ANNEXURE- 11

RISK ASSESSMENT REPORT

For

BS – IV & VI PROJECT AT GUJARAT REFINERY

BY

INDIAN OIL CORPORATION LTD.

AT

KOYALI

DISTRICT: VADODARA

STATE: GUJARAT

PREPARED BY

HUBERT ENVIRO CARE SYSTEMS (P) LTD

CHENNAI

AUGUST 2016

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1 ABBREVATIONS

DHDS	Diesel Hydro De-Sulphurisation
DHDT	Diesel Hydro treater Unit
VGO-HDT	Vacuum Gas oil Hydro-Treater Unit
IOCL	Indian Oil Corporation Limited
MMTPA	Million Metric Tonnes Per Annum
ALARP	As Low As Reasonably Practical
BLEVE	Boiling Liquid Expanding Vapor Explosion
TNO	Thai National Observatory
VCE	Vapor Cloud Explosion
MS	Motor Spirit

2 INTRODUCTION

2.1 PURPOSE OF THE REPORT

Indian Oil Corporation Limited (IOCL) is one of the largest oil refineries at Koyali (near Vadodara) in Gujarat, Western India. The refinery was commissioned in the year 1965 with a nameplate capacity of 3.0 MMTPA. Over the years, the capacity of the refinery has gradually been increased to 13.7 MMTPA with augmentation of old primary Atmospheric Units (AU-I, AU-II and AU-III) and addition of new primary units viz. Atmospheric Unit-IV in 1978 and AU-V in 1999 as well as augmentation of AU-IV in 2000.

The project scope involves DHDS, DHDT, VGO-HDT revamp and new SWS-VI under BS-IV and new units under BS-VI Project.

The Consequence Risk Analysis is been carried out for the Proposed tankers in IOCL Unit which is located in Koyali, Vadodara District, Gujarat State. Based on the available studies & plant layout the potential scenarios which can cause significant consequences like fire and explosion scenarios were identified. The consequences of the scenarios were assessed using the software PHAST 7.01 and analysis is carried by Hubert Enviro Care Systems Pvt Ltd, Chennai consultant.

The purpose of the study includes the following:

- To identify and assess those hazards and risks
- To eliminate or reduce to As Low As Reasonably Practical (ALARP) in terms of risk to human health, risk of injury, risk of damage to plant, equipment and environment, business interruption or loss etc.,
- To Prepare On-site and Off-site Mitigative Measures.

2.2 SCOPE OF STUDY

The main scope of the study is to carry out Quantitative Risk Analysis study as per The Indian Standard IS 15656: Code of practice - Hazard Identification and Risk Analysis

- Identification of hazards
- Consequence Modelling
- Contour Mapping on Google Earth Site
- Damage Distance identification & Quantification of risk
- To suggest Onsite and offsite emergency plan to mitigate the damage of potential events.

2.3 METHODOLOGY ADOPTED

The Assessment is carried out by using PHAST 7.01 version which is developed by DNV to examine the flammable and toxic hazards where individual risks are to be identified. It helps to quantify the severity of situations which present potential hazards to life, property and environment. PHAST examines the progress of potential incident from the initial release to far –field dispersion including modeling of pool spreading and evaporation, and flammable and toxic effects.

3 QUANTITATIVE RISK ANALYSIS

3.1 HAZARD IDENTIFICATION

Hazards will be identified based upon consideration of factors such as the physical & chemical properties of the fluids being handled, the arrangement of equipment & maintenance procedures and processing conditions.

3.1.1 Selection

The goal of selection is to limit the total number of incident outcome cases to be studied to a manageable size. The purpose of incident outcome selection is to develop a set of incident outcomes that must be studied for each incident included in the finalized incident study list. Each incident needs to be considered separately. Using the list of incident outcomes the risk analyst needs to determine which may result from each incident. This process is not necessarily straightforward. While the analyst can decide whether an incident involving the loss of a process chemical to the atmosphere needs to be examined using dispersion analysis because of potential toxic gas effects, what happens if the same material is immediately ignited on release?

3.1.2 Characterising The Failures

Accidental release of flammable or toxic vapours can result in severe consequences. Delayed ignition of flammable vapours can result in blast overpressures covering large areas. This may lead to extensive loss of life and property. Toxic clouds may cover yet larger distances due to the lower threshold values in relation to those in case of explosive clouds (the lower explosive limits). In contrast, fires have localized consequences. Fires can be put out or contained in most cases; there are few mitigating actions one can take once a vapour cloud gets released. Major accident hazards arise, therefore, consequent upon the release of flammable or toxic vapours or BLEVE in case of pressurized liquefied gases.

In a refinery, main hazard arises due to storage and handling of hydrocarbons. To formulate a structured approach to identification of hazards and understanding of contributory factors is essential.

3.1.3 Blast Overpressures

Blast Overpressures depend upon the reactivity class of material and the amount of gas between two explosive limits. The hydrocarbon that is expected to give rise to a vapour cloud on release is pressurized gases.

3.1.4 Inventory

Inventory Analysis is commonly used in understanding the relative hazards and short listing of release scenarios. Inventory plays an important role in regard to the potential hazard. Larger the inventory of a vessel or a system, larger the quantity of potential release. A practice commonly used to generate an incident list is to consider potential leaks and major releases from fractures of pipelines and vessels containing sizable inventories. The potential vapour release (source strength) depends upon the quantity of liquid release, the properties of the materials and the operating conditions (pressure, temperature). If all these influencing parameters are combined into a matrix and vapour source strength computed for each release case, a ranking should become a credible exercise.

Loss of Containment

Liquid Release may be instantaneous. Failure of a vessel leading to an instantaneous outflow assumes the sudden appearance of such a major crack that practically all of the contents above the crack shall be released in a very short time.

The more likely event is the case of liquid release from a hole in a pipe connected to the vessel. The flow rate will depend on the size of the hole as well as on the pressure in front of the hole, prior to the accident. Such pressure is basically dependent on the pressure in the vessel.

The vaporization of released liquid depends on the vapour pressure and weather conditions. Such consideration and others have been kept in mind both during the initial listing as well as during the short listing procedure. Initial listing of all significant inventories in the process plants was carried out. This ensured no omission through inadvertence.

Based on the methodology discussed above a set of appropriate scenarios was generated to carry out Risk Analysis calculations, as listed below:

Table 3.1 List of Scenarios Considered

1.	Rupture of benzene tank
2.	Rupture of Toluene Tank
3.	Rupture of Motor Spirit Tanker

4.	Rupture of Naphtha Tank
5.	Rupture of Pipelines

3.2 RISK ANALYSIS CALCULATIONS

3.2.1 Damage Criteria

In consequence analysis, use is made of a number of calculation models to estimate the physical effects of an accident (spill of hazardous material) and to predict the damage (lethality, injury, material destruction) of the effects. The calculations can roughly be divided in three major groups:

- Determination of the source strength parameters;
- Determination of the consequential effects;
- Determination of the damage or damage distances.

The basic physical effect models consist of the following:

3.2.2 Source Strength Parameters

- Calculation of the outflow of liquid out of a tank or pipe, in case of rupture.
- Calculation, in case of liquid outflow, of the instantaneous flash evaporation and of the dimensions of the remaining liquid pool.
- Calculation of the evaporation rate, as a function of volatility of the material, pool dimensions and wind velocity.
- Source strength equals pump capacities, etc. in some cases of pump discharge line ruptures for catastrophic cases.

3.2.3 Consequential effects

- Dispersion of gaseous material in the atmosphere as a function of source strength, relative density of the gas, weather conditions and topographical situation of the surrounding area.
- Intensity of heat radiation [in kW/ m^2] due to a fire, as a function of the distance to the source.
- Concentration of gaseous material in the atmosphere, due to the dispersion of evaporated chemical. The latter can be either explosive or toxic.
- The type of models depend on type of materials i.e.,
    - ❖ Physical state
    - ❖ Flammability & Toxicity

- Depends on Storage conditions
- Type of Failure

3.2.4 Selection of Damage Criteria

The damage criteria give the relation between extent of the physical effects (exposure) and the percentage of the people that will be killed or injured due to those effects. For instance, much more is known about the damage caused by heat radiation, than about the damage due to toxic exposure, and for these toxic effects, the knowledge differs strongly between different materials. In Consequence Analysis studies, in principle three types of exposure to hazardous effects are distinguished:

1. Heat radiation, from a jet, pool fire or flash fire.
2. Explosion
3. Toxic effects, from toxic materials or toxic combustion products.

Heat Radiation

The consequences caused by exposure to heat radiation is a function of:

- The radiation energy onto the human body [kW/m^2];
- The exposure duration [sec];
- The protection of the skin tissue (clothed or naked body).

The limits for 1% of the exposed people to be killed due to heat radiation, and for second-degree burns are given in the table below:

Table 3.2 - Damages to Human Life Due to Heat Radiation

Exposure Duration	Radiation energy (1% lethality, kW/m^2	Radiation energy for 2^{nd} degree burns, kW/m^2	Radiation energy for first degree burns, kW/m^2
10 sec	21.2	16	12.5
30 sec	9.3	7	4

Since in practical situations, only the people outside will be exposed to heat radiation in case of a fire, it is reasonable to assume the protection by clothing. It can be assumed that people would be able to find a cover or a shield against thermal radiation in 10-sec. time. Furthermore, 100% lethality may be assumed for all people suffering from direct contact with flames, such as the pool fire, a flash fire or a jet flame. The effects due to relatively lesser incident radiation intensity are given below.

Table 3.3 Effects Due To Incident Radiation Intensity

INCIDENT RADIATION – kW/m^2	TYPE OF DAMAGE
0.7	Equivalent to Solar Radiation
1.6	No discomfort for long exposure
4.0	Sufficient to cause pain within 20 sec. Blistering of skin (first degree burns are likely)
9.5	Pain threshold reached after 8 sec. second degree burns after 20 sec.
12.5	Minimum energy required for piloted ignition of wood, melting plastic tubing's etc.
18.47	Sufficient to cause damage
37.5	Heavy Damage to process equipment

*Source - Purple book from TNO, Netherlands.

Explosion

In case of vapour cloud explosion, two physical effects may occur:

· Flash fire over the whole length of the explosive gas cloud;

· A blast wave, with typical peak overpressures circular around ignition source.

As explained above, 100% lethality is assumed for all people who are present within the cloud proper.

For the blast wave, the lethality criterion is based on:

· Peak overpressure of 0.1 bar will cause serious damage to 10% of the housing/structures.

· Falling fragments will kill one of each eight persons in the destroyed buildings.

The following damage criteria may be distinguished with respect to the peak overpressures resulting from a blast wave:

Table 3.4 Damage due to Overpressures

Peak Overpressure	Damage Type	Description
0.83 bar	Total Destruction	Total Destruction of plant equipment structure
0.20 bar	Heavy Damage	Major damage to plant equipment structure
0.10 bar	Moderate Damage	Repairable damage to plant equipment & structure
0.03 bar	Significant Damage	Shattering of glass
0.01 bar	Minor Damage	Crack in glass

*Source: Green book from TNO, Netherlands.

3.2.5 Fire And Explosion Modelling

Jet Fire

Jet fires are burning jets of gas or atomized liquid whose shape is dominated by the momentum of the release. The consequence of the jet fire is directional depending on the release orientation. Jet fires typically have flame temperature of 2200 deg C and can produce high intensity thermal radiation. The jet flame stabilizes on or close to the point of release and continues until the release is stopped. Jet fires could occur during unloading or transfer operations when pressures are increased by compressors. Such fires could cause severe damage but will generally affect only the local area.

If compressed or liquefied gases are related from storage tanks or pipelines, the materials discharging through the hole will form a gas jet that entrains and mixes with the ambient air. If the material encounters an ignition sources while it is in the flammable range, a jet fire may occur. Jet fires could occur during unloading operations when pressures are increased by pumping. Such fires could cause severe damage but will generally affect only the local area.

The effect of jet flame impingement is severe as it may cut through equipment, pipeline or structure. The damage effect of thermal radiation is depended on both the level of thermal radiation and duration of exposure.

Flash Fire

When a volatile, flammable material is released to the atmosphere, a vapor cloud forms and disperses (mixes with air). If the resultant vapor cloud is ignited before the cloud is diluted below its LFL, a flash fire may occur. The combustion normally occurs within only portions of the vapor cloud (where mixed with air in flammable concentrations), rather than the entire cloud. A flash fire may burn back to the release point, resulting in a pool or jet fire but is unlikely to generate damaging overpressures (explode) when unconfined.

A flash fire occurs when a cloud of vapor/gas burns without generating any significant overpressure. The cloud is typically ignited on its edge, remote from the leak source. The combustion zone moves through the cloud away from the ignition point. The duration of the flash fire is relatively short but it may stabilize as a continuous jet fire from the leak source. For flash fires, an approximate estimate for the extent of the total effect zone is the area over which the cloud is above the LFL. It is assumed that this area is not increased by cloud expansion during burning.

Fire Ball (BLEVE)

BLEVE stands for Boiling Liquid Expanding Vapor Explosion. Sometimes referred to as a fireball, a BLEVE is a combination of fire and explosion with an intense radiant heat emission within a relatively short time interval. As implied by the term, the phenomenon can occur within a vessel or tank in which a liquefied gas is kept above its atmospheric boiling point.

It is the result of a liquid within a container reaching a temperature well above its boiling point at atmospheric temperature, causing the vessel to rupture into two or more pieces. BLEVE can be defined as a rapid failure of a container of flammable material under pressure during fire engulfment. Failure is followed by a fireball or major fire which produces a powerful radiant-heat flux.

BLEVE can occur when fire impinges on the tank shell at a point or points above the liquid level of the contents of the tank. This impingement causes the metal to weaken and fail from the internal pressure. A fireball is an intense spherical fire resulting from a sudden release of pressurized gas which is immediately ignited, burning as it expand forming a ball of fire, rising in the air. When this cloud is ignited, a fireball occurs, causing enormous heat-radiation intensity within a few seconds. This heat intensity is sufficient to cause severe skin burns and deaths at several hundred meters from the vessel, depending on the quantity of the gas involved. When a

BLEVE occurs, debris may travel hundreds of feet, with tremendous force, and the escaping fuel can ignite causing an expanding fireball.

Explosions

Explosions are characterized by a shock-wave which can be heard as a bang and which can cause damage to buildings, breaking windows and ejecting missiles over distances of several hundred meters. The injuries and damage are in the first place caused by the shock-wave of the explosion itself. People are blown over or knocked down and buried under collapsed buildings or injured by flying glass. Although the effects of over-pressure can directly result in deaths, this would be likely to involve only those working in the direct vicinity of the explosion. The history of industrial explosions shows that the indirect effects of collapsing buildings, flying glass and debris cause far more loss of life and severe injuries.

Vapor Cloud Explosion

Generally catastrophic gas explosions happen when considerable quantities of flammable material are released and dispersed with air to form an explosive vapor cloud before ignition takes place.

A vapor cloud explosion (VCE) occurs if a cloud of flammable gas burns sufficiently quickly to generate high overpressures (i.e., pressures in excess of ambient).

The following main types of explosion can be distinguished.

- Confined explosions where the burning gas is largely confined, typically inside a largely empty enclosed tank or building.
- Semi-confined explosions where the gas is partly confined, typically in an offshore process module therefore not considered for this study.
- Unconfined explosions where the gas cloud is largely unconfined, typically on an onshore installation, but there are sufficient obstacles to generate turbulence and start the build-up of pressure.

Toxic gas release

In case of release of toxic gas, when a gas that is heavier than air is released, it initially behaves very differently from a neutrally buoyant gas. The heavy gas will first "slump," or sink, because it is heavier than the surrounding air. As the gas cloud moves downwind, gravity makes it spread; this can cause some of the vapor to travel upwind of its release point. Farther downwind, as the cloud becomes more diluted and its density approaches that of air, it begins behaving like a neutrally buoyant gas.

This takes place when the concentration of heavy gas in the surrounding air drops below about 1 percent (10,000 parts per million). For many small releases, this will occur in the first few yards (meters). For large releases, this may happen much further downwind.

4 CONSEQUENCE ANALYSIS

4.1 Weather Data

For this study weather conditions pertaining to IOCL Gujarat are considered as per the Site Specific data.

Wind Speed

The average wind speed is considered as 3.5 m/sec.

Temperature

The annual mean of maximum and minimum mean daily temperature are 40°C and 25°C respectively.

Stability class

Dispersion of gases or vapour largely depends upon the Stability Class. Various stability classes that are defined as Pasquill classes are:

As per CPR 18E there are 6 representative weather classes:

Stability class	Wind speed
B	Medium
D	Low
D	Medium
D	High
E	Medium
F	Low

- Low wind speed corresponds with 1 – 2 m/s
- Medium wind speed corresponds with 3 – 5 m/s
- High wind speed corresponds with 8 - 9 m/s

The stability class for a particular location is generally dependent upon:

Table 4.1 Pasquill – Giffard Atmospheric Stability

S.No.	Stability Class	Weather Conditions
1	A	Very Unstable - sunny, light wind
2	A/B	Unstable - as with A only less sunny or more windy
3	B	Unstable - as with A/B only less sunny or more windy
4	B/C	Moderately unstable – Moderate sunny and moderate wind
5	C	Moderately unstable – very windy / sunny or overcast / light wind
6	C/D	Moderate unstable – Moderate sun and high wind

7	D	Neutral – little sun and high wind or overcast / windy night
8	E	Moderately stable – less overcast and less windy night
9	F	Stable – night with moderate clouds and light / moderate wind
10	G	Very stable – possibly fog

The stability class for a particular location is generally dependent upon:

- Time of the Day (Day or Night)
- Cloud Cover
- Season
- Wind Speed

Wind speed does not influence consequences as much as stability class and for a given stability class, the influence of wind speed is relatively less. On the other hand consequences vary considerably with stability class for the same speed. Except during the monsoon months little or no cloud cover along with the prevailing low wind velocities results in unstable conditions during the day (C or D) and highly stable conditions (E or F) at night. During the four months of monsoon the wind velocities are generally higher and cloud cover generally present. This results in stability class of D during the day and E or F during the night. The stability class distribution over the year roughly works out as below:

A - B - C	17%
D	50%
E or F	33%

The following wind velocity/stability class combinations & frequencies are used for Quantified Risk Analysis:

B	3 m/s	50%
E	1 m/s	50%

Table 4.2 Atmospheric data (Manual Input)

S.No	Parameter	Observation
1.	Wind Direction	SW-NE
2.	Months	March-May 2016

3.	Wind Speed Range	0.5 to 3.6 m/sec
4.	Average rainfall	1107 mm
5.	Average Wind Speed	3.5 m/sec
6.	Temperature Range	Max. Temp: 40°C Min. Temp: 25°C
7.	Humidity Range (24hr)	36% to 77%
8.	Cloud cover	Partly cloudy

Source: Site Specific Data

4.1.1 Accident Scenarios For the Tankers

Table 4.3 Details of tankers

S.No	Chemical	Internal Temp (^{0}c)	Location	Type	Capacity m^3	Diameter (m)	Height (m)
1.	Motor Spirit (C) Tk 203	40	Offsite	FLP	5000	22.8	12
2.	BH_Naphtha Tk 206	40	Offsite	FLP	5000	22.8	12
3.	Motor Spirit Tk 59	40	Offsite	FLP	5000	22.8	12
4.	Motor Spirit Tk 60	40	Offsite	FLP	5000	22.8	12
5.	Motor Spirit Tk 61	40	Offsite	FLP	5000	22.8	12
6.	Motor Spirit Tk 76	40	Offsite	FLP	5000	12	0
7.	Motor Spirit Tk 78	40	Offsite	FLP	5000	0	0
8.	Motor Spirit Tk 82	40	Offsite	FLP	5000	22.8	12
9.	Motor Spirit Tk 83	40	Offsite	FLP	5000	22.8	12
10.	Motor Spirit Tk 84	40	Offsite	FLP	5000	22.8	12
11.	Naphtha Tk 73	40	Offsite	FLP	5000	22.8	12

S.No	Chemical	Internal Temp (^{0}c)	Location	Type	Capacity m^3	Diameter (m)	Height (m)
12.	Naphtha Tk 74	40	Offsite	FLP	5000	22.8	12
13.	Naphtha Tk 75	40	Offsite	FLP	5000	22.8	12
14.	Naphtha Tk 77	40	Offsite	FLP	5000	22.8	12
15.	Naph_LCHS Tk 207	40	Offsite	FLP	5000	22.8	12
16.	Naph_LCHS Tk 208	40	Offsite	FLP	5000	22.8	12
17.	GOP Naph Tk-711	40	Offsite	FLS	10000	33	13.8
18.	GOP Naph Tk-712	40	Offsite	FLS	10000	33	13.8
19.	GOP Naphtha Tk-713	40	Offsite	FLS	10000	33	13.8
20.	GOP Naphtha Tk-714	40	Offsite	FLS	10000	33	13.8
21.	GAP Naphtha Tk-751	40	Offsite	FLS	350	8	8.1
22.	Benzene Tk-752	40	Offsite	FLS	200	6.5	8.1

S.No	Chemical	Internal Temp (^{0}c)	Location	Type	Capacity m^3	Diameter (m)	Height (m)
23.	MS Tk-753	40	Offsite	FLS	500	10	7.2
24.	MS Tk-755	40	Offsite	FLS	1000	12	9.9
25.	IP Naphtha Tk-513	40	Offsite	FLS	3000	0	14.3
26.	IP Naphtha Tk-514	40	Offsite	FLS	3000	0	14.3
27.	Naphtha Tk-523	40	Offsite	FLS	2000	0	11.8
28.	IP Naphtha Tk-516	40	Offsite	FLS	1000	0	10.9
29.	IP Nap Tk-527	40	Offsite	FLS	400	0	0
30.	IP Nap Tk-528	40	Offsite	FLS	400	0	0
31.	Benz Tk-64	40	Offsite	FCF	400	0	7.7
32.	Benz Tk-65	40	Offsite	FCF	400	0	7.7
33.	Toluene Tk-66	40	Offsite	FCF	400	0	7.7
34.	Toluene Tk-70	40	Offsite	FCF	400	0	7.7
35.	Toluene Tk-71	40	Offsite	FCF	400	0	7.7
36.	Toluene Tk-72	40	Offsite	FCF	400	0	7.7

S.No	Chemical	Internal Temp (^{0}c)	Location	Type	Capacity m^3	Diameter (m)	Height (m)
37.	Toluene Tk-67	40	Offsite	FCF	1000	12	9.1
38.	Toluene Tk-68	40	Offsite	FCF	1000	12	9.1
39.	Tolue Tk-69	40	Offsite	FCF	1000	0	9.1
40.	Benzene Tk-42	40	CRU	FCF	1000	12.33	11.85
41.	Benzene Tk-43	40	CRU	FCF	1000	12.33	11.85
42.	Benzene Tk-41	40	CRU	FCF	400	8.5	7.8
43.	Benzene Tk-50	40	CRU	FCF	400	8.5	7.5
44.	Benzene Tk-51	40	CRU	FCF	1000	18.5	10.75
45.	Benzene Tk-501	40	UDEX	FCF	1000	18.05	10.75
46.	Benzene Tk-507	40	UDEX	FCF	100	4.73	5.9
47.	Benzene Tk-508	40	UDEX	FCF	100	4.73	5.9
48.	Benzene Tk-509	40	UDEX	FCF	100	4.73	5.9
49.	Benzene Tk-510	40	UDEX	FCF	100	4.7	5.9
50.	Benzene Tk-214	40	AU-3	FCF	1000	12	9
51.	Benzene Tk-213	40	AU-3	FCF	1000	12	9
52.	IPCL Naph. Tk-	40	CRU	FLP	3000	18	13.5

S.No	Chemical	Internal Temp (^{0}c)	Location	Type	Capacity m^3	Diameter (m)	Height (m)
	554						
53.	IPCL Naph. Tk-555	40	CRU	FLP	3000	18	13.5
54.	PR.TR.Naph Tk-556	40	CRU	FLP	5000	22	14.5
55.	IP.Naphtha Tk-557	40	Offsite	FLP	6000	24	15.4
56.	IPCL Naph. Tk-558	40	Offsite	FLP	6000	24	15.4
57.	IPCL Naph. Tk-783	40	Offsite	FLP	500	10	0
58.	IPCL Naph. Tk-781	40	Offsite	FLP	500	10	0
59.	Benzene Tk-503	40	UDEX		1000	0	0
60.	Naphtha Tk-1507	40	DHDT area	Floating roof	2573	18	12

From the above tanks only the high capacity storage tankers of Motor spirit tank 203, Naphtha tank 206, Toluene tank 67 and Benzene tank 43 are considered for analysis.

4.1.2 Consequence Analysis Results

The analysis is carried out for the tankers and the results with contour maps are detailed below:

Tanker Scenarios

Table 4.4 Summary of consequence analysis for tankers

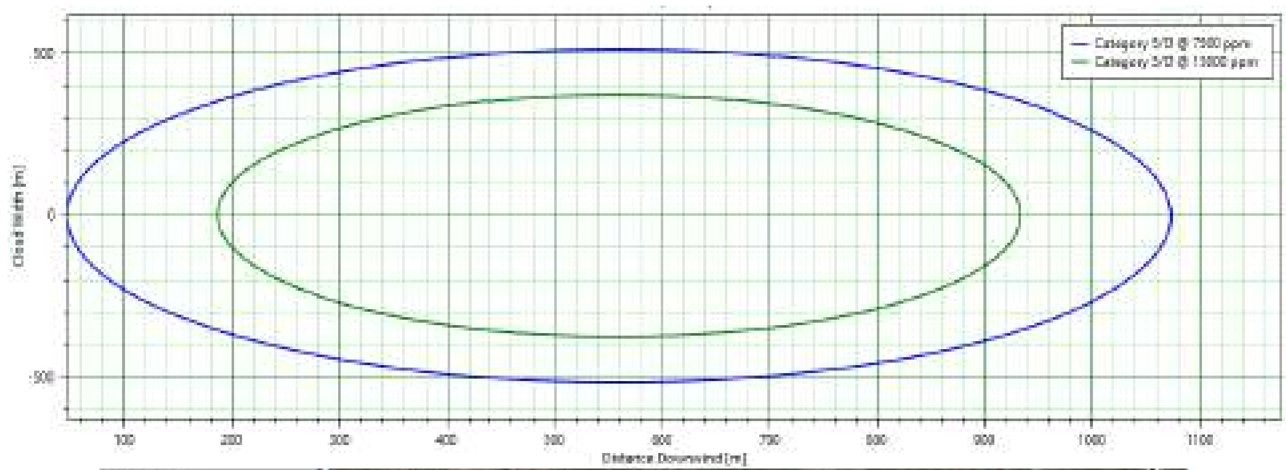
S.No	Description	Scenario	Event	Impact criteria	Consequence Distance (m)		
					Category 1.5/F	Category 1.5/D	Category 5/D
1.	Motor Spirit Tank 203	Rupture 100%	Dispersion of vapour cloud	UFL (90000)	164.126	218.535	128.18
				LFL (15000)	1342.7	1756.18	1126.42
				LFL Frac (7500)	2810.86	2830.09	2614.85
			Fireball	4 kW/m^2	1636.42	1636.42	1636.42
				12.5 kW/m^2	847.722	847.722	847.722
				37.5 kW/m^2	NR	NR	NR
			Flash Fire	7500 ppm	2810.86	2830.09	2614.85
				15000 ppm	1342.7	1756.18	1126.42
			Early Explosion	0.02068 bar	5449.89	5449.89	5449.89
				0.1379 bar	1059.22	1059.22	1059.22
				0.2068 bar	794.165	794.165	794.165
			Late ignition Explosion	0.02068 bar	5881.65	5945.06	5812.45
				0.1379 bar	2445.46	2747.93	2252.23
				0.2068 bar	2380.66	2682.08	2244.17
2	BH_NAPH tank 206	Rupture 100%	Dispersion of vapour cloud	UFL (65000)	97.3308	97.8746	95.8534
				LFL (8000)	968.669	734.099	776.955
				LFL Frac (4000)	1404.83	986.394	1394.89
			Late pool Fire	4 kW/m^2	750.047	841.98	743.76
				12.5	538.859	523.536	533.515

				kW/m^2			
				37.5 kW/m^2	Nr	NR	NR
			Flash Fire	4000 ppm	1404.83	986.394	1394.89
				8000 ppm	968.669	734.099	776.955
			Early Explosion	0.02068 bar	No Hazard	No Hazard	No Hazard
				0.1379 bar	No Hazard	No Hazard	No Hazard
				0.2068 bar	No Hazard	No Hazard	No Hazard
			Late ignition Explosion	0.02068 bar	3110.21	1948.22	3420.36
				0.1379 bar	1711.81	1030.84	1784.61
				0.2068 bar	1633.78	995.261	1685.87
3	Toulene Tk-68	Rupture 100%	Dispersion of vapour cloud	UFL (71000)	46.6943	53.6361	38.3934
				LFL (12000)	404.436	251.339	412.013
				LFL Frac (6000)	583.316	407.798	606.387
			Late pool Fire	4 kW/m^2	389.01	462.804	382.628
				12.5 kW/m^2	250.825	253.332	244.929
				37.5 kW/m^2	NR	NR	NR
			Flash Fire	6000 ppm	583.316	407.798	606.387
				12000 ppm	404.436	251.339	412.013
			Early Explosion	0.02068 bar	No hazard	No hazard	No hazard
				0.1379 bar	No hazard	No hazard	No hazard
				0.2068 bar	No hazard	No hazard	No hazard

			Late ignition Explosion	0.02068 bar	1474.41	1015.19	1381.12
				0.1379 bar	718.076	421.819	695.723
				0.2068 bar	678.519	399.186	663.461
4	Benzene Tk-43	Rupture 100%	Dispersion of vapour cloud	UFL (80000)	123.115	100.714	125.684
				LFL (12000)	758.282	412.611	738.557
				LFL Frac (6000)	1149.9	610.772	1190.65
			Late pool Fire	4 kW/m^2	371.646	441.489	364.789
				12.5 kW/m^2	236.978	237.044	230.885
				37.5 kW/m^2	NR	NR	NR
			Flash Fire	6000 ppm	1149.9	610.772	1190.65
				12000 ppm	758.282	412.611	738.557
			Early Explosion	0.02068 bar	No Hazard	No Hazard	No Hazard
				0.1379 bar	No Hazard	No Hazard	No Hazard
				0.2068 bar	No Hazard	No Hazard	No Hazard
			Late ignition Explosion	0.02068 bar	2464.3	1498.14	2147.13
				0.1379 bar	1332	652.823	1235.64
				0.2068 bar	1272.36	622.366	1215.32

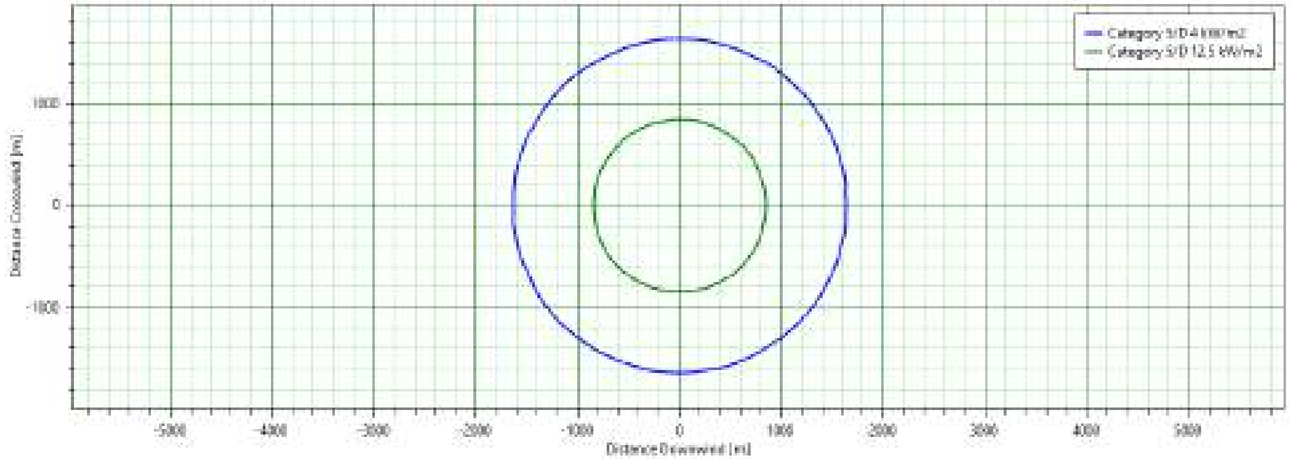
__Scenario -1 Catastrophic Rupture of Motor Spirit Tank - 203__

Case-1 Dispersion of vapor cloud for Motor Spirit Tank - 203



The distance of 218.535 m covered by dispersion of vapor cloud for the high conc. of UFL (90000) ppm in Category 5/D towards north east direction. It is observed that the max. conc. dispersion is slightly crossing the boundary and no habitation found in the impact area. However the onsite emergency plan shall be implemented to mitigate the impact.

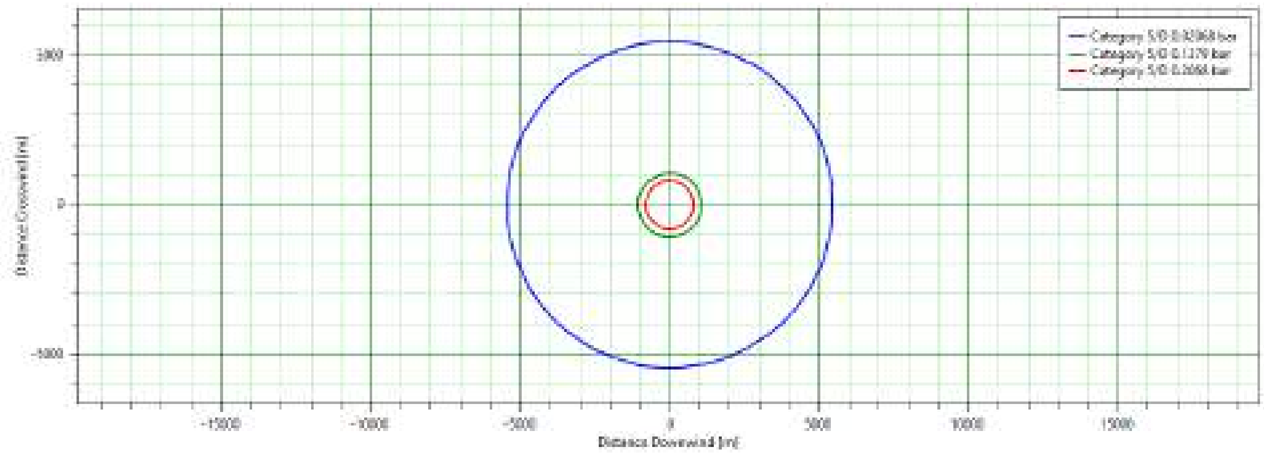
Case-2 Fireball for Rupture of Motor Spirit Tank - 203



The max. distance of 1636.42 m covered by BLEVE for the radiation level of 4 kW/m^2 in Category 5/D. It is observed that the minimum impact is covering entire refinery and slightly crossing the site and affecting minor habitation area such as dhanora village karachiya village which is 785m and 153m respectively. However the onsite & offsite emergency plan shall be implemented to mitigate the impacts.

HECS

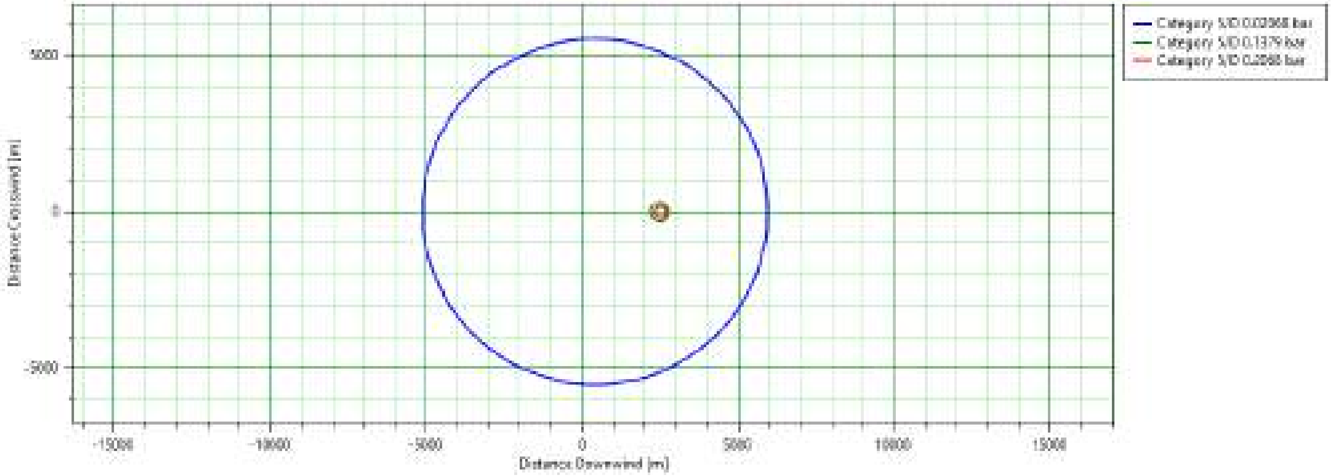
Case-3 Early Explosion Radii for Rupture of Motor Spirit Tank – 203



The max. distance of 5449.89 m covered by Early explosion for the radiation level of 0.02068 bar in Category 5/D. It is observed that the major impact is covered within the site and the minimum impact is covering beyond the site and affecting minor habitation area such as dhanora village 785m, karachiya village which is 153m, koyali village 80m, bajwa 470m. However the onsite & offsite emergency plan shall be implemented to mitigate the impacts.

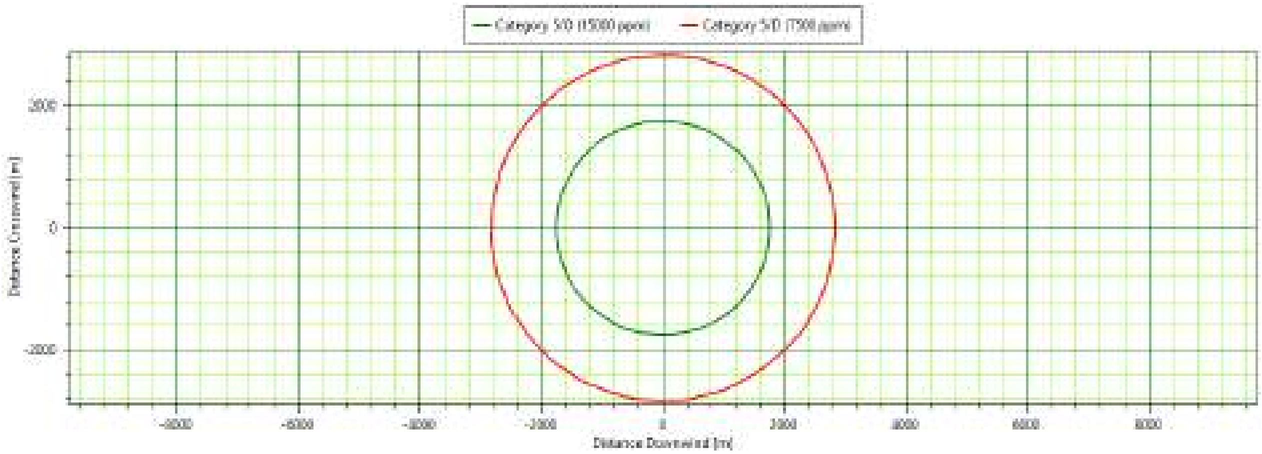
HECS

Case-4 Late ignition Explosion for Rupture of Motor Spirit Tank – 203



The max. distance of 5945.06 m covered by late ignition explosion for the radiation level of 0.02068 bar in Category 5/D towards north west direction. It is observed that the impact is covered in the site and as well as outside site covering the habitation area such as dhanora village 785m, karachiya village which is 153m, koyali village 80m, bajwa 470m, padmala village 3km and ranoli 1km away from the site boundary. However the onsite & offsite emergency plan shall be implemented to mitigate the impacts.

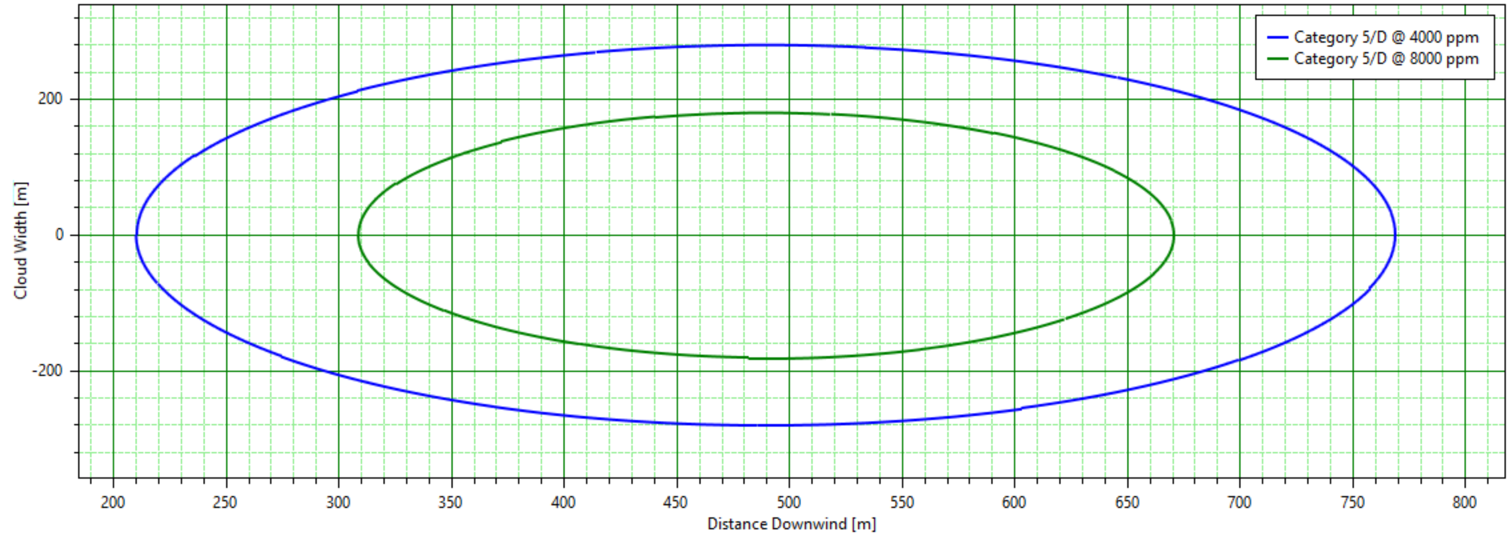
Case-5 Flash Fire Envelope for rupture of Motor Spirit Tank - 203



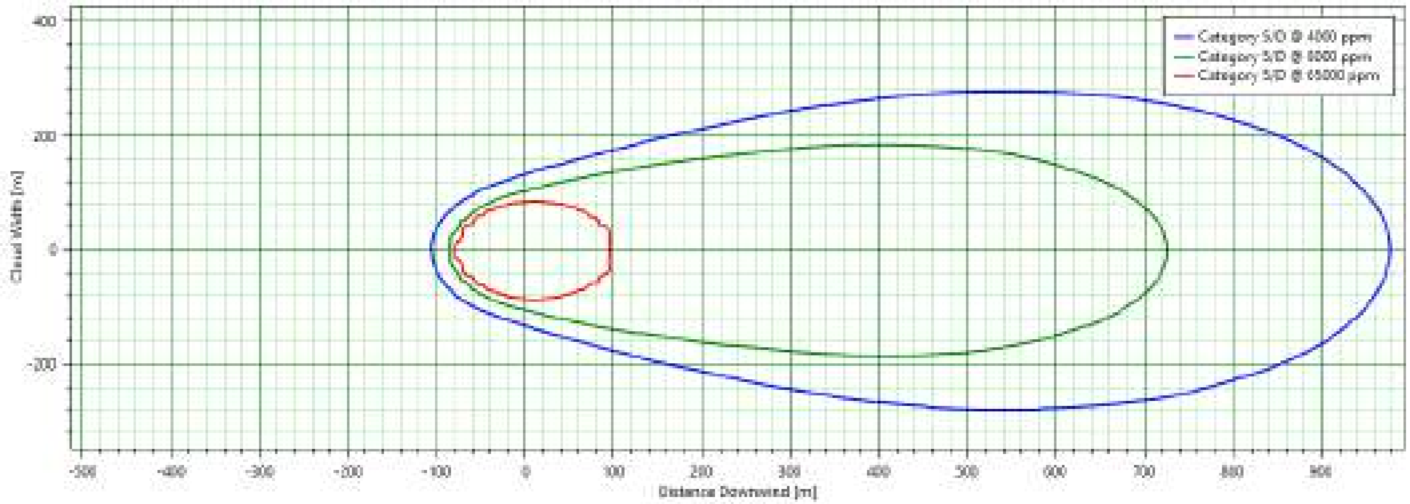
The max. distance of 2830.09 m covered by flash fire for the conc. of 7500ppm in Category 5/D. It is observed that the impact is covered in the site and as well as outside site covering the habitation area such as dhanora village 785m, karachiya village which is 153m, koyali village 80m, bajwa 470m away from the site boundary. However the onsite & offsite emergency plan shall be implemented to mitigate the impacts.

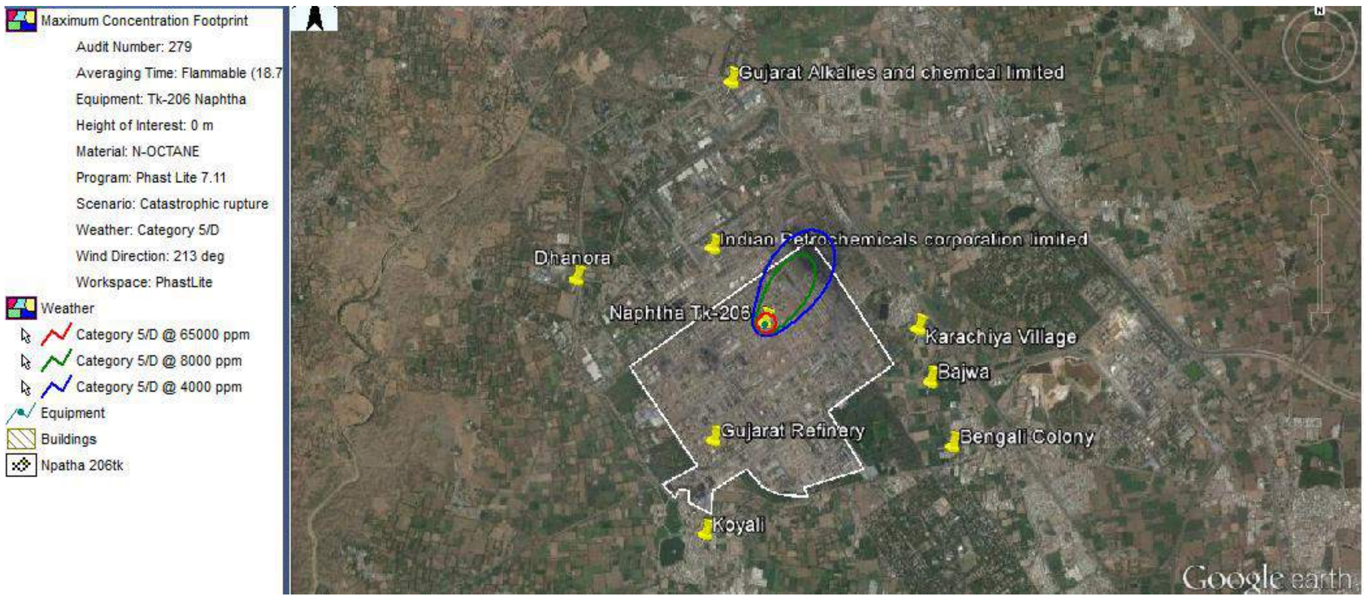
<u>Scenario -2 Catastrophic Rupture of Naphtha Tank 206</u>

Case-1 Dispersion of vapor cloud for of Naphtha Tank 206

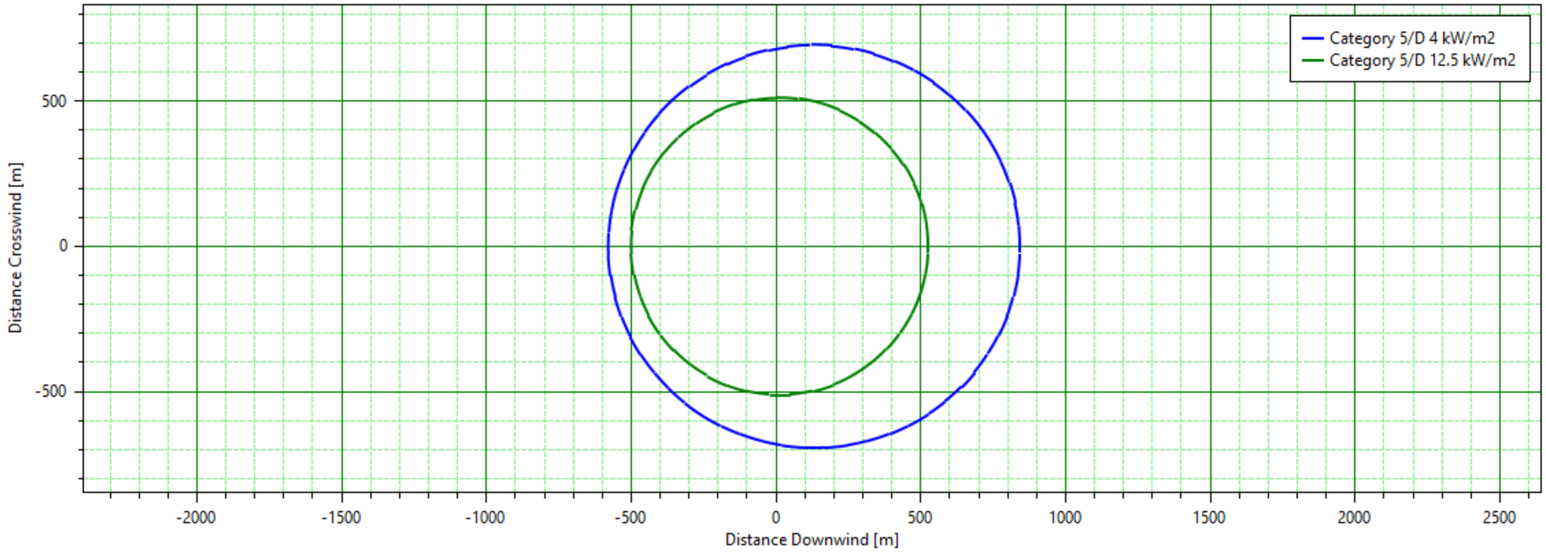


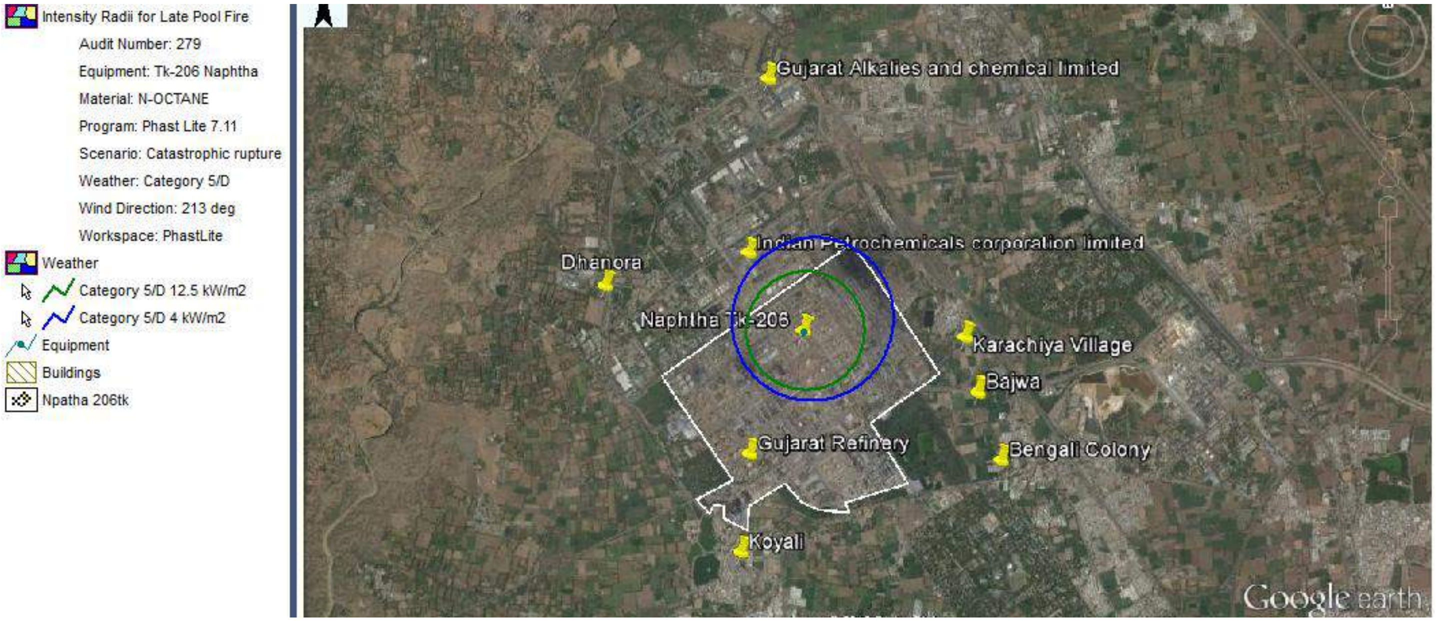
Case-2 Max. Conc of vapor Cloud for Naphtha Tank 206



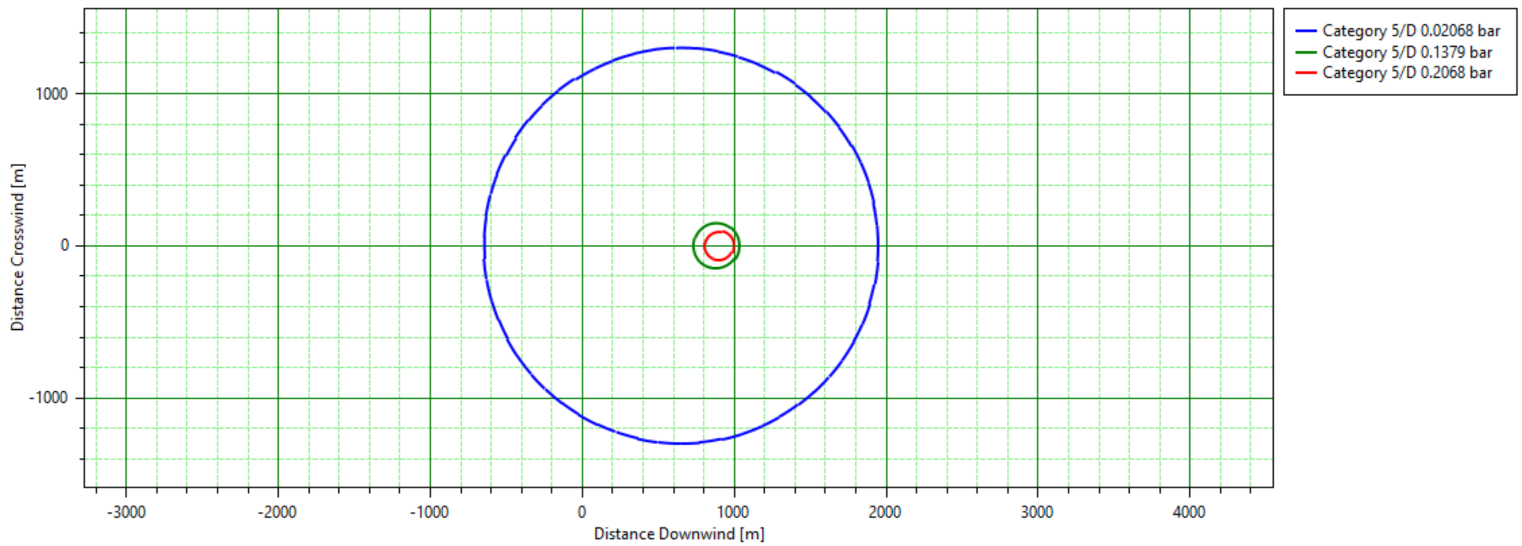


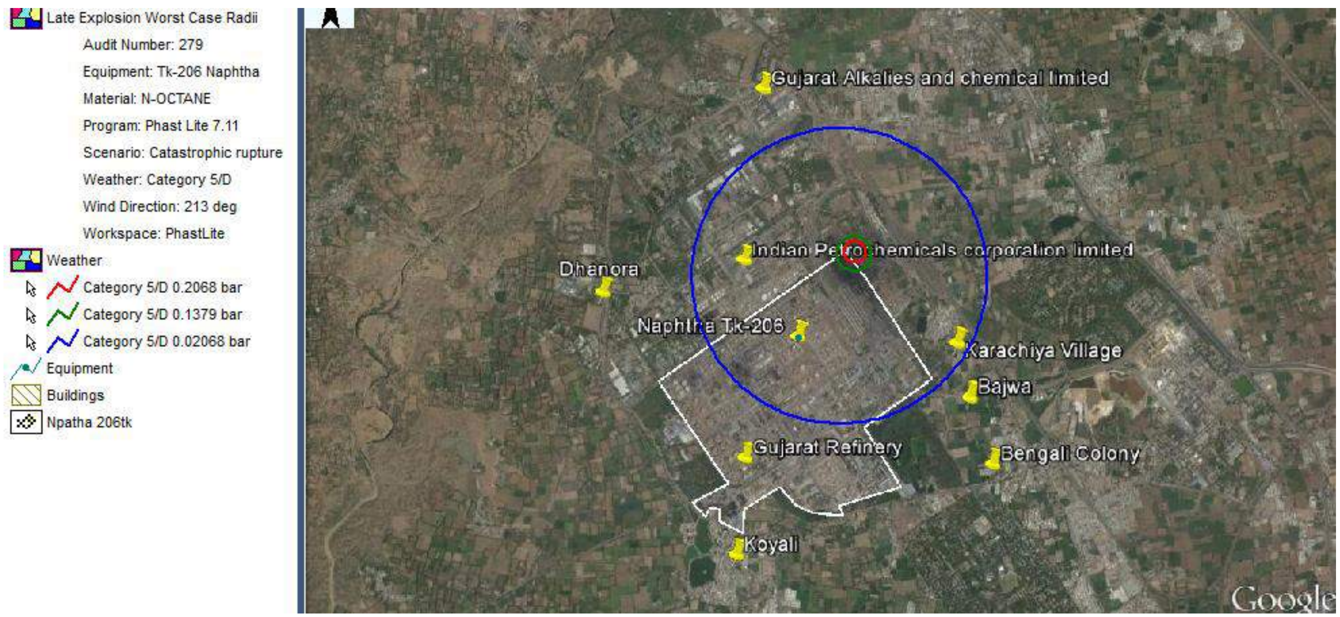
Case-3 Late Pool Fire for Naphtha Tank 206



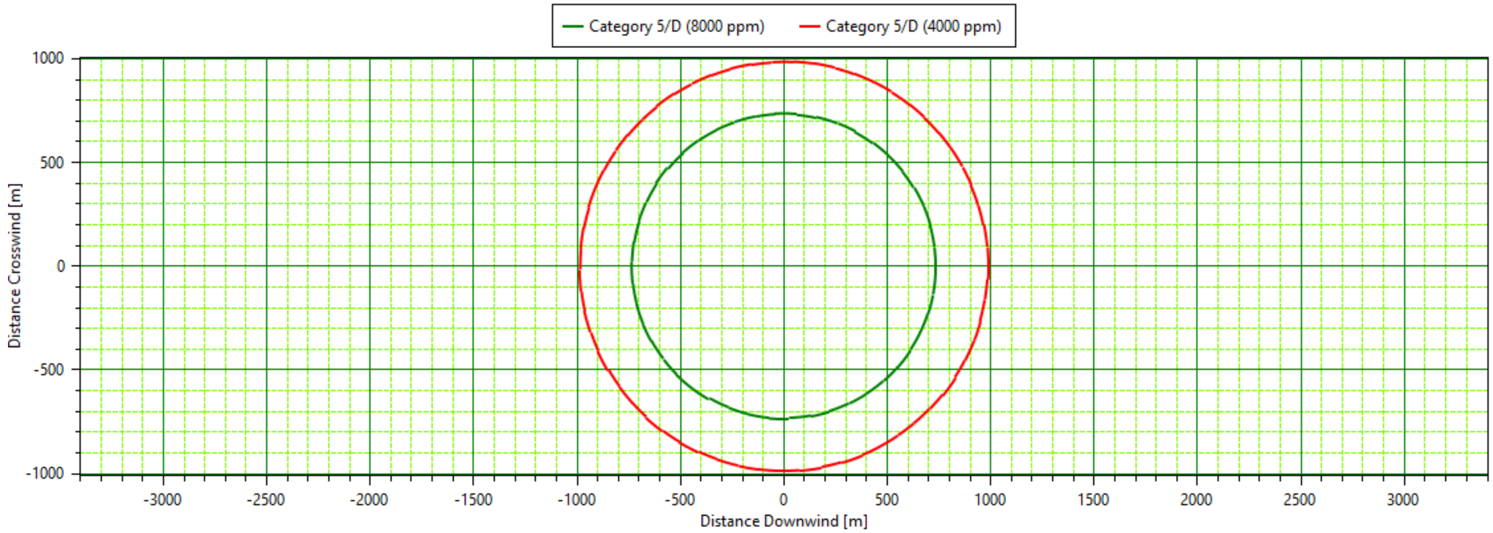


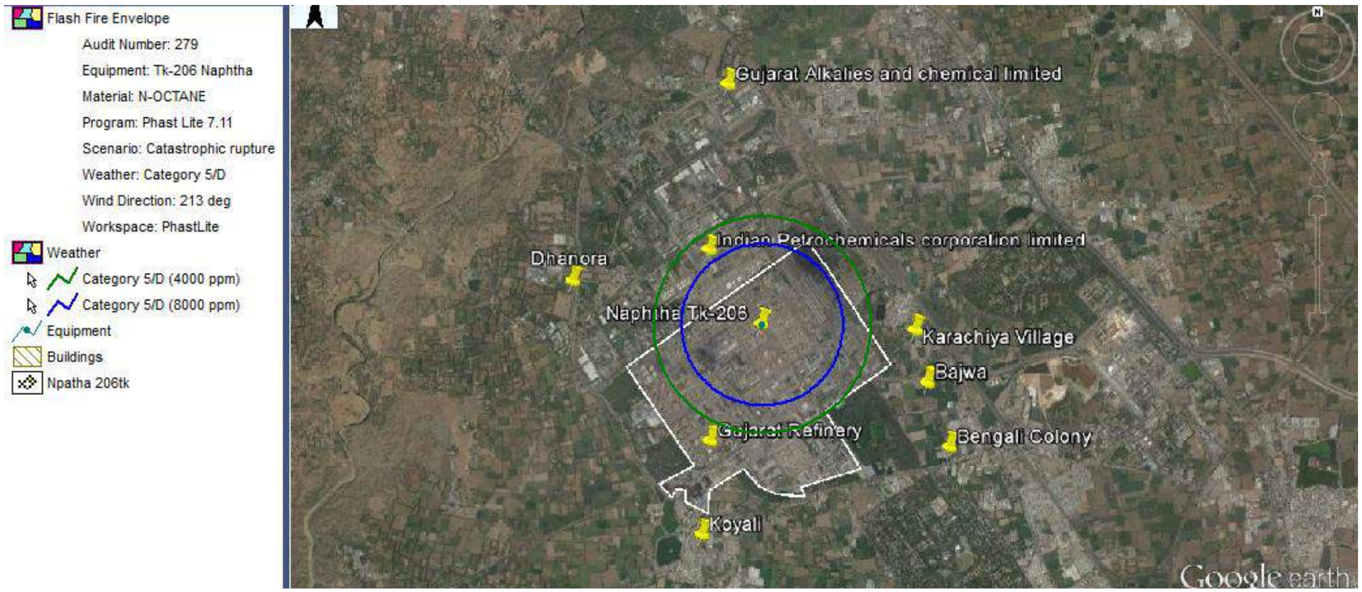
Case-4 Late explosion worst case Radii for Naphtha Tank 206





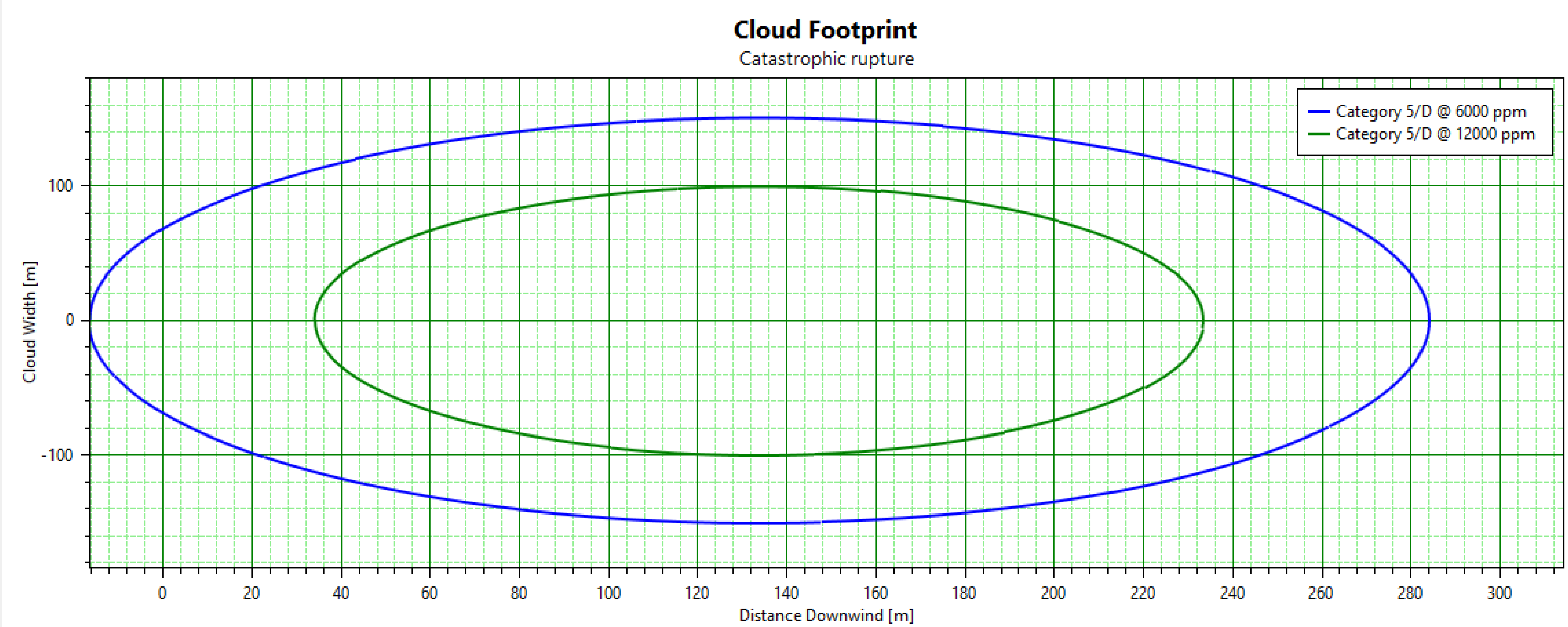
Case-5 Flash Fire for Naphtha Tank 206

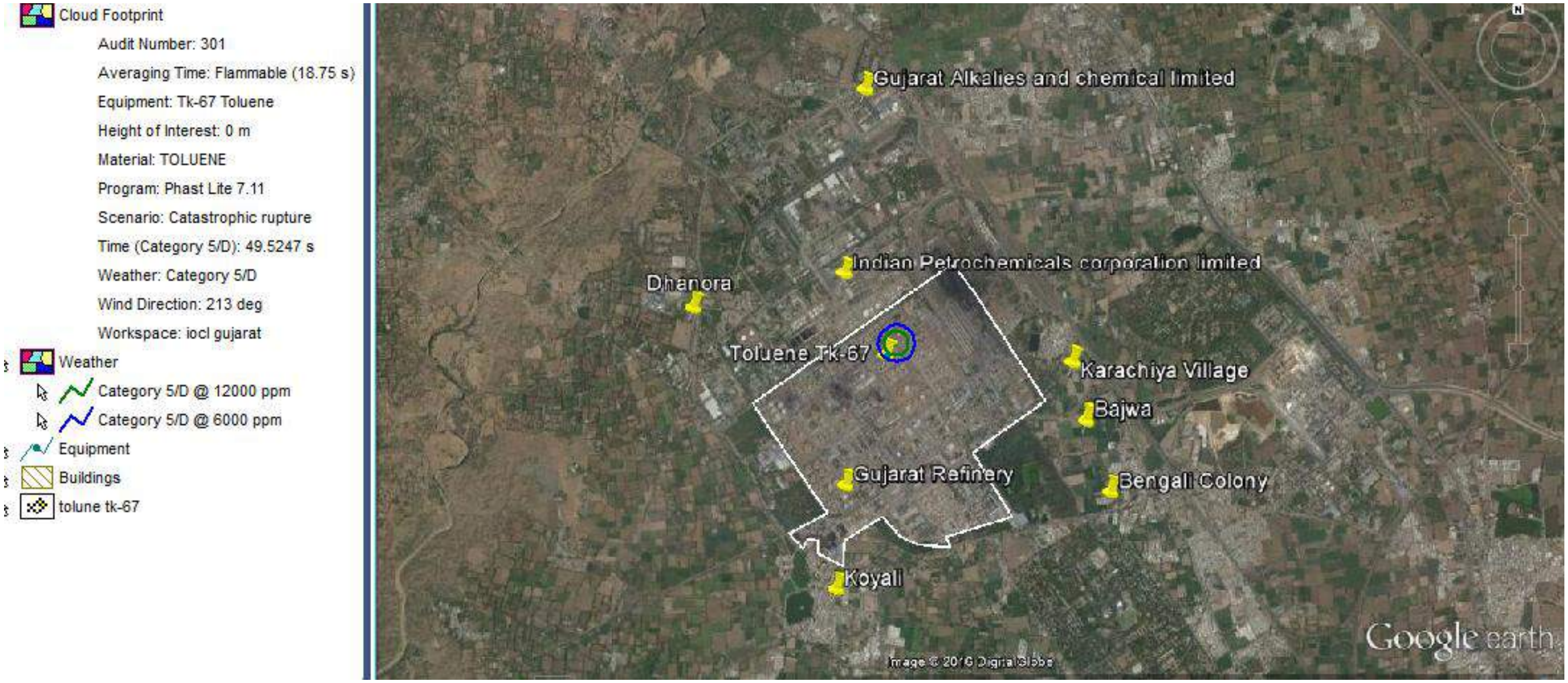




Scenario-3 Rupture of Toluene Tank Tk-67

Case-1 Dispersion of vapor cloud for the Rupture of Toluene tank





Case-2 Late pool fire for the rupture of Toluene tank

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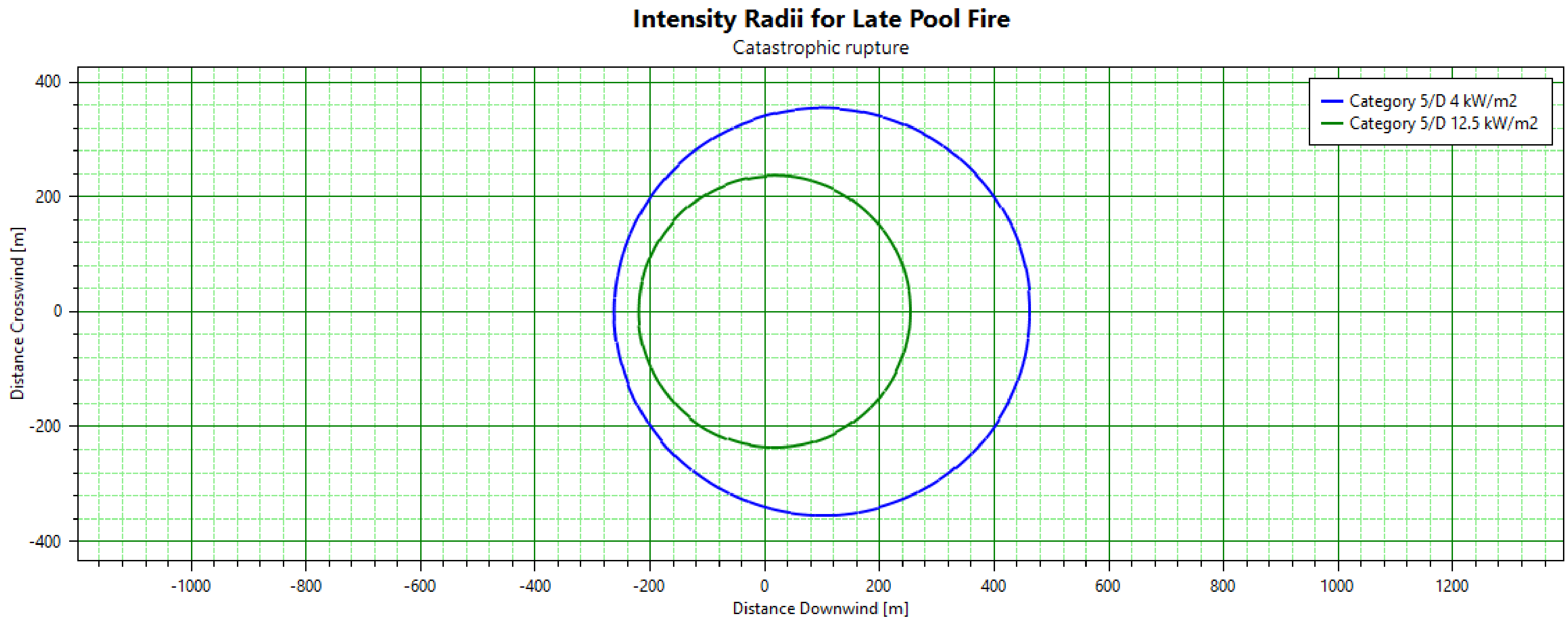
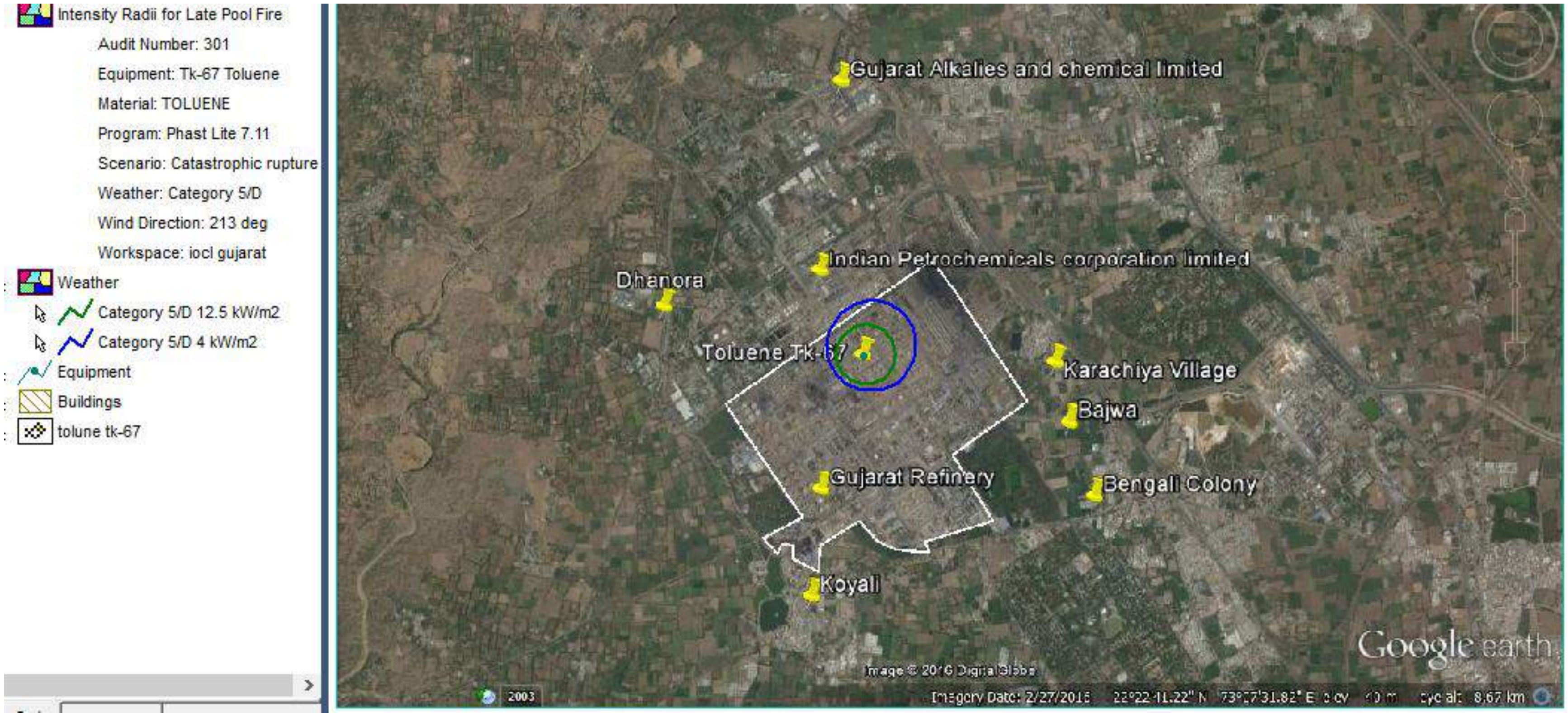
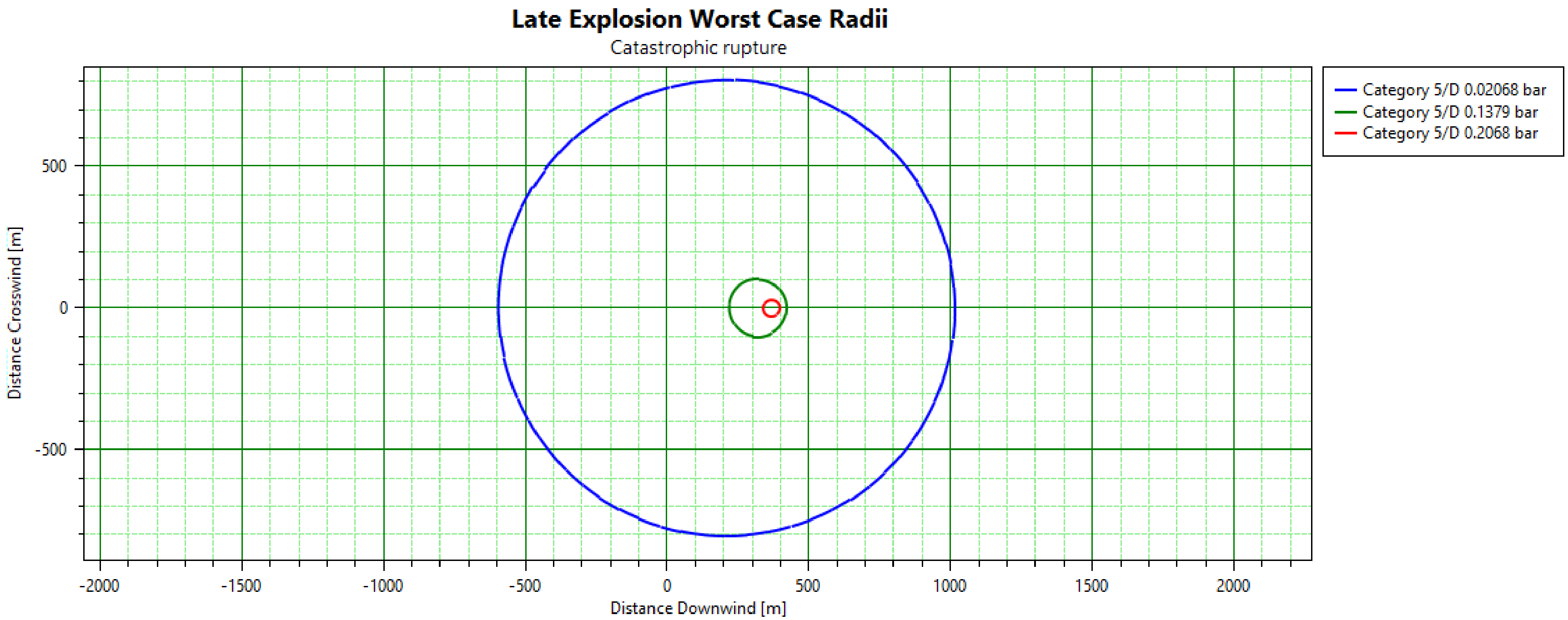
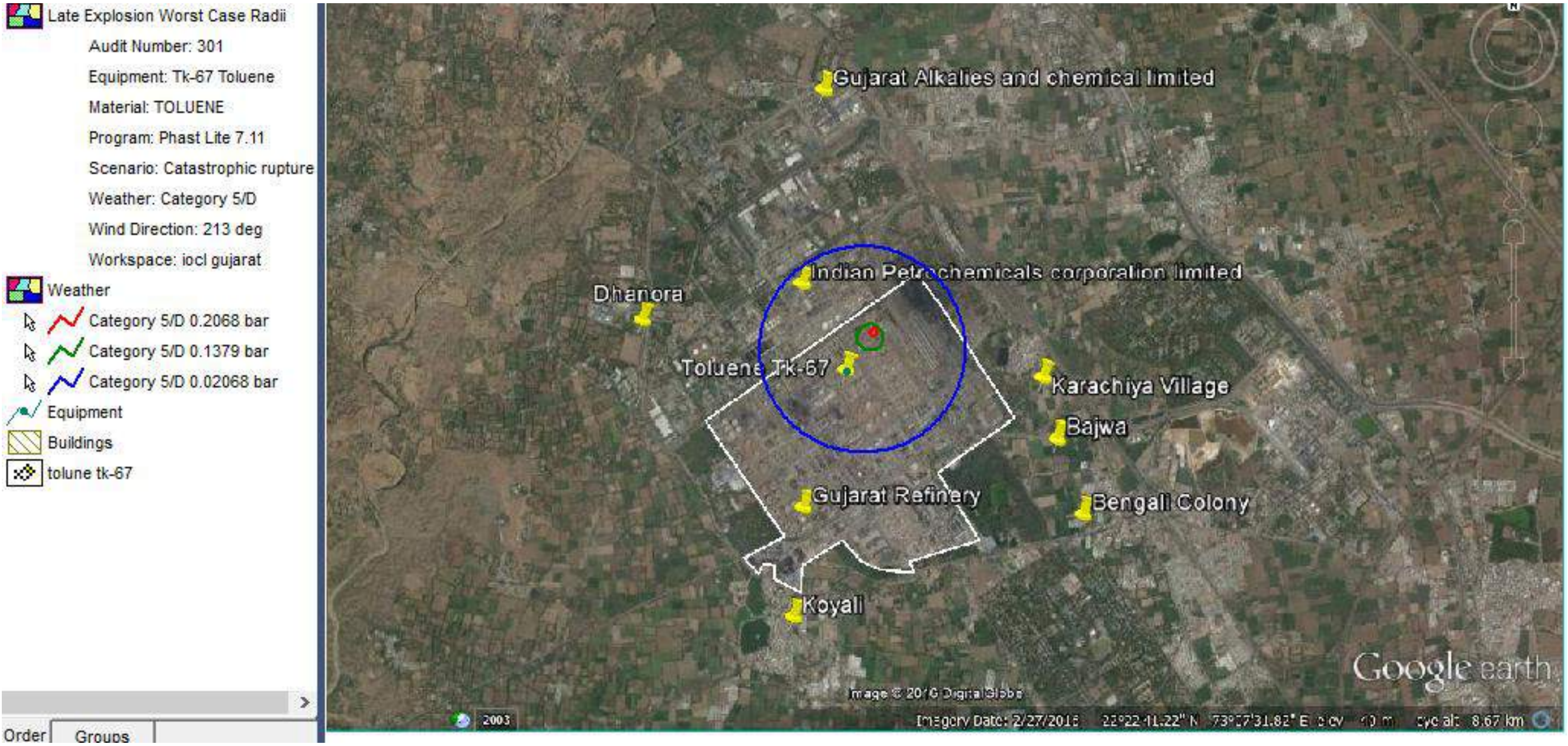


Intensity Radii for Late Pool Fire
Catastrophic rupture
Category 5/D 4 kW/m2
Category 5/D 12.5 kW/m2
400
200
0
-200
-400
Distance Crosswind [m]
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
1200
Distance Downwind [m]

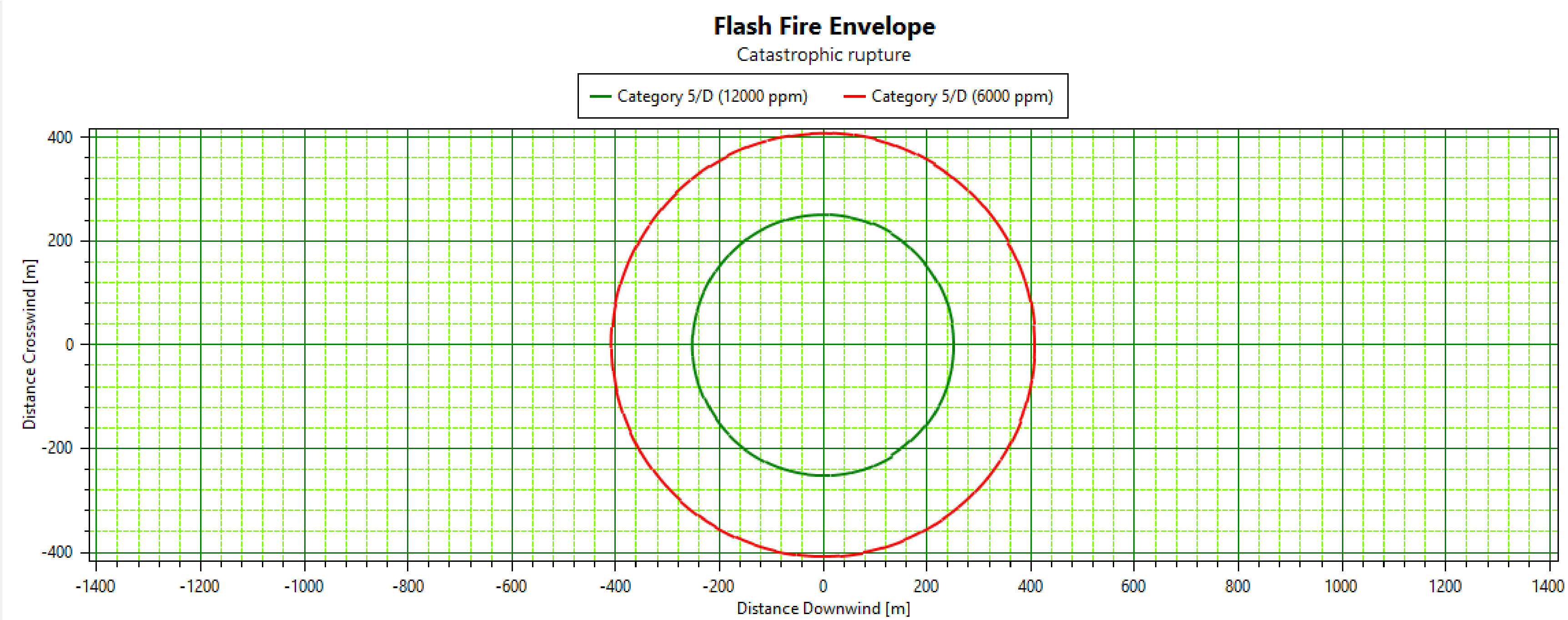


Case-3 Late Explosion worst case for rupture of Toluene tank

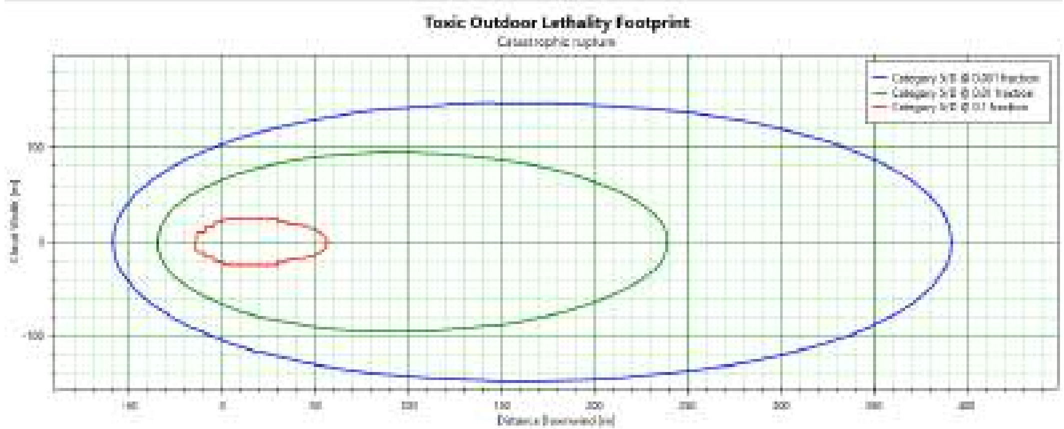

Late Explosion Worst Case Radii
Catastrophic rupture
Category 5/D 0.02068 bar
Category 5/D 0.1379 bar
Category 5/D 0.2068 bar
Distance Crosswind [m]
500
0
-500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
Distance Downwind [m]



Case-4 Flash Fire envelope for the rupture of Toluene tank

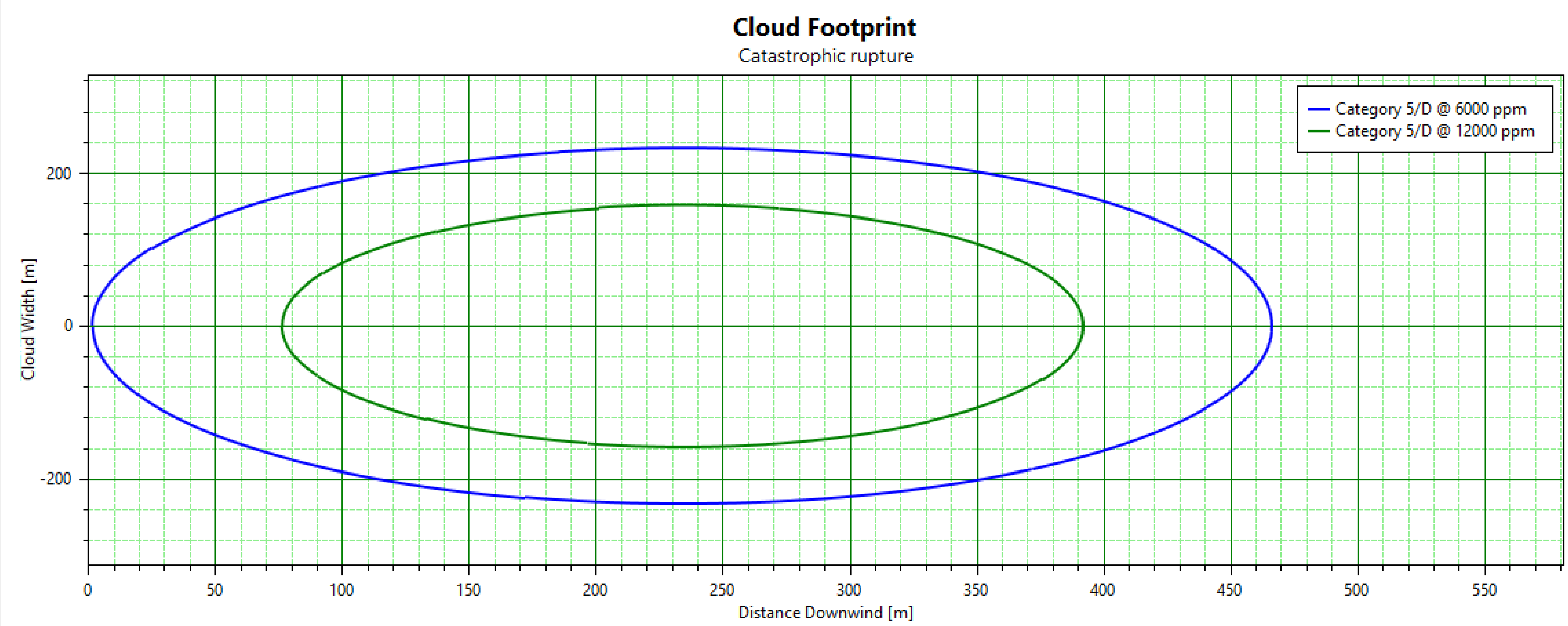

Flash Fire Envelope
Catastrophic rupture
Category 5/D (12000 ppm)
Category 5/D (6000 ppm)
400
200
0
-200
-400
Distance Crosswind [m]
-1400
-1200
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
1200
1400
Distance Downwind [m]

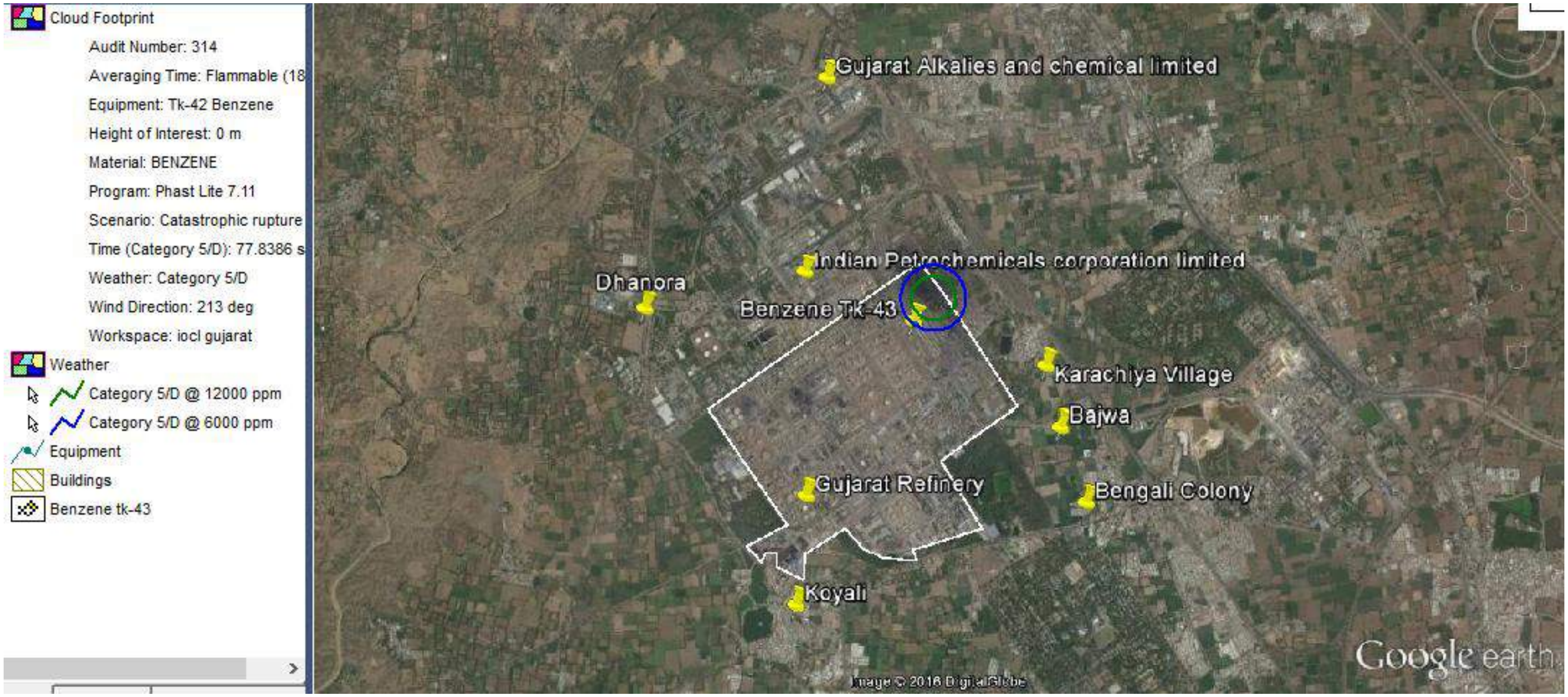
Case-5 Toxic outdoor lethality for the rupture of Toulene tank



<u>**Scenario-4 Rupture of Benzene tank Tk-43**</u>

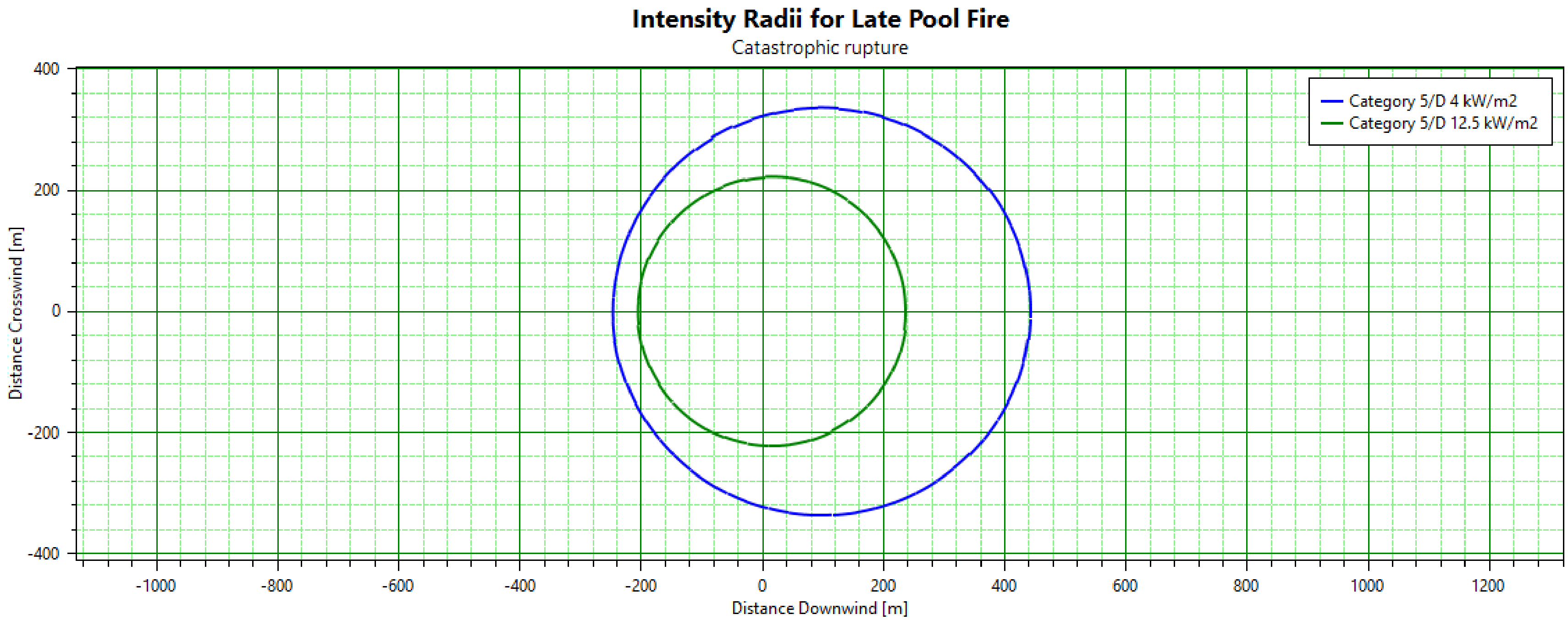
Case-1Dispersion of vapor cloud


Cloud Footprint
Catastrophic rupture
Category 5/D @ 6000 ppm
Category 5/D @ 12000 ppm
Cloud Width [m]
200
0
-200
0
50
100
150
200
250
300
350
400
450
500
550
Distance Downwind [m]



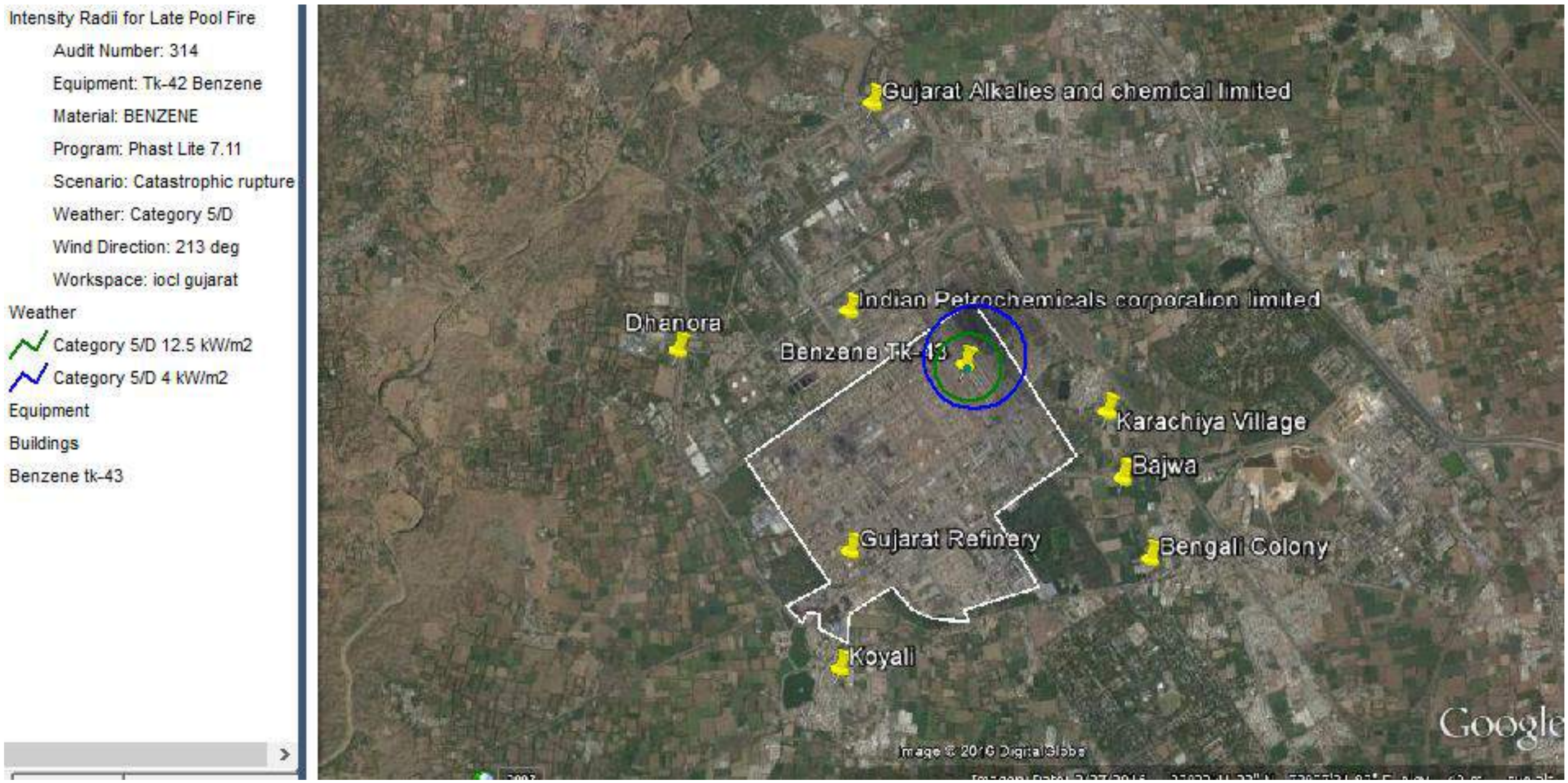
Case-2 Late pool fire

HECS

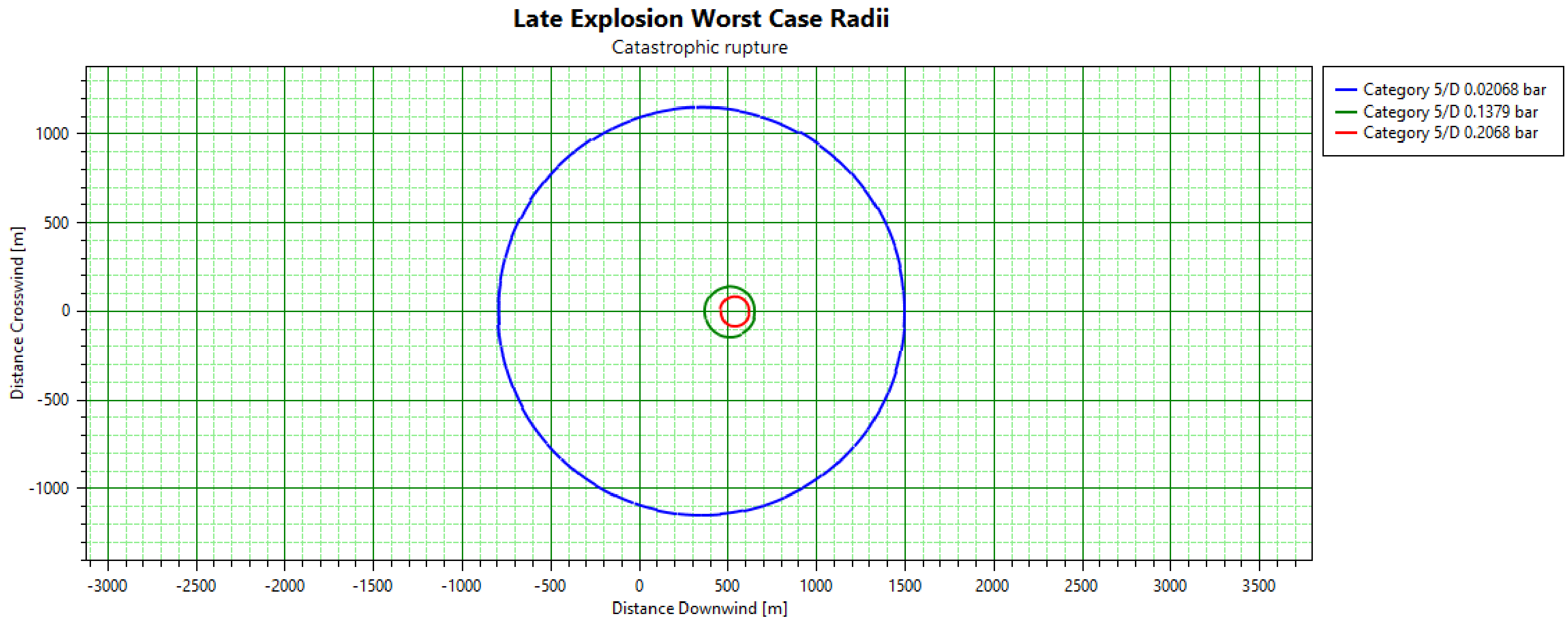


Intensity Radii for Late Pool Fire
Catastrophic rupture
Category 5/D 4 kW/m2
Category 5/D 12.5 kW/m2
Distance Crosswind [m]
400
200
0
-200
-400
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
1200
Distance Downwind [m]

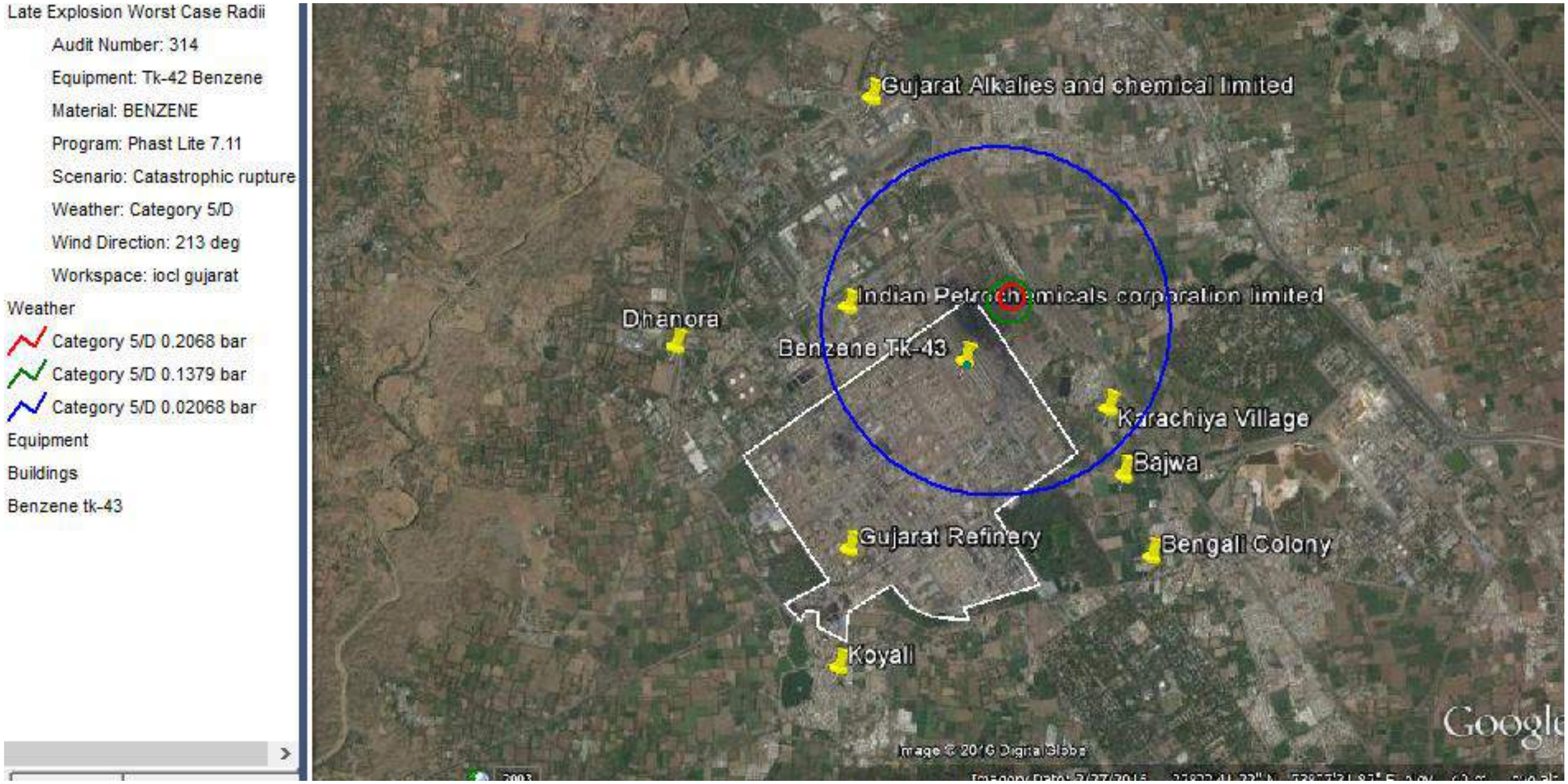
HECS



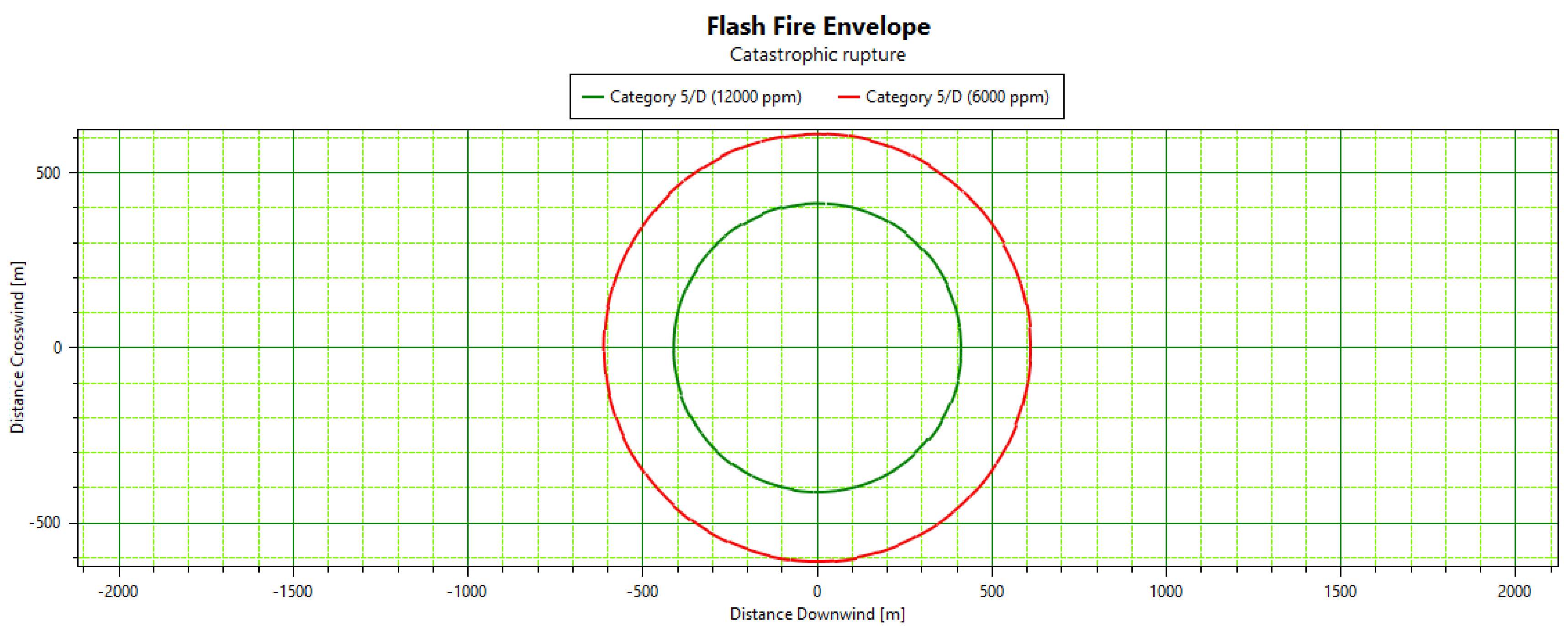
Case-3 Late explosion worst case

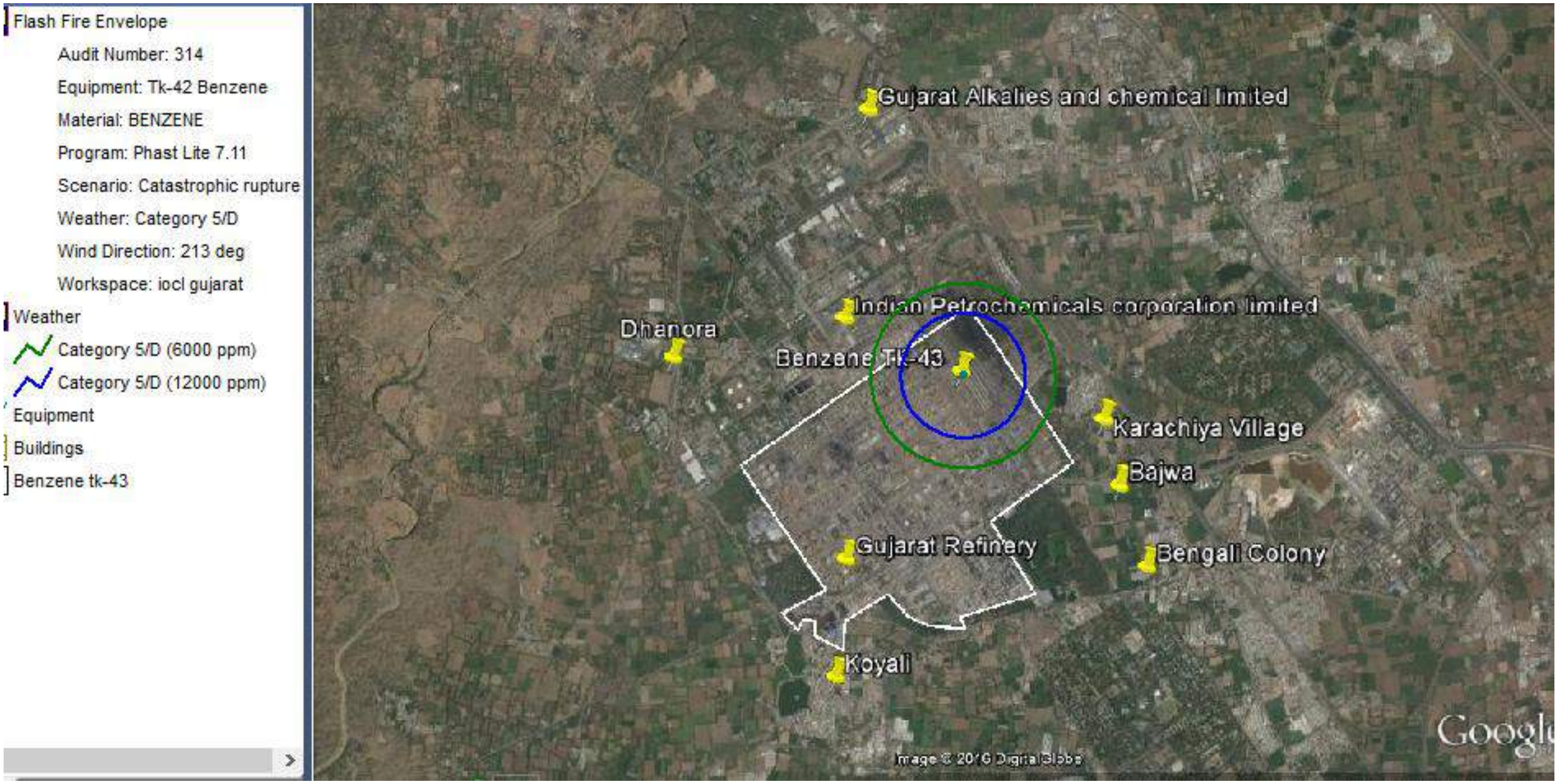


Late Explosion Worst Case Radii
Catastrophic rupture
Category 5/D 0.02068 bar
Category 5/D 0.1379 bar
Category 5/D 0.2068 bar
Distance Crosswind [m]
Distance Downwind [m]
1000
500
0
-500
-1000
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
3500

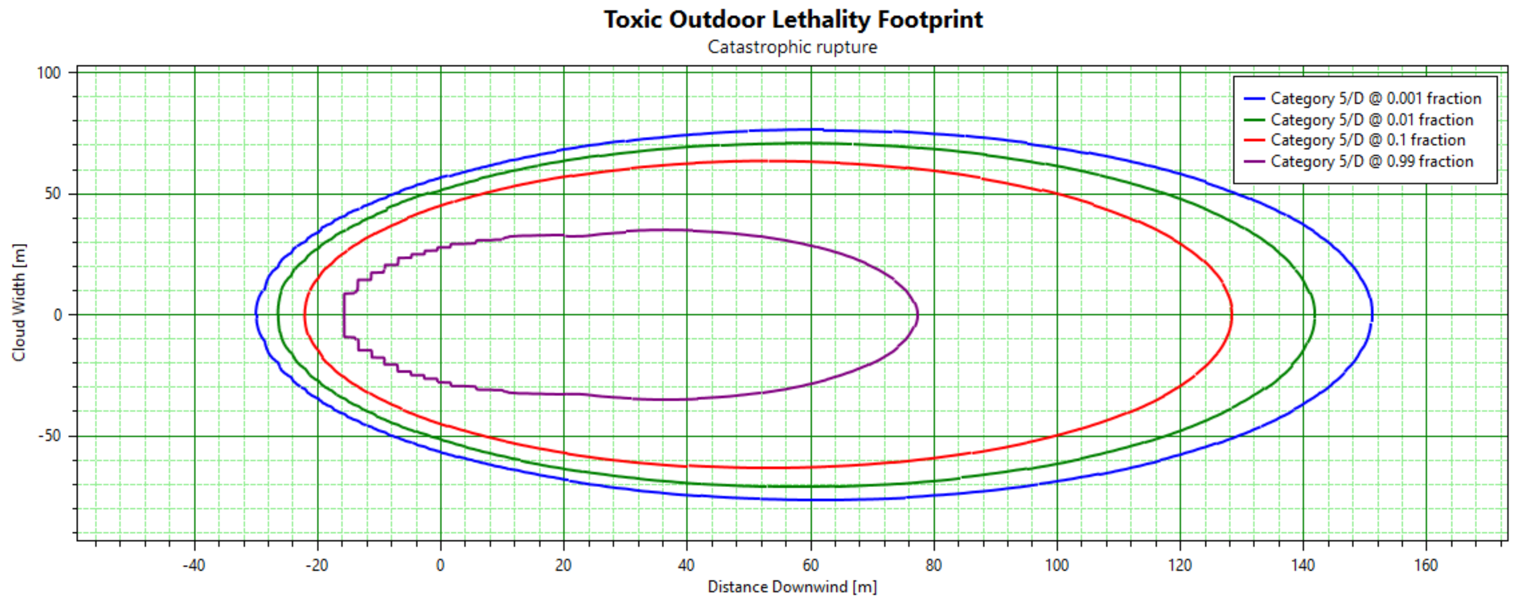


Case-4 Flash fire


Flash Fire Envelope
Catastrophic rupture
Category 5/D (12000 ppm)
Category 5/D (6000 ppm)
Distance Crosswind [m]
500
0
-500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
Distance Downwind [m]


Flash Fire Envelope
Audit Number: 314
Equipment: Tk-42 Benzene
Material: BENZENE
Program: Phast Lite 7.11
Scenario: Catastrophic rupture
Weather: Category 5/D
Wind Direction: 213 deg
Workspace: iocl gujarat
Weather
Category 5/D (6000 ppm)
Category 5/D (12000 ppm)
Equipment
Buildings
Benzene tk-43
Gujarat Alkalies and chemical limited
Indian Petrochemicals corporation limited
Dhanora
Benzene TK-43
Karachiya Village
Bajwa
Gujarat Refinery
Bengali Colony
Koyali
Image © 2016 DigitalGlobe

Case-5 toxic outdoor lethality



5 SUMMARY & CONCLUSION

1. The consequence analysis is performed for the highest storage capacity tanks such as Motor spirit, Naphtha, benzene, Toluene.
2. It is observed that motor spirit and naphtha impacts are outside the refinery which will be mitigated with offsite emergency response plan.
3. The disaster management shall be implemented during any fire hazard. The detailed report is attached in **Annexure- 15.**

5.1 Risk Reduction Measures

1. Proper inspection of small and bigger lines and tankers periodically.
2. Small leaks could occur frequently in routine operations like pump seal failure, sample point valve or drain valve left open, flange leak etc. They should be attended to immediately as they could escalate.
3. All interlocks should be kept and maintained in working condition at all times.
4. Emergency procedures should be well rehearsed and state of readiness to be achieved.
5. Ventilation should be provided for pump houses and any enclosed area where hydrocarbon vapours may accumulate.
6. Adequate number of portable fire extinguishers may be provided. These should be well maintained and easily accessible.
7. In locations where flammable vapours may be present, precautions should be taken to prevent ignition by eliminating / containing source of ignition. Source of ignition may include open flames, lightening, smoking, cutting and welding operations, lighting / hot surfaces, frictional heat, sparks (static, electrical and mechanical), spontaneous and radiant heat.
8. Smoke thermal detectors will be placed in the false ceiling and false flooring of the Control Room.