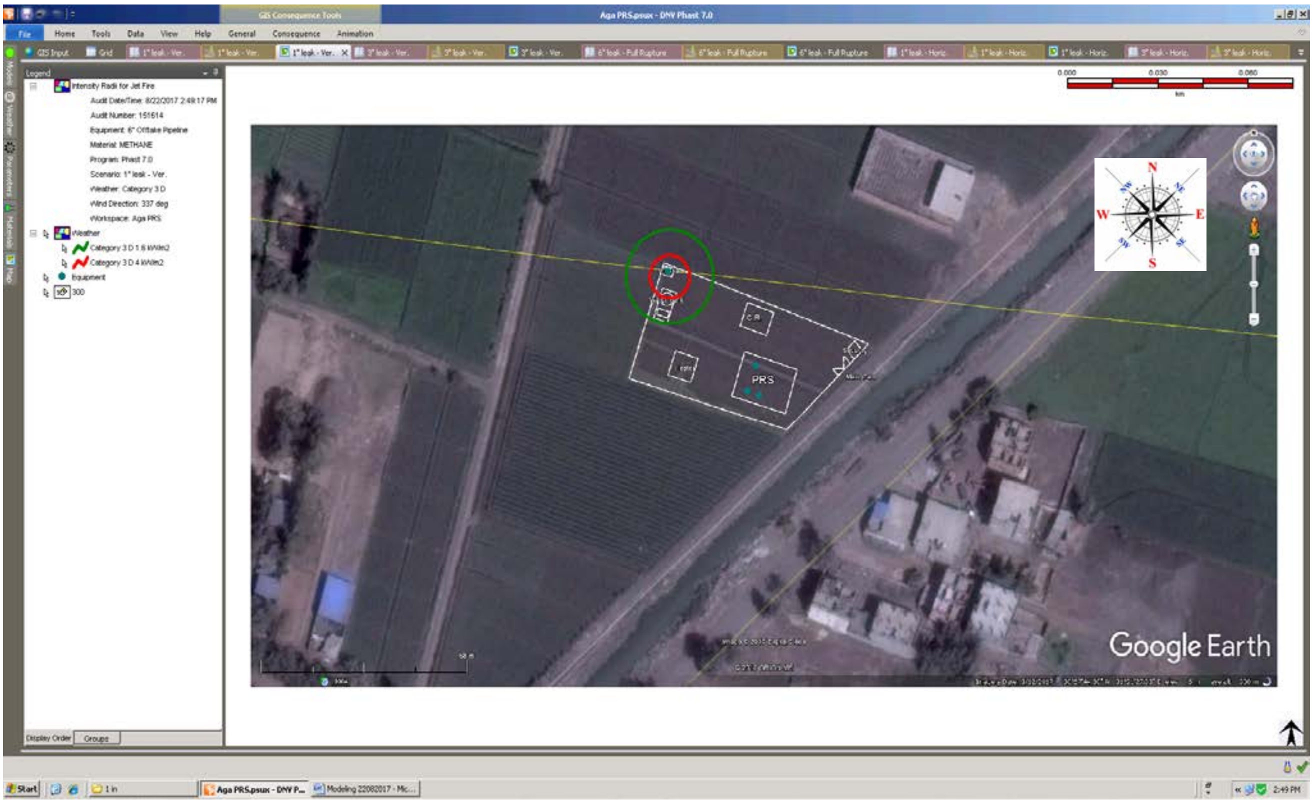


Figure (47) Heat Radiation Contours from Jet Fire (1" hole in 6" off-take Pipeline)

- The previous figure show that if there is a gas release from 1" hole size and ignited the expected flame length is about 10 meters height.
- The 1.6 kW/m^2 heat radiation contours extend about 16.11 meters downwind and 14.47 meters crosswind.
- The 4 kW/m^2 heat radiation contours extend about 8.49 meters downwind and 6.54 meters crosswind.
- The 9.5 kW/m^2 heat radiation not determined.
- The 12.5 kW/m^2 heat radiation not determined.
- The 25 kW/m^2 heat radiation not determined.
- The 37.5 kW/m^2 heat radiation not determined.

The modeling shows that the heat radiation values of 9.5, 12.5, 25 & 37.5 kW/m^2 will be limited inside the off-take valves room.

4/2- Consequence Modeling for 3 inch (Half Rup.) Gas Release

The following table no. (24) Show that:

Table (24) Dispersion Modeling for Off-take - 3" / 6" Gas Release

Gas Release				
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**	**Cloud Width (m)**
3.11 D	UFL	0.52	0 – 7.11	0.70
	LFL	3.15	0 – 19.50	2.50
	50 % LFL	5.90	0 – 26.79	6.50

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m²)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
3.11 D	34.08	1.6	51.47	46.93	0
		4	25.40	21.32	0
		9.5	Not Reached	Not Reached	0.72
		12.5	Not Reached	Not Reached	20% /60 sec.
		25	Not Reached	Not Reached	80.34
		37.5	Not Reached	Not Reached	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
3.11 D	0.020	97	N/D	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	25	N/D	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	19.50	N/D	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

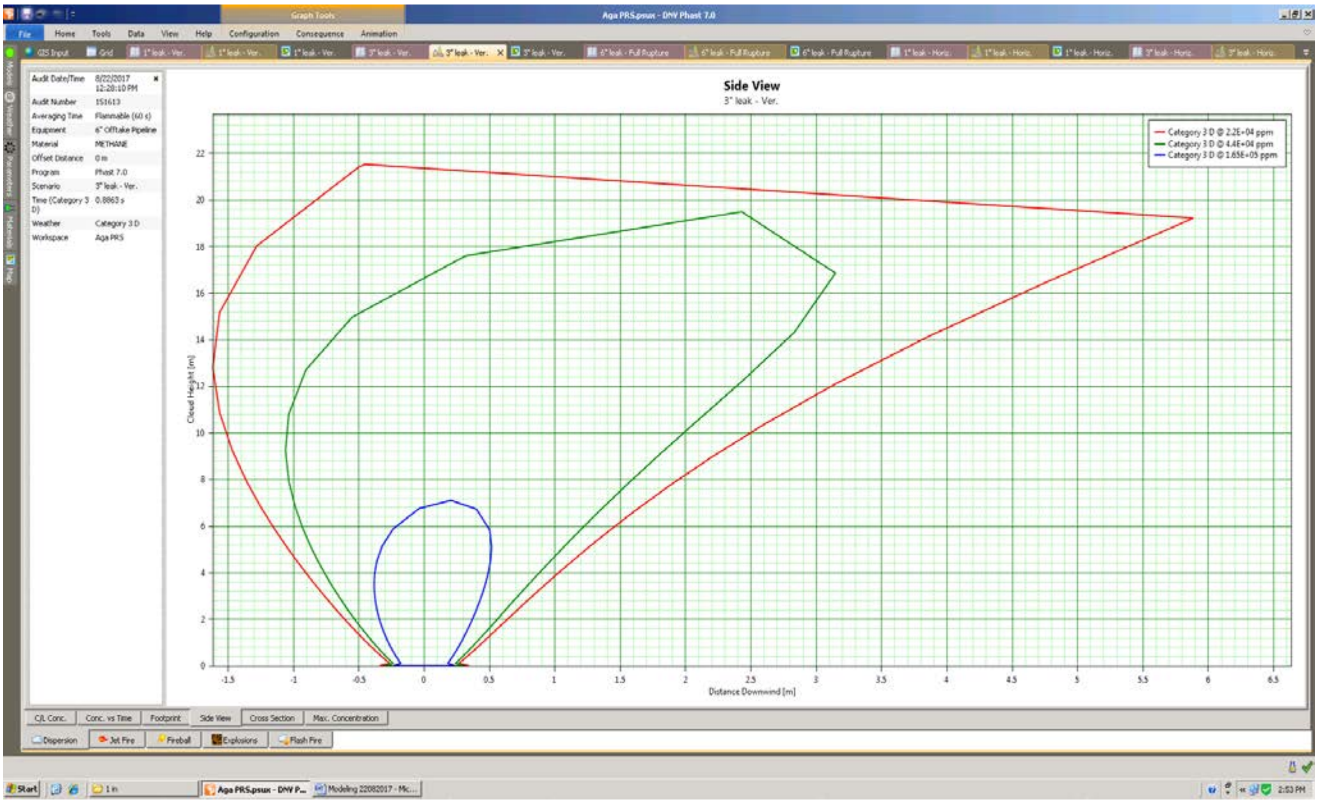


Figure (48) Gas Cloud Side View (UFL/LFL) (3" hole in 6" off-take Pipeline)

- The previous figure shows that if there is a gas release from 3" hole size without ignition the flammable vapors will reach a distance more than 5.90 m downwind and 20 m height (underground valves room)
- The UFL will reach a distance of about 0.52 m downwind with a height from - 6 to 7.11 m. and 0.70 m crosswind.
- The LFL will reach a distance of about 3.15 m downwind with a height from - 6 to 13.50 m. and 2.50 m crosswind.
- The 50 % LFL will reach a distance of about 5.90 m downwind with a height from - 6 to 20.79 m. and 6.50 crosswind.

The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.

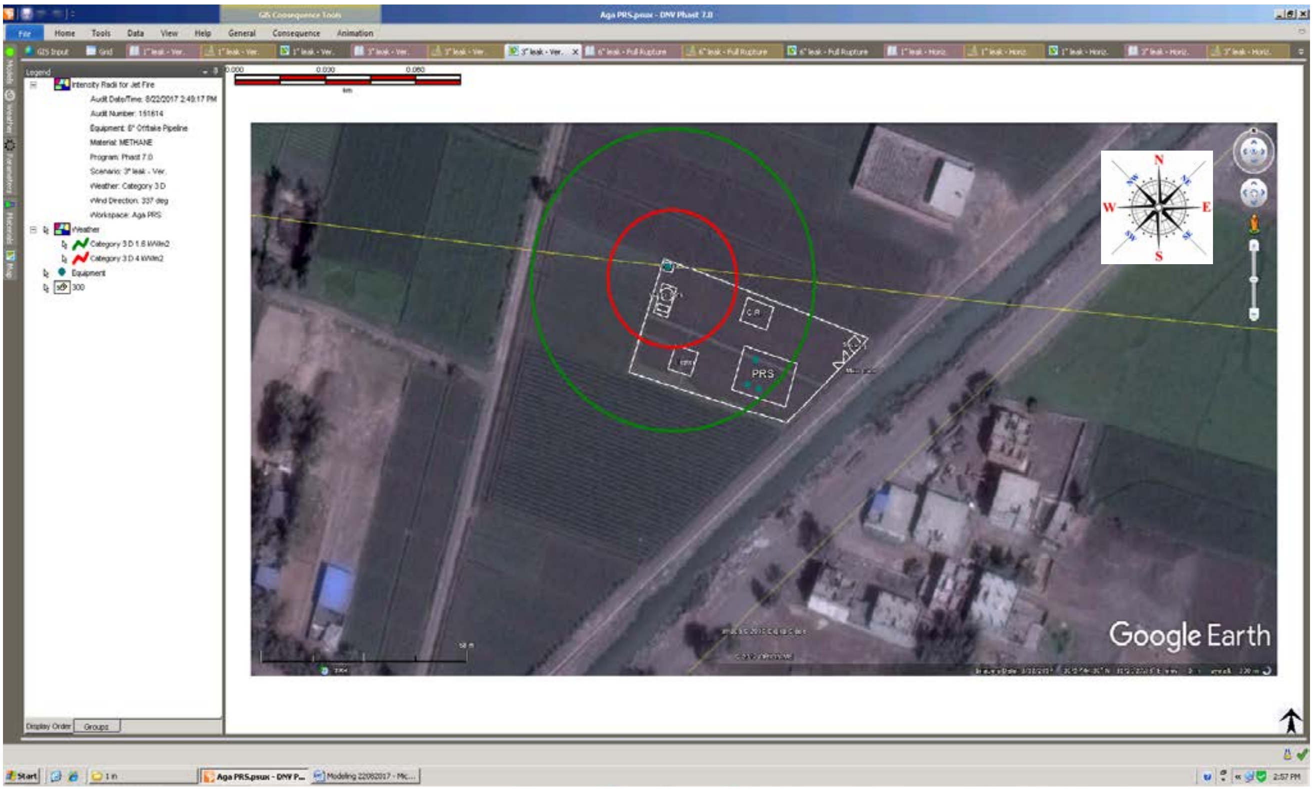


Figure (49) Heat Radiation Contours from Jet Fire (3" hole in 6" off-take Pipeline)

- The previous figure show that if there is a gas release from 3" hole size and ignited the expected flame length is about 34 meters height.
- The 1.6 kW/m^2 heat radiation contours extend about 51.47 meters downwind and 46.93 meters crosswind.
- The 4 kW/m^2 heat radiation contours extend about 25.40 meters downwind and 21.32 meters crosswind.
- The 9.5 kW/m^2 heat radiation not determined.
- The 12.5 kW/m^2 heat radiation not determined.
- The 25 kW/m^2 heat radiation not determined.
- The 37.5 kW/m^2 heat radiation not determined.

The modeling shows that the heat radiation values of 9.5, 12.5, 25 & 37.5 kW/m^2 will be limited inside the off-take valves room.

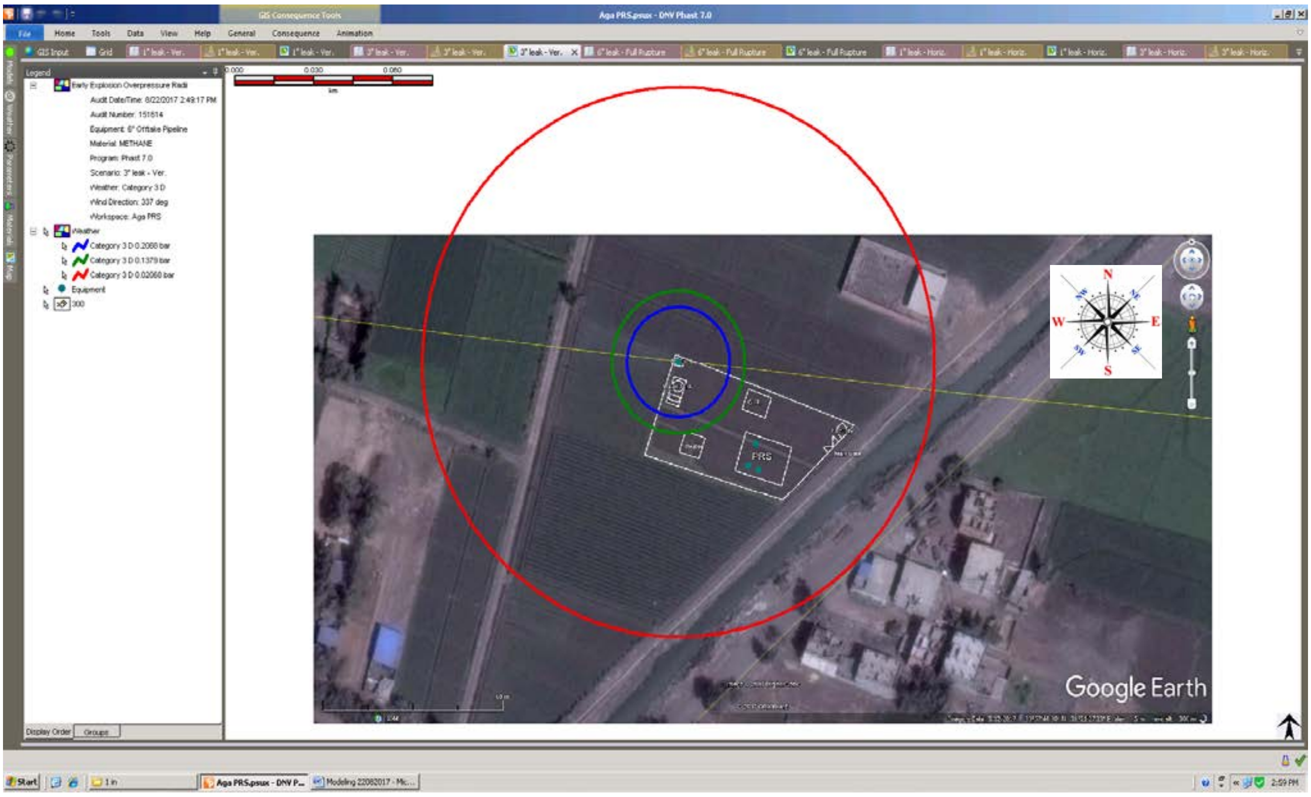


Figure (50) Early Explosion Overpressure Waves (3" hole in 6" off-take Pipeline)

- The previous figure show that if there is a leak from 3" hole size and early ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 97 meters radius.
- The 0.137 bar overpressure waves will extend about 25 meters radius.
- The 0.206 bar overpressure waves will extend about 19.50 meters radius.

The modeling shows that the value of 0.020 bar will extend outside the PRMS and reaching the NE building crosswind and near to the buildings SE downwind.

The value of 0.137 bar and 0.206 bar will extend outside the PRMS boundary NE &NW sides and affect the firefighting facilities (0.137 and 0.206 bar) SW side.

4/3- Consequence Modeling for 6 inch (Full Rup.) Gas Release

The following table no. (25) Show that:

Table (25) Dispersion Modeling for Off-take - 6” Gas Release

Gas Release

Wind Category	Flammability Limits	Distance (m)	Height (m)	Cloud Width (m)
3.11 D	UFL	1.00	16.10	0.50
	LFL	4.60	22.20	8.00
	50 % LFL	5.50	0 – 23.20	9.50

Jet Fire

Wind Category	Flame Length (m)	Heat Radiation (kW/m^2)	Distance Downwind (m)	Distance Crosswind (m)	Lethality Level (%)
3.11 D	77.80	1.6	148.78	103.70	0
		4	115.56	65.43	0
		9.5	91.14	39.86	0
		12.5	85.46	33.10	20% /60 sec.
		25	73.84	18.65	80.34
		37.5	62.09	12.56	98.74

Explosion Overpressure

Wind Category	Pressure Value (bar)	Over Pressure Radius (m)		Overpressure Waves Effect / Damage	
		Early	Late		
3.11 D	0.020	97	N/D	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	25	N/D	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	19.50	N/D	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

Fireball

Wind Category	Heat Radiation (kW/m^2)	Distance (m)	Heat Radiation (kW/m^2) Effects on People & Structures
3.11 D	1.6	59.71	**12.5** *20 % Chance of fatality for 60 sec exposure* **25** *100 % Chance of fatality for continuous exposure* *50 % Chance of fatality for 30 sec exposure* **37.5** *Sufficient of cause process equipment damage*
	4	36.07	
	9.5	19.71	
	12.5	15	
	25	Not Reached	
	37.5	Not Reached	

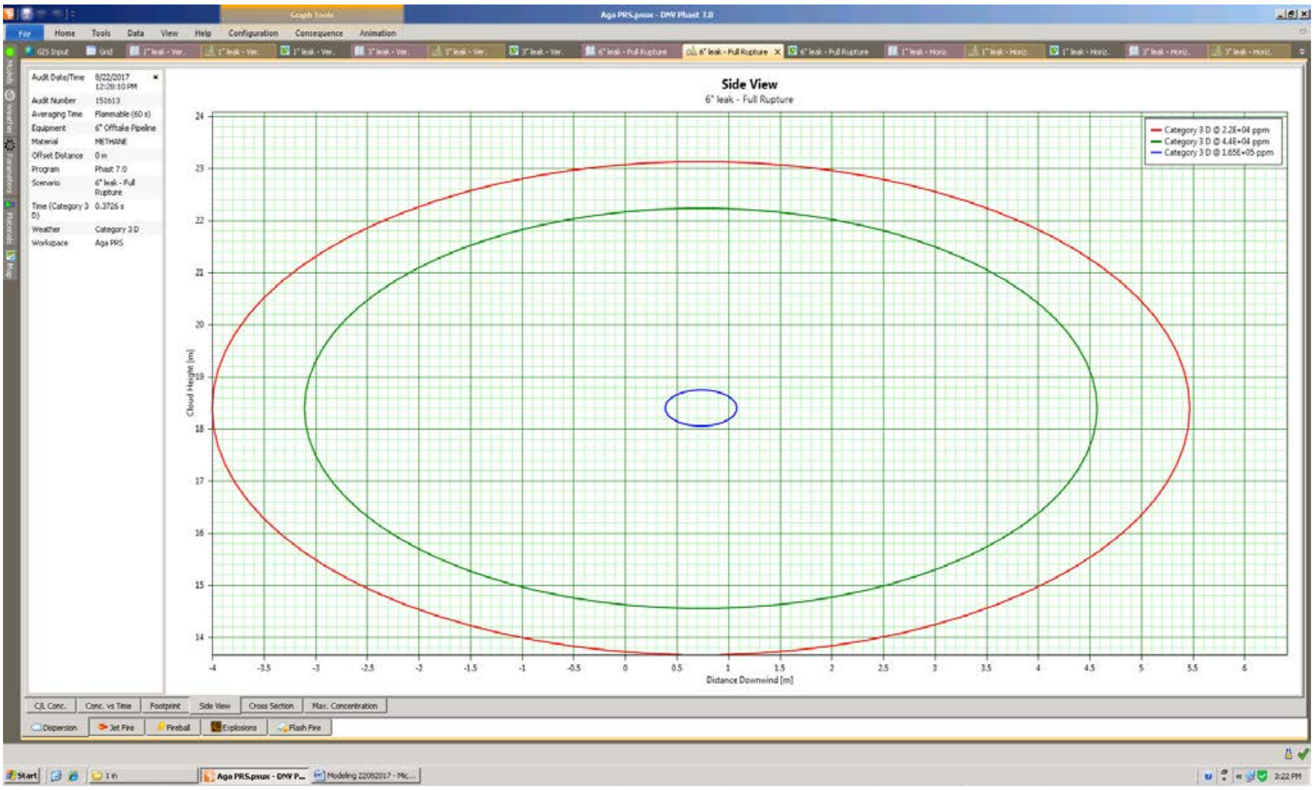


Figure (51) Gas Cloud Side View (UFL/LFL) (6" off-take Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 6" pipeline full rupture without ignition the flammable vapors will reach a distance more than 5 m downwind and over 23 m height.
- The UFL will reach a distance of about 1 m downwind with a height from - 6 to 10 m. and 0.50 m crosswind.
- The LFL will reach a distance of about 4.60 m downwind with a height from - 6 to 16.20 m. and 8 m crosswind.
- The 50 % LFL will reach a distance of about 5.50 m downwind with a height from - 6 to 23.20 m. and 9.50 crosswind.

The modeling shows that the gas cloud effects will extend to the PRMS facilities SE side downwind.

Figure (52) Heat Radiation Contours from Jet Fire (6" off-take Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 6" pipeline full rupture and ignited the expected flame length is about 77 meters height.
- The 9.5 kW/m^2 heat radiation contours extend about 91.14 meters downwind and 39.86 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 85.46 meters downwind and 33.10 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 73.84 meters downwind and 18.65 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 62.09 meters downwind and 12.56 meters crosswind.

The modeling shows that:

The heat radiation of 9.5 & 12.5 kW/m^2 will affect the control room crosswind NE side, near to the firefighting facility upwind NW side and extend to reach the main road downwind SE side.

The heat radiation of 25 & 37.5 kW/m^2 will affect the heater area and the PRMS facility, and with extension to reach the sub-way outside the site.

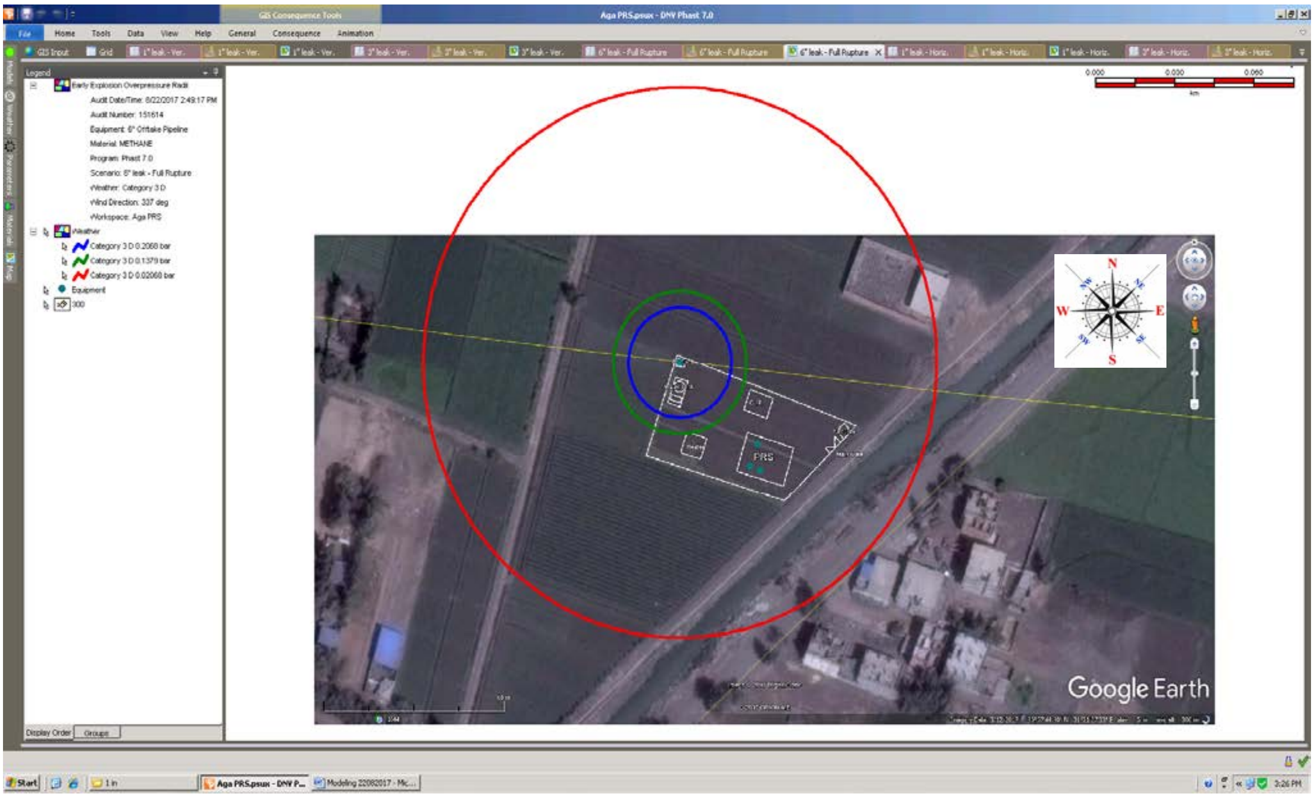


Figure (53) Early Explosion Overpressure Waves (6" off-take Pipeline Full Rupture)

- The previous figure show that if there is a leak from 6" pipeline full rupture and early ignited this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 97 meters radius.
- The 0.137 bar overpressure waves will extend about 25 meters radius.
- The 0.206 bar overpressure waves will extend about 19.50 meters radius.

The modeling shows that the value of 0.020 bar will extend outside the PRMS and reaching the NE building crosswind and near to the buildings SE downwind.

The value of 0.137 bar and 0.206 bar will extend outside the PRMS boundary NE &NW sides and affect the firefighting facilities (0.137 and 0.206 bar) SW side.

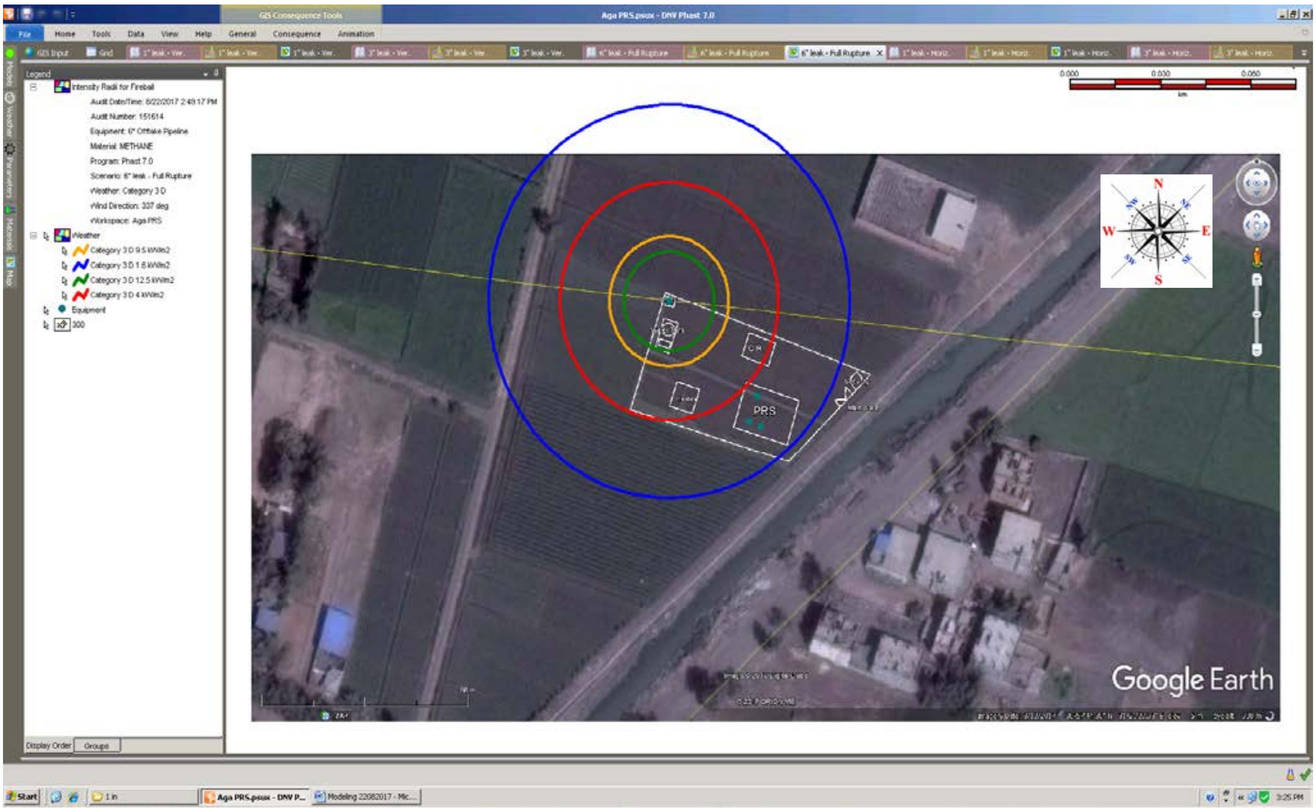


Figure (54) Heat Radiation Contours from Fireball (6" off-take Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 6" pipeline full rupture and ignited forming fireball this will gives a heat radiation with different values and contours and will extended in four dimensions.
- The 9.5 kW/m^2 heat radiation contours extend about 19.71 meters radius.
- The 12.5 kW/m^2 heat radiation contours extend about 15 meters radius.
- The 25 kW/m^2 heat radiation not reached.
- The 37.5 kW/m^2 heat radiation not reached.

The modeling shows that the heat radiation value of 9.5 & 12.5 kW/m^2 will extend outside the PRMS NW & NE sides with no effects on surroundings, but will affect the firefighting facility.

Individual Risk Evaluation

- **Risk Calculation**

All identified hazards should be subject to an evaluation for risk potential. This means analyzing the hazard for its probability to actually progress to loss event, as well as likely consequences of this event.

There are four steps to calculate risk, which determined as follows:

1- *Identify failure frequency (International Data Base)*

2- *Calculating the frequency against control measures at site by using Event Tree Analysis "ETA".*

3- *Identify scenarios probability.*

4- *Calculated risk to people regarding to the vulnerability of life loses.*

Basically, risk will be calculated as presented in the following equation:

Risk to people (Individual Risk – IR) =

Total Risk (Σ Frequency of fire/explosion) x Occupancy x Vulnerability

Where:

- *Total risk* — *Is the sum of contributions from all hazards exposed to (fire / explosion).*
- *Occupancy* — *Is the proportion of time exposed to work hazards. (Expected that x man the most exposed person to fire/explosion hazards on site. He works 8 hours shift/day)*
- *Vulnerability* — *Is the probability that exposure to the hazard will result in fatality.*

As shown in tables (5 & 6) – (Page: 34 & 35) *the vulnerability of people to heat radiation starting from 12 kW/m^2 will lead to fatality accident for 60 sec. Exposure and for explosion over pressure starting from 0.137 bar.*

The modeling of the different scenarios shows that the heat radiation and explosion overpressure waves would be a result from release scenarios for all sizes of crack and according to the space size for the PRMS, all of the sequence will be determined for three values (small, medium and large) release.

Calculating frequencies needs a very comprehensive calculations which needs a lot of data collecting related to failure of equipment's and accident reporting with detailed investigation to know the failure frequency rates in order to calculate risks from scenarios.

In this study, it decided that to use an International Data Bank for major hazardous incident data.

The following table (26) show frequency for each failure can be raised in pressure reduction station operations:

Table (26) Failure Frequency for Each Scenario

Scenario	Release Size	Failure Cause	Failure Rate
Gas Release from 1"/6" Pipeline 1"/8" Pipeline	***Small***	**Failure Cause**	**Failure Rate**
		Internal Corrosion	*1.19E-05*
		External Corrosion	*3.55E-06*
		Maintenance Error	*2.28E-05*
		Corrosive Liquid or Gas	*4.84E-04*
		Total	*5.22E-04*
Gas Release from 3"/6" Pipeline 4"/8" Pipeline	***Medium***	**Failure Cause**	**Failure Rate**
		Internal Corrosion	*2.71E-05*
		External Corrosion	*8.24E-06*
		Erosion	*4.85E-04*
		Total	*5.20E-04*
Gas Release from 6"/8" Pipeline Full Rupture	***Large***	**Failure Cause**	**Failure Rate**
		Internal Corrosion	*5.53E-06*
		External Corrosion	*1.61E-06*
		Weld Crack	*4.34E-06*
		Earthquake	*1.33E-07*
		Total	*1.16E-05*
Spotleak (Odorant Tank)	***Medium***	***As a package***	**Failure Rate**
			1.25E-05

- **Event Tree Analysis**

An event tree is a graphical way of showing the possible outcomes of a hazardous event, such as a failure of equipment or human error.

An ETA involves determining the responses of systems and operators to the hazardous event in order to determine all possible alternative outcomes.

The result of the ETA is a series of scenarios arising from different sets of failures or errors.

These scenarios describe the possible accident outcomes in terms of the sequence of events (successes or failures of safety functions) that follow the initial hazardous event.

Event trees shall be used to identify the various escalation paths that can occur in the process. After these escalation paths are identified, the specific combinations of failures that can lead to defined outcomes can then be determined.

This allows identification of additional barriers to reduce the likelihood of such escalation.

The results of an ETA are the event tree models and the safety system successes or failures that lead to each defined outcome.

Accident sequences represents in an event tree represent logical and combinations of events; thus, these sequences can be put into the form of a fault tree model for further qualitative analysis.

These results may be used to identify design and procedural weaknesses, and normally to provide recommendations for reducing the likelihood and/or consequences of the analyzed potential accidents.

Using ETA requires knowledge of potential initiating events (that is, equipment failures or system upsets that can potentially cause an accident), and knowledge of safety system functions or emergency procedures that potentially mitigate the effects of each initiating event.

The equipment failures, system upsets and safety system functions shall be extracted from the likelihood data presented before.

In the case of hydrocarbon release, the event tree first branch is typically represents "Early Ignition". These events are represented in the risk analysis as jet fire events.

This is because sufficient time is unlikely to elapse before ignition for a gas/air mixture to accumulate and cause either a flash fire or a gas hazard.

Subsequent branches for these events represent gas detection, fire detection, inventory isolation (or ESD) or deluge activation.

Delayed ignitions are typically represented by the fifth branch event. This is because, in the time taken for an ignition to occur, sufficient time is more likely to elapse for gas detection and inventory isolation.

The scenario development shall be performed for the following cases**:**

- Without any control measures
- With control measures

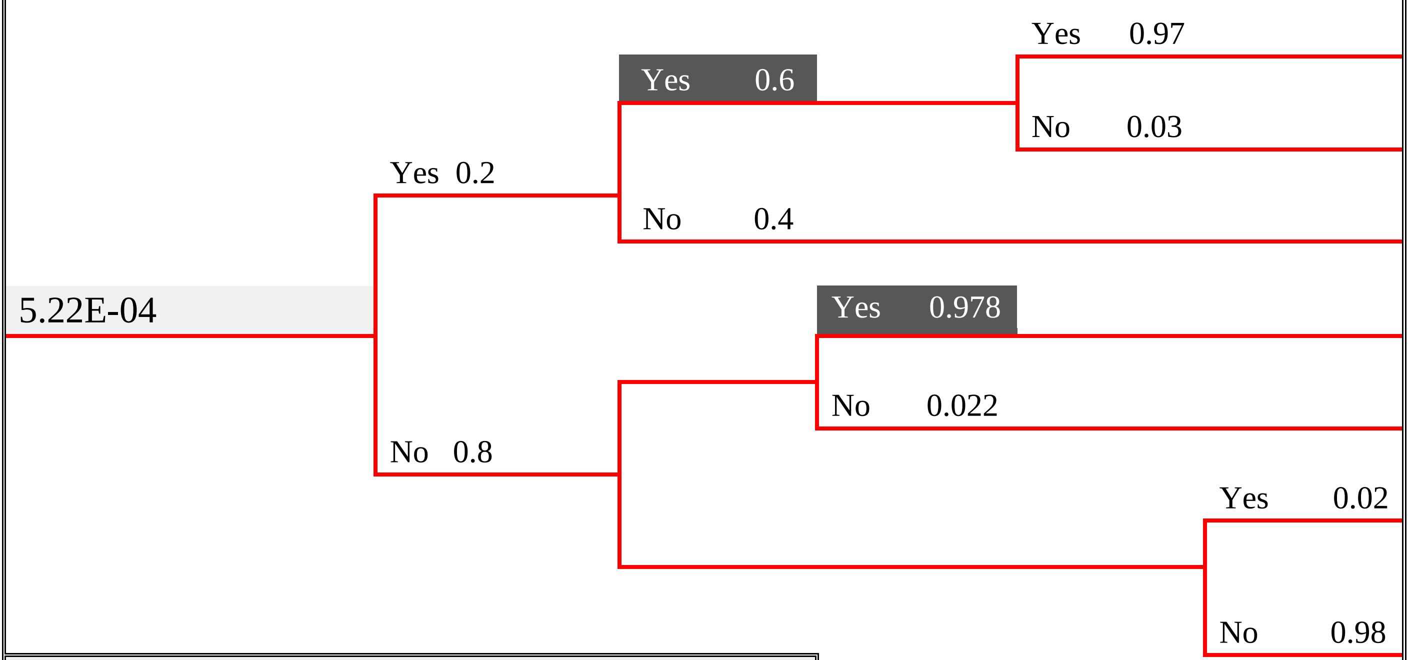
The event tree analysis outcomes can be classified into three main categories as follows:

"Limited Consequence"	*Indicates that the release has been detected and the inventory source has been isolated automatically.*
"Controlled Consequence"	*Indicates that the release has been detected but the source has not been isolated automatically. [Needs human intervention].*
"Escalated Consequence"	*Indicates that the release has not been detected and consequently the source has not been isolated.*

The event trees analysis for each scenario are presented in the below pages:

Table (27) Inlet 6" / Outlet 8" / Off-take 6" Pipeline Scenarios (Pin Hole Crack – 1" Release) – Event Tree Analysis

Release of Flammable Materials [1]	Immediate Ignition [2]	Fire Detection [3]	ESD System [3]	Fire Protec. [3]	Delayed Ignition [2]	Outcomes	Frequency
5.22E-04	**0.2**	**0.6**	**0.978**	**0.97**	**0.02**		



Outcomes	Frequency
Controlled Jet fire	***1.01E-04***
Not controlled jet fire	***3.13E-06***
Escalated jet fire	***4.18E-05***
Limited release	-------------
Large release	***9.18E-06***
Escalated jet fire	***8.35E-06***
Escalated release	***4.09E-04***
TOTAL	***5.33E-05***

(1) Refer to QRA Study Page 105.

(2) Ref. Handbook Failure Frequencies 2009.

(3) Ref. OGP – Report No. 434 – A1 / 2010.

Table (28) Inlet 6" / Off-take 6" Pipeline Scenarios (Half Diameter Release) – Event Tree Analysis

Release of Flammable Materials [1]	Immediate Ignition [2]	Fire Detection [3]	ESD System [3]	Fire Protec. [3]	Delayed Ignition [2]	Outcomes	Frequency
5.20E-04	**0.04**	**0.6**	**0.978**	**0.97**	**0.04**		
5.20E-04	Yes 0.04	Yes 0.6		Yes 0.97		Controlled Jet fire	***2.02E-05***
				No 0.03		Not controlled jet fire	***6.24E-07***
		No 0.4				Escalated jet fire	***8.32E-06***
	No 0.96		Yes 0.978			Limited release	-------------
			No 0.022			Large release	***1.09E-05***
					Yes 0.04	Escalated jet fire	***1.99E-05***
					No 0.96	Escalated release	***4.79E-04***
						TOTAL	***2.88E-05***

(1) Refer to QRA Study Page 105.
(2) Ref. Handbook Failure Frequencies 2009.
(3) Ref. OGP – Report No. 434 – A1 / 2010.

Table (29) Outlet 8" Pipeline Scenarios (Half Diameter Release) – Event Tree Analysis

Release of Flammable Materials (1)	Immediate Ignition (2)	Fire Detection (3)	ESD System (3)	Fire Protec. (3)	Delayed Ignition (2)	Outcomes	Frequency
5.20E-04	**0.2**	**0.6**	**0.978**	**0.97**	**0.02**		
5.20E-04	Yes 0.2	Yes 0.6		Yes 0.97		Controlled jet fire	***1.01E-04***
				No 0.03		Large jet fire	***3.12E-06***
		No 0.4				Escalated jet fire	***4.16E-05***
	No 0.8		Yes 0.978			Limited release	-------------
			No 0.022			Large release	***9.15E-06***
					Yes 0.02	Escalated jet fire	***8.32E-06***
					No 0.98	Escalated release	***4.07E-04***
						TOTAL	***5.30E-05***

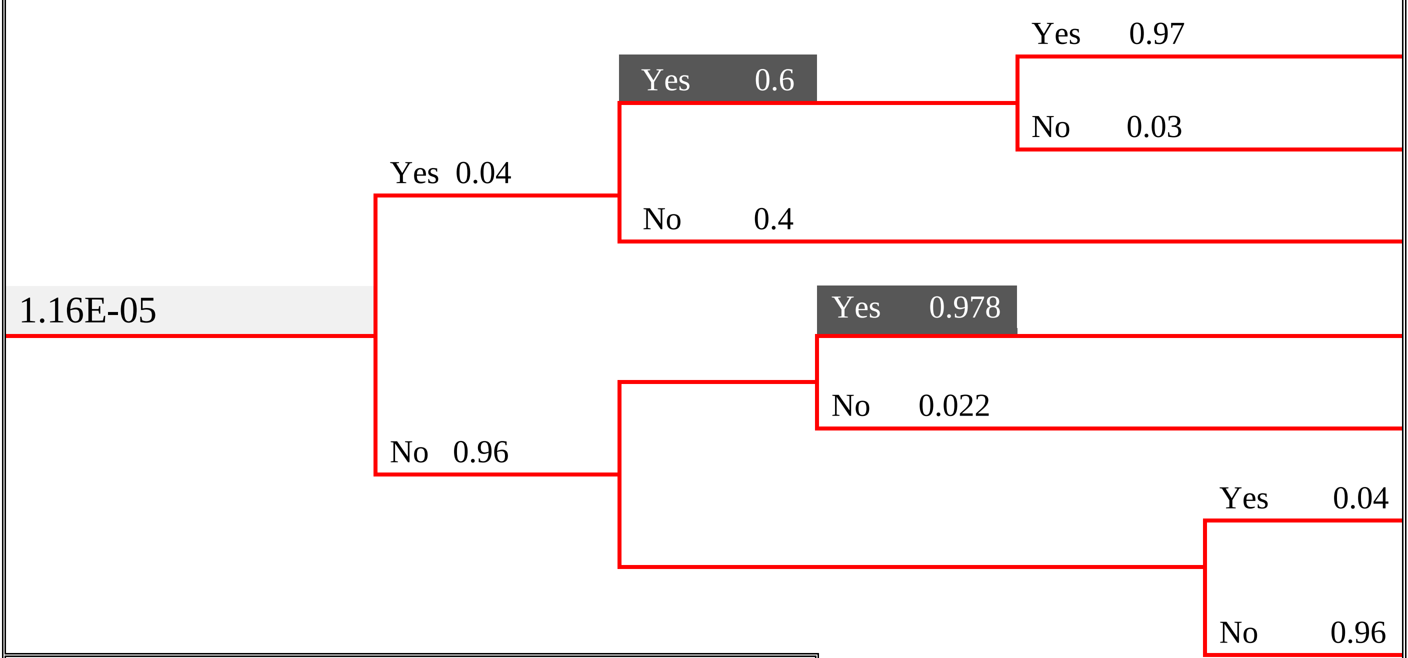
(1) Refer to QRA Study Page 105.

(2) Ref. Handbook Failure Frequencies 2009.

(3) Ref. OGP – Report No. 434 – A1 / 2010.

Table (30) Inlet 6" / Outlet 8" / Off-take 6" Pipeline Scenarios (Full Rupture Release) – Event Tree Analysis

Release of Flammable Materials [(1)]	Immediate Ignition [(2)]	Fire Detection [(3)]	ESD System [(3)]	Fire Protec. [(3)]	Delayed Ignition [(2)]
1.16E-05	**0.04**	**0.6**	**0.978**	**0.97**	**0.04**



Outcomes	Frequency
Controlled Jet fire	***4.50E-07***
Not controlled jet fire	***1.39E-08***
Escalated jet fire	***1.86E-07***
Limited release	-------------
Large release	***2.45E-07***
Escalated jet fire	***4.45E-07***
Escalated release	***1.07E-05***
TOTAL	***6.45E-07***

(1) Refer to QRA Study Page 105.

(2) Ref. Handbook Failure Frequencies 2009.

(3) Ref. OGP – Report No. 434 – A1 / 2010.

Table (31) Odorant Tank Release – Event Tree Analysis

Release of Flammable Materials (1)	Immediate Ignition (2)	Fire Detection (3)	ESD System (3)	Fire Protec. (3)	Delayed Ignition (2)	Outcomes	Frequency
1.25E-05	**0.2**	**0.6**	**0.978**	**0.97**	**0.06**		
1.25E-05	Yes 0.2	Yes 0.6		Yes 0.97		Controlled fire	***2.43E-06***
				No 0.03		Large fire	***7.50E-08***
		No 0.4				Escalated fire	***1.00E-06***
	No 0.8		Yes 0.978			Limited leak	-------------
			No 0.022			Large leak	***2.20E-07***
					Yes 0.06	Escalated fire	***6.00E-07***
					No 0.94	Escalated leak	***9.40E-06***
						TOTAL	***2.40E-05***

(1) Refer to QRA Study Page 105.
(2) Ref. Handbook Failure Frequencies 2009.
(3) Ref. OGP – Report No. 434 – A1 / 2010.

The following table (32) show the total frequency for each scenario from ETA - Tables (27 to 31):

Table (32) Total Frequencies for Each Scenario

Source of Release	Total Frequency (ETA)
1" / 6" Inlet / Off-take Pipeline Pin Hole	**5.33E-05**
1" / 8" Outlet Pipeline Pin Hole	
3" / 6" Inlet / Off-take Pipeline Half Rupture	**2.88E-05**
4" / 8" Outlet Pipeline Half Rupture	**5.30E-05**
6" Inlet / Off-take Pipeline Full Rupture	**6.45E-07**
8" Outlet Pipeline Full Rupture	
Odorant Tank 1" hole Leak	**2.40E-05**

The modeling shows that:

- The most effective scenarios on Egypt Gas employees are heat radiation and explosion overpressure from Inlet (Half - Full Rup) & Off-take (Full Rup.)
- The most effective scenarios on public are heat radiation and explosion overpressure from Inlet (Half Rup), Outlet / Off-take (Full Rup.) and Odorant.

Therefore, the risk calculation will depend on total risk from these scenarios, and as per equation page (103):

Risk to People (Individual Risk – IR) =

Total Risk (Σ Frequency of fire/explosion) x Occupancy x Vulnerability

Where:

- Total risk - is the sum of contributions from all hazards exposed to (fire / explosion).

  (Frequencies of Scenarios from Table-30)

- Occupancy - is the proportion of time exposed to work hazards. (Expected that x man the most exposed person to fire/explosion hazards on site. He works 8 hours shift/day).

  (As per Client data, Aga PRMS Occupancy is four persons 8 hour)

- Vulnerability - is the probability that exposure to the hazard will result in fatality.

  (Reference: Report No./DNV Reg. No.: 2013-4091/1/17 TLT 29-6 – Rev. 1)

The following tables (33 & 34) show the Individual Risk (IR) calculation for the workers and the public:

Table (33) Individual Risk (IR) Calculation for Employees

Source of Event	Frequency 1	Heat Radiation kW/m^2 & Overpressure	Vulnerability 2	Time Exposed 3	IR = 1 x 2 x 3
Gas Release from 3" / 6" Inlet Pipeline	2.88E-05	Explosion 0.137	0.3 (Indoor)	2.0 [2 Pers.]	***1.73E-05***
Gas Release from 6"/6" Inlet Pipeline	6.45E-07	Fire Ball 12.5	0.2 (Indoor)	2.0 [2 Pers.]	***2.58E-07***
		Explosion 0.137	0.3 (Indoor)	2.0 [2 Pers.]	***3.87E-07***
Gas Release from 6"/6" Off-take Pipeline	6.45E-07	Jet Fire 12.5	0.1 (Indoor)	2.0 [2 Pers.]	***1.29E-07***
TOTAL Risk for Workers					***1.81E-05***

Table (34) Individual Risk (IR) Calculation for Public

Source of Event	Frequency 1	Heat Radiation kW/m^2 & Overpressure	Vulnerability 2	Time Exposed 3	IR = 1 x 2 x 3
Gas Release from 3" / 6" Inlet Pipeline	2.88E-05	Jet Fire 12.5	0.7 (Outdoor)	15 Pers./min 1.25	***2.52E-05***
		Explosion 0.137	0.3 (Indoor)	8 Pers./12 h 4	***3.46E-05***
			0.1 (Outdoor)	15 Pers./min 1.25	***3.60E-06***
Gas Release from 8"/8" Outlet Pipeline	6.45E-07	Jet Fire 12.5	0.1 (Indoor)	8 Pers./12 h 4	***2.58E-07***
			0.7 (Outdoor)	15 Pers./min 1.25	***5.64E-07***
Gas Release from 6"/6" Off-take Pipeline			0.1 (Outdoor)	15 Pers./min 1.25	***8.06E-08***
Odorant Tank 1" Leak	2.40E-05	Jet Fire 12.5	0.7 (Outdoor)	15 Pers./min 1.25	***2.10E-05***
TOTAL Risk for Public					***8.53E-05***

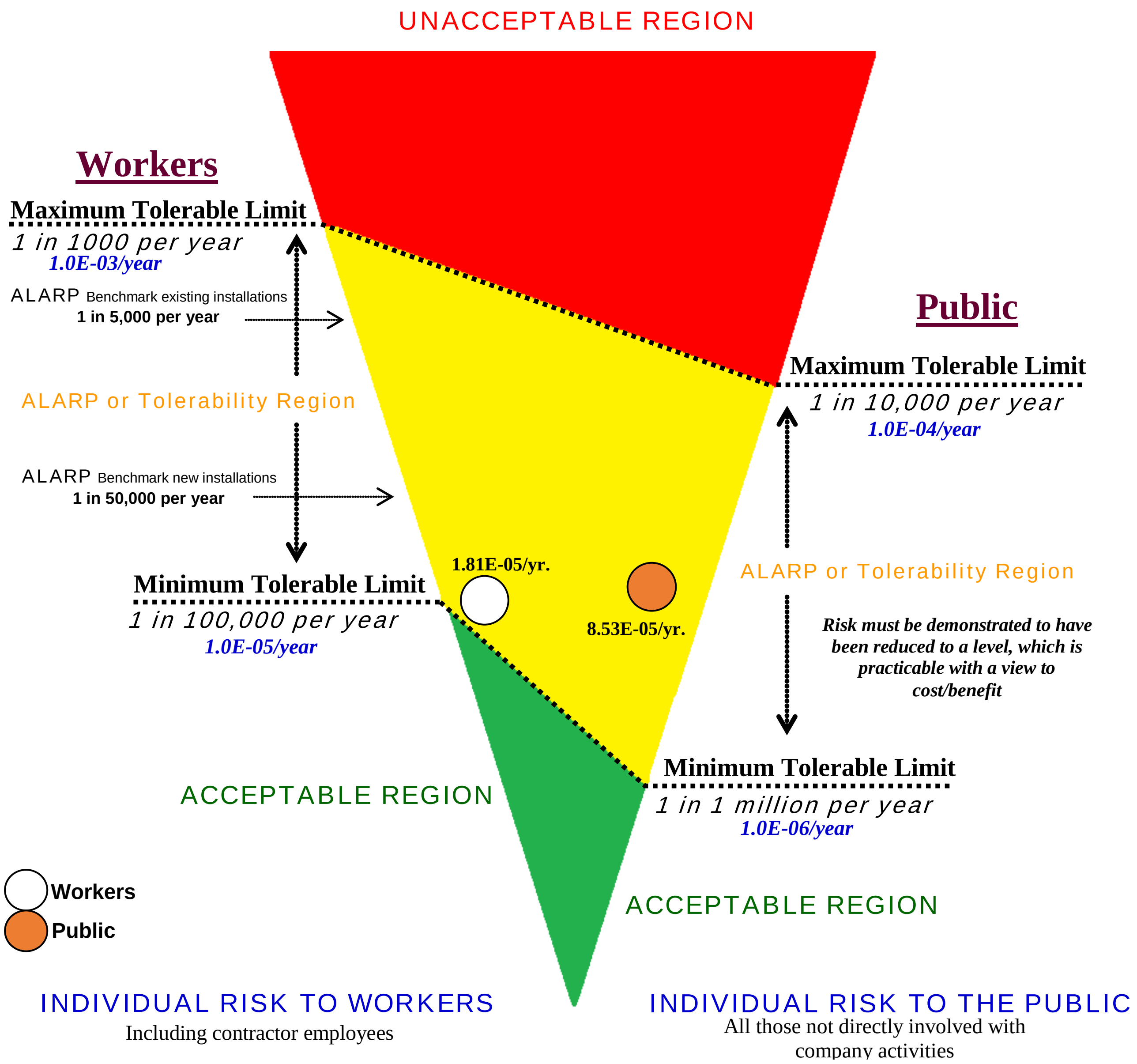


Figure (55) Evaluation of Individual Risk

The level of Individual Risk to the exposed worker at Aga PRMS, based on the risk tolerability criterion used is ALARP.

The level of Individual Risk to the exposed Public at Aga PRMS area, based on the risk tolerability criterion used is ALARP.

Conclusion

As per results from modeling the consequences of each scenario, the following table summarize the study, and as follows:

Event	Scenario	Effects
Pin hole (1") gas release 8" inlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value (4, 9.5, 12.5 & 25 kW/m^2) will be limited inside the PRMS and affecting the facilities.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the overpressure wave of 0.020 bar effects will extend outside the PRMS NE fence with about 3 m downwind and southwest fence with about 5 m crosswind.* *The overpressure waves of 0.137 & 0.206 bar will be limited inside the PRMS fence affecting the facilities.*
Half Rupture (3") gas release 6" inlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud will extend the NE fence downwind reaching the sub-way route outside the PRMS.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that all values will extend outside the NE fence downwind with various distances that reaching the sub-way route (25 & 37.5 kW/m^2), and the main road (9.5 kW/m^2).* *The main gate and security office will reached by the value of 4 & 1.6 kW/m^2.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching the housing area SE downwind and NE crosswind.* *The value of 0.137 bar will be limited*

Event	Scenario	Effects
		inside the PRMS from the NW side and extend the PRMS fences from NE (5m), SE (3m) & SW (5m), and will affect the control room, and heater area. *The value of 0.206 bar will be limited inside the PRMS from three sides and extend from SW (2m), and will affect the control room.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching housing area SE side downwind.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS from the SE side reaching the main road and near to the housing area.*
Full Rupture gas release 6" inlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects (UFL, LFL & 50 % LFL) will extend outside the SE fence covering the sub-way and irrigation canal.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values will extend outside the PRMS SE fence downwind affecting the sub-way and irrigation canal, and near to the main road.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching the housing area SE downwind and NE crosswind.* *The value of 0.137 bar will be limited inside the PRMS from the NW side affecting the control room and extend the PRMS fences from NE (5m), SE (3m) & SW (5m).* *The value of 0.206 bar will be limited inside the PRMS from three sides affecting the control room and extend from SW (2m).*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extended outside the PRMS fences from all sides reaching housing area SE side downwind.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS from the SE side reaching the housing area downwind.*

Event	Scenario	Effects
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value of 9.5 & 12.5 kW/m^2 will be limited inside PRMS fence and covering the control room NE side crosswind.*
Pin hole (1") gas release 8" outlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRMS boundary downwind.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).* *The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
Half Rupture (4") gas release 8" outlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud (UFL, LFL & 50% LFL) will limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that all radiation values will extend outside the PRMS SE downwind covering the sub-way (25 & 37.5 kW/m^2) and SW crosswind covering the sub-way and near to the main road (9. & 12.5 kW/m^2).*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).* *The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.*

Event	Scenario	Effects
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will be limited inside the PRMS boundary from NE & NW, (reaching the control room and heater) and will extend from SE & SW covering the sub-way.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS SE fence to the sub-way downwind.*
Full Rupture gas release 8" outlet pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will extend outside the PRMS SE fence to reach the sub-way downwind.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that all values will extend outside the SE fence and cover the sub-way, irrigation canal & main road (25 & 37.5 kW/m^2).* *The value of 12.5 kW/m^2 will be near to the housing building and 9.5 kW/m^2 will reach 2 buildings downwind.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS boundary from SW crosswind (22m), SE downwind (15m) & NE crosswind (5m).* *The value of 0.137 bar and 0.206 bar will be limited inside effects the PRMS facilities.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will be affect the PRMS facility from SE side; also will extend from SE & SW covering the sub-way and the irrigation canal to reach the main road.* *The value of 0.137 bar and 0.206 bar will be extend outside the PRMS SE fence to affects the irrigation canal downwind.*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values of 9.5 & 12.5 kW/m^2 will be limited inside the PRMS boundary.*

Event	Scenario	Effects
Odorant tank 1" leak		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the LFL, LFL and 50 % LFL will extend outside the PRMS SE fence to cover the sub-way and the irrigation canal and reach the main road downwind.* *Consideration should be taken when deal with liquid, vapors and smokes according to the MSDS for the material.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation of (9.5, 12.5, 25 & 37.5 kW/m^2) effects will be limited inside the PRMS boundary covering the pressure reduction facilities.* *The value of 9.5 kW/m^2 will be near to the control room at the front side.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of:* *0.020 bar will extend from the SE fence to reach the residential building, covering the sub-way and the main road downwind and crosswind.* *0.137 & 0.206 bar will extend to reach the main road downwind.*
Pin hole (1") gas release 6" off-take pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values of 9.5, 12.5, 25 & 37.5 kW/m^2 will be limited inside the off-take valves room.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*

Event	Scenario	Effects
Half Rupture (3") gas release 6" off-take pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will be limited inside the PRMS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation values of 9.5, 12.5, 25 & 37.5 kW/m^2 will be limited inside the off-take valves room.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS and reaching the NE building crosswind and near to the buildings SE downwind.* *The value of 0.137 bar and 0.206 bar will extend outside the PRMS boundary NE &NW sides and affect the firefighting facilities (0.137 and 0.206 bar) SW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
Full Rupture gas release 6" off-take pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling shows that the gas cloud effects will extend to the PRMS facilities SE side downwind.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that:* *The heat radiation of 9.5 & 12.5 kW/m^2 will affect the control room crosswind NE side, near to the firefighting facility upwind NW side and extend to reach the main road downwind SE side.* *The heat radiation of 25 & 37.5 kW/m^2 will affect the heater area and the PRMS facility, and with extension to reach the sub-way outside the site.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling shows that the value of 0.020 bar will extend outside the PRMS and reaching the NE building crosswind and near to the buildings SE downwind.* *The value of 0.137 bar and 0.206 bar will extend outside the PRMS boundary NE &NW sides and affect the firefighting facilities (0.137 and 0.206 bar) SW side.*

Event	Scenario	Effects
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*N/D*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling shows that the heat radiation value of 9.5 & 12.5 kW/m^2 will extend outside the PRMS NW & NE sides with no effects on surroundings, but will affect the firefighting facility.*

The previous table show that there are some potential hazards with heat radiation resulting from jet fire, and explosion overpressure waves in case of gas release and late ignited.

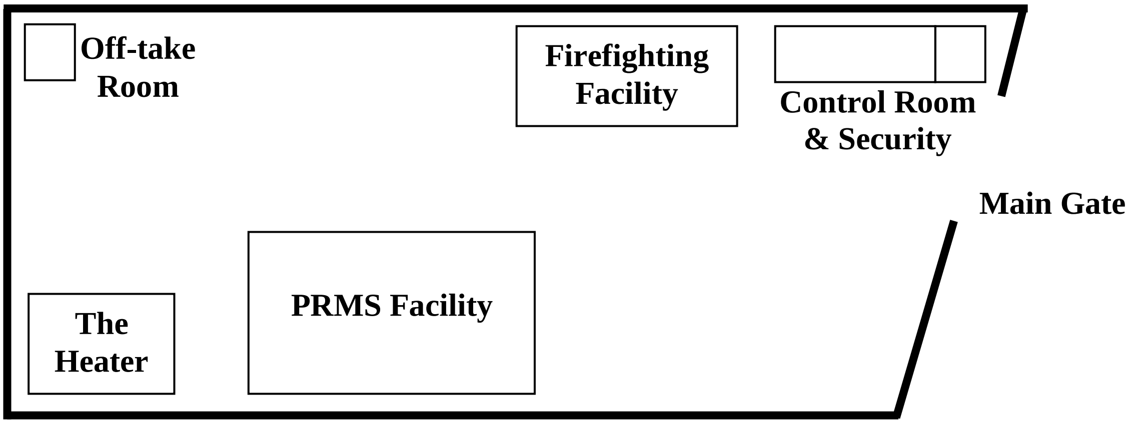
These hazards will affect the control room; also, some scenarios will extend over the site boundary like heat radiation (12.5, 25 and 37.5 kW/m^2) or explosion overpressure waves (0.137 & 0.206 bar) reaching main road or surrounding public house downwind (South East directions).

Regarding to the risk calculations the risk to ***workers is in ALARP Region***, and the risk for the ***public is in ALARP Region***, so there are some points need to be considered to keep the risk tolerability or reduced taking cost into account, and this will be describe in the study recommendations.

Recommendations

As per results from modeling, the consequences of each scenario and risk calculations it is recommended that:

- Rearrange of PRMS components (control room / firefighting facility) as these located in the range of high values of heat radiation and explosion overpressure waves. It is suggested that arrangement will be as shown in the following figure (considering standard spacing):



- For the condensates pipeline (4") owned by Mansoura Petroleum Company which passes under-ground through the PRMS, considerations should be took in account which will be as following:
  - A comprehensive work plan should be prepared jointly between Egypt Gas and Masoura Petroleum Company before starting construction work.
  - Removing soil above and around the pipeline route should be done by using manual excavation with supervision from Egypt Gas and Mansoura Company representatives.
  - Providing concrete plates on both sides of the pipeline covered by concrete slabs at the top to facilitate maintenance work. (Up-side down U-Shape tunnel)
  - Installing of isolation valves before and after pressure reduction station to facilitate maintenance or isolation in case of emergency.
  - Provide integrated coordination plan between the two companies including emergency communications plan along 24 hours.
- Ensure that all facility specifications referred to the national and international codes and standards.

- Ensure that the inspection and maintenance plans and programs are according to the manufacturers guidelines to keep all facility parts in a good condition.
- Ensure that all operation is according to standard operating procedure for the PRMS operations and training programs in-place for operators.
- Review and update the emergency response plan to include the main detailed elements for ERP and all scenarios in this study and other needs including:
  - Firefighting brigades, mutual aids, emergency communications and fire detection / protection systems.
  - First aid including dealing with the odorant according to the MSDS for it, with respect of means of water supply for emergency showers, eye washers and cleaning.
  - Safe routs and exits for the control room and security office according to the modeling in this study.
- Ensure that emergency shutdown detailed procedure including emergency gas isolation points at the PRMS and GASCO valves room in place.
- Ensure that the surface drainage system is suitable for containment of any odorant spills.
- Considering that all electrical equipment, facilities and connections are according to the hazardous area classification for natural gas facilities.
- Provide the site with SCBA "Self-Contained Breathing Apparatus" (at least two sets) and arrange training programs for operators.
- Provide a suitable tool for wind direction (Windsock) to be installed in a suitable place to determine the wind direction.
- Cooperation should be done with the concerned parties before planning for housing projects around the PRMS area.