GIS for Emergency Management

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Contents **Page**

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Introduction

Emergency management encompasses a wide range of activities. Government at all levels (federal, state, and local) has primary responsibility for emergency management. Traditionally, the military has responsibility for threats from foreign governments. Lawmakers and policy makers are debating the appropriate role of the National Guard and military concerning internal terrorism. This paper will identify emergency management activities and describe how GIS plays a critically important role. First, it is important to define a number of terms. These terms follow.

Terms Defined

Emergency: An emergency is a deviation from planned or expected behavior or a course of events that endangers or adversely affects people, property, or the environment.

Disaster: Disasters are characterized by the scope of an emergency. An emergency becomes a disaster when it exceeds the capability of the local resources to manage it. Disasters often result in great damage, loss, or destruction.

Risk: Risk is the potential or likelihood of an emergency to occur. For example, the risk of damage to a structure from an earthquake is high if it is built upon, or adjacent to, an active earthquake fault. The risk of damage to a structure where no earthquake faults exist is low.

Hazard: Hazard refers generally to physical characteristics that may cause an emergency. (For example, earthquake faults, active volcanoes, flood zones, highly flammable brush fields, are all hazards.)

General Types of Emergencies

Human-Caused

Human-caused emergencies include those unplanned events or accidents that result from human activity or human developments. Examples include chemical spills, nuclear radiation escapes, utility failures, epidemics, crashes, explosions, urban fires, and so forth.

Natural Disasters

Natural disasters include those unplanned events that occur as a result of natural processes such as earthquakes, tornadoes, tsunamis, freezes, blizzards, extreme heat or cold, drought, insect infestation, and so forth.

Internal Disturbances

Internal disturbances are those events or activities planned by a group or individual to intentionally cause disruption. This includes riots, demonstrations, large-scale prison breakouts, violent strikes, and so forth.

Energy and Material Shortages

Emergencies as a result of shortages include strikes, price wars, resource scarcity, and so forth.

Attack

This includes acts of large-scale terrorism or war using nuclear, conventional, or biological agents.

Emergency Management Phases

Emergency management activities can be grouped into five phases that are related by time and function to all types of emergencies/disasters. These phases are also related to each other, and each involves different types of skills.

Planning

Activities necessary to analyze and document the possibility of an emergency or disaster, and the potential consequences or impacts upon life, property, and the environment. This includes assessing the hazards, risks, determination of mitigation, preparedness, and response and recovery needs.

Mitigation

Activities that actually eliminate or reduce the probability of a disaster (for example, arms buildup to deter enemy attack or legislation that requires stringent building codes in earthquake-prone areas). It also includes long-term activities designed to reduce the effects of unavoidable disaster (for example, land use management, establishing comprehensive emergency management programs such as vegetation clearance in high fire danger areas, or building restrictions in potential flood zones).

Preparedness

Activities necessary to the extent that mitigation measures have not, or cannot, prevent disasters. In the preparedness phase, governments, organizations, and individuals develop plans to save lives and minimize disaster damage (for example, compiling state resource inventories, mounting training exercises, installing early warning systems, and predetermined emergency response forces). Preparedness measures also seek to enhance disaster response operations (for example, stockpiling vital food and medical supplies, performing training exercises, and mobilizing emergency response personnel on standby).

Response

Activities following an emergency or disaster. These activities are designed to provide emergency assistance for victims (for example, search and rescue, emergency shelter, medical care, mass feeding). They also seek to stabilize the situation and reduce the probability of secondary damage (for example, shutting off contaminated water supply sources, securing and patrolling looting-prone areas) and speed recovery operations (for example, damage assessment).

Recovery

Activities necessary to return all systems to normal or better. They include two sets of activities. Short-term recovery activities return vital life-support systems to minimum operating standards (for example, cleanup, temporary housing, and access to food and water). Long-term recovery activities may continue for a number of years after a disaster. The purpose of long-term recovery activities is to return life to normal or improved levels (for example, redevelopment loans, legal assistance, and community planning).

J-8283

GIS—The Foundation for Emergency Management

All phases of emergency management depend on data from a variety of sources. The appropriate data has to be gathered, organized, and displayed logically to determine the size and scope of emergency management program(s). During an actual emergency it is critical to have the right data at the right time displayed logically to respond and take appropriate action. Emergencies can impact all or a number of government departments. Emergency personnel often need detailed information concerning pipelines, building layout, electrical distribution, sewer systems, and so forth. By utilizing a GIS, all departments can share information through databases on computer-generated maps in one location. Without this capability, emergency workers must gain access to a number of department managers, their unique maps, and their unique data. Most emergencies do not allow time to gather these resources. This results in emergency responders having to guess, estimate, or make decisions without adequate information. This costs time, money, and, in some cases, lives. GIS provides a mechanism to centralize and visually display critical information during an emergency.

Most of the data requirements for emergency management are of a spatial nature and can be located on a map. The remainder of this section will focus on how data is acquired, displayed, and utilized in all aspects of public safety programs. This paper will illustrate how GIS can accomplish data requirement needs for planning and emergency operations and how GIS can become the backbone of emergency management.

Emergency management activities are focused on three primary objectives. These objectives are protecting life, property, and the environment. In order to accomplish these objectives, the following basic processes are necessary.

Planning

Emergency management programs begin with locating and identifying potential emergency problems. Using a GIS, officials can pinpoint hazards and begin to evaluate the consequences of potential emergencies or disasters. When hazards (earthquake faults, fire hazard areas, flood zones, shoreline exposure, etc.) are viewed with other map data (streets, pipelines, buildings, residential areas, power lines, storage facilities, etc.), emergency management officials can begin to formulate mitigation, preparedness, response, and possible recovery needs. Lives, property, and environmental values at high risk from a potential emergency or disaster become apparent. Public Safety personnel can focus on where mitigation efforts will be necessary, where preparedness efforts must be focused, where response efforts must be strengthened, and the type of recovery efforts that may be necessary. Before an effective emergency management program can be implemented, thorough analysis and planning must be done. GIS facilitates this process by allowing planners to view the appropriate combinations of spatial data through computer-generated maps.

Mitigation

As potential emergency situations are identified, mitigation needs can be determined and prioritized. In the case of an earthquake, what developments are within the primary impact zone of earthquake faults? Based on the expected magnitude of an earthquake, soils, and other geologic data, what damage may occur? What facilities require reinforced construction or relocation? What facilities are in high-hazard areas (key bridges, primary roads, freeway overpasses, hospitals, hazardous material storage facilities, etc.)? Mitigation may include implementing legislation that limits building in earthquake or flood zones. Other mitigation may target fire-safe roofing materials in wildland fire hazard areas. Values at risk can be displayed quickly and efficiently through a GIS. Utilizing existing databases linked to geographic features in GIS makes this possible. Where are the fire hazard zones? What combination of features (topography, vegetation, weather) constitutes a fire hazard? A GIS can identify specific slope categories in combination with certain species of flammable vegetation near homes that could be threatened by wildfire. A GIS can identify certain soil types in and adjacent to earthquake impact zones where bridges or overpasses are at risk. A GIS can identify the likely path of a flood based on topographic features or the spread of a coastal oil spill based on currents and wind. More importantly, human life and other values (property, habitat, wildlife, etc.) at risk from these emergencies can be quickly identified and targeted for protective action.

Preparedness

Preparedness includes those activities that prepare for actual emergencies. GIS can provide answers to questions such as Where should fire stations be located if a five-minute response time is expected? How many paramedic units are required, and where should they be located? What evacuation routes should be selected if a toxic cloud or plume is accidentally released from a plant or storage facility based on different wind patterns? How will people be notified? Can the road networks handle the traffic? What facilities will provide evacuation shelters? What quantity of supplies, bed space, and so forth, will be required at each shelter based on the number of expected evacuees?

GIS can display "real-time" monitoring for emergency early warning. Remote weather stations can provide current weather indexes based on location and surrounding areas. Wind direction, temperature, and relative humidity can be displayed by the reporting weather station. Wind information is vital in a chemical cloud release or anticipating the direction of wildfire spread upon early report. Earth movements (earthquake), reservoir level at dam sights, radiation monitors, and so forth, can all be monitored and displayed by location in GIS.

Response

GIS can provide one of the primary components for computer-aided dispatch (CAD) systems. Emergency response units based at fixed locations can be selected and routed for emergency response. The closest (quickest) response units can be selected, routed, and dispatched to an emergency once the location is known. Depending upon the emergency, a GIS can provide detailed information before the first units arrive. For example, during a commercial building fire, it is possible to identify the closest hydrants, electrical panels, hazardous materials, and the floor plan of the building while en route to the emergency. For hazardous spills or chemical cloud release, the direction and speed of movement can be modeled to determine evacuation zones and containment needs. Advanced Vehicle Locating (AVL) can be incorporated to track (in real time) the location of incoming emergency units. AVL can also assist in determining the closest mobile units (law enforcement) to be dispatched to an emergency, as they are located on the map through global positioning system (GPS) transponders.

During multiple emergencies (numerous wildfires, mud slides, earthquake damage) in different locations, a GIS can display the current emergency unit locations and assigned responsibilities to maintain overall situation status. If the emergency becomes a disaster and emergency response units arrive from outside the local area, they can be added and displayed.

Recovery

Recovery efforts begin when the emergency is over (immediate threat to life, property, and the environment). Recovery efforts are often in two phases, short-term and long-term.

Short-Term Recovery

Short-term recovery restores vital services and systems. This may include providing temporary food, water, and shelter to citizens who have lost homes in a hurricane or large wildfire; assuring injured persons have medical care; and/or restoring electrical services through emergency generators, and so forth. The effects of the emergency may be continuous and ongoing, but the immediate threats are halted, and basic services and vital needs are restored. A GIS can play an important role in short-term recovery efforts. One of the most difficult jobs in a disaster is damage assessment. A GIS can work in concert with GPS to locate each damaged facility, identify the type and amount of damage, and begin to establish priorities for action (triage). Laptop computers can update the primary database from remote locations through a variety of methods. GIS can display (through the primary database) overall current damage assessment as it is conducted. Emergency distribution centers supplies (medical, food, water, clothing, etc.) can be assigned in appropriate amounts to shelters based on the amount and type of damage in each area. GIS can display the number of shelters needed and where they should be located for reasonable access. A GIS can display areas where services have been restored in order to quickly reallocate recovery work to priority tasks. Action plans with maps can be printed outlining work for each specific area. Shelters can update inventory databases, allowing the primary command center to consolidate supply orders for all shelters. The immediate recovery efforts can be visually displayed and quickly updated until short-term recovery is complete. This "visual status map" can be accessed and viewed from remote locations. This is particularly helpful for large emergencies or disasters where work is ongoing in different locations.

Long-Term Recovery

Long-term recovery restores all services to normal or better. Long-term recovery (replacement of homes, water systems, streets, hospitals, bridges, schools, etc.) can take several years. Long-term plans and progress can be displayed and tracked utilizing a GIS. Prioritization for major restoration investments can be made with the assistance of GIS. As long-term restoration is completed, it can be identified and visually tracked through GIS. Accounting for disaster costs can be complicated. As funds are allocated for repairs, accounting information can be recorded and linked to each location. Long-term recovery costs can be in the millions (or more) for large disasters. Accounting for how and where funds are allocated will be demanding. A GIS can ease the burden of this task.

Summary

Emergency management programs are developed and implemented through the analysis of information. The majority of information is spatial and can be mapped. Once information is mapped and data is linked to the map, emergency management planning can begin. Once life, property, and environmental values are combined with hazards, emergency management personnel can begin to formulate mitigation, preparedness, response, and recovery program needs.

Historically, emergency management programs are planned, implemented, and modified based on volume of business or reaction to emergencies as they occur. GIS allows emergency management needs to be identified prior to an incident. Disaster events, such

J-8283

as wildfire spread, tsunami impacts, floods, earthquakes, hurricanes, epidemic spread, chemical cloud dispersion, oil spills, and so forth, can be modeled and displayed in GIS. Emergency management personnel can use modeling for training, for actual tactical deployment during a disaster, or to analyze the consequences of a possible disaster. The use of this technology takes emergency management planning information "off the shelf" for utilization by response personnel for real-world operations. In short, the thoughtful application of a GIS can take much of the panic and surprise out of emergencies.

For more than 30 years ESRI has been helping people manage and analyze geographic information. ESRI offers a framework for implementing GIS in any organization with a seamless link from personal GIS on the desktop to enterprisewide GIS client/server and data management systems. ESRI GIS solutions are flexible and can be customized to meet the needs of our users. ESRI is a full-service GIS company, ready to help you begin, grow, and build success with GIS.

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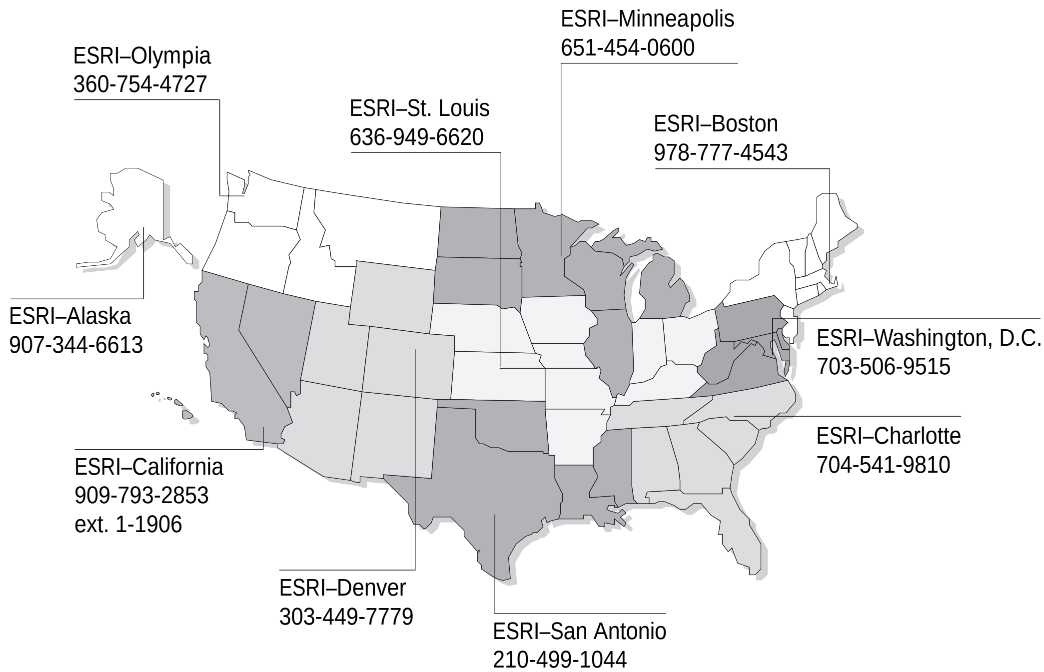

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