GIS Emergency Management for the University of Redlands

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Abstract

In times of crisis, the President and other senior official at the University of Redlands (UoR) have the primary responsibility for rapidly and effectively managing any emergency that might occur on or affect the UoR campus. To assist the University, a customized GIS application was developed enabling a temporal based analysis of a disaster occurrence integrated with concentrations of campus populations identified down to the room level. The GIS Emergency Management System (GEMS) application is an interactive system to be utilized in the Emergency Operation Center to support the direction of the response. If a disaster were to occur, the response and recovery efforts could be initially focused to the most critical areas with the largest concentrations of people.

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I. Overview:

Emergency management encompasses a wide range of activities and procedures that occur within all levels of government ranging from federal agencies down to individual localities. In addition, emergency management is a vital outside of government, and the safety of students, personnel, and visitors is a top priority for the University of Redlands (UoR). In times of crisis, the President of the University of Redlands, and other senior University officials have the primary responsibility for rapidly and effectively managing any emergency that might occur on or affect the UoR campus. The Crisis Management Plan (CMP) at the UoR is designed to be a framework for crisis management rather than step-by-step directions for handling any and every conceivable crisis. If a disaster were to occur, the response and recovery efforts could be initially focused to the areas with the most critical danger and the areas with the largest concentrations of people.

A Geographic Information System (GIS) is a flexible tool that can be utilized to provide detailed situational information for response to an emergency situation within the CMP framework. The GIS Emergency Management System (GEMS) application is an interactive system to be utilized in the Emergency Operation Center (EOC) at the University to direct the response. The intended audience in the EOC will consist of members from University Campus Safety, Facilities Management, and the Administration. To assist those responding to a disaster in the field, a campus map with concentrations of people identified and threat areas overlaid would be of invaluable benefit; this output can be printed from the GEMS application and delivered to response personnel as appropriate.

The GEMS application was developed to support the CMP at the UoR for mitigating, preparing, responding and recovering from a disaster. The overall goal for the GEMS application is to develop, promote, and implement location-based data and GIS technology in support of emergency management at the UoR. The GEMS approach is to integrate geographic and attribute data from the UoR with disaster occurrence data to analyze, support, record and track the different phases of emergency response management.

GEMS is an Environmental Systems Research Institute, Inc. (ESRI) ArcGIS 8.x application customized with the Visual Basic for Applications (VBA) development environment and the ArcObjects library. All code is saved within the GEMS.mxd (an ArcGIS map document) and can leverage the full GIS functionality of ArcGIS. An installation CD for GEMS has been created for all the required components to run on top of the ArcGIS application. GEMS can be easily implemented on any machine running ArcGIS 8.x.

II. Background

There are several key components that are required for an emergency management plan. For an application to best support this plan, it is important to first understand the threats facing the UoR and the surrounding areas. Second, it is essential to understand the benefits of using GIS for such an application. Third, one must understand the different phases of emergency management and the support GIS can provide to each phase.

A. Threats Facing the University of Redlands

Threats to public safety at the UoR can come from many sources including human and natural. Human-caused threats are those unintended events or accidents resulting from human activity. Examples include chemical spills, utility failures, airborne illness, plane crashes, truck crashes, explosions, and fires. In addition, other human caused disasters can be events or activities planned to intentionally cause disruption to a population. These

can include such actions such as riots, demonstrations or bomb threats. Finally, human threats can be attacks, particularly relevant with the current threats facing homeland security. This may include acts of terrorism using nuclear, conventional or biological agents (Johnson 2000). Although the UoR may never be a direct target, the University's close proximity to larger metropolitan areas and military bases poses a serious threat.

A second type of threat facing the UoR is from natural causes. The UoR location in near proximity to the San Andres fault makes it particularly vulnerable to earthquakes and their many secondary effects including building structural failure, pipeline breaks, release of hazardous chemicals, fire, and down electrical power lines. Another natural hazard facing the UoR is wild fires; the dry climate of the region increases the likelihood of danger and disruption caused by uncontrolled fires. Although the Redlands' area is dry most of the year, there is potential for excessive rain and the resulting floods during certain seasons. For example, the Seven Oaks Dam was completed to help mitigate flood damages; however, with the University being located 8 miles southwest of the dam, it is potentially in harms way if the dam was to experience a structural failure.

B. Benefit of GIS for Emergency Management

The threats identified have a spatial context as they all affect geographic locations and the population at those locations. Mapping and information acquisition is vital for disaster management and recovery efforts. There are a several reasons why GIS is well suited for a disaster management application. First, GIS systems produce information quickly, which is particularly important for emergency managers who need to make time-critical decisions. GIS applications can create maps quickly integrating data into one single picture, both dynamically on a computer screen and in the form of a printed map. Second, GIS data is typically portrayed in a map with structured data, and thus the information is well organized, accessible and easy to understand, promoting informed decision-making and ad hoc analysis and reporting capabilities. A map with critical areas identified can communicate data quickly and in a manner easily understood compared with a strictly tabular data output. Third, in GIS, data is easy to update, and it is easy to maintain current files and data integrity. It can provide a visual query interface that makes it is easy to enter and access the data stored in a structured format. (FEMA 2002)

C. Emergency Management Phases

To plan for and respond to threats, the UoR Crisis Management Plan details four key phases that are related by time and function to all types of emergencies and disasters. The phases are: Mitigation, Preparedness, Response and Recovery. GEMS is a tool that can be used to support each crisis management phase (University of Redlands 2002).

First, the *Mitigation Phase*, measures are taken to avoid crisis or to prevent small emergencies from becoming a large crisis (Green 2002). Developing proper rules and procedures can go a long way to avoid a disaster and protect the population. To assist this, GEMS can help with the situational awareness of the University and its surrounding areas with the spatial data layers that are incorporated into the application. In addition, a component of the GEMS application is the functionality to analyze where concentrations of people are throughout the day. Knowing where concentrations of populations are on campus throughout the day and proper locations to store hazardous material can help avoid a catastrophe.

Second, the *Preparedness Phase,* includes the activities necessary to analyze the possibility of an emergency or disaster and the development of plans and procedures to enable the

effective and efficient use of resources in the event of a crisis. The impact of a disaster will be minimized if the response is well planned and efficient (Green 2002). Knowing the populated locations on campus will provide insight, such as high risk areas, into forming the plans and procedures for the disaster response and evacuation. Through GEMS, one can enter simulated disaster occurrence to support planning and "what-if" analysis for disaster management. Those responsible for disaster response and management now have a tool to better visualize the effects of a disaster and how it relates to the population on campus. Preparing and learning to use tools, such as GEMS, in a disaster situation is also part of the Preparedness Phase. GEMS entails the modeling and analysis of threats and disasters, allowing actions to be taken prior to events turning into a full blown disaster occurrence. However, this will only provide benefit if the users know how to model and analyze the threats and disasters.

Activities following an emergency or disaster make up the *Response Phase,* which is the third phase in emergency management and disaster planning. These activities are designed to provide coordinated emergency assistance for the population in need. The Response Phase also seeks to stabilize the situation by rapidly identifying risk areas and cordoning off those areas, reducing the probability of secondary casualties and damage (Green 2002). This is done in GEMS by recording a disaster and threats through a circular threat range or a modeled plume area. Identifying the location and area of a disaster can be combined with the population locations in GEMS to identify the population in harms way. This will provide information for the evacuation effort and/or the recovery efforts. Recording the disaster occurrence with a threat range or plume, the risk areas can easily be identified with a visual map display and then cordoned off as appropriate. Additionally, by incorporating a campus grid overlay with the spatial data of the University, GEMS can be use in the Emergency Operations Center (EOC) to direct responders in the field.

The final phase is the *Recovery Phase* when all systems return to normal operations and capacity after responding to a threat or disaster. By recording the disaster occurrence in GEMS with a timeframe and detailed descriptions, the system can help manage and track the recovery status for each disaster occurrence. In addition, each disaster occurrence can be further analyzed with ad hoc spatial queries by a knowledgeable GIS user. As information changes, reports and maps can easily be updated and generated.

III. GEMS Overview

For the initial implementation of a GIS emergency management system at the University of Redlands, there are several key functional components being delivered. The first component, Population Locator, includes the capability for spatially locating concentrations of people throughout the day on campus, utilizing records extracted from the Office of the Registrar to aggregate known population concentrations. The second component, Disaster Occurrence, provides the capability to record disasters with a threat range or modeled plume into the database. The final Query and Analysis component enables the campus population to be analyzed with the threat areas for a given date and time query. Additional ad hoc analysis is promoted with the available data and the full GIS functionality of ArcGIS.

A. Population Locator Component

The first component developed for GEMS is the function to locate the concentration of people throughout the day for classes located on the main UoR campus. This integrates several data sources from the UoR Registrar's office into the GEMS database. The first record set from the Registrar's office is the classroom location schedule which includes the day and the time frame for each class in the semester. The second record set is the

aggregated student class data to be able to determine the number of students in each class. Records can be updated on an as needed basis throughout a semester with inputs provided the Office of the Registrar. As an updated record set is provided, the corresponding semester records in the database will be overwritten.

Additionally, to accommodate for known population concentrations outside of classes, such as dining hall crowds or football game crowds, population estimations can be recorded directly into a table in the GEMS database. Although not currently implemented, a future upgrade might be to incorporate the data from an electronic conference room or event planner utilized at the University of Redlands, allowing for more accurate population identification.

GEMS incorporates population concentrations and does not model locations of an individual person. As a result, faculty and professors are not included in the population calculations. The intent of the application is to identify where the larger concentrations of people are located to initially focus the response and recovery. Once those locations have been responded to, a recovery effort can then be initiated for the remaining people throughout the disaster or threat areas.

To improve the granularity of data analysis, the floor plans for the classroom buildings at the University have been added to this application. Additional floor plans can be added to the geodatabase through a standard ArcGIS import routine for the respective layers.

Using the population component in GEMS there is potential to analyze the crisis management plans. For example, it is possible to identify and review proposed evacuation sites and routes. With the population component factored into the equation, these plans can be further tailored for each semester based on the changes in population concentrations or for population fluctuations throughout the day. Another example utilizing the population information would be to assist the location of first aid stations and/or phone banks when required. Nevertheless, the most important feature of GEMS is the ability to identify the large concentrations of people to help focus the initial rescue and evacuation efforts.

B. Disaster Occurrence Component

It is important to document and track disaster occurrences to support the phases in a disaster management plan, a component implemented with GEMS. Once a disaster occurs, it can be recorded into the application through a graphical user interface. As events unfold, the user can document the location, the disaster or threat area, time frame, hazard type, and detailed description of the disaster.

Two types of disaster or threat areas can be defined. The first is a circular threat or disaster range suitable for occurrences such as a bomb threat. This only requires a source location and threat radius to create the area. The second is for areal hazards as complex plume areas can be modeled with the Environmental Protection Agency's (EPA) Areal Locations of Hazardous Atmospheres (ALOHA) model and utilized within GEMS. ALOHA estimates air dispersions to evaluate hazardous chemical release scenarios and predict dispersion scenarios.

As a disaster or threat is discovered, plotting its location on the map allows crisis managers to make informed decisions regarding the threat to the campus population and to identify priorities for campus evacuation if required. Once a disaster is recorded, it can be used to analyze the location of people in harms way. Figure 1 shows an example of the outputs possible with a GIS enabled system. Additionally, key roads can be identified for evacuation

planning. With the hazard area identified, one can quickly visualize a safe evacuation route on the applications map.

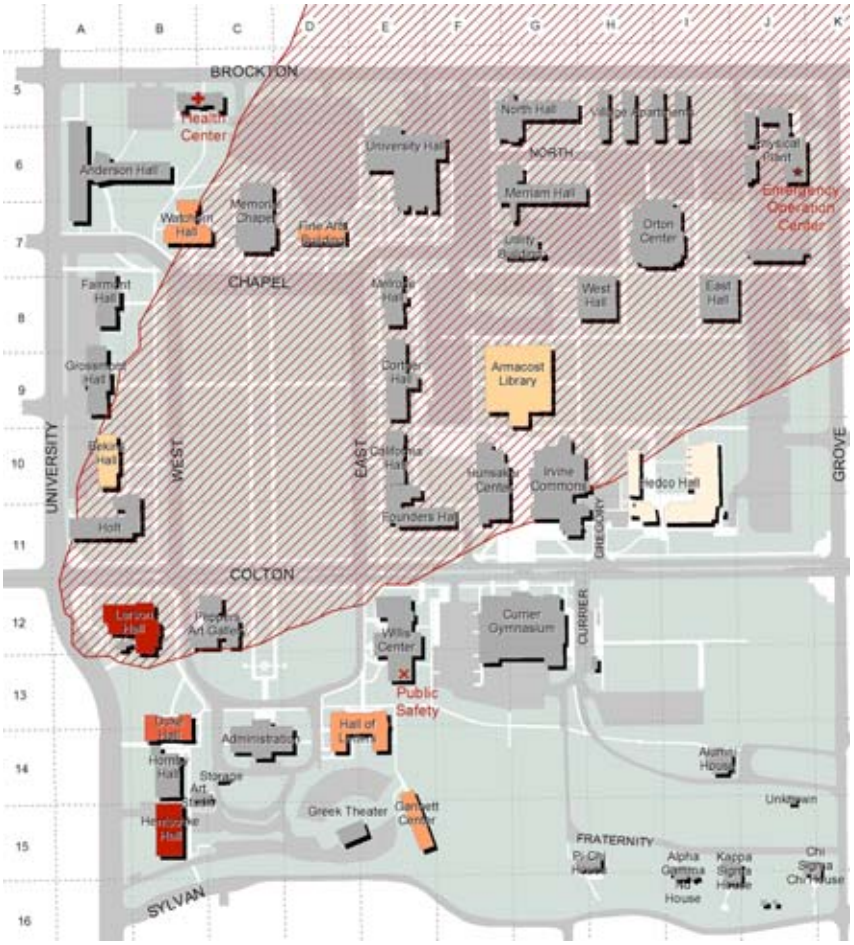

Figure 1 – Simulated GEMS disaster occurrence with buildings symbolized by population

C. Query and Analysis Component

With the population concentrations and disaster or threat areas incorporated into GEMS, the final component developed is for querying and analyzing the data. Concentrations of the population can be isolated for a specific date/time through a query. For the initial implementation of this application the results are displayed on the map at the building level, but an output table can be generated to identify populations at the room level. The key spatial data set used to display the results is the UoR building spatial layer. A look-up table creates the relation between the registrar attribute data and the building spatial data based on the query. As queries are generated in the application, the results are displayed as map layers with a population field. In addition, a Hypertext Markup Language (HTML) report is created with the location of population concentrations displayed to the room level.

With the threats previously entered into the system, a threat query based on time can be displayed on the map. This will allow analysis with the threat area defined and displayed on the map interface. Additionally, the population concentrations can be identified within the threat ranges for a given time, identifying the specific population concentrations in harms way.

Another query capability is to zoom down to the room level of the buildings. By selecting a date/time and clicking on a room will display the contact information for the students registered for that class and any special medical conditions are pertinent to the safety of a student. This may be particularly useful in lock down situations to inform the contacts for each student, as shown in Figure 2.

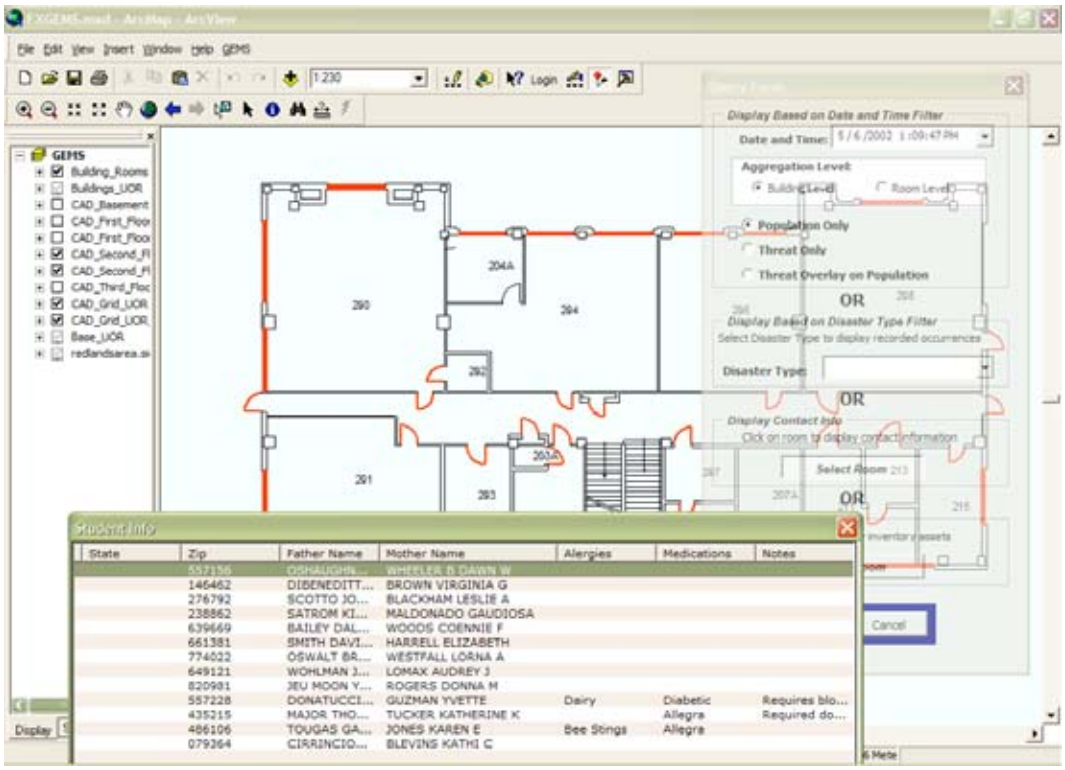

Figure 2 – Drill down to Student Contact information

The results of the other queries are a generated html report with tabular data and a map. This can be printed out easily, used interactively in the EOC, or quickly and easily copied to a web server to share information across the internet. Figure 3 is a sample HTML report generated by the GEMS application.

Note: Critical buildings containing populations within a threat zone are labeled

The following buildings have populations and are located within the threat zone

Building (Student Count)
Armacost Library (13)
Currier Gymnasium (26)
Duke Hall (78)
Gannett Center (42)
Hall of Letters (186)
Hedco Hall (45)
Hornby Hall (38)
Peppers Art Gallery (17)

Date Printed: 12/3/2002 5:43:11 PM

Figure 3 – Sample HTML document output

IV. GEMS Design Considerations

The overall goal of the GEMS application is to develop, promote, and implement location-based data and GIS technology in support of emergency management at the UoR. The GEMS approach is to integrate sources of geographic and attribute data from the UoR with threat or disaster occurrences in a GIS application to analyze, support, record and track the different phases of emergency response management (Figure 4).

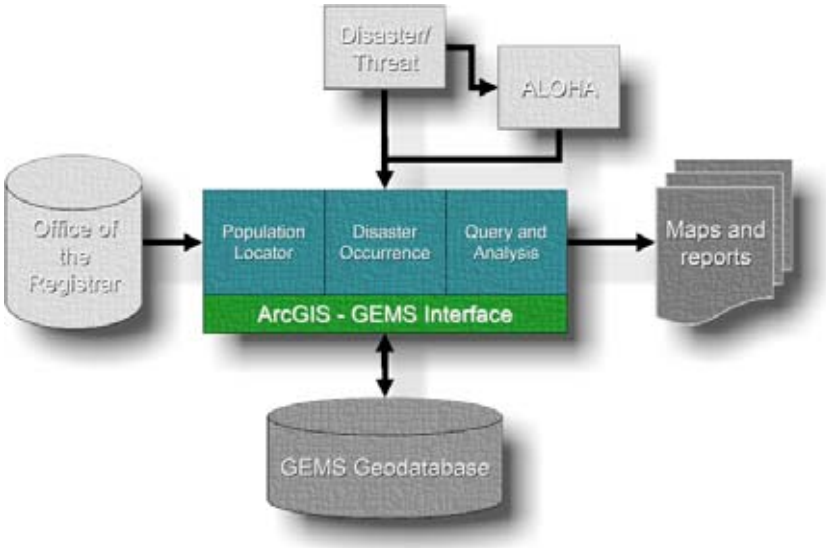

Figure 4 – GEMS overview architecture

GEMS is built on ArcGIS 8.x, a customizable commercial off the shelf (COTS) GIS software package. The software is developed and distributed by Environmental Services Research Inc. (ESRI) of Redlands, CA. GEMS is developed in compliance with the UoR campus wide software license for ESRI products. The emphasis for the GEMS application is a focus on a simple interface with the key functionality readily available for the purpose of avoiding additional stress on the user when employing GEMS in response to a disaster.

The data for the system is stored in the ArcGIS personal geodatabase, which uses Microsoft Access technology. This will allow easy replication and duplication in case stand-alone machines are required in the time of crisis. The concentrations of populations will remain on the closed network and should not be stored on a shared network drive. With the current terrorism threats facing the U.S., this is sensitive data that should not be in the public domain and used only for public safety at the UoR.

A. Selection of GIS Technology

There are numerous GIS technologies available for purchase within a broad range of prices. Most of the available technologies are viable for an emergency management system. GEMS was developed using ESRI ArcView 8.2 technology for several reasons.

First, ArcGIS 8.x is a full featured GIS application designed for a familiar Windows user interface. Out of the box functionality includes three desktop applications providing data display, query, analysis, geographic and tabular data management, creation, organization and basic data conversions. Using the three applications together, there is a wide range of GIS tasks that can be performed. GEMS is built using ArcView, which is the cheapest purchase level for the ArcGIS 8.x platform. ArcView provides comprehensive mapping and analysis tools along with simple editing and geoprocessing tools (ArcGIS Manual).

Second, ArcGIS includes the programming language Visual Basic for Applications for a robust customization environment. The ArcObjects library with over 1200 objects is currently one of the worlds largest object oriented application environments. Sophisticated forms and code can be quickly developed for customized applications.

Third, ArcGIS can interact with a variety of spatial formats including the personal geodatabase which is highly practical for the smaller scale, self-contained emergency management applications, such as GEMS. While ArcGIS uses Microsoft Access technology, it is not Microsoft Access and is not required to be installed on the machine, only the Jet database engine technology that is automatically installed with ArcGIS. This is the default installation and does not require sophisticated configuration or setup of the database.

A personal geodatabase format has many benefits with an emergency management system. First, it may be a more familiar format for those who are not GIS experts and makes it easier and more intuitive to use GIS across many applications. During stressful situations, such as a disaster response, one's instincts tend to take over and a familiar storage application can be crucial for its usability. In addition, this facilitates use for ad hoc queries and reports, which are often required in a disaster situation. Additionally, the data stored in the geodatabase can be accessed through Structured Query Language (SQL), an information technology industry standard.

Another benefit is that all the vector and attribute information for the application is stored in one COTS RDBMS. Given the inherent properties of the DBMS, the geodatabase is well structured for handling both the spatial and attribute data within its own framework. Replicating the geodatabase is much easier within such a structured system, particularly with the personal database. To move or copy the spatial data to additional machines or to create a backup only requires the copying or moving of one file that can be exponentially compressed using tools such as Winzip. Unlike other spatial data structures such as ESRI Coverages, this can easily be done with a windows file management utility, such as Windows Explorer, without relying on specialized applications. In times of disaster response, complete data sets for the University can quickly be copied to stand alone machines without a functional network.

There are limitations to using the personal geodatabase such as size limitations and performance issues as the database grows. However, the smaller scale of the GEMS database should not come close to the size limitation of approximately 250,000 objects and can support several simultaneous clients viewing the data.

The final consideration, and perhaps the most important, is the cost of the application. The software is available site wide for the University of Redlands and thus does not cost Public Safety or Facilities Management more funds to leverage this technology. Based on these considerations, GEMS was developed as a customized ArcGIS application.

V. Recommendations for the Use of GEMS

The GEMS application could be of great benefit, not only in response to a threat or disaster, but also in planning scenarios for the University of Redlands. For these benefits to be achieved, it will take a minimal effort from several organizations.

- The data must be kept up-to-date in the application. This requires those responsible for the public safety at the University to keep the registrar and class data updated at least once a semester. If these records are not entered into the system then the population component of the application is rendered useless.
- Information Technology Services (ITS) at the UoR must continue to provide the Registrar data files in the requested format at least once a semester. As their technology infrastructure gets upgraded, new procedures may need to be established to make the registrar data available for importation in the GEMS application.
- A commitment is required to learn the basic foundations of operating a GIS application and learning the key functionality of GEMS before an emergency occurs.

An on going review of emergency management plans should include regular practice and exploration with GEMS.

With the minimal effort for maintenance, the GEMS application and GIS platform provides the University of Redlands a powerful analysis tool to be used in all facets of emergency management and response planning and procedures.

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