American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Capability of GIS in the Analysis of Explosion Hazard from BLEVE Event in LPG Terminal

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Abstract

Geographical Information System (GIS) is getting popular in controlling of risk in chemical installations for handling hazardous substances. The capability of GIS is to combine image map with the corresponding information at each level offering is being recognized as a new dimension to the management of industrial safety and environment surrounding. Catastrophic failure of liquefied petroleum gas (LPG) terminal is always regarded to failure its storage tank. A BLEVE is recognized as one of the worst type accidents cause of life and property. Consequences of BLEVE event are rapid and include peak over pressure from the blast, missiles projection from ruptured vessels and broken structures. This paper emphasizes on a methodology to evaluate effects of peak over pressure and missiles events from the BLEVE hazard due to catastrophic failure of a storage tank which filled by 140 tons of LPG. TNT model and selected equations are used to estimate the probability of fatality and structure damages and GIS techniques is used as a tool for analysis explosion due to a BLEVE event in LPG terminal. The developed technology capable to estimate explosion effects from a BLEVE event in which the result of consequences are plotted by buffer zones 10%, 50%, and 90% likelihood for managing risk in an industrial zone. Stakeholders can make use the developed technology for mitigating risk of LPG explosion in a LPG terminal and also for future land development in the areas outside of an industrial zone.

Keywords: LPG; GIS; BLEVE; Probit; Explosion.

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1. Introduction

LPG is the abbreviation or short form of liquid natural gas. It comprises of two major mixture of hydrocarbon (propane and butane) stored in liquid form under pressurised conditions in steel cylinders or bulk storage tanks. Utilisation of LPG seems more attractive than other liquid and solid fuels due its clean burning, simplicity of its plant design and operation, ease of its handling; and plant operation, available in potable cylinders or can be supplied by pipeline system from bullets or spheres tanks. Release of LPG from its installations due to failures of pipework or vessels could propagate to emergency situations and ultimately to fire and explosion disaster. Fire is the most common but explosion is more significant in terms of its damage potential, often leading to fatalities and damage to property. The most severe LPG disaster in history was Mexico City on 1984. At the time of the disaster the complete storage may have contained (11,000-12,000) m^3 of LPG. Approximately 500 people were killed and over 7,000 were seriously injured [1]. The development in geographic information system (GIS) technology has come a long way in the past decade. It was first introduced by Canadian Government in early 1960 [2] GIS can provide a comprehensive database of contaminated site conditions, tool for spatial and customized interface of risk assessment, and visual presentation of modelling results and site conditions. Especially, integration of the risk assessment results with spatial land-use information will be helpful for identifying and assessing hazard impacts on specific receptors through various exposure pathways, where map can be valuable for risk analysis.

This paper presents an application of mathematical models with integration of GIS to evaluate the final events hazards i.e blast wave from the Boiling Liquid Expanding Vapour explosion BLEVE/ and fragmentations.

2. Explosion Assessment of LPG

The main damage effect of any flammable gas accident is results of blast wave coming from explosion due to BLEVE/fireball. A blast wave generated from an explosion in air that is accompanied by sudden rise in pressure. Pressure effects are limited in magnitudes and thus, the main interest is to predict domino effects on adjacent vessels and equipment rather than assessing harm to neighbouring communities. The blast effects can be estimated from the TNT equivalence method. The blast wave generated by an explosion event may cause building damage or personnel injury. Workers may be injured as a result of direct or indirect effects of an explosion. Direct effects result from direct exposure to the blast wave generated from an explosion. For example, eardrum rupture and lung haemorrhage can occur from direct exposure to excessive overpressures. Pressure effects are usually limited to a small area and the effect of pressure on the environment is therefore seldom discussed. When people are killed due to blast waves, it is usually because objects fall on them. Indirect effects of an explosion include injuries resulting from building damage (e.g., collapse of a wall or root) or flying fragments. The same discussion as for humans is also valid, for both the general environment and animals; namely any adverse effect or injuries are more dependent on being hit by a flying object [3]. This present paper is concerns with calculating the potential hazards to humans and constructions.

2.1 Estimation the Explosion Hazards

The TNT equivalent model has been widely used to model vapour cloud explosions. An early application was that of Brasie and Simpson [4], who used it to study the damage from three accidental explosions. Crowl D. and Louvar J, [5] used TNT method to estimate the damage for common structures and process equipment. This damage is result of the explosion. The explosion is involving peak overpressure and flammable material. The TNT is the easier model and it is based on the assumption of equivalence between the flammable material and TNT, factored by an explosion yield term. An equivalence mass of TNT is calculated using the following equation [6].

$$m_{TNT} = \frac{\eta m \Delta H_c}{E_{TNT}} \tag{1}$$

where

m_{TNT} is the equivalent mass of TNT (*kg*),

η is the empirical explosion efficiency (0.01-0.10),

m is the mass of explosive (*kg*),

ΔH_c is the lower heat of combustion (*kJ/kg*) and

E_{TNT} is the energy of explosion of TNT, (*kJ/kg*).

The distance to a given overpressure is calculated from the equation (Ozog, 1996):

$$r = 0.3967 \times m_{TNT}^{1/3} \exp\left[3.5031 - 0.7241 \ln(p_o) + 0.0398 (\ln p_o)^2\right] \tag{2}$$

where

r is the distance, (m),

ΔH_c is the lower heat of combustion $(kcal/kg)$ and

p_0 is the peak overpressure (Psi),

The logic diagram for using TNT method for calculation on the effects of peak overpressure from explosion hazard is summarized in Figure 1.

The TNT equivalence predicts peak overpressure with distance. It should be noted that the pressure depends strongly on the distance between the place of the explosion and the structure. Depend on locations of the explosive charge., the consequences of same explosive charge give very different overpressures The principal parameters of the blast wave from TNT explosion are the peak overpressure, p_0, the impulse of the positive phase duration, i_p and the duration of the positive phase of t_d [7,8], have given their values of the peak overpressure, impulse and duration time from an explosion of 1 *kg* of TNT in the form of network equations.

The scaled peak over pressure:

$$p_s = \frac{808\left[1+(z/4.50)^2\right]}{\left[1+(z/0.048)^2\right]^{0.5}\left[1+(z/0.32)^2\right]^{0.5}\left[1+(z/1.35)^2\right]^{0.5}} \tag{3}$$

for the impulse:

$$i_p = \frac{0.067\left[1+(z/0.23)^4\right]^{0.5}}{z^2\left[1+(z/0.32)^3\right]^{1/3}} \tag{4}$$

and for the scaled duration time:

$$t_d = m^{1/3}\frac{980\left[1+(z/0.54)^{10}\right]}{\left[1+(z/0.02)^3\right]\left[1+(z/0.74)^6\right]\left[1+(z/6.9)^2\right]^{0.5}} \tag{5}$$

where

p_s : is the scaled peak over pressure,

i_p : is the impulse $(bar.ms)$,

t_d : is the duration time (ms),

m : is the mass of explosive (kg) and

z : is the scaled distance (m/kg)

In order to estimate the consequences of an accident on people, a function relating the magnitude of the impact, usually, the method used is the Probit analysis, which relates the Probit (from "probability unit") variable to the probability. Probit analysis has been widely used to express injury relations [9, 10. 11, 12, 13.,14]. The Probit variable Y, is a measure of the percentage of a population submitted to effect with a given intensity (V) which will undergo certain damage. This variable follows a normal distribution, with an average value of 5 and a normal deviation of 1.

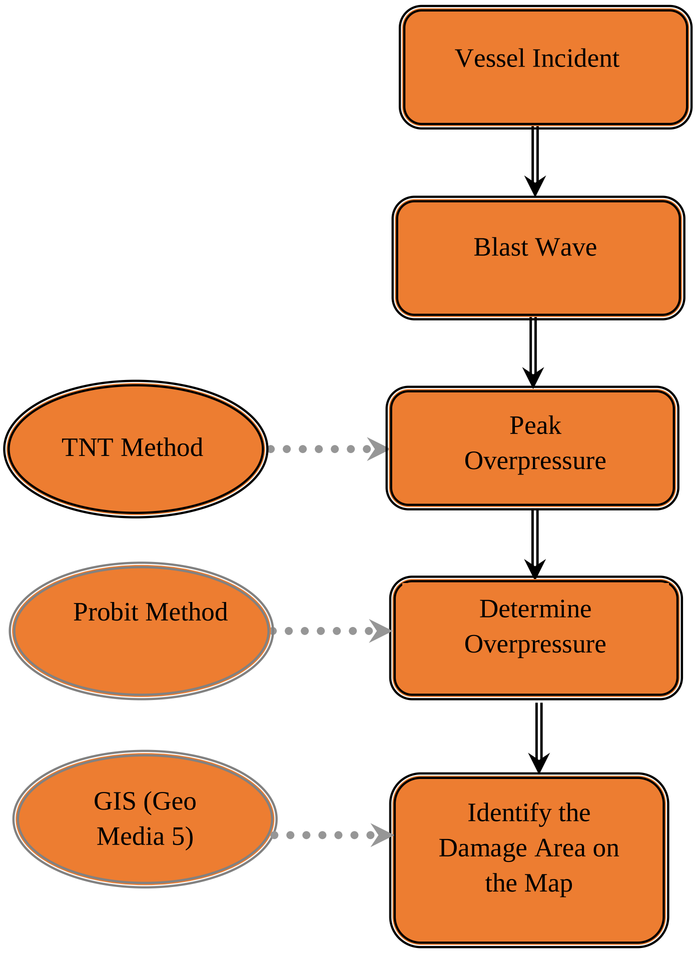

Figure 1: Logic diagram for the calculation the peak overpressure and its harm as result from explosion hazard.

The relationship between the Probit variable (*Y*) and the probability (P_r) is the following [15]:

$$P_r = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{5} \exp\left(-\frac{V^2}{2}\right) dV \qquad (6)$$

Eq. (6) provides a relationship between the probability P_r and the Probit variable *Y*. for spreadsheet computations a more useful expression for performing the conversion from Probits to percentage is given by [4]:

$$P_r = 50\left[1 + \frac{Y-5}{|Y-5|} erf\left(\frac{|Y-5|}{\sqrt{2}}\right)\right] \qquad (7)$$

where *erf* is the error function and for rational approximation for digital computation becomes:

$$erf(x) \approx 1 - \left(a_1\phi + a_2\phi^2 + a_3\phi^3\right)\exp\left(-x^2\right) + \varepsilon \qquad (8)$$

where:

$$\phi = \frac{1}{(1+\alpha x)} \quad ; \quad \alpha = 0.47047 \quad ; \quad a_1 = 0.34802 \; ; \ldots\ldots\ldots\ldots\ldots \quad (9)$$

$$a_2 = -0.09587 \; ; \quad a_3 = 0.74785 \quad \text{and} \quad \varepsilon \le 2.5\times10^{-5}$$

Most of the previous works about Probit analysis [12, 13. 14, 15, 16, 17]. The following expression is normally used to calculate the value of *Y*:

$$Y = a + b\ln V \qquad (10)$$

where Y is the Probit variable, *a* and *b* are constants which are experimentally determined from the information on accidents, or, in some cases, from experimentation with animals. V is a measure of intensity of the damaging effect; it can be just one parameter (for example, the overpressure in this case) or a combination of various parameters (for example, the concentration and time in toxic gas release).

2.2 Effects of Overpressure on Humans and Constructions

The direct effects of overpressure on humans are eardrum rupture, lung haemorrhage, whole body displacement injury and injury from shatter glasses. It must be remembered that the most likely harm to people in an explosion results from the indirect effects of them being inside or close to a building or wall when it collapses. The typical causes from explosion are; (i) burning, (ii) fragments hitting the people, (iii) buildings or other structure falling down or being disintegrated, (iv) people falling or “flaying” and subsequently hitting a solid object. The Probit equation for eardrum rupture is giving by Eq. (11) [9]:

$$Y = -15.6 + 1.93\ln p_o \qquad (11)$$

Direct blast effects, particularly lung haemorrhage have been studied by Eisenberg *et. al*., (1975):

$$Y = -77.1 + 6.91\ln p_o \qquad (12)$$

The shattering of window glass is an important blast damage effect, since the flaying glass can cause severe injury to human. There have been a number of experimental and theoretical studies of the behaviour of shattering and flying glass and also studies of glass breakage following accidental explosions. [9] gives Eq. (13) to estimate the glass breakage from peak overpressure:

$$Y = -18.1 + 2.79\ln p_o \qquad (13)$$

Eisenberg *et. al*., (1975) have derived a Probit equation relating lethality for body translation to impulse:

$$Y = -46.1 + 4.82 \ln J \quad (14)$$

with: $$J = \int_0^{td} p_0(t)dt \quad (15)$$

where:

J is the impulse $(Pa.s)$

p_0 is incident overpressure (Pa)

Structural damage caused by blast waves from explosions has traditionally been correlated in terms of the peak overpressure of the explosion. The effects of the blast damage on the construction are based on the determination of the peak overpressure resulting from the pressure wave. Good estimates of blast damage, however, can be obtained using just the peak overpressure. It is important to know that the small structures suffer less from diffraction loading because the time interval in which the shock wave envelopes the object may be less than the plastic response of the object to differential loading. For very large buildings and structures, differential loading may cause damage ranging up to complete destruction. Damage to a building in the case of an accident gas explosion is not a serious problem as long as the building is not collapsing or dangerous fragments are not generated within or from the building. The following Probit equation has been applied for determine effect of building damage due to gas explosion [9]:

$$Y = -23.8 + 2.92 \ln p_o \quad (16)$$

2.3 Fragmentation Hazards

When the explosion occurs in a close system, fragments of the containment may form missiles. Therefore it's important to consider the analysis of the fragments generated by the explosion hazard. Lees [7] has indicated that there were 113 events involving fire on which sufficient information was available and of these 89 involved fragment generation. Fragmentations are potentially the furthest reaching immediate hazard from a blast wave and BLEVE. Fragmentations are also one of the most difficult hazards to quantify accurately because of their random behaviour [18]. Projectiles will generate from a blast wave, which are parts of the rocket or buildings. These can travel distances up to the order of kilometres. Basically there are two kinds of projectiles: (i) Primary projectiles which are major pieces of the tank and (ii) Secondary projectiles which are generated by the acceleration of nearby objects (attached pipe, support legs, other attachments, adjacent structures or objects, etc.). The fragments can travel considerable distances and they are sometimes accompanied with quantities of burning LPG. Analyses of the travel range of fragment missiles from a number of BLEVEs suggest that the majority land within 700 *m*. Some, however, have been observed at over 1000 *m* from the site. The direction is difficult to predict but there is some evidence that cylindrical vessels tend to more likely to travel in the direction of their longitudinal axis [19]. The risk of missile damage is often low because the probability of being is very low. However, if a large missile impacts there is a good chance for a domino event to result. It would usually be assumed that being hit by a large missile will result in death or severe damage to construction [18].

2.4 Blast Wave Hazard

A blast wave is the result of an explosion in air that is accompanied by a very rapid rise in pressure. Pressure effects are usually limited in magnitude and are thus of interest mainly for prediction of domino effects on adjacent vessels and equipment rather than for harm to neighbouring communities. The blast effects can be estimated from the TNT equivalence method. The blast wave generated by an explosion event may cause building damage or personnel injury. Personnel may be injured as a result of direct or indirect effects of an explosion. Direct effects result from direct exposure to the blast wave generated from an explosion. For example, eardrum rupture and lung haemorrhage can occur from direct exposure to excessive overpressures. Pressure effects are usually limited to a small area and the effect of pressure on the environment is therefore seldom discussed. When people are killed due to blast waves, it is usually because objects fall on them. Indirect effects of an explosion include injuries resulting from building damage (e.g., collapse of a wall or root) or flying fragments. The same discussion as for humans is also valid, for both the general environment and animals; namely any adverse effect or injuries are more dependent on being hit by a flying object (Andersson, 1995).

2.5 Estimation the Fragmentation Hazards

It is possible to make approximate estimates of the behaviour and effects of the fragments from the container in which an explosion has occurred. The problem is considered under the following aspects; size, number, velocity, energy and range. This paper is discussed the danger distance, safety distance and projectile ranges.

According to [20] as a crude approximation, projectile ranges it can be related to the fireball radius. The following is suggested as a guide:

• 80 to 90% of rocketing fragments fall within 4 times the fireball radius.

• Severe rocketing fragments may travel up to 15 times the fireball radius.

• In very severe, rare cases, rocketing fragments may travel up to 30 times the fireball radius.

For estimating the danger areas, [21] has been assumed that the local public will have access to most places outside. The formula below has been given for danger areas where the public have access to the immediate area:

$$r_d = 634(m)^{1/6} \qquad (17)$$

where:

r_d is range, (*m*) and

m is weight of the explosive material, (kg)

The fragmentation zone safety distance should be calculated to reduce the risk of harm from fragmentation thrown out from the explosion to those working on the worksite and to the local population. Theoretical methods can be used, but the calculation of fragmentation hazards zone areas is a more complex operation than that for blast hazard zone. [8] suggest a very simple formula for estimating a safety distance from a bomb explosion:

$$r_s = 120 m_{TNT}^{0.33} \tag{18}$$

where:

r_s is the safety distance from missiles, (90 m minimum)

It is well to know that, some explosion creates a crater and in this case fragments are ejected. A treatment of the fragments from cratering has been given by [22]. For the maximum range of fragments Richmond and Fletcher give the following equations:

$$R_r = 70 m_{TNT}^{0.4} \quad \text{:Rock} \tag{19}$$

$$R_s = 30 m_{TNT}^{0.4} \quad \text{:Soil} \tag{20}$$

where:

R is the maximum range, (ft) and

m_{TNT} is the equivalent mass of TNT, (lb)

2.6 Estimation the Effects of the Missiles on Humans

The risk of missile damage is often low because the probability of being hit is very low. However, if a large missile impacts on process plant there is a good chance that a domino event will result. It would usually be assumed that being hit by a large missile will result in death or severe damage to equipment. Fatality probability for human from missiles can be found from Eq. (27). This equation is using to calculate the average fatality probabilities for humans at distance from the detonation of high explosives (Merrifield, 2000).

$$H_p = 0.286 \ln[0.01m].e^{-0.01r} \tag{21}$$

where:

H_p is the average fatality probability for humans,

m is quantity of explosive material, (kg), and

r is distance/range, (m).

Lees, (1996) gives the following Probite for injury from missiles.

$$Y = -27.1 + 4.26 \ln J \tag{22}$$

The logic diagram for the calculation the fragmentation hazards is presents in Figure 2.

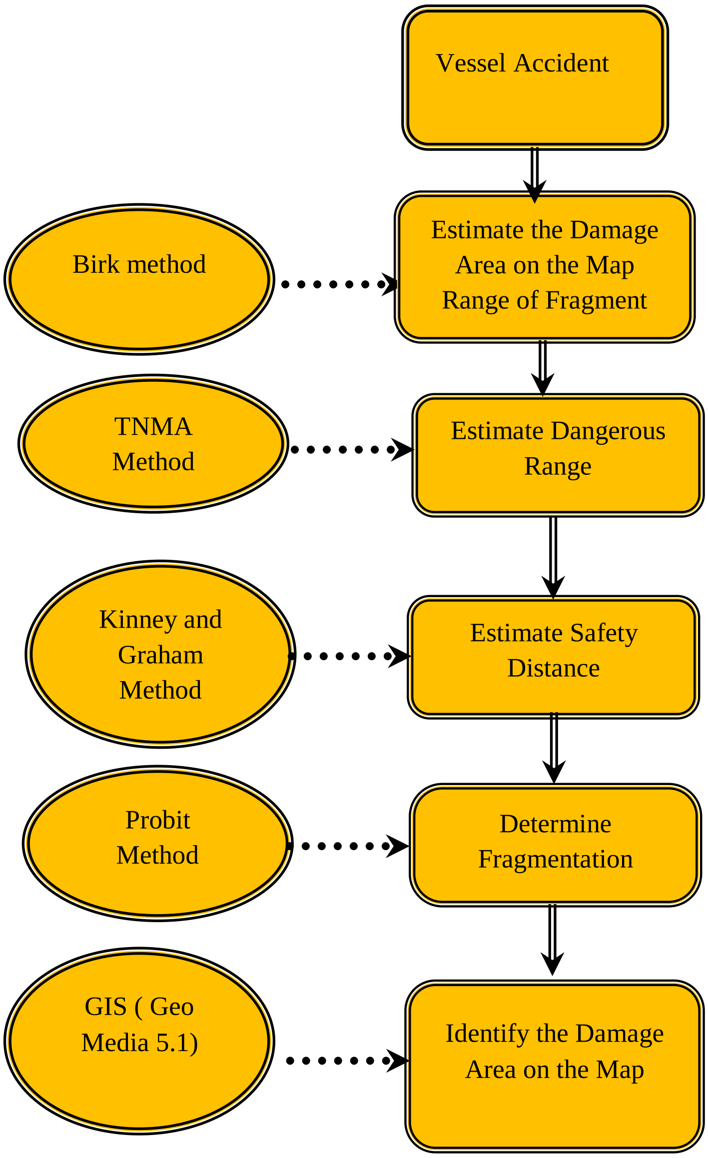

Figure 2: Logic diagram for the calculation the fragmentation hazards as result from vessel incident.

3. Case study

Geomedia Professional 5.1 was used to model an explosion due to BLEVE/fireball and the impact of the of the explosion in the area surrounding of a LPG terminal. The terminal is divided into five distinct areas: Unloading shed, LPG Storage area. The terminal is divided into five distinct areas: Unloading shed, LPG Storage area: LPG filling facility; Administration office , warehousing and utilities; and firewater system area. A LPG filling facility is located at the middle of the terminal, 15 m toward west of the administration building. The system comprise of LPG filling pump shed, air compressor shed and LPG filling hall. LPG consist 40% propane and 60% butane. There was an average amount 140 metric tones (MT) of LPG stored in a bullet type tank. It was transferred through outlet connections to an eight inch collection header towards the LPG filling pump shed which is located on the east side of the storage bullet, outside the bounded area. The pump shed consists of 4 pumps (three on duty, one standby) which each having a pumping capacity of 30 m^3/hr. The filling area is designed with high roof with open sides to allow for high ventilation rate and rapid dilution of any potential release of LPG vapor in the filling hall. A manually activated deluge system is provided to allow dispersion of any major leaks. The potential accidents that can occur at the LPG facility and thus, chance to release LPG was assessed from a combination of past history of release from similar installations and their specific information from hazard identification. Causes of failures were found due to failure of hose, failure of mobile tanker component, failure of connecting system, failure of breakaway coupler, tanker departed while connected, human error [23]. Basically this paper is arranged into four main parts. First part is identification catastrophic accident whereby it is due to the overpressure and fragmentations from the BLEVE/fireball.in LPG terminal. Second part is a modelling and estimation of explosion hazard. The third part is construction of a working GIS software environment that gives integration interface for the selected equations and procedures that are used to evaluating the hazard effect and the fourth parts is creation map for a target source.

3.1 GIS For Risk Assessment

An important element is the preparation of topical maps, using local GIS data around the accident site and for this case of study it was an industrial zone in Malaysia. Maps, as a familiar format, are an effective basis for the communication of complex information by providing a familiar context. The most restrictive definition insists that a GIS must have a spatial data structure with topology, with geographic features linked to a relational database management system. Spatial analysis is the strength of GIS as is its ability to manipulate spatial data. With the facilities of handling large quantities of spatially referenced data and properly structured database, the GIS is able to manage, analyse, and display large multidisciplinary data sets for various applications with their geographical-related information. The role of the GIS, therefore, is to allow a modeller to visualize development changes to the landscape and to produce resultant input values for the individual models and create a map of a target source.

3.2 Developing GIS System for LPG Case Study

GIS enables the integrated model to handle the data management, computational aspects and the integrated needs as emphasized in the hazards approach. The data used in the creation of a GIS database include a location map of the LPG tank. The map module is prepared for storing various types of GIS-related maps, such as the buildings, roads, stations, lakes and etc. The techniques allow the identification of areas that are affected by accidents. Building a database consists of three major steps: (a) identifying the geographic features, attributes, and required data layers; (b) defining the storage parameters for each attribute; and (c) ensure co-ordinate registration. The collection of cartographic data can be achieved by any of the alternative procedures: extent maps through digitizing, scanning, photogrammetric procedures or terrestrial surveying measurements. The results from the mathematical models can be linked with GIS software to create the hazard vulnerability maps. Figure 4 shows the building of the database into GIS to get the graphical results.

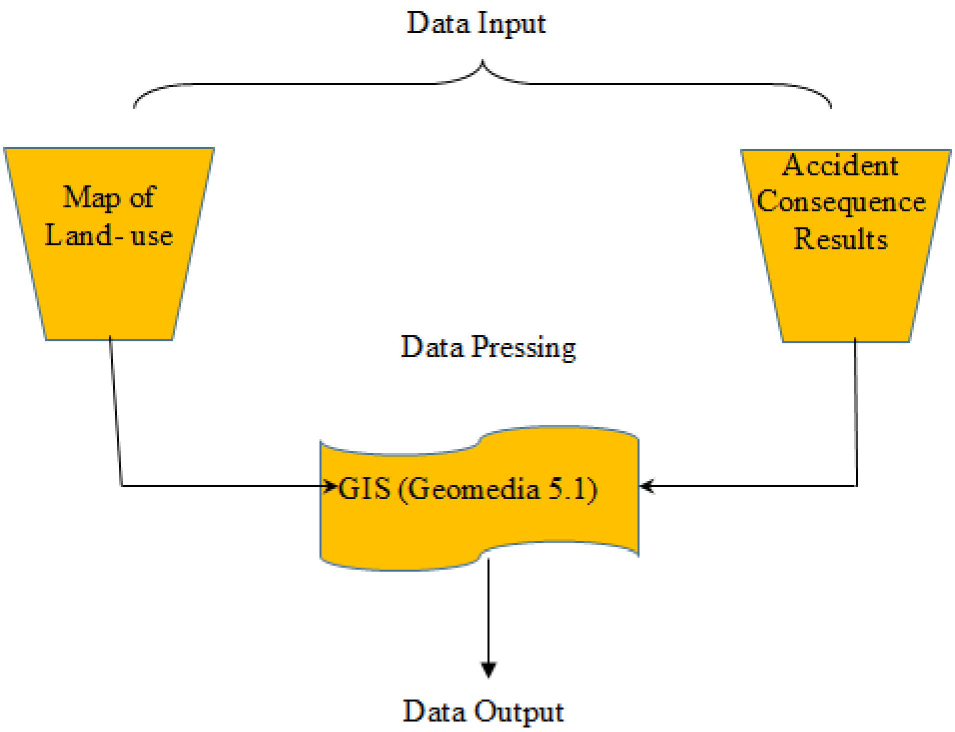

Figure 4: Simplified architecture of GIS at an Industrial Zone in Malaysia

The data used in developing of a GIS database include a map of place LPG terminal of an industrial zone. The map module is prepared for storing various types GIS related maps such as main road, highway, river and lots in the industrial zone (emphasized in Figure 5 and Figure 13. The applied techniques permit the identification of areas that are exposed by the accidents. There are three steps to generate a database which are identifying the geographic features, attributes and required data layers; defining the storage parameters for each attribute and ensuring co-ordinate registration.

4. Result and Discussion

As discussed earlier, there are two major hazards are concerned for this discussion; peak overpressure and fragments generated from blast wave from BLEVE/fireball. It was envisaged that the blast was due to BLEVE whereby all of LPG (140 metric) contained in the storage tanks was jetted to atmosphere after the tank broken and immediately ignited and exploded. The peak overpressure from the blast was calculated based on TNT model which is the simplest model for calculating the explosion. Result of the calculation was plotted by buffer zones 10%, 50%, and 90% likelihood for further analysis of the consequences. Peak overpressure was calculated using Eq. (1) and the probabilities using Eqs. (7) to (10) for eardrum rupture, lung haemorrhage, glass breakage, lethality for body translation to impulse, and construction damage Three major hazards will be discussed also; peak overpressure, fragments generated from blast wave and thermal radiation emitted from BLEVE/fireball. TNT model is the simplest model used for calculating the peak overpressure from the blast wave hazard. The probabilities for human casualty or construction damage have been calculated using Probit functions. The probabilities likely were drowned as buffer zones for 10, 50, and 90 % likelihood to evaluate the exact geographical region where the consequences are most intense for the population. Geomedia Professional 5.1 is one of the GIS software and was used here to indicate the area to be affected by blast wave from explosion of LPG tank.

Table 1 gives the effects of thermal radiation on construction [5]:

Table 1: Effect of thermal radiation on construction

Thermal radiation $\left(kW/m^2\right)$	**Effect**	**Distance** (m)
37.5	Spontaneous ignition of wood after long exposure. Unprotected steel will reach thermal stress temperatures which can cause failures.	286
23-25	Non-piloted ignition of wood occurs.	346-360
25	Cable insulation degrades.	346
18-20	Piloted ignition of wood occurs.	385-405
12.5	Thermal stress level high enough to cause structural failure.	481
12.6	Minimum energy required for piloted ignition of wood, melting of plastic tubing.	488
12	Plastic melts.	491

The results of peak overpressure from Equation (2) and the probabilities from Eqs. (11) to (16) for eardrum rupture, lung haemorrhage, glass breakage, lethality for body translation to impulse, and construction damage have been summarized in Table 2 and illustrated in Figures 1 to 5 respectively. According to the results tabulated in Table 1, the 90 % likelihood of eardrum rupture, lung haemorrhage, glass breakage, lethality for body translation to impulse, and construction damage will cover 4418 m^2, 2552 m^2, 79 m^2, 184745 m^2 and 24053 m^2 of area around the LPG tank.

Table 2: Probabilities for human fatality or injury by peak overpressure

Human Effect	$r(m)$	$p_o(kPa)$	$ip\,(kpa.\text{sec})$	t_d (sec)	P_r (%)
Eardrum Rupture	219	17	0.03	0.58	10
	124	43	0.05	0.41	50
	75	109	0.07	0.27	90
Lung Haemorrhage	74	113	0.075	0.26	10
	65	147	0.083	0.24	50
	57	191	0.910	0.21	90
Death due to impulse	90	89	0.065	0.312	10
	68	164	0.080	0.246	50
	10	8140	0.141	0.007	90
Glass Breakage	1302	2	0.005	0.79	10
	782	4	0.008	0.78	50
	485	8	0.012	0.74	90
Construction Damage	386	10	0.019	0.833	10
	256	19	0.029	0.700	50
	175	36	0.043	0.554	90

People exposed in the open to the direct effects of blast appear to be able to withstand explosions rather better than most buildings. The probable total destruction of buildings will happen at overpressure equal to 68.9 *kPa*. These results from the blast wave hazard have been linked with GIS software and the areas of probable damage are displayed as circular buffer zones on a computerised map in Figures 1 to 5.

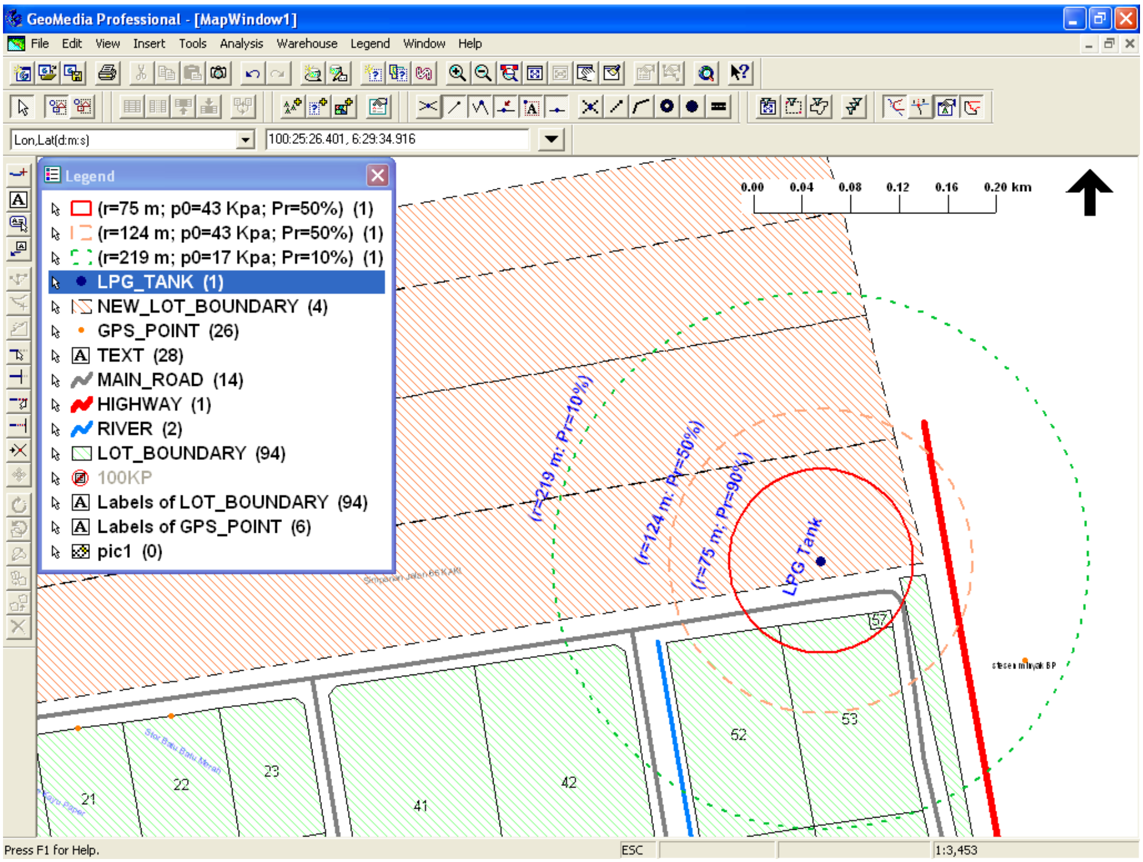

Figure 1: Buffer zones for probability of human eardrum rupture around LPG tank.

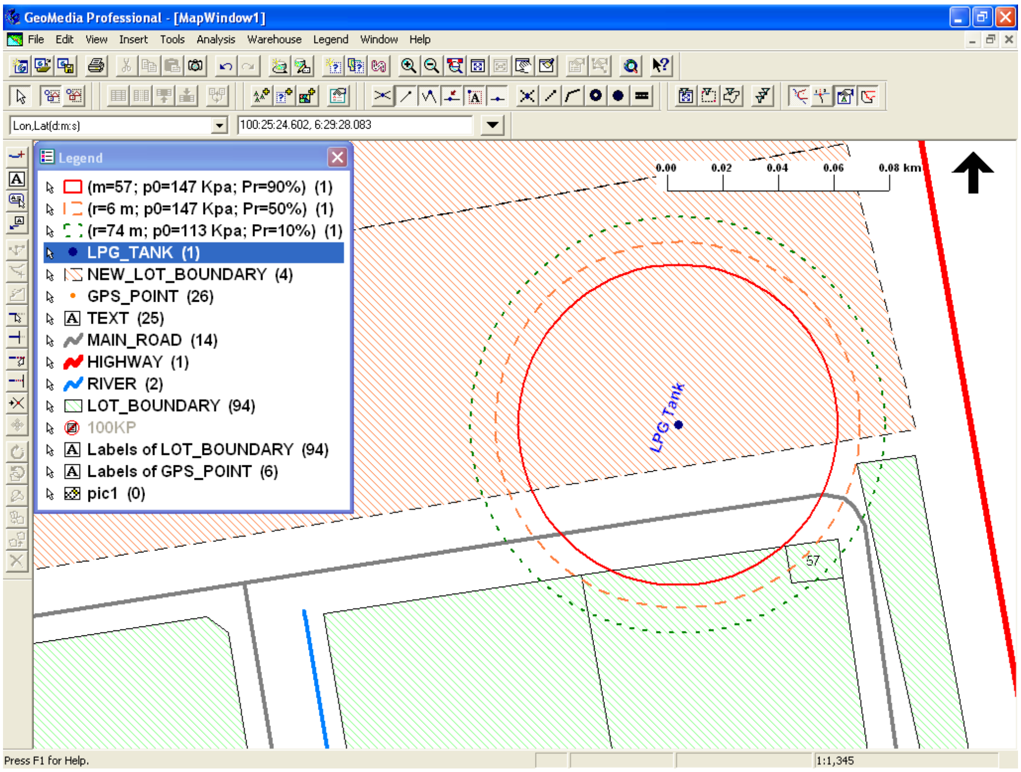

Figure 2: Buffer zones for probability of human lung haemorrhage around LPG tank

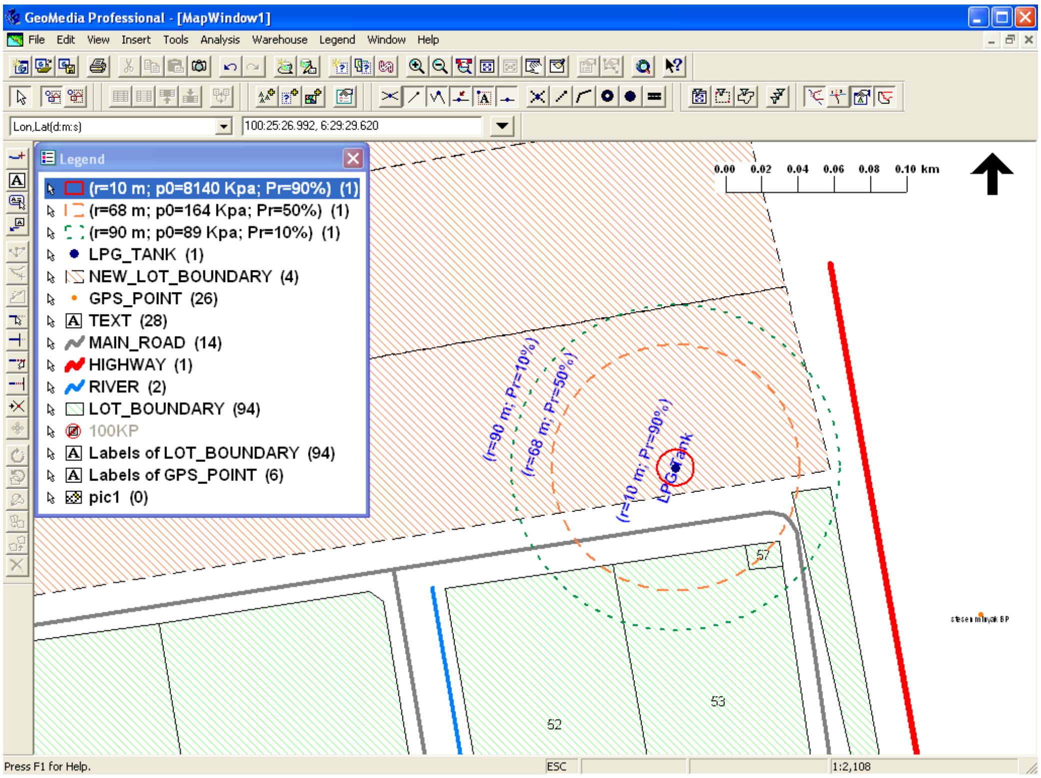

Figure 3: Buffer zones for probability of human fatality around LPG tank.

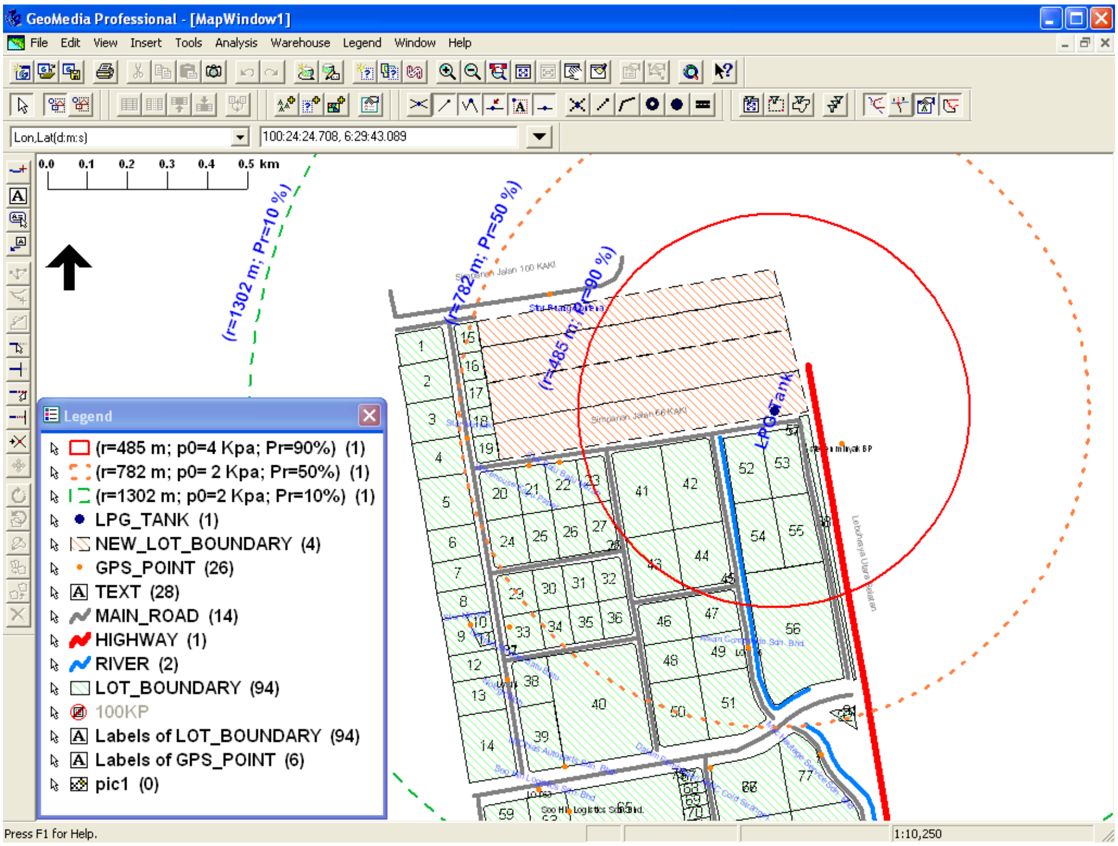

Figure 4: Buffer zones for probability of glass breakage around LPG tank.

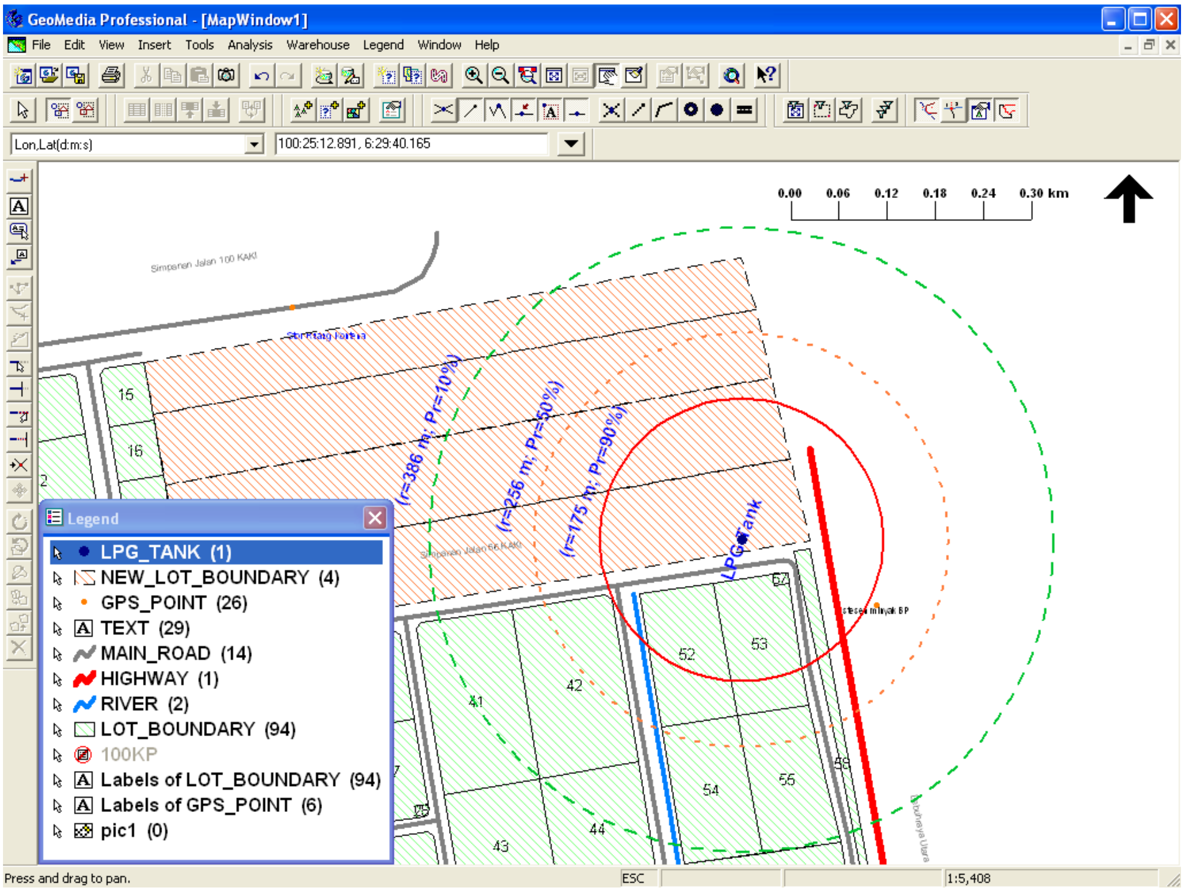

Figure 5: Buffer zones for construction damage around LPG tank (an industrial zone where numbers in the boxes are lots of land occupied by other industries)

For calculating the hazards from fragmentations shattered by explosion, the best estimation is done by Equations 23 and 24 to evaluate the danger and safety distances respectively. Furthermore information's have been given by Equations 25 and 26 to estimate maximum ranges of rocks and soils which can shatter and fly from the explosion. The results are indicated in Table 3.

Table 3: Fragments travel distances from explosion

m (kg)	$D_{\max}$ (m)	t_{BLEVE} (s)	$t_{liftoff}$ (s)	H_{BLEVE} (s)	D_{intial} (m)
60,000	231.46	14.41	6.88	173.59	300.89

According to point-source model 80 to 90% of rocketing fragments fall within 926 *m*; and as illustrated from the analyses of the travel range of fragment missiles where 90% probability of rocketing would be effected on majority land (Figure 6) in a circle 700 *m* radius. Some debris might be reached over 1 *km* from the accident and thus, personnel should be shifted beyond anticipated area in case of evacuation needed (Birk ,1995).

The probability of human fatality and injury has been calculated by using Eqs. 27 and 28. The results is summarised in Table 4and the probabilities of fatality and injury was drown graphically around the LPG location as presented in Figures 7 and 8.

Table 4: Probabilities for human fatality or injury by fragmentation

Probability $P,(\%)$	Fatality $r(m)$	Injury $r(m)$
10	291	1692
50	130	1100
90	71	725

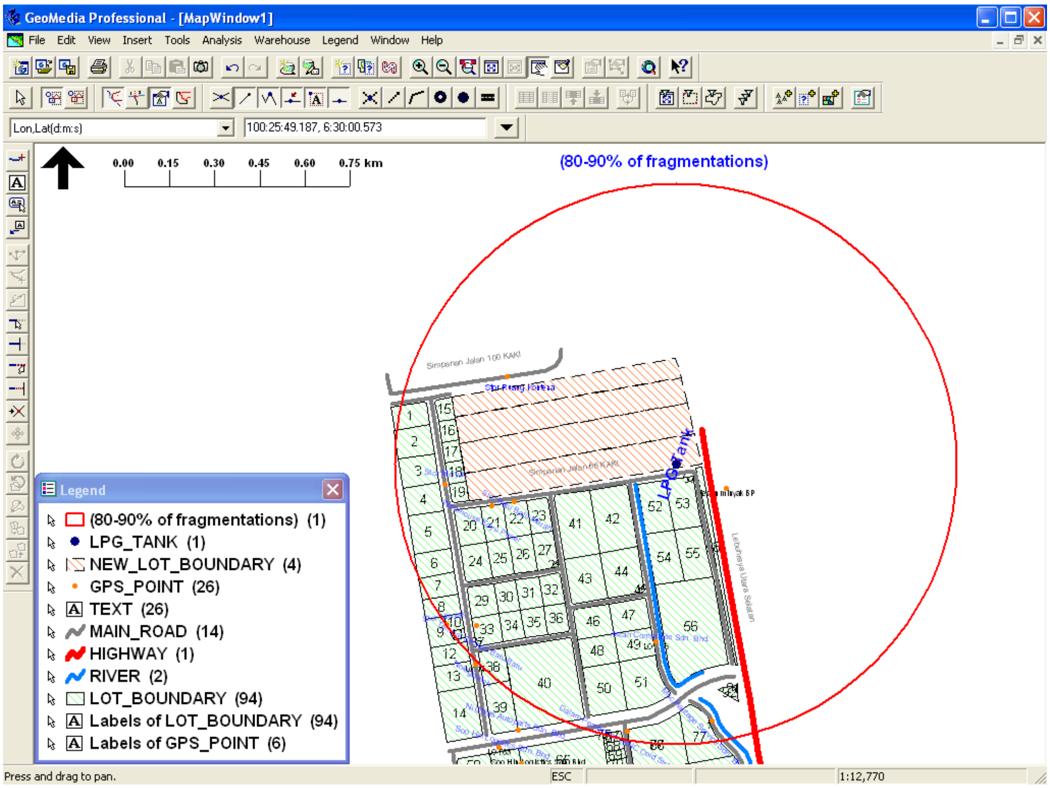

Figure 6: Fragmentation range.

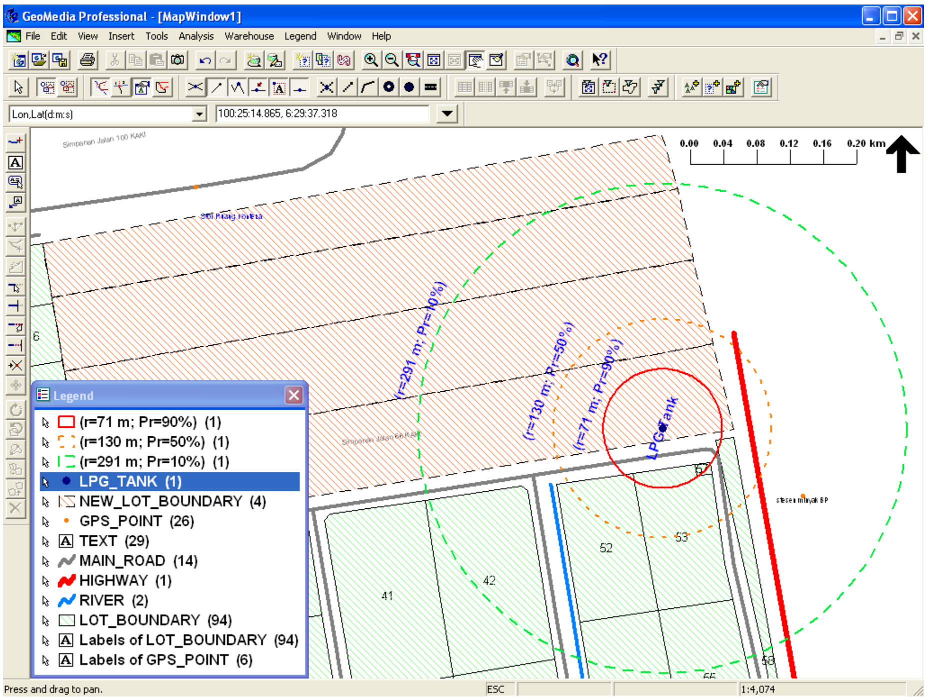

Figure 7: Probability of human fatality from fragmentation.

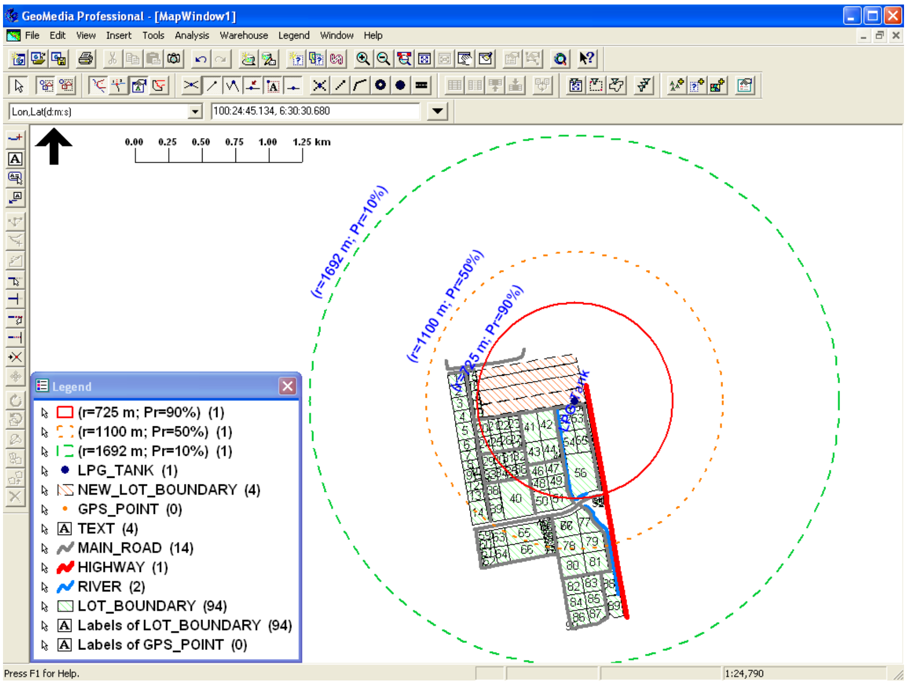

Figure 8: Probability of human injury from fragmentation (an industrial zone where numbers in the boxes are lots of land occupied by other industries)

5. Conclusion

Mapping, the visual display of information, is an extremely powerful tool for understanding and managing risk. Risk inherently involves a geographical component. It occurs at locations in space where receptors (human or environment) and hazards come together. GIS powerful tools can pinpoint all the chemical hazards events and mapping of environmental and risk area. The blast wave from BLEVE can damage structures in the industrial zone and effects to people and the environment. It is a good estimation of safe distances for the industrial zone and surrounding community. These important information could be presented by utilising of GIS and in fact can be seen clearly on the maps. Zones for probabilities of human fatality and injury and construction damage have been classified on the location map. Consequences result was obtained from calculation using TNT equivalent model and selected equations. The probit functions have been used here to identify probability and effect of peak overpressure to people and structures. The stakeholders can make use the technology for estimating explosion effects from a BLEVE event in which the result of consequences are plotted by buffer zones 10%, 50%, and 90% likelihood for managing risk in an industrial zone. Based on the estimation probability, consequences and on the information retrieved by the available databases and GIS in the operational center, future development outside the industrial zone must be beyond a radius of 1000 *m* of the LPG terminal.

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