

**Application of ALOHA into GIS software for
Management of Accidental Chemical Leakage: A Case
Study**

MAJOR PROJECT

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**Master of Engineering (Civil)
in
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CERTIFICATE

Certified that the major project titled **Application of ALOHA into a GIS software for Management of Accidental Chemical Leakage: A Case Study**”, which is being submitted by Mr. Jagadeesh Bhangari, in partial fulfillment for the award of degree of Master of Engineering (Civil) in Environmental Engineering, is a record of student’s own work carried out by him under my supervision and guidance. The matter embodied in this report has not been submitted for the award of any other degree or diploma.

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(Jagadeesh Bhangari)

CONTENTS

1.	Abstract1
2.	Introduction2
3.	ALOHA, Air Dispersion Model for Toxic Releases4
4.	MapObjects13
5.	Case Study14
6.	Results and Discussions22
Appendix - 1	Sample Output from ALOHA25
Appendix - 2	Visual Basic Code33
Appendix - 3	Selection key for ALOHA41
Appendix - 4	Manufacture, Storage and Import of Hazardous Chemical (Amendment) Rules, 2000.45
References:	49

Abstract

One of the identified areas of weakness in the entire emergency management structure and systems in the country has been the effective availability of on the spot information and tools for decision making during emergency. The rapid growth in the use of hazardous chemicals in industry and other locations over the last few decades has significantly increased the potential of accidents. The Bhopal tragedy, where such large-scale human tragedy took place due to accidental release of toxic Methyl Isocyanate (MIC), is a grim reminder of what is possible. It is therefore essential to develop a system, which integrates the critical information required to combat chemical emergencies.

A project was conceived by the Ministry of Environment and Forestry to identify a tool and develop a system to equip the local administrators for any chemical emergency planning in the areas of Major Accident Hazard. A spatial analysis system called GEPR (GIS based Emergency Planning and Response) was developed using ALOHA, a chemical model and MapObjects, GIS components for user deployment. ALOHA, under CAMEO suite, is a widely used vapour dispersion program that allows the prediction and display of the hazardous vapour cloud zone on a map of the area. It is an emergency response model, intended primarily for rapid deployment by responders as well as for use in emergency pre-planning. It incorporates source strength as well as Gaussian and heavy gas dispersion models and an extensive chemical library. Its output includes a footprint plot of the area downwind of a release where concentrations may exceed a user-set threshold level. The output of ALOHA is taken to a GIS platform for further analysis of hazard prone areas and strengthening the combat system.

Chapter 1: Introduction

The year 1984 witnessed a world's worst industrial disaster in Bhopal. Deadly gas, methyl isocyanate, was leaked in a chemical industry owned by Union Carbide, killing thousands of people and leaving an unknown chronically ill. The leakage was never expected. No one knew what to do and where to go. The local administration was ill equipped with consequence management. Had there been any preparedness, many of the lives would have been saved. Proper emergency planning will greatly reduce the potential for loss of life and property damage, as well as increase the safety of all employees and provide protection to the environment. Later in the year 1996, Ministry of Environment and Forests, came out with rules on emergency planning, preparedness and response for chemical accidents. Under this umbrella, crisis groups are constituted at different levels of administration for the preparation of onsite/offsite emergency response plans.

The present study focuses on

1. A computer based air dispersion model Areal Locations of Hazardous Atmospheres (ALOHA) and
2. Integration of ALOHA with a spatial analysis tool GIS based emergency planning and response (GEPR).

An accidental release of toxic chemicals from a storage facility or a chemical transportation vehicle would require nearby municipal agencies to track the chemical's gas cloud or "plume" in order to determine its potential impact on nearby population centers and take necessary steps to prevent the danger arising out of it. ALOHA is one of the modules of CAMEO (Computer-Aided Management of Emergency Operations) program, which is sponsored by the National Oceanic and Atmospheric Administration (NOAA), Office of Response and Restoration, and the U.S. Environmental Protection Agency, Chemical Emergency Preparedness and Prevention Office (EPA CEPPO) and is designed to help first responders and emergency planners plan for and quickly respond to such chemical accidents. It can predict how a hazardous gas cloud might disperse in the

atmosphere by generating a visual representation of the plume created by the chemical release, where concentrations may exceed a user-set threshold level.

ALOHA contains a database of approximately 1,000 common chemicals. Using information from this database, including chemical type, accident location (urban or rural), weather conditions (temperature, wind speed, and wind direction), and accident parameters (storage medium, size of opening, pressure of storage medium), ALOHA can predict the atmospheric dispersion rate and direction of vapors from a broken pipe, tank, or other source. ALOHA can predict rates of chemical release from broken gas pipes, leaking tanks, and evaporating puddles, and can model the dispersion of both neutrally buoyant and heavier-than-air gases and display a "footprint" plot of the area downwind of a release where concentrations may exceed a user-set threshold level.

The CAMEO suit of products comes with mapping software called MARPLOT. It can be used to map the outputs from ALOHA along with other themes of the location such as population centers, schools, hospitals, fire stations and etc. But it is not user friendly to input and define the user defined layers. Hence a need was felt to develop a GIS tool to overcome this.

Objectives:

The objective of this study is to develop a GIS application tool that integrates ALOHA and ESRI's MapObjects technology to provide rapid, real-time modeling and reporting for chemical plumes and the areas that they affect.

Chapter 2: ALOHA, Air Dispersion Model for Toxic Releases

ALOHA (Areal Locations of Hazardous Atmospheres) is a computer program, as described earlier, that uses information provided by the user, along with physical property data from its extensive chemical library, to predict dispersion of hazardous gas cloud in the atmosphere after an accidental chemical release. It can predict rates of chemical release from broken gas pipes, leaking tanks and evaporating puddles, and can model the dispersion of both neutrally buoyant and heavier-than-air gases.

ALOHA can display a "footprint" plot of the area downwind of a release where concentrations may exceed a user-set threshold level. It also displays plots of source strength (release rate), concentration, and dose over time. It accepts weather data transmitted from portable monitoring stations, and can plot footprints on electronic maps displayed in a companion mapping application.

ALOHA originated as an in-house tool used by NOAA's emergency responders. It was originally based on a simple model--a continuous point source with a Gaussian plume distribution. It has evolved over the years into a tool used for response, planning, training, and academic purposes. It is distributed worldwide to thousands of users in government and industry. Because ALOHA is intended for use during hazardous chemical emergencies, it was designed to meet the following criteria:

- *Operates on common computers:* ALOHA runs quickly on small computers (IBM-compatible or Macintosh) that are easily transportable and affordable for most users. Its algorithms represent a compromise between accuracy and speed; it has been designed to produce good results quickly enough to be of use to responders.
- *User friendly:* ALOHA is designed to be easy to use so that people can use it during high-pressure situations like a chemical incident response.
- *Reliable:* ALOHA's user interface is designed to minimize operator error. The program checks and crosschecks information entered by the user before proceeding to

solutions. If a particular input value is unlikely or not physically possible, ALOHA requests a new value.

ALOHA runs on Microsoft Windows (Version 3.0 or later) and in Apple Macintosh computers. It requires at least 1 megabyte of random access memory (RAM) and a hard drive. The current version is ALOHA 5.2.3.

What ALOHA Does and Does Not Do

ALOHA has the following attributes:

- **Rapid deployment.** Emergency responders can use ALOHA to predict the behavior of a chemical gas in the event of an accidental release. An extensive chemical library, automatic conversion of chemical and physical units, online help, and other features make ALOHA convenient and quick to use.
- **Quality control.** ALOHA checks user inputs for reasonableness and guides the user in selecting appropriate inputs. Numerous warnings and help messages can be invoked during an ALOHA run.
- **Usable accuracy.** Although ALOHA makes many approximations in order to produce results quickly, its predictions have been checked against estimates made by similar models and measurements made during field experiments to ensure that results are as accurate as possible.
- **Variety of source types.** ALOHA models emissions from boiling and non-boiling pools, pressurized gas pipelines, pressurized tanks containing gas or liquid, unpressurized liquid tanks, and refrigerated tanks containing liquefied gases.
- **Neutral and heavy gas models.** ALOHA models dispersion of both neutrally-buoyant and heavier-than-air gases.
- **Concentration and dose.** ALOHA predicts indoor and outdoor ground-level concentrations of chemical in the air and the dose of chemical to which people may be exposed, at any location selected by the user.

- **Footprint mapping.** ALOHA's footprint is a plan view of the area within which the ground-level concentration of pollutant gas is predicted to exceed the user-specified Level of Concern (LOC) at some time during the hour after a release begins. ALOHA footprints may be displayed on a grid and can be scaled to a user-selected scale in an ALOHA window. ALOHA footprints can also be overlaid on electronic maps displayed in ALOHA's companion application, MARPLOT (Mapping Application for Response, Planning, and Local Operational Tasks).
- **Contingency planning.** ALOHA can be used for industrial site characterization. Users can save accident scenarios as ALOHA-readable files, then easily evaluate a variety of scenarios and archive results. Contents of output windows can be readily transferred to documents and reports in word-processing or graphics applications.

ALOHA is compact and fast and, as a result, cannot do everything. Following are its major limitations:

- **Topography.** ALOHA does not account for topographic effects. The earth is assumed to be flat and the mean wind speed and direction are assumed to be uniform at any given reference height.
- **Particulates.** ALOHA does not model particulate transport (including dispersion of radioactive material).
- **Buoyant gases.** ALOHA does not account for the initial positive buoyancy of a gas that has been heated or is lighter than air.
- **Low-level background.** The emergency responder is the primary target audience of ALOHA, and hence the model does not address air quality issues. ALOHA is not designed to model chronic, low-level (fugitive) emissions. The maximum duration of a release in ALOHA is 1 hour.

- **Near-field.** ALOHA does not account for near-field influences on dispersion, such as effects of momentum jets or concentration patchiness very near the point of release. If the distance to a threshold concentration is shorter than 100 m, ALOHA will not display a footprint.
- **Liquids in pipes.** ALOHA does not model releases from liquid pipelines.
- **Reactivity.** ALOHA does not account for chemical reactions. It assumes that the substance escaping from a storage vessel or evaporating from a pool surface is the substance that disperses downwind. However, when the user selects an air- or water-reactive chemical, ALOHA alerts him or her that the chemical is reactive, and describes the type of reaction and reaction products to expect.
- **Solutions and mixtures.** ALOHA's algorithms are appropriate for pure chemicals only.
- **Fires.** ALOHA cannot model the dispersion of chemicals that are involved in a fire. It does not account for fire effects such as heating of escaping vapors or heat-induced chemical reactivity that causes the chemicals dispersing downwind to be different from the chemical that was originally stored.

ALOHA Inputs and Outputs

Inputs

To predict behavior of an escaping chemical, ALOHA requires the following information, which the user can enter easily with the help of a graphical interface.

- **Geographic location, time, and date.** ALOHA uses latitude and longitude as well as time and date to estimate incoming solar radiation, and uses elevation to estimate ambient air pressure. Latitudes, longitudes, and elevations of most major U.S. cities and some locations outside the U.S. are stored in ALOHA's built-in city library. The user can add entries to this library and can either manually specify time and date or allow ALOHA to take this information from the computer's internal clock.



- **Site definition.** The user can either enter a building air exchange rate or indicate the most common building type downwind of a release (this can also be the building type of greatest concern). ALOHA makes use of this information in its predictions of indoor concentration and dose.
- **Chemical definition.** ALOHA's physical property library contains 947 pure chemicals. Complete property information necessary for full source emission modeling is available for 492 of these chemicals (users may add new chemicals or property values to the library). Because ALOHA does not account for chemical reactivity within a dispersing cloud, the user is warned when he or she selects an air- or water-reactive chemical or a pyrophoric substance from ALOHA's library, and the implications of chemical reactivity for dispersion modelling are discussed in ALOHA's online help system and in printed documentation.
- **Atmospheric Data.** The atmospheric parameters used in ALOHA's calculations are (a) stability class, (b) inversion height, (c) wind speed, (d) wind direction, (e) air temperature, (f) ground roughness, (g) cloud cover, and (h) relative humidity. If a SAM (Station for Atmospheric Measurements) is connected to ALOHA, then wind speed, wind direction, standard deviation of wind direction (and thus stability class), and air temperature are updated automatically in real time.
- **Source definition.** The source can be any of the following types:
 1. *Direct:* A point release of gas directly into the atmosphere, with the following characteristics: (a) release type, as continuous or instantaneous; (b) release amount, as either release rate (if continuous) or mass or volume of release (if instantaneous); (c) release duration if continuous; (d) storage temperature and pressure (for releases described by volume only) and (e) source height (for neutrally-buoyant gases only).

Atmospheric Options

Wind Speed is : Knots MPH Meters/sec

Wind is from : Enter degrees true or text (e.g. ESE)

Measurement Height above ground is:

  OR enter value : Feet Meters

Ground Roughness is :

Open Country Urban or Forest OR Input Roughness [Z₀] : in cm

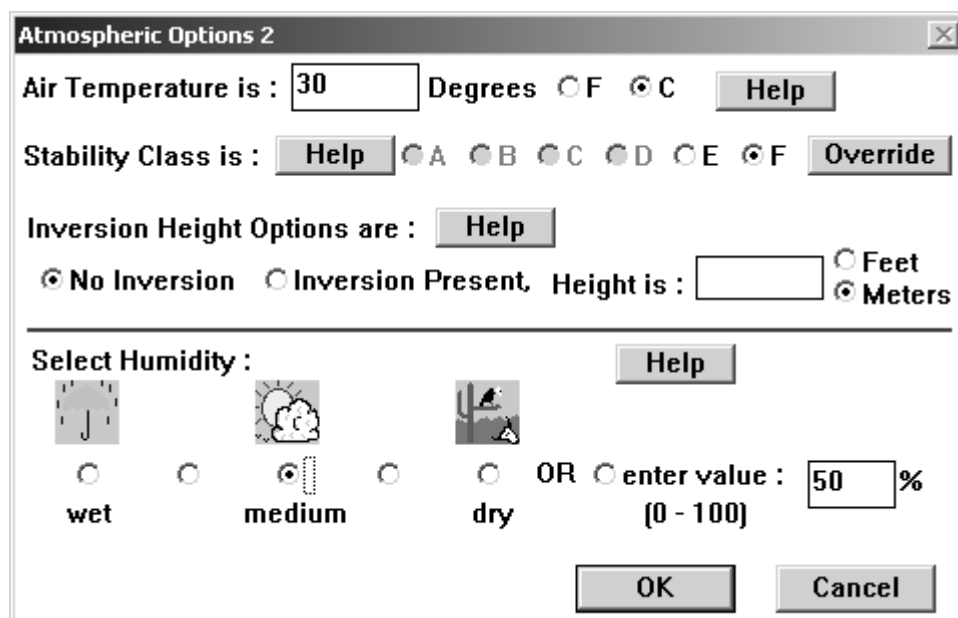


Figure 2.2

2. *Puddle*: A puddle of evaporating liquid on the ground, with the following characteristics: (a) puddle area; (b) puddle volume, depth, or mass; (c) ground temperature; (d) ground type; and (e) puddle temperature.
3. *Tank*: Release of a gas, liquid, or liquefied gas from a storage vessel, with the following characteristics: (a) tank shape (cylinder or sphere); (b) tank dimensions; (c) hole shape and size; (d) hole location on tank wall; (e) mass or volume of chemical in the tank; (f) tank temperature; if the tank contains only gas (e) internal gas pressure (unless chemical mass is known); and if the tank contains

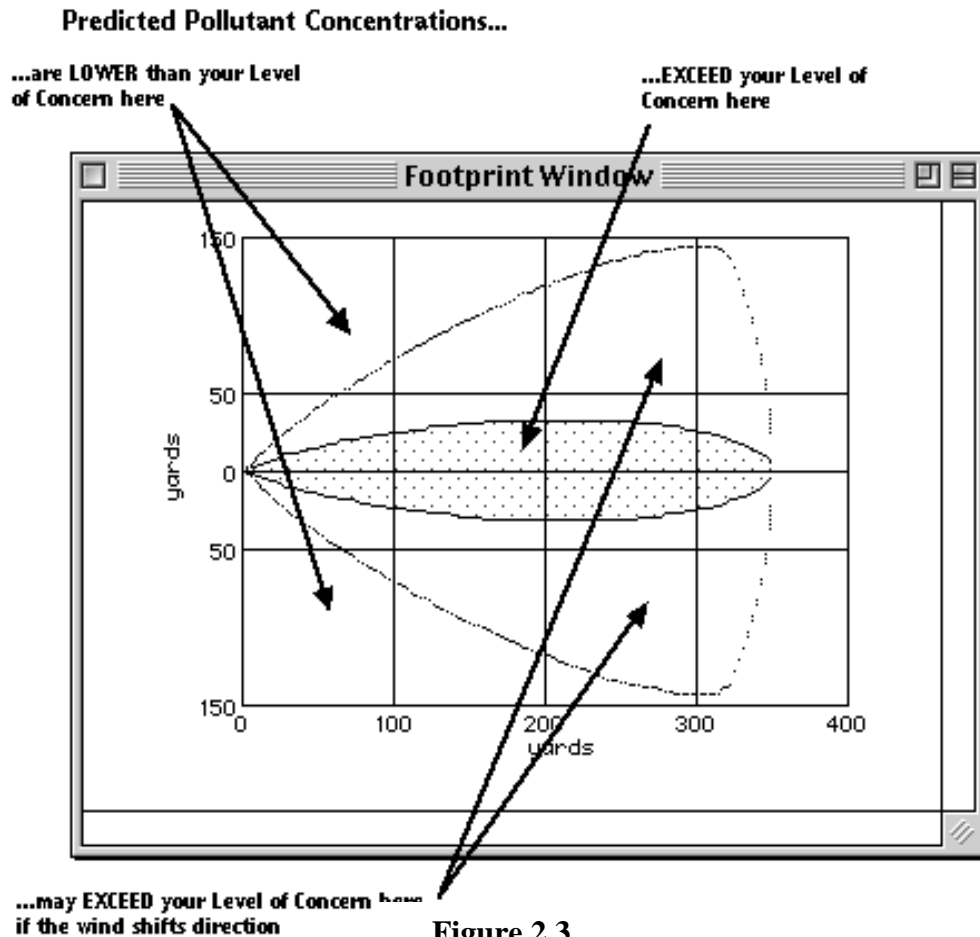
- nonpressurized liquid, (f) ground type, (g) ground temperature, and (h) maximum puddle diameter (if the tank is diked).
4. *Pipe*: Release of gas from a ruptured gas pipeline, with the following characteristics: (a) pipe length; (b) pipe diameter; (c) pipe pressure; (d) pipe temperature; (e) inner pipe surface roughness, as either rough or smooth; and (f) pipe either connected to a very large ("infinite") source, or unconnected to a source.
- **Atmospheric dispersion.** ALOHA predicts atmospheric gas dispersion using either of the two methods below. ALOHA automatically selects the best method to use based on the properties of the selected chemical and the mass and temperature of the dispersing cloud. However, the user also has the option of choosing the most appropriate method, and can select the LOC for ALOHA to use in making dispersion predictions. He or she may choose to allow ALOHA to automatically use the chemical's IDLH, if a value is available.
1. *Neutral Gas*: ALOHA uses a modified Gaussian model to predict dispersion of passive gases that do not alter the dynamic behavior of the atmosphere.
 2. *Heavy Gas*: If a vapor that is more dense than the air is released at ground level, ALOHA will account for its initial spreading under the influence of gravity while it is advected and dispersed by atmospheric turbulence.

Outputs

ALOHA displays the following five output windows. Window contents can be copied and pasted into documents or saved for later reference.

- **Text summary.** Information entered by the user, physical properties of the selected chemical, weather data either entered by the user or transmitted from a meteorological monitoring station, and ALOHA's source strength, footprint, and concentration estimates are displayed as text in this window.

- **Dispersion footprint.** ALOHA's footprint is displayed in this window. Dashed lines on either side of the footprint represent the uncertainty in footprint location that results from uncertainty in wind direction. The distance between the two lines is affected by atmospheric stability.



- **Concentration vs. time.** This plot displays predicted chemical concentration in the air at ground level at a location specified by the user. The two curves shown on this plot represent (outdoor and indoor) concentrations averaged over a few minutes (peak concentrations may significantly exceed the concentrations shown on this graph). The plot displays concentrations predicted only for the first hour after the start of a release.
- **Dose vs. time.** This plot displays predicted accumulated dose of chemical to which a person at the specified location might be exposed. The dose graph also

includes two curves, representing dose accumulated within and outside of buildings. Each dose curve represents the dose accumulated during the hour after the start of the release.

- **Source strength vs. time.** This plot displays the predicted rate of release of the chemical into the atmosphere. ALOHA calculates source strength for each release in a series of many short time steps, then averages these values into a series of from one to five longer-duration time steps (it is the averaged values that are used in ALOHA's dispersion calculations). The source strength plot displays the averaged source strength values.

Chapter 3: MapObjects

MapObjects software is a powerful collection of embeddable mapping and geographic information system (GIS) components. Developers can use MapObjects to create applications that include dynamic live maps and GIS capabilities.

MapObjects provides the tools required to create specialized solutions for desktop mapping and GIS needs. With MapObjects one can

- Add mapping components to enhance existing applications.
- Build lightweight data viewing applications.
- Create customized mapping and GIS programs that fulfill specific tasks and requirements.
- Develop simple query-based applications that easily enable access to data generated by sophisticated GIS solutions.

MapObjects is an ActiveX control with nearly 50 programmable ActiveX automation objects that can be plugged into many standard Windows development environments such as Visual Basic, Visual Basic for Applications (VBA), Visual C++, Visual Studio.NET (VB.NET and C#), Delphi, Borland C++ Builder, Visual FoxPro, and PowerBuilder.

GIS based Emergency Planning and Response System: (GEPR)

GIS based Emergency Planning and Response System (GEPR) is one such application tool, which utilizes the capabilities of ALOHA to map its output in a map viewer developed using MapObjects. It has been developed for Major Cluster of Industries in selected industrialized States in the Country. It is a complete software package comprising of GIS tools and data along with district databases. The program is user-friendly and can be used along with district level offsite emergency plan not only for planning and mock trials of major chemical emergencies but also during actual emergency.

Chapter 4: Case Study

GIS has become an essential tool in emergency response planning and in enabling decision makers to manage a crisis situation effectively. Having accurate information on areas impacted or potentially impacted by a disaster, such as the release of a hazardous gas, helps ensure the proper utilization of critical resources. By integrating applications designed for specific disaster scenarios with customizable GIS technology and real-time data, planners can be much better prepared for these scenarios than they have been in the past. The current study involves development of a tool that transforms the Aloha output in the format readable by GEPR. Following is the procedure involved in the transformation.

1. Input to Aloha
 - a. Location and surrounding
 - b. Atmospheric options (wind speed and direction, ground roughness, cloud cover and etc.)
 - c. Chemical source strength
2. Run Aloha (the coordinates of footprint plot downwind of chemical release are stored in a ASCII file with extension .pas)
3. The ASCII file is imported in GEPR using a conversion module developed in Visual Basic environment using MapObjects.

Case study: Gujarat Narmada Valley Fertilizer Corporation:

Gujarat Narmada Valley Fertilizers Company Ltd. (GNFC), a major chemical industry, is a joint sector enterprise promoted by the Government of Gujarat and the Gujarat State Fertilizer Company Ltd. (GSFC) was set up in Bharuch, Gujarat in 1976. It is one of the world's largest single stream fuel oil based ammonia and urea complex. It is Primarily involved in manufacturing, marketing and distribution of ammonia / urea based fertilizers and agricultural chemicals. As per the MANUFACTURE, STORAGE AND IMPORT OF HAZARDOUS CHEMICAL RULES, 1989, MINISTRY OF ENVIRONMENT AND

FORESTS, (Annexure -4) Govt. of India, GNFC is classified as a Major Accident Hazard (MAH) site/industry. The industry stores the following toxic hazardous chemicals.

Toxic Chemical	Largest single storage in MT	Total Storage in MT
Acetic acid	2937	3147
Ammonia	10800	10800
Chlorine	1	18

A reference map of Bharuch district and industrial pockets is shown in Figures 3.1 and 3.2. It can be seen in the map that GNFC is on the bank of River Narmada.

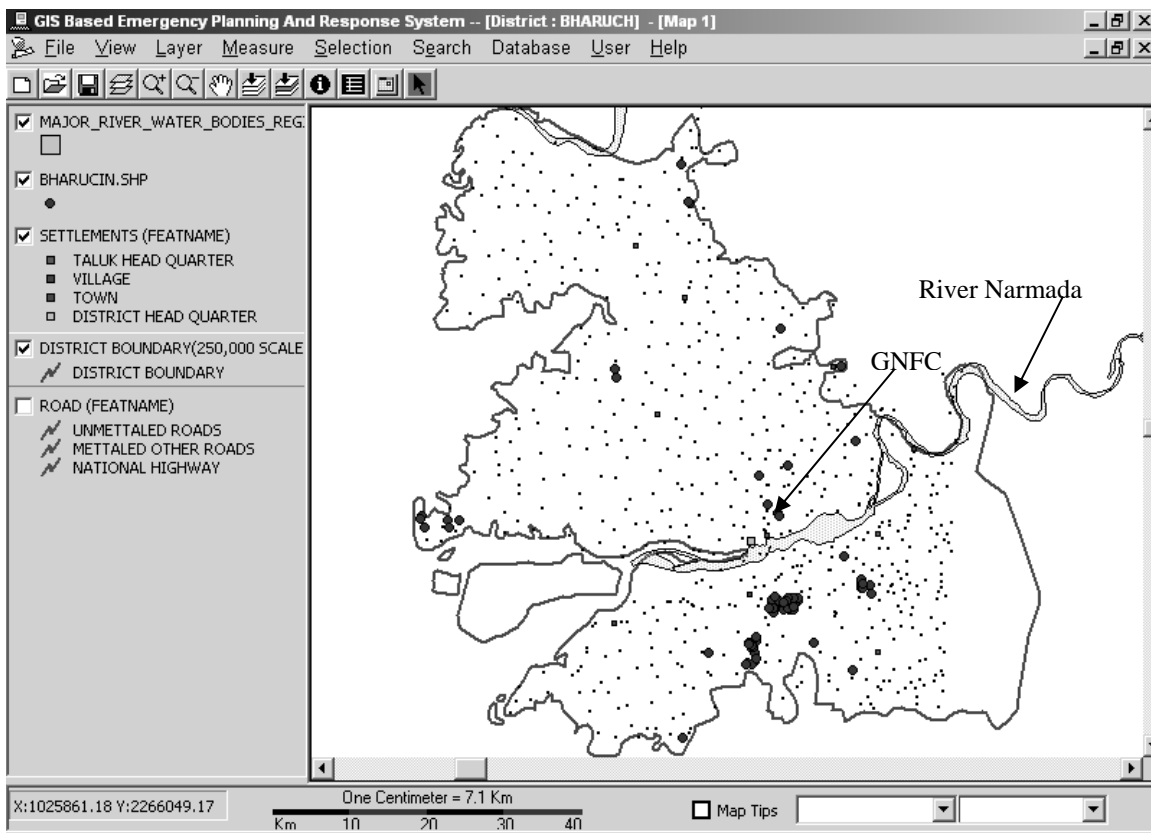


Figure 4.1: Bharuch District with Industry locations

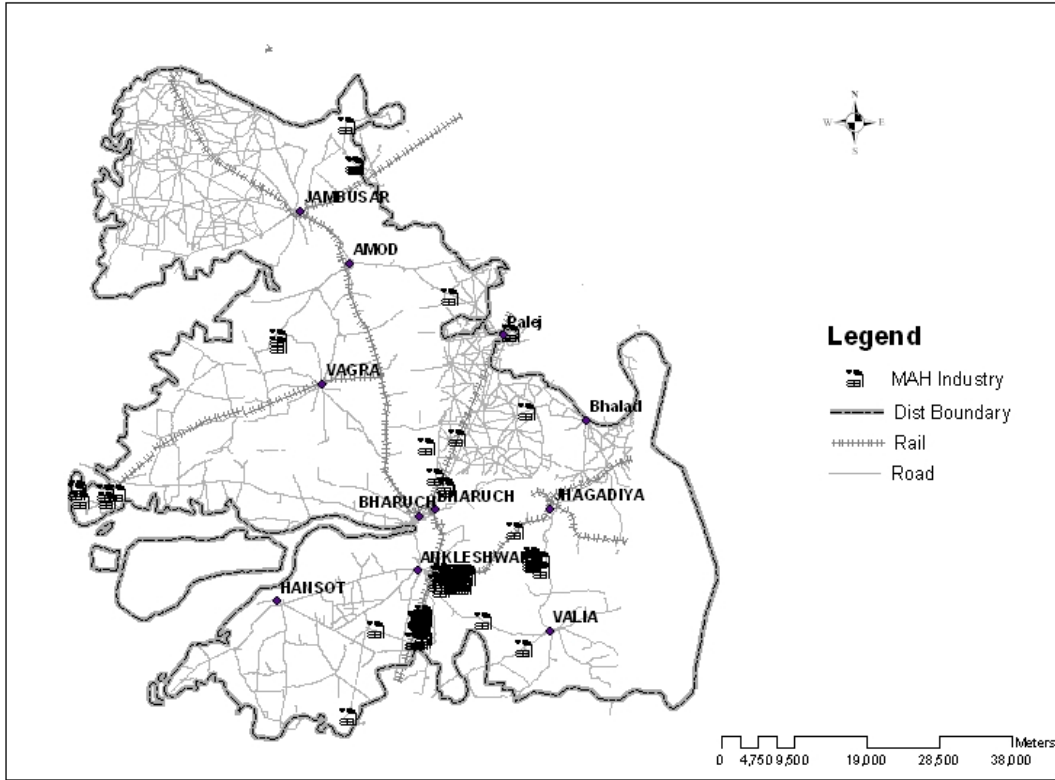


Figure 4.2: Bharuch District with Road/Rail Network

The application window consists of tool bar, table of contents (on the left hand side), map window (rt. hand side) and a scale bar at the bottom. The core tool of the software, which integrates Aloha and GEPR, is named as **SEARCH** (figure 3.3). It basically converts the footprint plot (*.pas file of Aloha) of a chemical release in an industry and places the output (in Shape format) at the point of release. The search tool will list the layers available in the project. Industry is one of the layers containing the MAH industries, where in all the industry names will be displayed.



Figure 4.3

The following screenshots of the software demonstrate the working of the tool.



Fig. 4.4: Tool to search the Industry

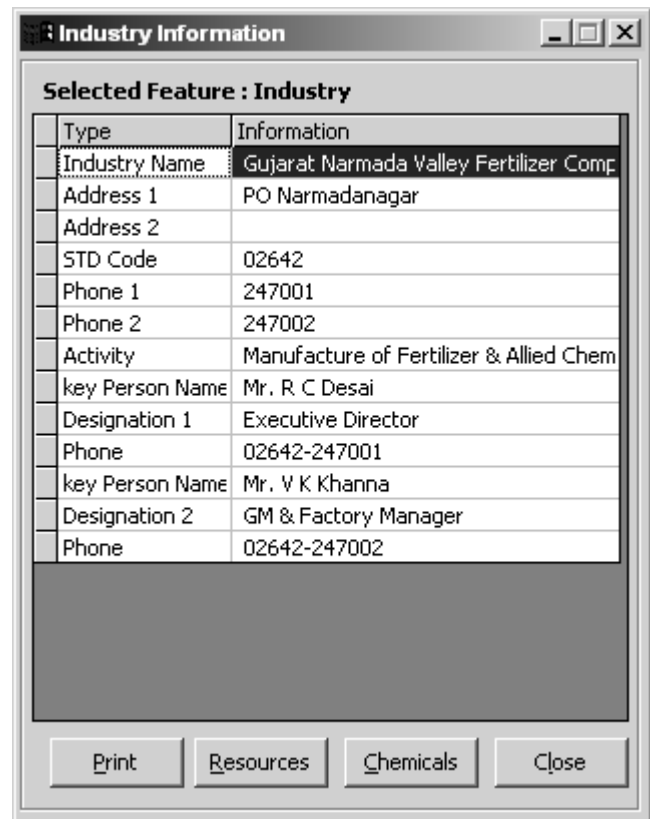


Fig. 4.5: Industry Information

Industry Resources

Type	Information
Industry Name	Gujarat Narmada Valley Fertilizer Comp
Ambulance(s)	3
OHC with more then 5 b Y	
Fire Tender(s)	5
Water Storage(KL)	13000
Fire Entry Suit(s)	1
Fire Proximity Suit(s)	2
SCBA(s)	65
Canister Mask(s)	25
Bus(es)	7
Truck(s)	3
Car/Jeep/Van(s)	29

Print Close

Fig. 4.6: Emergency Resources in Industry

Chemical Details

Chemical Details for Industry : Gujarat Narmada Valley Fertilizer Company Ltd.

Modeling Type	Chemical	Largest Storage(MT)	Total Storage(MT)	Fire Injury Radius(m)	Fire Fatality Radius(m)	Distance To LFL(m)	Explosion Inju
Toxic	Chlorine	1	18	-	-	-	-
Toxic	Chlorine	1	18	-	-	-	-
Explosion	Liquefied Petroleum G	80	80	-	-	543	-
Toxic	Ammonia	10800	10800	-	-	-	-
Toxic	Ammonia	10800	10800	-	-	-	-
Fire	Methanol	2155	6990	106	74	-	-
Fire	Acetic Acid	2937	3147	79	55	-	-
Toxic	Acetic Acid	2937	3147	-	-	-	-
Toxic	Acetic Acid	2937	3147	-	-	-	-

Display Print Close

*** Note : Double click on the Chemical name to view the RIDS Information**

Fig. 4.7: Chemical details and their impact under accidental hazard

Figure 4.7, as the title reads, indicate the maximum capacity of chemical storages available in the industry. The modeling type in the list identifies the nature of the chemical i.e. the kind of hazard it can create in the event of the release from the storage. The two possibilities of hazard namely fire and toxic are modeled in GEPR. They are modeled using ARCHIE and Aloha respectively. The largest storage and the total storage, as the name recognises, are the capacities of the largest tank and total of the individual capacities of all the tanks. EPA has defined the worst-case scenario as the release of the largest quantity of a regulated substance from a single vessel or process line failure that results in the greatest distance to an endpoint. In broad terms, the distance to the endpoint is the distance a toxic vapor cloud will travel before dissipating to the point that serious injuries from short-term exposures will no longer occur. ALOHA has an artificial distance cutoff of 6 miles. Under circumstances where the endpoint distance is significantly greater than 6 miles, it is suggested for any other model, which supports the condition.

Processing the Plume

The footprint of the plume movement is obtained after processing the inputs as required by ALOHA and mentioned in chapter 2. After selecting the chemical and other conditions (Figure 4.7), the system asks for the direction of wind, which can be either specified by direction or the rotation angle from the north. Figure 4.8 describes the option for selection of the wind direction.

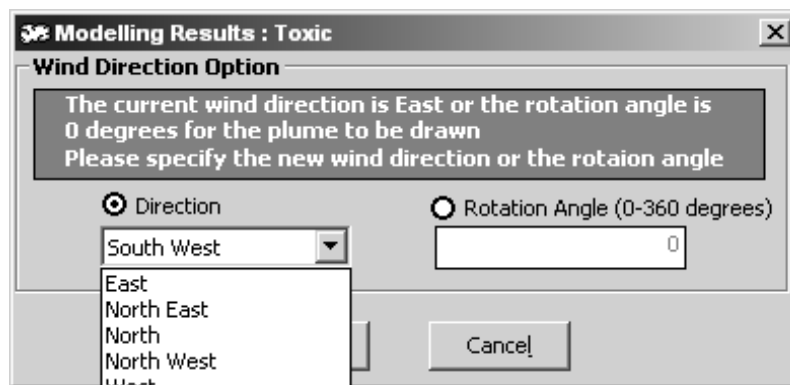


Figure 4.8

Finally it arrives at depiction of the plume blanket where the toxicity level crosses LOC.

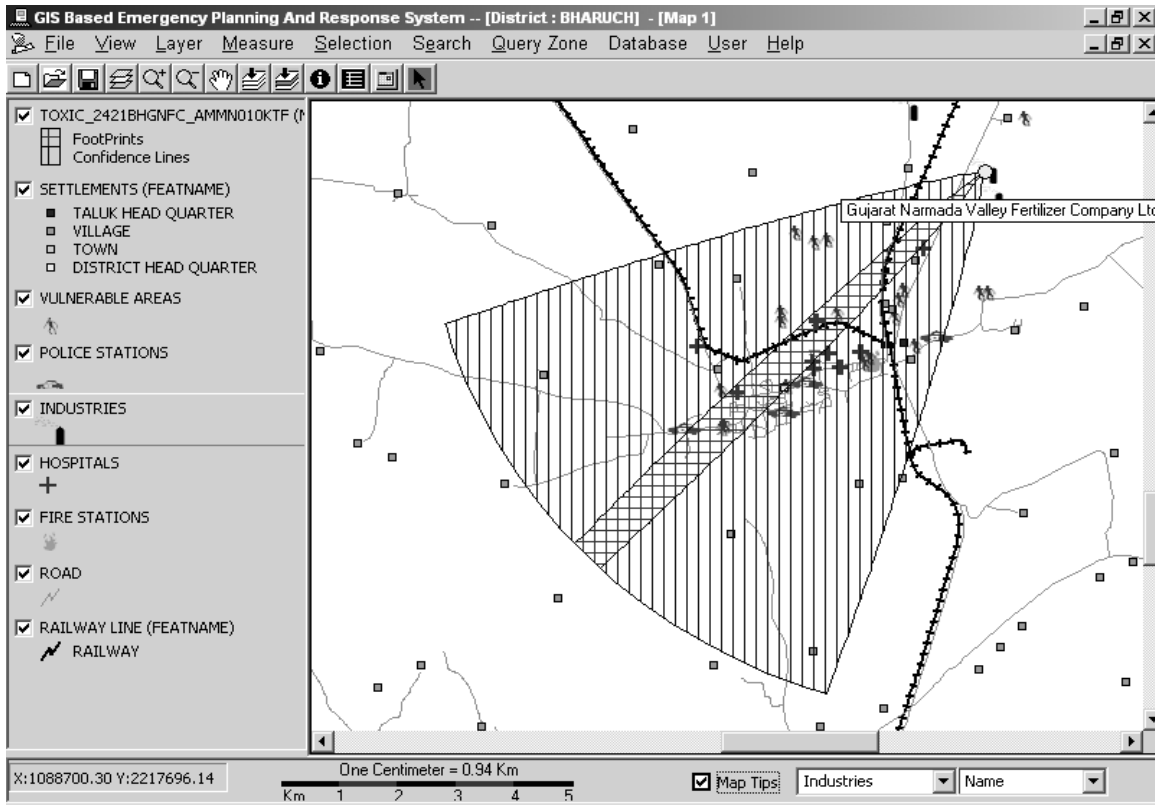


Figure 4.9

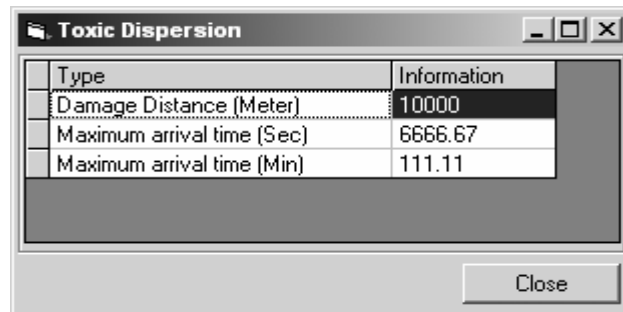


Figure 4.10

Two polygons, representative of the plume's outline, as defined by user-specified Level-of-Concern (LOC) values, are created by ALOHA. The first (inner) polygon in figure 4.9, also called the plume footprint, represents an area where, with 100 percent probability, LOC values will be exceeded. The second (outer) polygon, represented as confidence lines, encloses the footprint closely at its upwind end but more broadly downwind. It

represents an area where, with 95 percent probability, LOC values will be exceeded. The outer lines that demarcate the larger zone represent potential changes in wind direction that might affect the direction, size, or shape of the plume. The application processes each of these shapes into a single shape-file (GIS data format) with attribute values for each of the two polygons being automatically generated. Once the shapefile is created, it is projected into the coordinate system defined by the user. The system also displays a table (figure 4.10) showing the distance to the farthest point of damage in the direction of wind and the time of arrival plume at the point.

Chapter 5: Discussions and Results

Modeling Issues

The consequences of an accidental chemical release depend on the conditions of the release and the conditions at the site at the time of the release. The endpoint distances are based on results of modeling, for estimation of worst-case consequence distances. Worst-case consequence distances obtained in this study are not intended to be precise predictions of the exact distances that might be reached in the event of an actual accidental release. For these results, worst-case distances are based on modeling results assuming the combination of worst-case conditions required by the rule. This combination of conditions occurs rarely and is unlikely to persist for very long. The results derived and presented here are rough estimates of potential consequence distances. Other models may give different results; the same model also may give different results if different assumptions about release conditions and/or site conditions are used. Modeling uncertainties are likely to increase as distances increase because conditions (e.g., atmospheric stability, wind speed, surface roughness) are not likely to remain constant over large distances.

Determining the Worst-Case Scenario

A worst-case release is defined as:

- The release of the largest quantity of a regulated substance from a vessel or process line failure, and
- The release that results in the greatest distance to the endpoint for the regulated toxic or flammable substance.

The assumptions required for the worst-case analysis are intended to provide conservative worst-case consequence distances, rather than accurate predictions of the potential consequences of a release; that is, in most cases the results will overestimate the effects of a release. In certain cases, actual conditions could be even more severe than

these worst-case assumptions (e.g., very high process temperature, high process pressure, or unusual weather conditions, such as temperature inversions); in such cases, the results might underestimate the effects. However, the required assumptions generally are expected to give conservative results. The chemical release is assumed to take place at ground level for the worst-case analysis.

Results:

The model result for one of the worst-case scenario for Ammonia is tabulated in the following lines.

Wind Direction:	South West
Damage Distance:	10000 m. (10 km.)
Maximum Arrival time:	111.10 minutes
Census Villages under threat zone:	11
Affected Population:	20872
Affected Police stations:	3
Affected Hospitals:	12
Sensitive Areas:	16
(Education institutes, public places and etc)	
Fire Station:	1

The most immediate requirements in emergency are evacuation of the population coming under the threat zone, first aid to the affected population and emergency resources available in the industries surrounding the one where the accident occurs. The following table briefly summarizes the rescue resources available around GNFC under any chemical emergency.

Facility	Radius	Number
Hospitals outside threat zone	1 km.	0
	2 kms.	3
	5 kms.	5
Industries where the resources available (Life saving materials, vehicles for evacuation, and etc	1 km.	1
	2 kms.	2
	5 kms.	24
Police Stations	2 kms.	6
	5 kms.	7
Fire Stations	2 kms.	3
	5 kms.	4

APPENDIX - 1: Sample Output from ALOHA

//Sample .pas file from ALOHA

T ALOHA Gaussian footprint

T AMMONIA

T LOC: IDLH (300 ppm)

T Footprint exceeds 10 km

FOOTPRINT

M 0.0 0.0

L 209.3 128.3

L 398.3 236.3

L 567.0 337.5

L 708.8 425.3

L 823.6 499.5

L 924.8 560.3

L 1005.8 600.8

L 1059.8 641.3

L 1093.6 661.5

L 1107.1 661.5

L 1188.1 715.5

L 1275.8 776.3

L 1370.3 843.8

L 1464.8 911.3

L 1572.8 978.8

L 1674.1 1053.1

L 1782.1 1134.1

L 1903.6 1215.1

L 2018.4 1302.8

L 2146.6 1390.6

L 2241.1 1458.1

L 2335.6 1525.6

L 2430.2 1593.1

L 2531.4 1667.4

L 2632.7 1741.6

L 2727.2 1822.6

L 2835.2 1903.6

L 2936.4 1977.9

L 3044.4 2058.9

L 3159.2 2146.6

L 3253.7 2214.1

L 3341.5 2288.4

L 3442.7 2362.6

L 3544.0 2436.9

L 3638.5 2517.9
L 3739.7 2592.2
L 3841.0 2666.4
L 3942.2 2754.2
L 4050.3 2835.2
L 4151.5 2922.9
L 4246.0 2990.4
L 4340.5 3071.4
L 4435.0 3138.9
L 4529.5 3220.0
L 4630.8 3294.2
L 4725.3 3375.2
L 4826.6 3463.0
L 4927.8 3537.2
L 5029.1 3625.0
L 5137.1 3706.0
L 5224.8 3780.2
L 5319.3 3861.2
L 5413.8 3942.2
L 5515.1 4016.5
L 5609.6 4097.5
L 5704.1 4178.5
L 5798.6 4259.5
L 5899.9 4333.8
L 6001.1 4421.5
L 6102.4 4509.3
L 6190.1 4583.5
L 6284.6 4664.5
L 6379.1 4745.5
L 6480.4 4819.8
L 6574.9 4900.8
L 6669.4 4981.8
L 6763.9 5062.8
L 6858.4 5143.8
L 6959.7 5231.6
L 7060.9 5319.3
L 7067.7 5326.1
L 7101.4 5346.3
L 7141.9 5386.8
L 7216.2 5447.6
L 7297.2 5515.1
L 7405.2 5609.6
L 7526.7 5717.6
L 7668.5 5832.4
L 7830.5 5980.9
L 8012.8 6136.1

M 6136.1 8012.8
L 5980.9 7830.5
L 5832.4 7668.5
L 5717.6 7526.7
L 5609.6 7405.2
L 5515.1 7297.2
L 5447.6 7216.2
L 5386.8 7141.9
L 5346.3 7101.4
L 5326.1 7067.7
L 5319.3 7060.9
L 5231.6 6959.7
L 5143.8 6858.4
L 5062.8 6763.9
L 4981.8 6669.4
L 4900.8 6574.9
L 4819.8 6480.4
L 4745.5 6379.1
L 4664.5 6284.6
L 4583.5 6190.1
L 4509.3 6102.4
L 4421.5 6001.1
L 4333.8 5899.9
L 4259.5 5798.6
L 4178.5 5704.1
L 4097.5 5609.6
L 4016.5 5515.1
L 3942.2 5413.8
L 3861.2 5319.3
L 3780.2 5224.8
L 3706.0 5137.1
L 3625.0 5029.1
L 3537.2 4927.8
L 3463.0 4826.6
L 3375.2 4725.3
L 3294.2 4630.8
L 3220.0 4529.5
L 3138.9 4435.0
L 3071.4 4340.5
L 2990.4 4246.0
L 2922.9 4151.5
L 2835.2 4050.3
L 2754.2 3942.2
L 2666.4 3841.0
L 2592.2 3739.7
L 2517.9 3638.5

L 2436.9 3544.0
L 2362.6 3442.7
L 2288.4 3341.5
L 2214.1 3253.7
L 2146.6 3159.2
L 2058.9 3044.4
L 1977.9 2936.4
L 1903.6 2835.2
L 1822.6 2727.2
L 1741.6 2632.7
L 1667.4 2531.4
L 1593.1 2430.2
L 1525.6 2335.6
L 1458.1 2241.1
L 1390.6 2146.6
L 1302.8 2018.4
L 1215.1 1903.6
L 1134.1 1782.1
L 1053.1 1674.1
L 978.8 1572.8
L 911.3 1464.8
L 843.8 1370.3
L 776.3 1275.8
L 715.5 1188.1
L 661.5 1107.1
L 661.5 1093.6
L 641.3 1059.8
L 600.8 1005.8
L 560.3 924.8
L 499.5 823.6
L 425.3 708.8
L 337.5 567.0
L 236.3 398.3
L 128.3 209.3
L 0.0 0.0

CONFIDENCE LINES

M 0.0 0.0
L 229.5 94.5
L 432.0 162.0
L 614.3 236.3
L 769.5 297.0
L 891.1 351.0
L 1005.8 398.3
L 1093.6 418.5
L 1154.3 452.3
L 1194.8 465.8

L 1201.6 459.0
L 1296.1 499.5
L 1383.8 546.8
L 1491.8 600.8
L 1593.1 648.0
L 1721.4 695.3
L 1829.4 749.3
L 1950.9 816.8
L 2085.9 870.8
L 2207.4 938.3
L 2355.9 1005.8
L 2457.2 1053.1
L 2565.2 1107.1
L 2666.4 1154.3
L 2774.4 1208.3
L 2889.2 1269.1
L 3003.9 1329.8
L 3118.7 1390.6
L 3233.5 1451.3
L 3348.2 1512.1
L 3476.5 1572.8
L 3584.5 1626.9
L 3685.7 1687.6
L 3793.7 1741.6
L 3901.7 1795.6
L 4016.5 1856.4
L 4131.3 1917.1
L 4239.3 1971.1
L 4354.0 2045.4
L 4475.5 2099.4
L 4590.3 2173.6
L 4691.5 2220.9
L 4799.6 2288.4
L 4900.8 2335.6
L 5015.6 2396.4
L 5123.6 2450.4
L 5231.6 2517.9
L 5346.3 2592.2
L 5461.1 2639.4
L 5575.8 2713.7
L 5690.6 2774.4
L 5791.9 2835.2
L 5906.6 2895.9
L 6007.9 2956.7
L 6122.6 3017.4
L 6223.9 3078.2

L 6331.9 3145.7
L 6446.7 3206.5
L 6554.7 3260.5
L 6669.4 3334.7
L 6784.2 3395.5
L 6885.4 3456.2
L 6993.4 3523.7
L 7094.7 3584.5
L 7209.5 3645.2
L 7310.7 3706.0
L 7425.5 3766.7
L 7533.5 3834.2
L 7634.7 3895.0
L 7749.5 3969.2
L 7864.2 4030.0
L 7871.0 4036.8
L 7911.5 4050.3
L 7958.7 4084.0
L 8039.8 4138.0
L 8134.3 4192.0
L 8255.8 4259.5
L 8397.5 4347.3
L 8552.8 4435.0
L 8741.8 4556.5
L 8944.3 4678.0
A -332.4 -322.6 10092.4
A -307.4 -297.6 10092.4
M 4678.0 8944.3
L 4556.5 8741.8
L 4435.0 8552.8
L 4347.3 8397.5
L 4259.5 8255.8
L 4192.0 8134.3
L 4138.0 8039.8
L 4084.0 7958.7
L 4050.3 7911.5
L 4036.8 7871.0
L 4030.0 7864.2
L 3969.2 7749.5
L 3895.0 7634.7
L 3834.2 7533.5
L 3766.7 7425.5
L 3706.0 7310.7
L 3645.2 7209.5
L 3584.5 7094.7
L 3523.7 6993.4

L 3456.2 6885.4
L 3395.5 6784.2
L 3334.7 6669.4
L 3260.5 6554.7
L 3206.5 6446.7
L 3145.7 6331.9
L 3078.2 6223.9
L 3017.4 6122.6
L 2956.7 6007.9
L 2895.9 5906.6
L 2835.2 5791.9
L 2774.4 5690.6
L 2713.7 5575.8
L 2639.4 5461.1
L 2592.2 5346.3
L 2517.9 5231.6
L 2450.4 5123.6
L 2396.4 5015.6
L 2335.6 4900.8
L 2288.4 4799.6
L 2220.9 4691.5
L 2173.6 4590.3
L 2099.4 4475.5
L 2045.4 4354.0
L 1971.1 4239.3
L 1917.1 4131.3
L 1856.4 4016.5
L 1795.6 3901.7
L 1741.6 3793.7
L 1687.6 3685.7
L 1626.9 3584.5
L 1572.8 3476.5
L 1512.1 3348.2
L 1451.3 3233.5
L 1390.6 3118.7
L 1329.8 3003.9
L 1269.1 2889.2
L 1208.3 2774.4
L 1154.3 2666.4
L 1107.1 2565.2
L 1053.1 2457.2
L 1005.8 2355.9
L 938.3 2207.4
L 870.8 2085.9
L 816.8 1950.9
L 749.3 1829.4

L 695.3 1721.4
L 648.0 1593.1
L 600.8 1491.8
L 546.8 1383.8
L 499.5 1296.1
L 459.0 1201.6
L 465.8 1194.8
L 452.3 1154.3
L 418.5 1093.6
L 398.3 1005.8
L 351.0 891.1
L 297.0 769.5
L 236.3 614.3
L 162.0 432.0
L 94.5 229.5
L 0.0 0.0

t Time: Feb. 27, 2004 1738 hours ST (using computer's clock)

t Chemical Name: AMMONIA

t Wind: 3 meters/sec from SW at 3 meters

t FOOTPRINT INFORMATION:

t Dispersion Module: Gaussian

t User-specified LOC: equals IDLH (300 ppm)

t Max Threat Zone for LOC: greater than 10 km

APPENDIX - 2: Visual Basic Code

```
Public Function DrawPlume(MOOriginPt As MapObjects2.Point, IndustryCode As
String, HazardCode As String, PasFile As String, iRotationAngle As Double,
sIndustryName As String, sChemicalName As String) As Boolean
    Dim fso As New FileSystemObject
    Dim fFile
    Dim path As String
    Dim Sline As String
    Dim sLineContents() As String
    Dim sValueType As String
    Dim iLineCount As Integer
    Dim MOdc As New DataConnection
    Dim MOGD As MapObjects2.GeoDataset
    Dim TblDesc As New TableDesc
    Dim MONewLayer As New MapObjects2.MapLayer
    Dim MOpts As MapObjects2.points
    Dim MoNewPt As MapObjects2.Point
    Dim MOPlumePoly As MapObjects2.Polygon
    Dim MORotPlumePoly As MapObjects2.Polygon
    Dim MOMidPt1 As MapObjects2.Point
    Dim MOMidPt2 As MapObjects2.Point
    Dim MOFirstRotPoint As MapObjects2.Point
    Dim bPlumeStarted As Boolean
    Dim bIsMidPt As Boolean
    Dim iArcCount As Integer
    Dim iPolyCount As Integer
    Dim polyCol As New Collection
    Dim PointsCol As New Collection
    Dim iColCounter As Integer
    '-----Footprint arc variables-----
    Dim MOFootPrintPT1 As New MapObjects2.Point
    Dim MOFootPrintPT2 As New MapObjects2.Point
    Dim dFootPrintRadius As Double
    Dim MOFootPrintPoly As New MapObjects2.Polygon
    '-----Confidence arc variables-----
    Dim MOConfidencePT1 As New MapObjects2.Point
    Dim MOConfidencePT2 As New MapObjects2.Point
    Dim dConfidenceRadius As Double
    '-----
    Dim MOUnionPoly As New MapObjects2.Polygon
    '-----for rendering-----
    Dim MOVMRend As New MapObjects2.ValueMapRenderer
    Dim MOLblPlacer As New MapObjects2.LabelPlacer
    Dim MOLblPlacer As New MapObjects2.LabelRenderer
```

```

Dim MOGroupRend As New MapObjects2.GroupRenderer
Dim MOTxtSys As New MapObjects2.TextSymbol
Dim bIsConfidence As Boolean
'-----
On Error GoTo ErrorCheck
bIsConfidence = False
bPlumeStarted = False
Set polyCol = New Collection
If Not fso.FileExists(PasFile) Then
    MsgBox "Cannot locate the PAS File" & vbCrLf & "Aborting plume creation
process", vbExclamation, MSGTITLE
    DrawPlume = False
    Exit Function
End If
Set fFile = fso.OpenTextFile(PasFile, ForReading)
iLineCount = 0
iPolyCount = 1
iArcCount = 0
bIsMidPt = False
dFootPrintRadius = 0
Do While Not fFile.AtEndOfLine
    Sline = fFile.ReadLine
    Debug.Print Sline
    Erase sLineContents
    sLineContents = Split(Sline, " ")
    sValueType = Trim(sLineContents(0))
    If StrComp(sValueType, "A", vbTextCompare) = 0 Then
        '----check if the plume poly has started---
        If Not bPlumeStarted Then
            '---if plume poly has not started then the first A is for the small arc at the end of the
footprint plume poly--
            dFootPrintRadius = val(sLineContents(3))
        Else
            '---get the arc radius for the confidence plume poly----
            If iArcCount >= 1 Then
                If bIsConfidence Then
                    dConfidenceRadius = val(sLineContents(3))
                End If
            End If
        End If
        iArcCount = iArcCount + 1
    ElseIf StrComp(sValueType, "M", vbTextCompare) = 0 Then
        '-----the plume poly started---
        bPlumeStarted = True
        '-----start points collection ---
        If iLineCount <> 0 Then
            If iPolyCount = 2 And bIsConfidence Then iArcCount >= 2 Then

```

```

'-----if end of the first line for confidence poly is reached -----arc --
'-----then save the last point of the first line and the first---
'-----point of the second line of the confidence poly for generating the arc--
Set MOConfidencePT2 = MOPts.Item(MOPts.Count - 1)
Set MOConfidencePT1 = New MapObjects2.Point
MOConfidencePT1.x = MOOriginPt.x + Cdbl(sLineContents(1))
MOConfidencePT1.y = MOOriginPt.y + Cdbl(sLineContents(2))
Set MoNewPt = New MapObjects2.Point
MoNewPt.x = MOOriginPt.x + val(sLineContents(1))
MoNewPt.y = MOOriginPt.y + val(sLineContents(2))
MOPts.Add MoNewPt
'----
Else
Set MOMidPt1 = New MapObjects2.Point
Set MOMidPt1 = MOPts.Item(MOPts.Count - 1)
bIsMidPt = True
Set MoNewPt = New MapObjects2.Point
MoNewPt.x = MOOriginPt.x + val(sLineContents(1))
MoNewPt.y = MOOriginPt.y + val(sLineContents(2))
MOPts.Add MoNewPt
End If
Else
Set MOPts = New MapObjects2.points
Set MOPlumePoly = New MapObjects2.Polygon
Set MORotPlumePoly = New MapObjects2.Polygon
iLineCount = 1
MOPts.Add MOOriginPt
Set MoNewPt = New MapObjects2.Point
MoNewPt.x = MOOriginPt.x + val(sLineContents(1))
MoNewPt.y = MOOriginPt.y + val(sLineContents(2))
MOPts.Add MoNewPt
Set MOFirstRotPoint = MOOriginPt
End If
ElseIf StrComp(sValueType, "CONFIDENCE", vbTextCompare) = 0 Then
'----add the points collection to the polygon object---
MOPlumePoly.Parts.Add MOPts
bIsConfidence = True
'-----if the FootPrint Arc radius is present -----
If dFootPrintRadius <> 0 Then
'-----generate the footprint arc-----
Set MOUnionPoly = GeneratePolyArc(MOOriginPt, MOPlumePoly,
dFootPrintRadius, MOPts.Item(1), MOPts.Item(MOPts.Count - 1), True)
If iRotationAngle <> 0 Then
Set MORotPlumePoly = RotatePlume(MOUnionPoly, MOFirstRotPoint,
iRotationAngle)
Else

```

```

        Set MORotPlumePoly = MOUnionPoly
    End If
Else
    '-----if footprint arc is not present then simply rotate the poly according to the user
specified angle
    If iRotationAngle <> 0 Then
        If MOPlumePoly.Parts.Count > 0 Then
            Set MORotPlumePoly = RotatePlume(MOPlumePoly, MOFirstRotPoint,
iRotationAngle)
        Else
            Set MORotPlumePoly = MOPlumePoly
        End If
    Else
        Set MORotPlumePoly = MOPlumePoly
    End If
End If
'-----
If MORotPlumePoly Is Nothing Then
    MsgBox "Enable to create FootPrint Polygon." & vbCrLf & "Aborting Plume
creation", vbCritical, MSGTITLE
    DrawPlume = False
    Exit Function
End If
PointsCol.Add MOPts, "P" & iPolyCount & iLineCount
polyCol.Add MORotPlumePoly, "P" & iPolyCount
Set MOFootPrintPoly = MORotPlumePoly
iPolyCount = iPolyCount + 1
Set MOPts = New MapObjects2.points
iLineCount = 0
ElseIf StrComp(sValueType, "L", vbTextCompare) = 0 Then
    '----add the x and y to the points collection----
    Set MoNewPt = New MapObjects2.Point
    MoNewPt.x = MOOriginPt.x + val(sLineContents(1))
    MoNewPt.y = MOOriginPt.y + val(sLineContents(2))
    MOPts.Add MoNewPt
    If bIsMidPt Then
        Set MOMidPt2 = MoNewPt
        bIsMidPt = False
    End If
ElseIf StrComp(UCase(sValueType), "T", vbTextCompare) = 0 Then
    '---- Do nothing ----
End If
Loop
MOPlumePoly.Parts.Add MOPts
'----generate the arc for the confidence poly----

```



```

Set MOUnionPoly = GeneratePolyArc(MOOriginPt, MOPlumePoly,
dConfidenceRadius, MOConfidencePT1, MOConfidencePT2, False)
'PlumbetempPolColPlumbe.Add MOUnionPoly
'----rotate the confidence poly according to the user specified angle--
If iRotationAngle <> 0 Then
    If MOUnionPoly.Parts.Count > 0 Then
        Set MORotPlumePoly = RotatePlume(MOUnionPoly, MOFirstRotPoint,
iRotationAngle)

        If MORotPlumePoly Is Nothing Then
            MsgBox "Unable to rotate the plume according to specified direction" & vbCrLf &
"Aborting Plume creation", vbCritical, MSGTITLE
            DrawPlume = False
            Exit Function
        End If
    Else
        Set MORotPlumePoly = MOUnionPoly
    End If
Else
    Set MORotPlumePoly = MOUnionPoly
End If
'---if footprint arc radius is present then merge the footprint poly to the confidence poly
to get the back arc for the confidence poly--
If dFootPrintRadius <> 0 Then
    'Dim penV As New MapObjects2.Rectangle
    'Set MORotPlumePoly = GeneratePolyArc(MOOriginPt, MORotPlumePoly,
dFootPrintRadius, MOPts.Item(1), MOPts.Item(MOPts.Count - 1), True)
    'Set MORotPlumePoly = MORotPlumePoly.Union(MOFootPrintPoly,
MORotPlumePoly.Extent)
End If
polyCol.Add MORotPlumePoly, "P" & iPolyCount
PointsCol.Add MOPts, "P" & iPolyCount & iLineCount
If Not (CheckExistingLayer("Toxic_" & IndustryCode & "_" & HazardCode)) Then
    MsgBox "The toxic modelling results for the selected chemical is already present on
the map" & vbCrLf & "Please remove the toxic modelling result layer from the map and
then try again", vbExclamation, MSGTITLE
    DrawPlume = False
    Exit Function
End If
With TblDesc
    .FieldCount = 9
    '---set the field names---
    .FieldName(0) = "Name"
    .FieldName(1) = "Area"
    .FieldName(2) = "Perimeter"
    .FieldName(3) = "Ind_Name"

```

```

.FieldName(4) = "Chem_Name"
.FieldName(5) = "Ind_Code"
.FieldName(6) = "Haz_Code"
.FieldName(7) = "Desc"
.FieldName(8) = "MaxTZone"
'---set the type of field---
.FieldType(0) = moString
.FieldType(1) = moDouble
.FieldType(2) = moDouble
.FieldType(3) = moString
.FieldType(4) = moString
.FieldType(5) = moString
.FieldType(6) = moString
.FieldType(7) = moString
.FieldType(8) = moString
'---set the length of a character field---
.FieldLength(0) = 20
.FieldLength(3) = 20
.FieldLength(4) = 20
.FieldLength(5) = 20
.FieldLength(6) = 20
.FieldLength(7) = 30
.FieldLength(8) = 20
' set the number of digits used in the field
.FieldPrecision(1) = 15
.FieldPrecision(2) = 15
' set the number of digits to the right of the decimal point
.FieldScale(1) = 3
.FieldScale(2) = 3
End With
FilePath:
path = ""
Load frmDirectory
frmDirectory.InitForm
frmDirectory.Show vbModal
path = frmDirectory.SelectedPath
Unload frmDirectory
If Len(Trim(path)) = 0 Then
    DrawPlume = False
    Exit Function
End If
MOdc.DATABASE = path
If Not MOdc.Connect Then
    MsgBox "Unable to connect to selected folder for saving plume shape file " & vbCrLf
    & "Please select another folder to save plume as shape file", vbOKOnly, MSGTITLE
    GoTo FilePath

```

```

End If
Set MOGD = MOdc.AddGeoDataset("Toxic_" & IndustryCode & "_" & HazardCode,
moPolygon, TblDesc)
If MOGD Is Nothing Then
    If MsgBox("Unable to create shape file to save the plume in the selected directory" &
vbNewLine & "Do you want to save the plume in some other folder?", vbExclamation +
vbYesNo, MSGTITLE) = vbYes Then
        MOdc.Disconnect
        GoTo FilePath
    Else
        DrawPlume = False
        Exit Function
    End If
End If
Set MONewLayer.GeoDataset = MOGD
MONewLayer.Name = "Toxic_" & IndustryCode & "_" & HazardCode
Set MOPlumePoly = New MapObjects2.Polygon
For iColCounter = 1 To polyCol.Count
For iColCounter = polyCol.Count To 1 Step -1
    Set MOPlumePoly = polyCol.Item(iColCounter)
    With MONewLayer.Records
        .AddNew
        .Fields("Shape").Value = MOPlumePoly
        If iColCounter = 1 Then
            .Fields("Name").Value = "FootPrints"
            .Fields("Area").Value = Abs(MOPlumePoly.Area)
            .Fields("Perimeter").Value = Abs(MOPlumePoly.Perimeter)
            .Fields("Ind_Name").Value = sIndustryName
            .Fields("Chem_Name").Value = sChemicalName
            .Fields("Ind_Code").Value = IndustryCode
            .Fields("Haz_Code").Value = HazardCode
            .Fields("Desc").Value = "Most Likely Threat Zone"
            .Fields("MaxTZone").Value = ""
        Else
            .Fields("Name").Value = "Confidence Lines"
            .Fields("Area").Value = Abs(MOPlumePoly.Area)
            .Fields("Perimeter").Value = Abs(MOPlumePoly.Perimeter)
            .Fields("Ind_Name").Value = sIndustryName
            .Fields("Chem_Name").Value = sChemicalName
            .Fields("Ind_Code").Value = IndustryCode
            .Fields("Haz_Code").Value = HazardCode
            .Fields("Desc").Value = "Possible Threat Zone"
            .Fields("MaxTZone").Value = dConfidenceRadius
        End If
        .Update
    End With

```

```

Next
MONewLayer.Records.StopEditing
With MOVMRend
.SymbolType = moFillSymbol
.Field = "Name"
.ValueCount = 2
.Value(0) = "FootPrints"
.Symbol(0).Color = moRed
.Symbol(0).Style = moCrossFill
.Value(1) = "Confidence Lines"
.Symbol(1).Color = moBlue
.Symbol(1).Style = moCrossFill
End With
MOGroupRend.Add MOVMRend
MONewLayer.Renderer = MOVMRend
'---add the new plume shapefile as new theme to the map---
Call DOMModule.AppendLayer(DOMMaps.Item(frmMDIMain.ActiveForm.Caption),
App.path & "\" & path, "Toxic_" & IndustryCode & "_" & HazardCode, MONewLayer)
Call
DOMModule.SetMODIFIEDAttribute(DOMMaps.Item(frmMDIMain.ActiveForm.Capti
on))
frmMDIMain.legmap.setMapSource frmMDIMain.ActiveForm.Map
frmMDIMain.legmap.LoadLegend True
frmMDIMain.CreateLocatorMap
'----call procedure to store the modeling result layer name into collection for query zone-
--
Call StoreModResLyrName("Toxic_" & IndustryCode & "_" & HazardCode)
frmMDIMain.mnuQuery.Visible = True
'--- to referesh the map tips combos call cbotiplayer's click procedure----
MOdc.Disconnect
Set MOdc = Nothing
Set MOGD = Nothing
Set MONewLayer = Nothing
DrawPlume = True
Exit Function
ErrorCheck:
DrawPlume = False
Call ShowError("DrawPlume")
End Function

```

APPENDIX - 3: Selection key for Aloha

1.	Is the release happening outdoors?	
	Yes.	Continue to 2.
	No, it's an indoor release.	Don't use ALOHA. It can only account for the forces that move and disperse gases in the open atmosphere.
2.	Is the substance very hot or burning?	
	No	Continue to 3.
	Yes.	Don't use ALOHA. It does not account for the way that very hot gases rise upwards in the atmosphere or for reactions among chemicals in a fire. Usually, what's released in a fire is a complex mixture of combustion and reaction byproducts rather than the original chemical.
3.	Is the substance a pure chemical?	
	A pure chemical is not mixed with other chemicals and is not in solution in water or any other liquid. Examples of common pure chemicals are chlorine, anhydrous ammonia, and propylene. In contrast, many chemicals exist in mixtures or solutions. Examples of common mixtures or solutions are oleum, most acids, most petroleum products including vehicle fuels like gasoline—and liquid formaldehyde.	
	Yes.	Continue to 4.
	No, it's a mixture or solution.	<p>Avoid using ALOHA. It can't help you <i>unless</i> you can estimate how rapidly one component of a liquid solution is evaporating from a pool. For example, you might be able to estimate how fast hydrogen chloride gas is evaporating from a pool of hydrochloric acid.</p> <p>If you have such an estimate, continue to 3. If after completing all remaining steps in this decision key you find that you can use ALOHA, you should choose the Direct source option. Skip the Source Selection Key and turn to your User's Manual to learn how to enter information about a direct release.</p>

<p>4.</p>	<p>Is the substance a particulate or solid?</p> <p>Particulates include dusts, powders, and radioactive particles. Solids include granules and crystals, such as ammonium nitrate and phosmet.</p>
<p>No, it's a gas or liquid.</p>	<p>Continue to 5.</p>
<p>Yes.</p>	<p>Avoid using ALOHA. It doesn't account for the way that particulates fall out of the atmosphere as they travel downwind. Granular and crystal solids rarely enter the atmosphere in significant amounts.</p> <p>Consider using ALOHA only if</p> <p>(a) you can estimate the sublimation rate of a solid (some solids, such as solid carbon dioxide and iodine, pass from the solid to the gas phase without first becoming liquids. This is called sublimation. If you have a sublimation rate estimate, continue to 5. If after completing all remaining steps in this decision key you find that you can use ALOHA, you should choose the Direct source option. Skip the Source Selection Key and turn to your User's Manual to learn how to enter information about a direct release.</p> <p>(b) The particulates you're concerned about are so fine that they remain suspended in the air for a very long time; such substances may behave enough like gases to be modeled in ALOHA. If this is the case, and you have an estimate for the rate at which the substance is entering the atmosphere or the amount that has entered, continue to 5. If after completing all remaining steps in this decision key you find that you can use ALOHA, you should choose the Direct source option. Skip the Source Selection Key and turn to your User's Manual to learn how to enter information about a direct release.</p>

5.	Is it raining or snowing?	
	No.	Continue to 6.
	Yes.	Don't use ALOHA if it's raining or snowing hard. You may wish to use ALOHA if precipitation is very light, but be aware of two possible problems: (1) ALOHA may overestimate gas concentrations, and (2) many chemicals react with water, sometimes forming new compounds with very different properties.
6.	Is the release located in relatively level terrain?	
	Yes.	Continue to 7.
	No, the terrain is very hilly, or there are many buildings in the area.	Avoid using ALOHA. Use ALOHA only to get an impression of the scale of the release. For example, use it to find out whether hazardous gas concentrations may extend for many city blocks or for just a few yards downwind. Because ALOHA expects terrain to be relatively level, <i>don't</i> expect the footprint to accurately represent the area at risk. If you just want to estimate the scale of the release, continue to 7.
7.	Do you only want to estimate gas concentrations very near the release point?	
	No.	Continue to 8.
	Yes.	Don't use ALOHA. It can't accurately predict gas concentrations very close to the release point. ALOHA will not display a footprint plot if the distance to your level of concern is less than 109 yards (100 meters).
8.	Do you want to predict gas concentrations for very long distances (more than 6 miles, or 10 kilometers, from the release point)? You might be interested in predicting the very long-distance dispersion of a gas if you are concerned about a very large accidental release (a very large cloud may travel long distances before it disperses), or if you are studying air pollution emitted from power plants, factories, or other sources of long-term emissions.	

	No.	Continue to 9.
	Yes.	Don't use ALOHA. ALOHA cannot predict concentrations more than 6 miles (10 kilometers) from the release point. This is because the factors that influence the movement of a gas cloud, especially wind speed and direction, and is almost certain to change over that distance.
9.	Is the chemical in ALOHA's chemical library, or do you know its properties?	
	<p>ALOHA needs to know some of the properties of a chemical before it can predict that chemical's behavior. For about 470 chemicals, ALOHA's chemical library contains all necessary property information. (For the rest of the chemicals in the library, depending on the source option you choose, you may need to add more property information.) If a chemical is not in the library, you must add the necessary property information to the library before you can run ALOHA. You can find out which properties ALOHA needs by checking the Properties Table (page 16).</p>	
	Yes.	Continue to 10.
	No.	Don't use ALOHA. Without the necessary property values, it can't make any predictions.
10.	Do you have a level of concern (LOC) for the chemical?	
	Yes.	You can use ALOHA. Turn to the Source Selection Key (next page).
	No.	<p>Either</p> <p>consult a specialist to obtain an LOC. A toxicologist or industrial hygienist may be able to help you. ALOHA requires an LOC because the footprint plot is a diagram of the area where predicted airborne gas concentrations exceed the LOC.</p> <p>don't use ALOHA.</p>

APPENDIX - 4
MANUFACTURE, STORAGE AND IMPORT OF HAZARDOUS CHEMICAL
RULES, 1989
SCHEDULE I

[See rule 2(c)(i), 4(1)(a), 4(2), 17 and 18]

Indicative Criteria and List of Chemicals

PART I

(a) Toxic Chemicals: Chemicals having the following values of acute toxicity and which owing to their physical and chemical properties, are capable of producing major accident hazards:

Sr.No	Toxicity	Oral toxicity LD50(mg/kg)	Dermal toxicity LD50(mg/kg)	Inhalation toxicity LC50(mg/l)
1.	Extremely toxic	> 5	<40	< 0.5
2.	Highly toxic	>5-50	>40-200	< 0.5 - 2.0
3.	Toxic	>50-200	> 200-1000	>2-10

(b) Flammable Chemicals:

- i. flammable gases: Gases which at 20⁰C and at standard pressure of 101.3 KPa are:-
 - a. ignitable when in a mixture of 13 percent or less by volume with air, or
 - b. have a flammable range with air of at least 12 percentage points regardless of the lower flammable limits.

Note: - The flammability shall be determined by tests or by calculation in accordance with methods adopted by International Standards Organisation ISO Number 10156 of 1990 or by Bureau of Indian Standards ISI Number 1446 of 1985.

ii. extremely flammable liquids: chemicals which have flash point lower than or equal to 23⁰C and boiling point less than 35⁰C

(iii) very highly flammable liquids: chemicals which have a flash point lower than or equal to 23⁰C and initial boiling point higher than 35⁰C.

(iv) highly flammable liquids: chemicals which have a flash point lower than or equal to 60⁰C but higher than 23⁰C.

(v) flammable liquids: chemicals which have a flash point higher than 60⁰C but lower than 90⁰C.

(c) Explosives: explosives means a solid or liquid or pyrotechnic substance (or a mixture of substances) or an article.

(a) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings;

(b) which is designed to produce an effect by heat, light, sound, gas or smoke or a combination of these as the result of non-detonative self sustaining exothermic chemical reaction.

SCHEDULE 2

[(See rule 2(e)(ii), 4(1)(b), 4(2) (1) and 6(1)(b)]

Isolated storage at Installations other than those covered by Schedule 4

(a) The threshold quantities set out below relate to each installation or group of installations belonging to the same occupier where the distance between installation is not sufficient to avoid, in foreseeable circumstances, any aggravation of major accident hazards. These threshold quantities apply in any case to each group of installations belonging to the same occupier where the distance between the installations is less than 500 metres.

(b) For the purpose of determining the threshold quantity of hazardous chemical at an isolated storage, account shall also be taken of any hazardous chemical which is:-

(i) in that part of any pipeline under the control of the occupier having control of the site which is within 500 metres of that site and connected to it;

(ii) at any other site under the control of the same occupier any part of the boundary of which is within 500 metres of the said site; and

(iii) in any vehicle, vessel, aircraft or hovercraft, under the control of the same occupier which is used for storage purpose either at the site or within 500 metres of it;

but no account shall be taken of any hazardous chemical which is in a vehicle, vessel, aircraft or a hovercraft used for transporting it.

Sl. No.	Chemicals	Threshold Quantities (tonnes)	
		For application of Rules 4, 5 and 7-9	For application of Rules 10 to 15
1	2	3	4
1	Acrylonitrile	350	5,000
2	Ammonia	60	600

3	Ammonium nitrate (a)	350	2,500
4	Ammonium nitrate fertilizers (b)	1,250	10,000
5	Chlorine	10	25
6	Flammable gases as defined in Schedule 1, paragraph (b) (i)	50	300
7	Highly flammable liquids as defined in Schedule 1, paragraph (b) (ii)	10,000	100,000
8	Liquid oxygen	200	2,000
9	Sodium chlorate	25	250
10	Sulphur dioxide	20	500
11	Sulphur trioxide	15	100

(a) This applies to ammonium nitrate and mixtures of ammonium nitrates where the nitrogen content derived from the ammonium nitrate is greater than 28 per cent by weight and to aqueous solutions of ammonium nitrate where the concentration of ammonium nitrate is greater than 90 per cent by weight

(b) This applies to straight ammonium nitrate fertilizers and to compound fertilizers where the nitrogen content derived from the ammonium nitrate is greater than 28 per cent by weight (a compound-fertilizer contains ammonium nitrate together with phosphate and/or potash).

References:

- *RISK MANAGEMENT PROGRAM GUIDANCE FOR OFFSITE CONSEQUENCE ANALYSIS*, Guidance document by Chemical Emergency Preparedness and Prevention Office EPA Publication No. 550-B-99-009.
- *Paul N. Cheremisinoff and Richard A. Young (1975), Pollution Engineering Practice Handbook*, Ann Arbor Science Publishers inc., Ann Arbor, Mich, USA
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- <http://www.epa.gov/ceppo/cameo/index.htm>, ALOHA software download and reference manual.
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