

**Activities in Guatemala
In Support of the
U.S. Hurricane Mitch Reconstruction Program**

**A Final Report Submitted to the
U.S. Agency for International Development**

by the

U.S. Geological Survey

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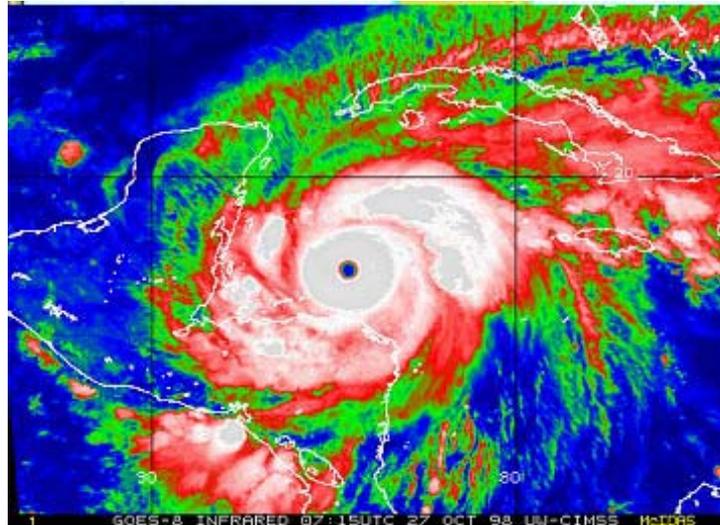
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Overview

Rafael Rodriguez

On October 25, 1998, Hurricane Mitch, the fourth most intense Atlantic Ocean hurricane on record, slammed into the Central American coastline. At its height on October 26 and 27, the hurricane had sustained winds of 180 mph and triggered 4 days of heavy incessant rains. The devastation wrought across a broad portion of Central America was unprecedented. This short-lived extreme event set back economic development in the most affected countries by perhaps more than a decade. The image below, taken by NOAA's GOES satellite, shows the Mitch's position on October 28, 1998.

Hurricane Mitch hit Guatemala hardest on the south coast, in the central and northwest river valleys of Polochic and Motagua near Lake Izabal and on the Caribbean coast – damaging an area the size of El Salvador. While loss of life in Guatemala was minimal due to preventive evacuation of populations most at risk, direct



damages to infrastructure, crops, housing, schools and health clinics is estimated at \$550 million plus \$280 million in foregone revenues from exports and reduced economic growth. The estimates of damage included 268 dead, 106,600 evacuees, and a total of 750,000 people affected. The damage to infrastructure was great, with 53 bridges damaged and 68 destroyed; 90 stretches of road affected, and 19,332 houses damaged and another 2,293 destroyed. On the productive sector agriculture was hardest hit, with 225,000 acres of losses in basic grains, coffee, vegetables, and bananas. Fifty major and over 200 minor irrigation systems were also damaged.

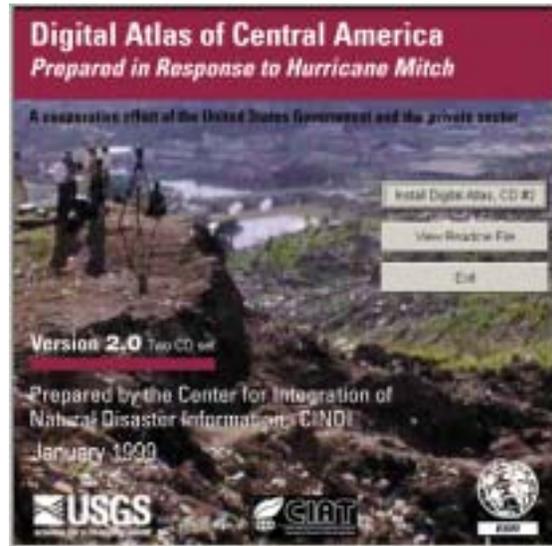
It is estimated that perhaps 70% of the livestock, 80% of the banana crop and 75% of the fruits and vegetables grown for export were destroyed. Towns and villages toward the El Salvador border and along the southern coast experienced food, fuel, and emergency services shortages due to lack of adequate transportation.

Man-made factors and management deficiencies aggravate the effects of natural disasters, such as Hurricane Mitch, in Central America. These include poorly developed and maintained infrastructure, poor watershed management, inappropriate situation of population centers, and limited capacity to anticipate and respond to extreme climate events.

To manage and eliminate these and other weaknesses, Guatemala proposed to carry out a series of national level reconstruction activities in public health, economic reactivation,

reconstruction efforts, but also to mitigate the human and economic impacts of future natural disasters.

As part of this effort, the USGS's Center for Integration of Natural Disaster Information (CINDI) provided integrated geologic, geographic, hydrologic, and biological information needed to support emergency managers and international relief organizations and enable them to understand and respond effectively to the devastation on the ground. Within weeks following the tragic event, the CINDI created a digital atlas communicating more than 60 different types of geospatial information in a form that can be manipulated for analysis. The new maps showed the locations of landslides and floods, damage to roads, bridges, and other infrastructure,



precipitation information, and impacts on agricultural lands. The information was extracted from satellite images, existing geologic maps, airphotos, and dozens of other digital and paper sources. This integrated information has continued to be critical for allocating resources for understanding the disaster's long-term impact on ecosystems, and for planning the region's economic recovery and reconstruction.

The U.S. Geological Survey brought its expertise, resources, and capabilities to bear in a cooperative effort with USAID, other U.S. Government agencies, and Guatemalan national and local agencies, to assist in the reconstruction following Hurricane Mitch. This effort encompasses both short-term and long-term goals. It is intended not only to support relief and reconstruction activities already under way but also to assist in developing Guatemala and developing strategies for long-term sustainability and the mitigation of vulnerability to natural hazards.

Approach Taken:

The USGS program in Guatemala included the following projects:

- 1) Development of Digital Topographic Maps**
- 2) Acquisition and Distribution of Satellite Imagery and Aerial Photography**
- 3) Streamflow Monitoring, Hydrologic Data Collection and Management**
- 4) Development of an Internet Data Clearinghouse**
- 5) Landslide Hazard Assessment**

6) Volcano Hazard Assessment

7) Municipal Geographic Information Systems

Development of Digital Topographic Maps

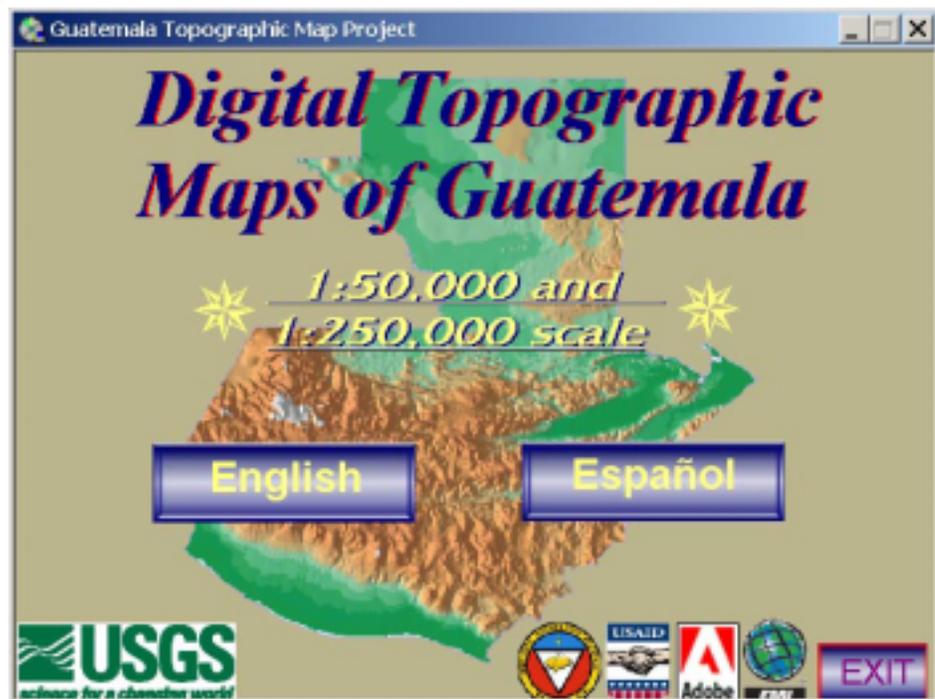
Sharon Hamann and Cassasndra Ladino

Objectives:

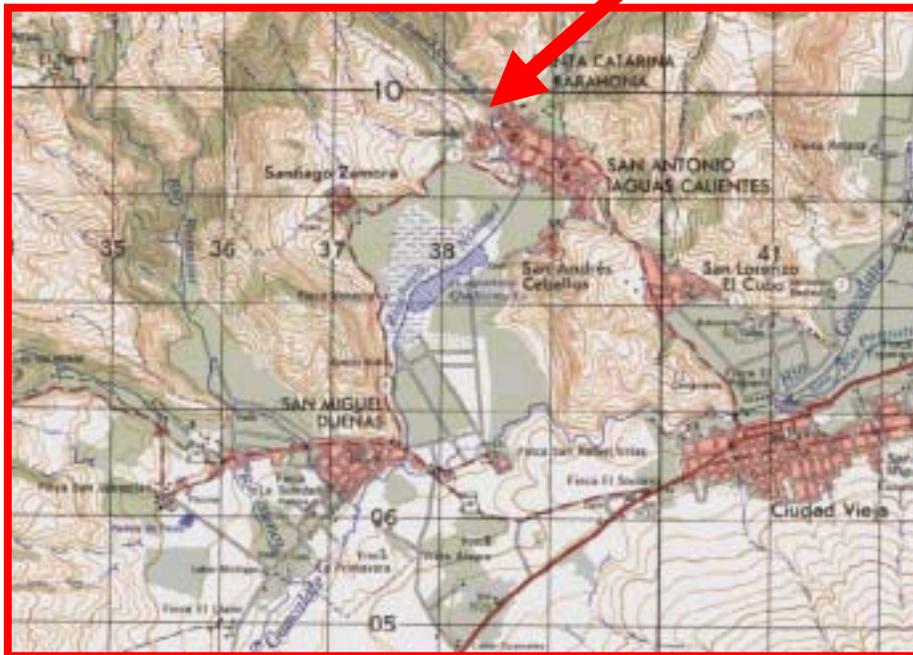
One of the most important basic tools needed to support reconstruction and hazard mitigation activities were accurate topographic base maps showing topographic contours, locations or rivers and streams, roads, and layouts of cities, towns, and villages. Although paper topographic maps at scales of 1:250,000 and 1:50,000 had been available in Guatemala for some time, these maps were not available in digital form at the time Mitch occurred in 1998.

Digital maps allow much more rapid and accurate measurements of distances and surface areas, and provide the base upon which to add additional information in the development of geographic information system (GIS) products. The objective of this project was to compile and package digital topographic maps for Guatemala in a compact convenient format and assist the Government of Guatemala in making these maps publicly available.

The USGS, working through the U.S. National Imagery and Mapping Agency (NIMA), compiled and packaged digital maps for Guatemala at scales of 1:250,000 and 1:50,000. The equivalent of approximately 300 individual map sheets were mozaicked and indexed.



The maps were digitally compressed and packaged on a single CD-ROM together with GIS software to view the maps, make measurements, and print copies of selected areas.. These maps have been delivered to the Instituto Geografico Nacional, who will assume responsibility for their distribution.



These products will significantly increase access to large-scale topographic maps for Guatemalan government agencies and the general public. This represents a major step forward in getting basic products such as this into the hands of the public and educating them as to their potential applications. These maps will be used

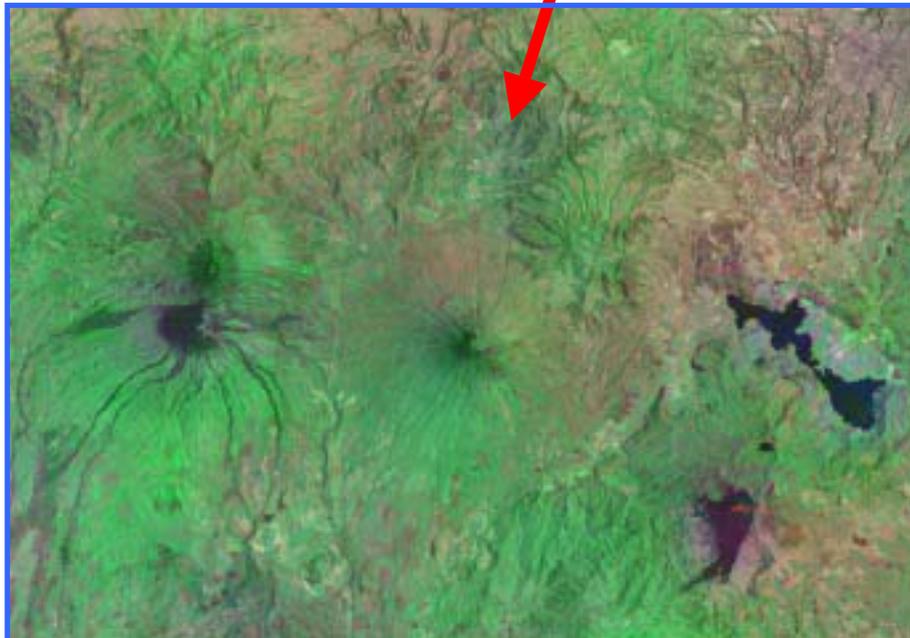
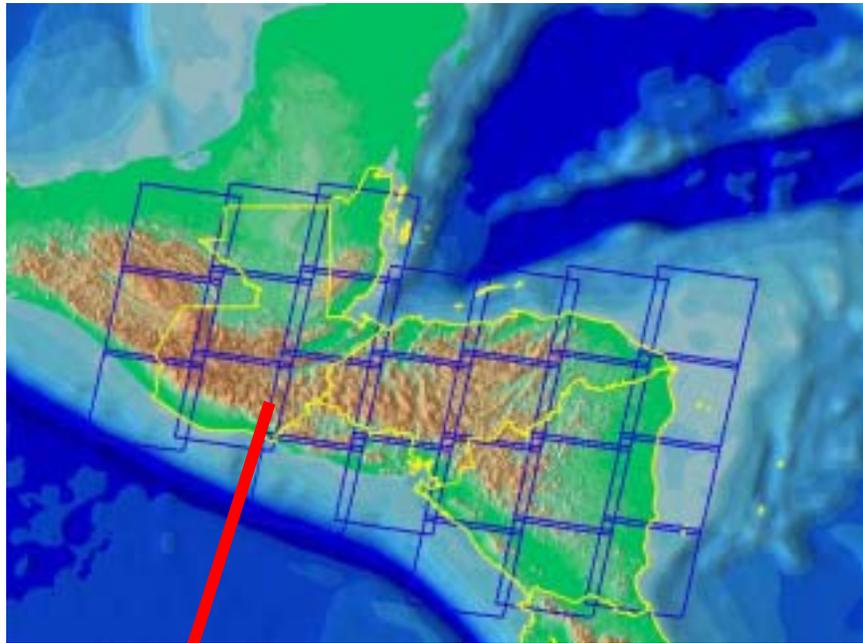
as the basis for a national disaster-preparedness GIS for Guatemala and are also serving a host of other applications, including risk assessments, roadbuilding, watershed analysis, and urban development.

Satellite Imagery and Aerial Photography

Mike Crane and Ron Risty

Although topographic maps are essential for providing a geographic frame of reference, the information they contain is only as current as their dates of publication. The best alternative to doing extensive observations on the ground is acquiring imagery of priority areas from satellites or aircraft.

Landsat satellite imagery provides 15-30 meter resolution and the ability to detect subtle differences in vegetation and land cover. The figure to the right shows the location of individual Landsat images (scenes) covering the Mitch-affected countries. The USGS compiled and mozaicked complete Landsat satellite imagery coverage for Guatemala, Belize, Honduras, El Salvador, and Nicaragua, both in digital form on CD-ROM, and as large format prints.

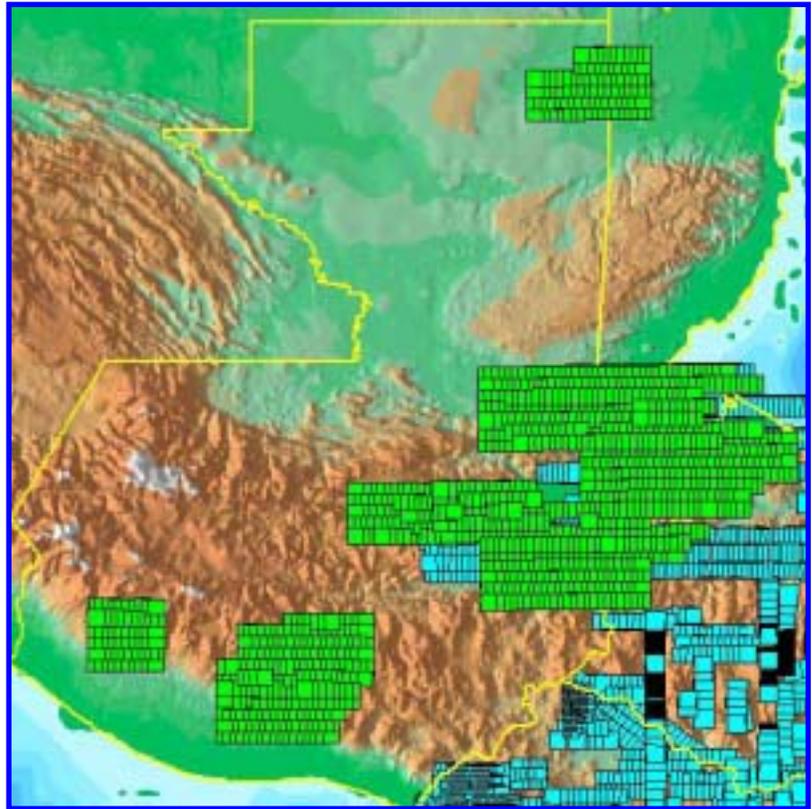


The sample Landsat image to the left shows Lago Amatitlan, and to the west, Volcan Agua and Volcan Fuego.

Landsat image products were provided to U.S. and Guatemalan counterpart agencies participating in USAID-funded Hurricane Mitch relief activities, and are also available to the public and private sector on a cost-of-reproduction basis. This imagery is

being used for a wide variety of applications, including land-use and land-cover analysis and assessment of agricultural areas.

Aerial photography – The USGS acquired approximately 1800 frames of black and white aerial photography over Guatemala, principally in the Motagua River Valley and around selected volcanic centers (see figure to the right). This photography was utilized for fine-scale analysis and mapping of landslides and flood inundation patterns, and also provided the base for municipal information systems developed for several Guatemalan cities. All photography has been catalogued, indexed, and archived at USGS’s EROS Data Center and is available to the public for the cost of reproduction.



The figure to the left shows the port of Puerto Barrios, and Guatemala’s northern coast. Most of the aerial photography flown over Guatemala was flown at a scale of 1:40,000, however high-resolution scanning of negatives produces images with resolutions of 2-3 feet, equivalent to much larger scale photography.

Streamflow Monitoring, Hydrologic Data Collection and Management

Mark Smith

As part of the Hurricane Mitch Supplemental Program, the U.S. Geological Survey (USGS) provided technical assistance in the area of surface-water hydrology to counterpart agencies in Guatemala. Objectives of the USGS hydrologic program were:

1. Reconstruction and improvement of the national hydrologic monitoring network (streamflow and rainfall);
2. Development of a centralized hydrologic database for storage and analysis of hydrologic data collected;
3. Intensive training and capacity-building within counterpart agencies to provide them with skills to independently collect, store, and analyze hydrologic data for use in flood forecasting and water-resources management; and
4. Implementation of nation wide (and region wide) quality-control standards for hydrologic data collection, storage, and analysis.

In conjunction with Objective 4, the USGS emphasized the value of sharing basic hydrologic data among government agencies, municipalities, and the public. The USGS counterpart in Guatemala was the Instituto Nacional de Sismología, Vulcanología, Meteorología, e Hidrología (INSIVUMEH), the GOG agency primarily responsible for maintenance of the nation-wide hydrologic monitoring network and storage of hydrologic data. The USGS provided equipment, training, and technical support to INSIVUMEH as part of the surface-water hydrology program in Guatemala.

National Hydrologic Monitoring Network

It was evident following Hurricane Mitch that the hydrologic monitoring network in Guatemala was in need of improvement if it was to be useful for early flood warning and in planning for disaster preparedness and mitigation. To help address this need, the USGS worked closely with INSIVUMEH (and with other USG agencies such as NOAA) to identify critical areas where stream flow data were needed to mitigate future damage and deaths from flooding and to enhance management of water resources. The hydrologic program in Guatemala addressed needs in the Motagua River basin (heavily impacted by Mitch), the Coyolate River basin (drainage to the Pacific Ocean), and the Ostúa River basin (upper Lempa River basin – part of the regional watershed management program administered by USAID-GCAP).

USGS and Guatemalan counterparts installed 2 state-of-the-art hydrologic monitoring stations in the Motagua and Coyolate River basins as part of the bilatera program and 2 monitoring stations in the Lempa River basin as part of the regional program (fig. 1). Ongoing monitoring and management of water resources in these river basins are deemed critical to the safety and economic well-being of the country.

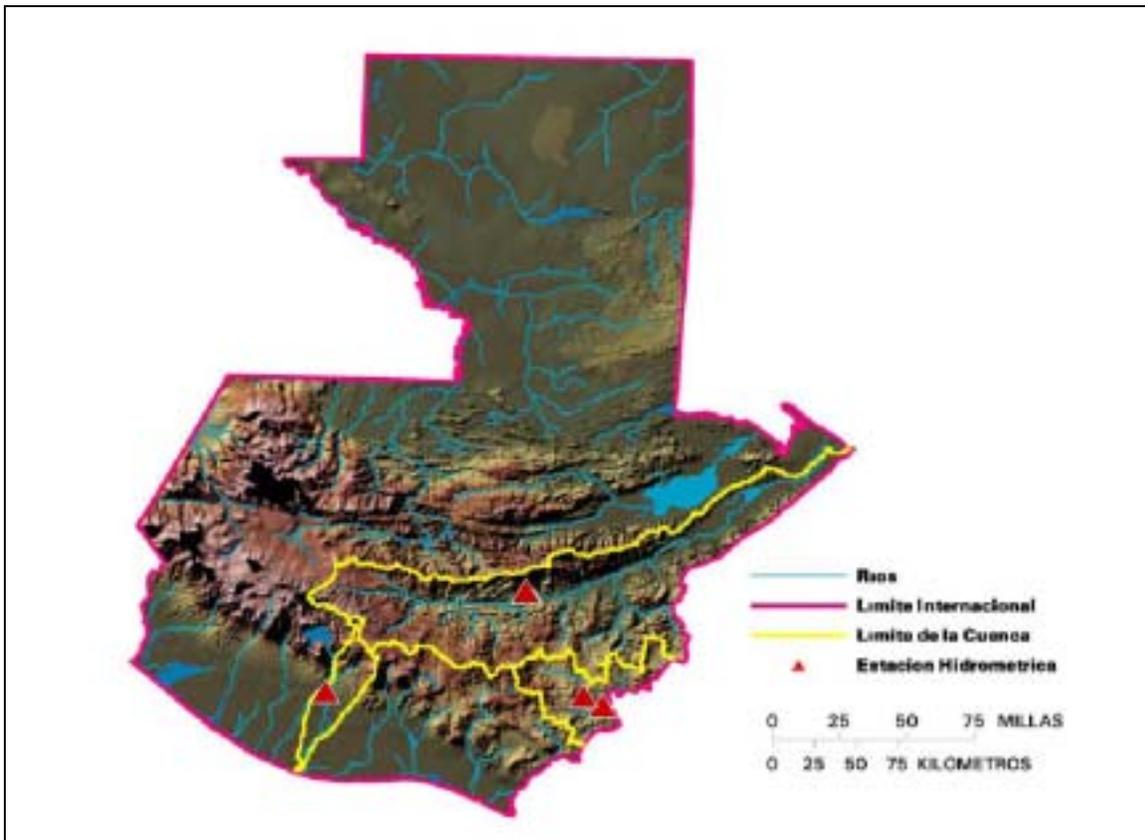


Figure 1. Hydrologic monitoring stations, each equipped with satellite telemetry, operational in Guatemala.

Real-time transmission of data from hydrologic monitoring stations is new to Guatemala – the technology implemented in Guatemala is the same as that used by the USGS in the United States. Each station transmits hydrologic data via satellite, which is received in real-time by downlink stations in Guatemala and Puerto Rico. There are two modes of operation: 1) normal mode, in which hydrologic data collected every 15 minutes are transmitted via satellite at 3-hour intervals; and 2) emergency mode, in which hydrologic data are transmitted as frequently as every 5 minutes during periods of flooding or heavy rainfall. An example of the streamflow gaging stations installed as part of the USGS program in Guatemala is shown in Figure 2.



Figure 2. Streamflow monitoring station Río Ostúa at Las Cruces.

Table 1 at the end of this report shows a complete listing of hydrologic monitoring stations that were installed in Guatemala. Hydrologic data from the telemetric monitoring stations are being used by government agencies, municipalities, and private interests involved with flood warning, disaster mitigation and water-resources planning in Guatemala.

Problems and future needs

As a result of intensive formal and on-the-job training, counterparts at INSIVUMEH (and its contractors) are quite capable of installing, operating, and maintaining the electronic monitoring equipment used in the gaging stations. In addition, cooperative planning by USGS, NOAA/NWS, and regional agencies such as SICA, has resulted in the procurement of enough spare equipment to support the monitoring network for the next 2-5 years.

Program continuity and maintenance of trained technical personnel at INSIVUMEH will be critical to continued success of this program. Adequate operating budgets for maintenance of the monitoring network (vehicles, fuel, staff per diem, and routine repair costs) need to be maintained within the agency. Based on an analysis of operating costs by USGS and INSIVUMEH personnel, the estimated net annual cost (not including staff salaries) to operate and maintain the 4 streamflow monitoring stations installed in Guatemala as part of this program is \$6,500.

Centralized Hydrologic Database

INSIVUMEH is primarily responsible for collection, analysis, and storage of hydrologic data in Guatemala. In order to accurately apply and statistically manipulate hydrologic data to determine discharge values, historic and current hydrologic information needs to be available in a comprehensive, centralized database. The existing computer database used by INSIVUMEH was obsolete and did not meet the needs of their hydrologic program.

To this end, the USGS worked with INSIVUMEH to implement the USGS surface-water database system, NWIS/ADAPS, in Guatemala. The USGS provided INSIVUMEH with a SUN workstation, capable of supporting 15-20 users, and advanced hydrologic-analysis software used by the USGS in the United States. INSIVUMEH hydrologists and technicians are responsible for data entry, analysis and storage using the NWIS/ADAPS system. Real-time data from each station are stored on computer systems at INSIVUMEH and at USGS offices in Puerto Rico. These data are displayed via the World Wide Web at the USGS site in Puerto Rico:

<http://pr.water.usgs.gov>

Hydrologic information recorded by each station is displayed in graphical and tabular for the previous seven days (fig. 3).

As part of the database program, the USGS purchased a small satellite receiving station for INSIVUMEH. The receiving dish is 1 meter in diameter, simple to install, and can be moved with relative ease. The transmission and data-processing system, called EMWIN (Emergency Managers Information System), is operated by NOAA and provides reliable, real-time access to meteorologic (and now hydrologic) information via the receiving platform and a PC computer. The program in Central America is the first use of the EMWIN system for transmission of

hydrologic data via the network.

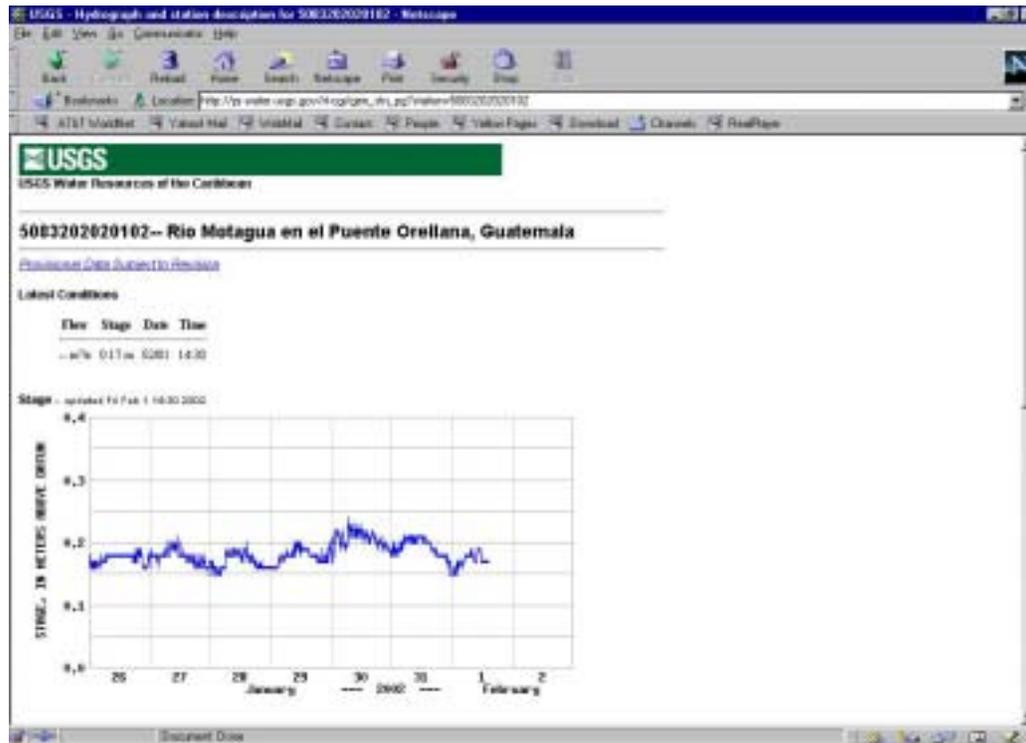


Figure 3. Graphical display of river stage for the Río Motagua at the Orellana Bridge, Guatemala.

EMWIN provides primary data reception for the NWIS/ADAPS system at INSIVUMEH, and can also serve also as a backup to larger receiving stations. The EMWIN system is highly reliable even during storms and flooding.

Problems and future needs

The USGS provided intensive formal and on-the-job training of counterparts at INSIVUMEH in the analysis of hydrologic data using the NWIS/ADAPS system. Counterpart data analysts showed they were very capable of learning and implementing the technology provided. However, certain equipment defects led to substantial system down time, which slowed the learning curve of INSIVUMEH technicians. The computer system and software components are complex, so that equipment problems necessitated extensive troubleshooting efforts by USGS experts.

INSIVUMEH personnel are capable of providing normal maintenance to the Sun workstation. Other recurring costs to maintain the database will be salary for the data analysts at INSIVUMEH, and service costs to maintain the phone line and modem connection for internet access – INSIVUMEH has programmed these costs into their operating budget.

Counterpart Training

USGS personnel conducted on-the-job training of INSIVUMEH personnel (hydrologists and technicians) during each visit to Guatemala. As of December 31, 2001 counterpart (and contractor) personnel were adequately-trained to conduct routine streamflow measurements, gage

construction, gage operation and maintenance activities, and basic troubleshooting of electronic equipment. The USGS views this as a significant factor in the sustainability of the program.

Formal and informal training in the areas of streamgage operation and maintenance, hydrologic data collection, data analysis using NWIS/ADAPS, and computer-system maintenance was conducted in Guatemala; counterparts from INSIVUMEH (personnel from the hydrology and meteorology divisions) participated in all formal courses presented by the USGS. Personnel from INSIVUMEH also participated in regional USGS courses that included participants from the four Mitch-affected countries. Regional training was successful in promoting uniform standards for data-collection methods in each country, sharing of scientific information, and professional camaraderie among peers in each country. A summary of formal training courses presented to Guatemalan counterparts is shown in Table 2.

Program Successes

INSIVUMEH hydrologists, as well as other emergency-response and disaster-management agencies, have monitored the real-time data from the telemetric stations in the Guatemala during periods of flooding for the past two years. During the passage of Hurricane Keith in October 2000, and the passage of Tropical Storm Michelle in October 2001, real-time data from the streamgages in Guatemala were monitored closely by INSIVUMEH.

Internet Data Clearinghouse

Eric Van Praag

Project Objectives

The Mitch reconstruction and planning activities in Guatemala by USAID, the United States and Guatemalan government agencies, and other donor organizations have generated a tremendous amount of spatial data and information, to complement the spatial data holdings already held by national institutions. The ability to search for and locate these data sets, the ready accessibility by local governmental agencies and various aid agencies, and the distribution of these data and information are critical elements of both short-term reconstruction efforts and longer term planning. To facilitate management and access to relevant data, this project has implemented a national Clearinghouse node and associated WEB Site in Guatemala, with the following main objectives:

- Facilitate discovery and access of spatial data;
- Reduce duplication of efforts in the production of spatial data;
- Facilitate evaluation of data quality, suitability and accessibility;
- Foster better communications and cooperation amongst data producing agencies.

Project description

Prior to the project, Guatemala lacked the means to catalog and describe their spatial data holdings or make them easily available. Data was simply produced and stored in national agencies, leaving the burden of finding it, assessing its value or acquiring it entirely to the user - who was often unable to even localize the data he was searching for.

Based on the model provided by the U.S. Federal Geographic Data Committee's (FGDC) pioneering work in spatial data cataloging and standardization, and on previous EDC projects in the region administered jointly with the Pan-American Institute of Geography and History and the United Nations Environment Programme, project staff assisted partner institutions to establish a Clearinghouse node and Clearinghouse WEB Site. The Clearinghouse node supports a spatial data catalog, registered on the International Clearinghouse system, accessible through several Internet "gateways" (search engines specializing on spatial data catalogs) in the world, and containing all data descriptions (metadata) developed by partner agencies in Guatemala and by USGS projects in Central America. The WEB Site complements the Clearinghouse node by providing: access to the data catalogs - either by topic or by institution, access to institutional spatial data inventories, Internet Map Services, download spatial data options, and an assorted gamut of other services.



Five national organizations have participated in the project: The National Planning and Programming Secretariat (Secretaria de Planificacion y Programación - SEGEPLAN); the National Institute for Seismology, Vulcanology, Meteorology and Hydrology (Instituto Nacional de Sismología, Vulcanología, Metereología e Hidrología - INSIVUMEH); the National Geographic Institute (Instituto Geográfico Nacional - IGN), the National Coordination Agency for Disaster Mitigation (Coordinadora Nacional para la Reducción de Desastres – CONRED); and the El Valle University (Universidad del Valle).

Work was coordinated by a Steering Committee featuring one representative from each participating institution, plus the regional USGS project coordinator. A technical coordinator at IGN was hired half-time by the project. Each partner agency developed a project workplan and a metadata development plan, produced digital spatial data inventories, cataloged all – or most – of their spatial data holdings, and participated in the development of the Clearinghouse node and associated WEB Site. EROS provided training and capacity building in Clearinghouse implementation, GIS and WEB programming and design; a methodological framework; basic hardware and software needed to construct the node; technical assistance and overall coordination. Work was developed under the framework of the National Geospatial Information System (Sistema Nacional de Informacion Geoespacial) advanced by sixteen national institutions over the last five years.

Results and Accomplishments

Guatemalan partners implemented and made operational the two systems described above: a Clearinghouse data catalog node and its associated WEB Site. More than 400 spatial data sets were described and cataloged inside metadata records and carefully validated - with a significant proportion featuring links to browse graphics. The WEB Site features two browse sections for metadata consultation, and will in the very near future host an Internet Map Service offering basic GIS functionality and access to public

data holdings (now under construction). The physical Clearinghouse server computer - featuring the Clearinghouse node and Web Site - is located at Segeplan.

The project strengthened the role of the National Geospatial Information System (SNIG) by allowing members to successfully undertake and complete a needed mechanism for spatial data exploration. It has also proven the benefits of working cooperatively to reach common objectives, and propagated and reinforced the value of data sharing amongst spatial data producers— although still being far from an ideal situation.

All deliverables were designed and built by partner agencies, generating the know-how needed to maintain, improve and adapt these products in the future. The SNIG has formally embraced the Clearinghouse system as one of their regular programs, and the partner agencies senior management has shown commitment to sustain the system operation.

TITULO DEL DATO	FUENTE	FECHA	FORMATO	PRESENTACIÓN	
MAPA DE LA CIUDAD DE GUATEMALA 1:15,000					
Enlaces Download	Ciudad de Guatemala	IGN	31/05/99	Impreso en papel	Análogo
MAPA TOPOGRÁFICO 1:250,000					
	Mapa Digital De La Republica De Guatemala Proyecto SUNE	IGN	01/06/00	Shapefile/Comet Atribs	DIGITAL
	Mapa Topográfico De Guatemala	IGN	03/02/98	Impreso en papel	Análogo
	Mapa Topográfico De Guatemala	IGN	31/01/77	Impreso en papel	Análogo
	Mapa Topográfico De Chiquimula	IGN	30/11/90	Impreso en papel	Análogo
	Mapa Topográfico De Escuintla	IGN	30/09/90	Impreso en papel	Análogo
	Mapa Topográfico De Cusco	IGN	31/07/95	Impreso en papel	Análogo
	Mapa Topográfico De Cobán	IGN	31/07/95	Impreso en papel	Análogo
	Mapa Topográfico De Puerto Barrios	IGN	31/05/01	Impreso en papel	Análogo
	Mapa Topográfico De Escuintla	IGN	30/09/90	Impreso en papel	Análogo

Project involvement varied considerably: IGN, Segeplan and Universidad del Valle became active project participants, while Conred and Insivumeh were less involved. It should be noted that two training workshops on Clearinghouse technologies were provided to eight additional SNIG institutions, and some like the Ministry of Mining and Energy and the Forest Institute have become members of the initiative and have started cataloging their data.

System maintenance and improvement looks sustainable due to the following considerations:

- Having designed and built the system, partners agencies acquired the resources and know-how needed to maintain and upgrade it;
- Partners appreciate the benefits obtained;

- Maintenance costs are low. The main hardware pieces needed have already being acquired, and all basic software in use is free. Costs of items like Internet connectivity and WEB maintenance are mostly internalized by agencies as part of their operational budgets.
- There is political support to sustain the system.

However, it should be acknowledged that further funding would make certain enhancements to the system possible in the near future:

- Incorporation of new institutions to the network - with the goal of reaching a “critical” mass of data cataloged as to make the system truly sustainable;
- Training in associated technologies and themes: Internet Map Servers, encryption, copyright, legislation, data standards, advanced WEB programming and design, e-commerce;
- Full implementation of an Internet Map Server;
- WEB Site upgrade: feedback mechanisms, statistical tools to track usage, restricted access to Web pages based on level of membership, e-commerce;
- Response to issues of copyright protection and unlawful data distribution;
- Data protection.

Due to the new system put in place public agencies and other users find themselves in a better position to locate, analyze and distribute spatial data needed for important rescue, mitigation and planning efforts needed to respond to natural disasters.

The Guatemala Clearinghouse WEB Site is located at <http://www.guatemalaclearinghouse.gob.gt>. The Clearinghouse metadata catalog node can be searched by choosing the “Guatemala-Clearinghouse/SNIG” node from the list of servers in a given gateway (i.e. <http://130.11.52.184/servlet/FGDCServlet>)

Landslide Hazard Assessment

Robert Bucknam

Objectives

The intense rains of Hurricane Mitch in late October and early November 1998 produced landslides in Guatemala that disrupted transportation and destroyed productive agricultural areas and farm-to-market access roads and trails. Small farmer coffee processing infrastructure was also seriously affected. Landslides added sediment to many stream drainages. However, little was known or documented about the nature and distribution of these landslides, and many areas remain exposed to landslides from future periods of sustained heavy rainfall.

The USGS Landslide Mapping project focused on developing a comprehensive inventory of slope failures to provide a basis for characterizing the impact of Mitch-related landslides in areas in the eastern Motagua Valley and adjacent ranges and the Polochic Valley and adjacent ranges of Guatemala. These areas were a priority in the USAID Hurricane Mitch Reconstruction program. The maps and associated analysis of data collected by the project provide a basis for evaluating the landslide threat from future high-intensity rainfall events in Guatemala to population, infrastructure, and agriculture. Additional goals were to provide equipment and training to our in-country counterpart in the Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH) to enhance the organization's capability to monitor and assess on-going landslide activity in Guatemala.

Key Accomplishments

Through this project, the distribution and characteristics of about 11,500 landslides produced by the late stages of Hurricane Mitch as it passed through Guatemala have been documented over a 10,000 km² area. The area encompasses mountainous terrain underlain by diverse types of rock and soil. The mapped landslides were of two general types; relatively small, shallow landslides that commonly mobilized into debris flows (fig. 1), and large, deep-seated landslides that sometimes generated debris flows and covered between 15 ha to 25 ha in area (figs. 2 and 3).

The distribution and characteristics of rainfall-triggered landslides determined by this project can be used as a partial guide to future landslide activity triggered by rainstorms in Guatemala. On the basis of our data, hazardous areas include: moderate to steep hillslopes and less steep areas directly below these hillslopes, drainage channels downslope from landslide prone hillslopes, and alluvial fans at the mouths of drainages along mountain or hillslope fronts. Evidence for, and frequency of, past landslides at individual sites can be used to determine the level of future hazard. That is, one of the best indicators for future landslide activity is evidence of past landslide activity. For this reason, the development of landslide inventory maps showing modern and historical landslides, as well as landslides within the past few thousand years are of critical

importance. Areas susceptible to rainfall-triggered landslides are not necessarily the same as those susceptible to earthquake triggered landslides.

Digital Elevation Model (DEM) data developed through this project provided a demonstration of methods of analyzing topographic characteristics and rainfall from Hurricane Mitch to develop a landslide susceptibility map.

Recommendations

Attempts should be made to prevent development of housing and infrastructure in potentially hazardous areas. In order to specifically identify these areas, inventories of landslides should continue to be made after local and widespread rainstorms. Additionally, to the extent possible, physical-property information on colluvial soils should be compiled. Physical-property data can then be combined with DEM data to produce landslide susceptibility maps. The next step beyond susceptibility maps, would be hazard maps that include downslope areas that lie in landslide flow paths. The creation of hazard maps will require additional mapping of Quaternary and historic landslide and debris-flow deposits.

For hazardous areas that are already inhabited, a method for predicting and delivering landslide warnings can be developed. One of the easiest, and most accurate ways to predict the timing of rainfall-triggered landslides, is by using a rainfall threshold. When such a threshold has been exceeded, or is expected to be exceeded by an approaching storm, a landslide warning can be issued for hazardous areas. The data to develop a preliminary rainfall threshold may already exist. Two thresholds should be developed, one for debris flows that commonly develop from shallow landslides during intense bursts of rainfall, and one for deep-seated landslides that are usually triggered by prolonged rainfall. The primary data needed to develop a rainfall threshold are landslide times of occurrence and rainfall data from a nearby raingage. Also, of nearly equal importance, are rainfall amounts that do not trigger landslides. Because the most hazardous types of landslides are typically debris flows, raingage data used to develop a rainfall threshold for debris flows (shallow landslides) should have at least hourly resolution.

Enhanced Capability of Host Counterpart Organization

Training and equipment provided under this project to INSIVUMEH and their landslide geologist has provided them with the capability to document and collect rainfall threshold data needed to develop methods for predicting and delivering landslide warnings. Funding for this type of work appears to be very limited, and without funding to pursue field studies of on-going landslides, the data needed to develop a landslide warning capability will be unavailable. Additional funding to INSIVUMEH to support basic geologic field studies of landslides is critical. INSIVUMEH maintains a network of meteorological stations that can provide general information on rainfall that triggers landslides, and maintaining the flow of data from this network is essential to developing information on triggering rainfall-induced landslides. Development of a network of simple raingage sites in collaboration with farms would provide important details on rainfall characteristics at negligible cost.

Figures



Figure 1. Landslides typical of the central part of the Sierra de las Minas, eastern Guatemala.



Figure 2. Landslide dam on the Río La Lima, looking upstream (north) from a point 4 km north (upstream) of the town of Jones; photograph taken 25 January 2000. The landslide originated on the steep slope in the upper left corner of the photograph. The point of discharge of the river from the debris that forms the dam is at the point where the water is first visible at the middle right part of the photograph.



Figure 3. Oblique aerial view to north of the landslide that produced the dam on the Río La Lima; photograph taken 12 January 2001. Smooth even-toned surface crossed by Río La Lima at the toe of the landslide is the sediment fill behind the landslide dam.

Volcano Hazard Assessment

James Vallance and Steve Schilling

1. The chief objectives of the Guatemala volcanoes project were: (a) to conduct an analysis of volcano hazards, especially lahar (volcanic debris flow) hazards at target volcanoes identified in consultation with INSIVUMEH (Instituto Sismología, Vulcanología, Meteorología, y Hidrología), CONRED (Coordinadora Nacional para la Reducción de Desastres) and the local USAID mission, (b) to produce maps depicting zones of potential inundation from lahars, and (c) to train local geoscientists and engineers to conduct lahar-hazards analyses. The maps were to identify hazardous areas as well as provide information on the probability of occurrence of lahars of various sizes.

Particular objectives of the project were selected in response to the disaster at Casita volcano, Nicaragua and to ongoing volcano hazards at Guatemalan volcanoes. Experience at Guatemala volcanoes shows that population centers and infrastructure located near active volcanoes are at risk from a variety of hazardous events--both related and unrelated to volcanic eruptions. In historical time, active volcanoes, Fuego, Santiaguito, and Pacaya have produced destructive lava flows, hot ash flows called pyroclastic flows, and damaging ash-falls that drop damaging ash more than 100 km downwind. These and other volcanoes have produced destructive volcanic debris flows called lahars during rainy periods (Figure 1). In 1541, a lahar triggered by a torrential rainstorm at Agua volcano destroyed the ancient capital of Guatemala during a torrential rainstorm.



Figures 1&2 - Bridge near San Filipe before (left) and after (above) sedimentation from lahars (volcanic debris flows). The difference in base level of the river bed is about 25 meters.

At Casita, Hurricane Mitch triggered a 1.6-million-cubic-meter landslide that transformed into a rapidly moving debris flow that destroyed two villages and killed about 2500 people. If field investigations and lahar-hazard analyses had been conducted at Casita volcano prior to Hurricane Mitch, they would have shown that the towns

destroyed were located in an active lahar pathway that was extremely hazardous. The 1998 tragedy at Casita volcano, like that at Agua in AD 1541 illustrates hazards associated with volcanoes even when they are not erupting.

In Guatemala, cities are located at the bases of large, active and inactive volcanoes, and smaller communities and coffee plantations encroach onto the volcanoes themselves. Thus, significant numbers of people are at risk from hazardous events at Guatemala's volcanoes. In the course of this study, we learned that active volcanoes that produced pyroclastic flows later produced voluminous lahars that extended more than 20 km from source. Moreover, older dissected volcanoes whose rocks have been weakened by hydrothermal alteration were most susceptible to failure-generated lahars of the type that occurred at Casita. Lahars of this second type could also be voluminous but occurred less often. The USGS is attempting to provide information that can help prevent disasters near active and inactive volcanoes, like that at Casita, by identifying areas subject to volcanic hazards, particularly identifying areas subject to inundation by lahars of various sizes. The planned impact of this project was to identify, for the first time, areas subject to hazardous lahars of various sizes, and to provide some sense of the likelihood of occurrence of these types of events.

2. Key accomplishments of the project are threefold: a) development of formal reports on hazards at the target volcanoes; b) transfer of technology; and c) development of in-country capability.

Formal reports: The project produced two formal reports that identify hazards at 3 volcanoes:

Vallance, J.W., Schilling, S.P., Matías O., Rose, W.I., and Howell, M.M., 2001, Volcano Hazards at Fuego and Acatenango: USGS Open-File Report 01-431, 17 p.

Schilling, S.P., Vallance, J.W., Matías O., and Howell.M.M., 2001, Lahar Hazards at Agua Volcano: USGS Open-File Report 01-432, 8 p.

These reports are accessible online at:

<http://vulcan.wr.usgs.gov/Volcanoes/Guatemala/Publications/OFR01-431/framework.html>

and

<http://vulcan.wr.usgs.gov/Volcanoes/Guatemala/Publications/OFR01-432/framework.html>

Each report contains maps that depict hazard zones related to lahars and other volcanic phenomena (eg., http://vulcan.wr.usgs.gov/Volcanoes/Guatemala/Publications/OFR01-432/OFR01-432_plate_1_color.pdf), and all reports and maps were translated into

Spanish. Versions of the reports and maps will be posted on the USGS Cascades Volcano Observatory web page by late February. They will also be accessible through the Hurricane Mitch clearinghouse website.

The project also produced a compact disk (CD) that contains digital elevation models of 1:50,000 scale topographic maps of the target volcanoes and surrounding areas. The CD also includes vector files of the transportation network, hydrology, and contours.

Technology transfer: The project convened a one-week workshop for about one dozen Central American scientists from El Salvador, Guatemala, and Nicaragua on volcano hazards and GIS. A key element of the workshop included training on a recently developed GIS-based model for objectively, and reproducibly, producing hazard maps that depict zones of inundation by lahars having various volumes. Workshop participants learned about the statistical basis for the model, how the model is coded and implemented within GIS, the input information and elements needed to run the model, the output information given by the model, the limitations of the model, how to run the model, and the computer hardware and software necessary to run the model. Each participant was given copies of the scientific literature (translated into Spanish) that describes the basis of the model as well as a copy of the model software. Representatives of INSIVUMEH, CONRED, IGN (Instituto Geografico Nacional) were selected as most appropriate for transferring the technology to a wide scientific audience within the country.

Development of in-country capability: To develop in-country capability to conduct lahar hazard analyses and other GIS applications, the project provided training and consulting on the use of computer workstation for INSIVUMEH, the national geosciences agency and CONRED, the national hazard-response agency. The Japanese foreign aid agency (JICA) provided INSIVUMEH, CONRED, and IGN with GIS workstations and ARCGIS 8 software, so it was not necessary for us to do so. This computer hardware and software, along with the training described above, provides in-country counterparts the capability to conduct lahar and volcano hazards analyses on their own. Investment in this capability can be protected through the Central American mitigation initiative (CAMI) and subsequent projects funded by OFDA through the USGS Volcano Disaster Assistance Program by ensuring that INSIVUMEH and CONRED maintain core capability in GIS, that they maintain the annual updates to the ARCGIS license, and that they periodically update the computer hardware. Periodic funding may be needed to help INSIVUMEH maintain necessary computer hardware and software capability. USGS will help maintain in-country capability by periodically providing updates to the lahar simulation software.

3. As a result of the project, the government of Guatemala and the local USAID mission now have probabilistic assessments of lahar hazards at Fuego, Acatenango, and Agua volcanoes. In addition to these probabilistic assessments, the country now has maps that clearly outline zones of volcano hazard, particularly lahar hazards at Fuego and Acatenango. The country also has, for the first time, in-house capability to produce these types of hazards assessments and maps. The maps produced by the project, and future maps produced by INSIVUMEH and CONRED, will greatly aid in planning and potential reconstruction efforts by identifying zones of particular hazard. The reports produced also discuss hazard warnings and forecasts, and what communities can do to

protect their citizens. This information is being widely distributed to the affected municipalities, and it will provide information regarding hazards, hazardous areas, and mitigation strategies.

4. During the course of the project, we collaborated with the local USAID mission, in particular with Mr. John Chudy. He was instrumental in helping us identify target volcanoes, and in transferring technology to counterpart agency, INSIVUMEH and CONRED. We did not interact with other USG agencies or other donors during the course of the project.

Biological Assessments of Damage to Coastal Zones

Edward Proffitt

Project Objectives: The U.S. Geological Survey (USGS) biology projects in Guatemala were developed at the request of USAID and Guatemalan government agencies responsible for natural resources and tourism, two of the major components of the Guatemalan economy. The USGS coastal resource damage and recovery projects had two primary objectives: (a) evaluation of the degree of destruction caused by Hurricane Mitch to coastal and marine resources (mangrove forests and seagrass beds) of the Caribbean coast, and (b) evaluation of the effect of Hurricane Mitch on nutrient loading, sedimentation, and vegetation communities in Lake Izabal.

To meet these objectives we involved a number of USGS biological scientists and contractors (mostly from the National Wetlands Research Center [NWRC]), a collaborator from the National Park Service (NPS), and representatives from local non-government organizations (NGOs; see Primary Collaboration Efforts, below).

Accomplishments:

Caribbean Coast – Initial meetings with in-country officials and aerial surveys to assess damage to coastal habitats were conducted in December 1998 (by Michot and Roetker) and again in December 1999 (by Michot and Arrivillaga). The latter team also conducted ground surveys with local guides to evaluate and survey areas of greatest impact. Based on those initial surveys, a plan was developed to conduct a study that would be parallel and comparable to the evaluation of similar habitats in the Bay Islands on the nearby Caribbean coast of Honduras. To accomplish this, we put together a team that would evaluate Hurricane Mitch impacts in four areas: impacts to the seagrass beds and marine bottom communities (Michot, Arrivillaga, and Burch), impacts to mangrove and coastal forest structure (Proffitt and Hensel), impacts to forest soil chemistry (McKee, Anteau, and McGinnis), and impacts to soil elevations (Cahoon, Perez, and Hensel). All investigators were USGS or contractor biologists from NWRC except for Burch, who is a biologist with NPS.

Studies were conducted in the vicinity of Punta Manabique, Izabal where hurricane damage was primarily in the form of wind damage to trees, shoreline retreat, and sedimentation. Three study sites were established: (1) Cabo Tres Puntas (seagrasses), (2) Bahia La Graciosa (seagrasses, forest structure, soil chemistry, and soil elevations), and (3) Boca Rio Piteros (forest structure, soil chemistry, and soil elevations).

We found the greatest impact from Hurricane Mitch to be at Boca Rio Piteros, where wave energy from the storm resulted in shoreline retreat of >30 m. Forest structure at that site, soil chemistry, and sediment changes all showed some degree of impact.

We found that seagrass beds at Cabo Tres Puntas were patchy and subjected to a high sedimentation rate when compared to beds at the more protected Bahia la Graciosa site, but within-patch biomass was comparable to other sites in Honduras and we did not detect a change in growth rate associated with Hurricane Mitch. Seagrass shoots were

younger (mean = 1.5 y) at the two Guatemala sites than at four sites in Honduras (mean = 2 to 3.5 y), and species diversity and richness of bottom communities was lower in Guatemala. These differences could be due to higher sedimentation and turbidity at the Guatemala sites, but those conditions are probably chronic and not related solely to Hurricane Mitch. Overall impacts of Hurricane Mitch to seagrass beds and bottom communities in Guatemala were found to be negligible.

Lake Izabal – Previous studies (Dix 1999) have shown that the increase in runoff and river volume associated with Hurricane Mitch caused a significant spike in the input of nutrients (nitrates, phosphates, ammonium, etc.) into the lake from the Rio Polochic in November of 1998. Based on an aerial survey of the Lake in December 1999 (by Michot and Arrivillaga, USGS), we conducted field studies to evaluate Hurricane Mitch impacts to water quality, wetland vegetation, and sedimentation. In January 2001, we evaluated the temperature and dissolved oxygen profile in the water column at 7 sites near the mouth of the Polochic and at one site near the lake center. We found no stratification and good oxygenation at the seven nearshore sites, whereas the lake-center profile showed a drop in oxygen (but not to lethal levels) below 5 m depth. A phytoplankton bloom was present in the lake, but water quality did not appear to be significantly degraded. Sediment cores were taken from eight sites near the Polochic delta. We cored to a maximum depth of 60 cm and noted stratification of sediments, but did not detect any apparent impacts from Hurricane Mitch. The area seems to be influenced, however, by a high sedimentation rate from the river outflow in the prograding delta, and it is possible that a Hurricane Mitch deposit was present at a depth greater than 60 cm. Nutrient input into the lake is a potential problem that should be studied with a more rigorous sampling regime.

Resulting Benefits:

At coastal sites, documentation of various levels of impact of Hurricane Mitch on the important biological resources associated with seagrass and coastal forest communities to local subsistence (fisheries, ecotourism, etc.) is of considerable benefit to local humans of the area. At Lake Izabal, fisheries and ecotourism, benefit from assessments of sediment and biota made by these projects.

Success Stories:

USGS biologists formed personal and professional ties with natural resource managers and NGO's of the area. One Guatemalan citizen, Dr. Alex Arrivillaga, who works at NWRC as a contractor, was instrumental in the success of these projects and in facilitating, and hopefully maintaining, the contacts that were made.

Primary Collaboration Efforts:

Collaborators included FUNDARY (Punta Manabique) and Defensores de la Naturaleza (Lake Izabal).

Formal Reports: Formal technical reports and maps are currently in draft stage, and reports are being peer reviewed. These will eventually be provided to AID and other

interested parties as hardcopy, on compact disk, or on the NWRC or Hurricane Mitch Web sites. In addition, articles for most studies are being prepared for publication in scientific journals, which will broaden the degree of impact of these projects far outside Honduras. A listing of draft report titles and authors follows.

Cahoon, D. R., P. Hensel, J. Rybczyk, and B. C. Perez. 2002. Hurricane Mitch: Impacts on mangrove sediment elevation dynamics and long-term mangrove sustainability: U.S. Geological Survey, draft report.

Hensel, P. And C. E. Proffitt 2002. Hurricane Mitch: Acute impacts on mangrove forest structure and an evaluation of recovery trajectories: U.S. Geological Survey, draft report.

McKee, K. L. and T. E. McGinnis. 2002. Hurricane Mitch: Effects on mangrove soil characteristics and root contributions to soil stabilization: U.S. Geological Survey, draft report.

Michot, T. C., J. Burch, A. Arrivillaga, P. S. Rafferty, T. W. Doyle, and R. S. Kemmerer. 2002. Hurricane Mitch: Seagrass beds and associated shallow reef communities on the Caribbean coast of Honduras and Guatemala: U.S. Geological Survey, draft report.

Michot, T. C., R. G. Boustany, A. Arrivillaga, and B. Perez. 2002. Investigation of potential impacts of Hurricane Mitch on Lake Izabal, Guatemala: U.S. Geological Survey, draft report.

Visuals:



Thalassia testudinum ca. 70 m from shoreline of western Punta de Manabique, Guatemala; depth ca. 2 m. The substrate is sandy and appears to be accreting in much of the area. *Thalassia* forms sparse colonies here, and appears to be partly covered with accreting substrate.



Thalassia testudinum ca. 20 m from shoreline of East End, Cayo Grande, Cayos Cochinos, Honduras; depth ca. 1 m. Substrate is rocky with shell fragments and other pulverized calcium carbonate skeletons. *Thalassia* forms moderately dense colonies, growing in

porous substrates among coral rocks.

Municipal Geographic Information Systems

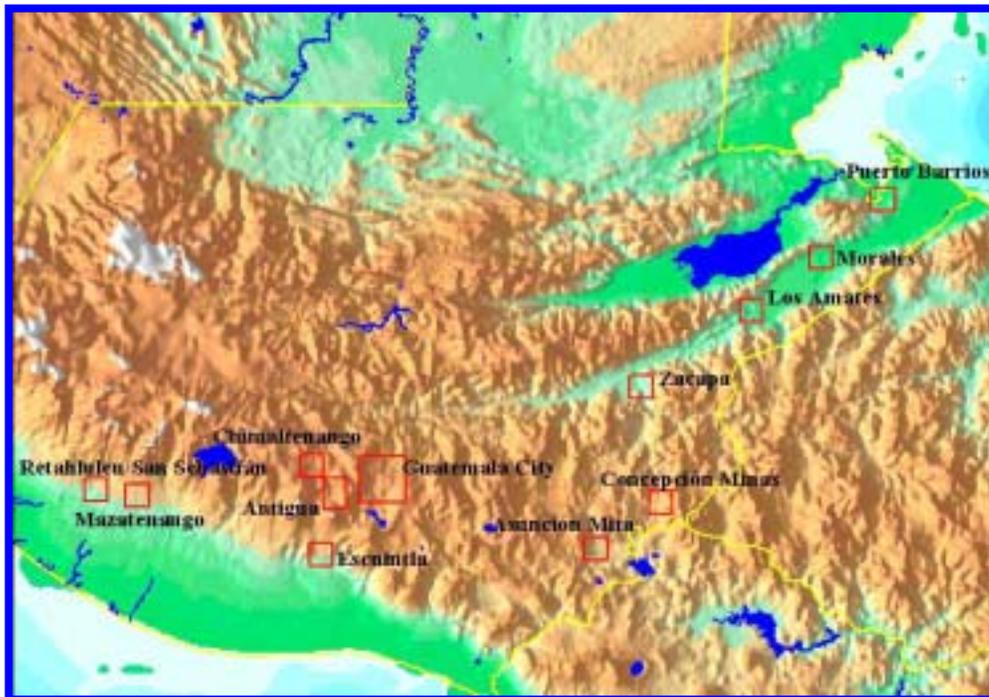
Manollo Barillas and Peter Chirico

Objectives

The main purpose of the Municipal GIS project was to provide municipal governments new maps, aerial photographs, natural hazard data, hardware, software and training for natural disaster preparedness, mitigation and urban development.

Particular objectives of the project were:

- Provide municipal officials with access to disaster mitigation/management information.
- Technicians trained in GIS development and geo-referenced data analysis.
- Provide training on the implementation of disaster response and mitigation actions.
- Provide training on access to and use of information for natural disaster management.
- Provide GIS analysis for the identification of vulnerable areas, infrastructure, settlements and natural systems.



GIS systems were installed and municipal staff trained in 12 towns in Guatemala (see figure above). These towns included:

Puerto Barrios	Los Amates	Morales	Zacapa
Concepción Las Minas	Asunción Mita	Guatemala City	Antigua
Escuintla	Retalhuleu	Chimaltenango	Mazatenango

Activities

- **Project Presentation to Mayors and Municipal Councils**

All the Municipalities were visited, in coordination with the CONRED Departmental delegates, in order to explain them the project's objectives and methodology. In most cases, the Mayors were visited before the meeting with Municipal Council and/or the Coordinadora Municipal de Reducción de Desastres (Municipal Coordinator to Reduce Disasters–COMRED). During these first efforts, the Mayors appointed the Municipal officials who were involved in the project and were trained accordingly.



COMRED, Puerto Barrios



Municipal Council, Retalhuleu

- **Introductory Training: Arc View and Basic Cartography**

Due the number of technicians and the distance between the municipalities, three work groups were organized for these first training sessions: The first one included Puerto Barrios, Morales, Los Amates and Zacapa; the second one, Retalhuleu, Mazatenango, Escuintla and Asunción Mita, and the third one, Chimaltenango, Antigua Guatemala, Guatemala City and Concepción Las Minas. Each group was composed of at least 12 technicians who were full time trained for one week at CONRED's Centro de Operaciones de Emergencia (Emergency Operations Center–COE).

In this training course the trainees acquired knowledge about the basic principles of installing, operating and maintaining Geographical Information Systems (hardware and software), basic cartography, aerial photographs, etc. In the course there were also lectures on the Natural Disaster Cycle and Classifying Hazards.



Northeastern Group



Southeastern Group

- **Equipment Delivery and On-site Training**

After the first training session, the Municipalities were provided with one computer, a GPS unit, and a digital camera, which were personally delivered, installed, and configured at the Municipal Government's headquarters. The licensed program Arc View and all additional licensed programs were also installed, and on-site training was provided on the use and operation of the digital camera and the GPS portable unit.



Mayor of Escuintla



Delivery in Zacapa

- **GIS Databases**

At the same time with the training sessions and the delivery of the equipment, The basic information that will be part of the Municipal GIS was gathered, produced and edited. With a few exceptions, the information produced during the project for each municipality was generally the following:

- Topographic and vector information at 1:250,000 scale, provided by the GIS of the Ministry of Agriculture, Cattle and Food (13 information layers)
- Topographic and vector information at 1:50,000 scale, generated by the USGS Guatemala staff, with the assistance of project participants (more than 30 quadrangles with layers containing contour lines, the hydrographic network, the communications network and the population centers).
- Digital orthophotos at 1:20,000 scale, produced by the USGS Guatemala staff and the USGS Reston staff, with the assistance of project participants.
- GPS points of critical infrastructure for emergency situations (shelters, police stations, hospitals, etc.), gathered by the project participants and digitalized with the support of the USGS Guatemala staff.
- Database of the streets and avenue of urban areas, gathered by the project participants and digitalized with the assistance of the USGS Guatemala staff.

- **Intermediate Training: Arc View Applications and Info Analysis**

Intermediate training was provided after the GIS had been installed in the Municipalities and the basic information had been generated and edited. The following criteria were taken into account when organizing the work groups for the intermediate training: 1) The type of natural hazards that are common in the municipalities, and 2) the type of information available. For example, Puerto Barrios, Morales, Los Amates and Retalhuleu were included in the same work group because they all experience flooding every year.

These Training included lectures and exercises about the basic Arc View applications used to natural disaster mitigation, focusing on how to create hazard maps (for landslides, flooding, etc.); how to use ortophotos; how to digitalize and prepare databases; how to design layouts; how to print final maps, etc. As in the first training session, the participants worked full time for one week at CONRED'S COE laboratories.

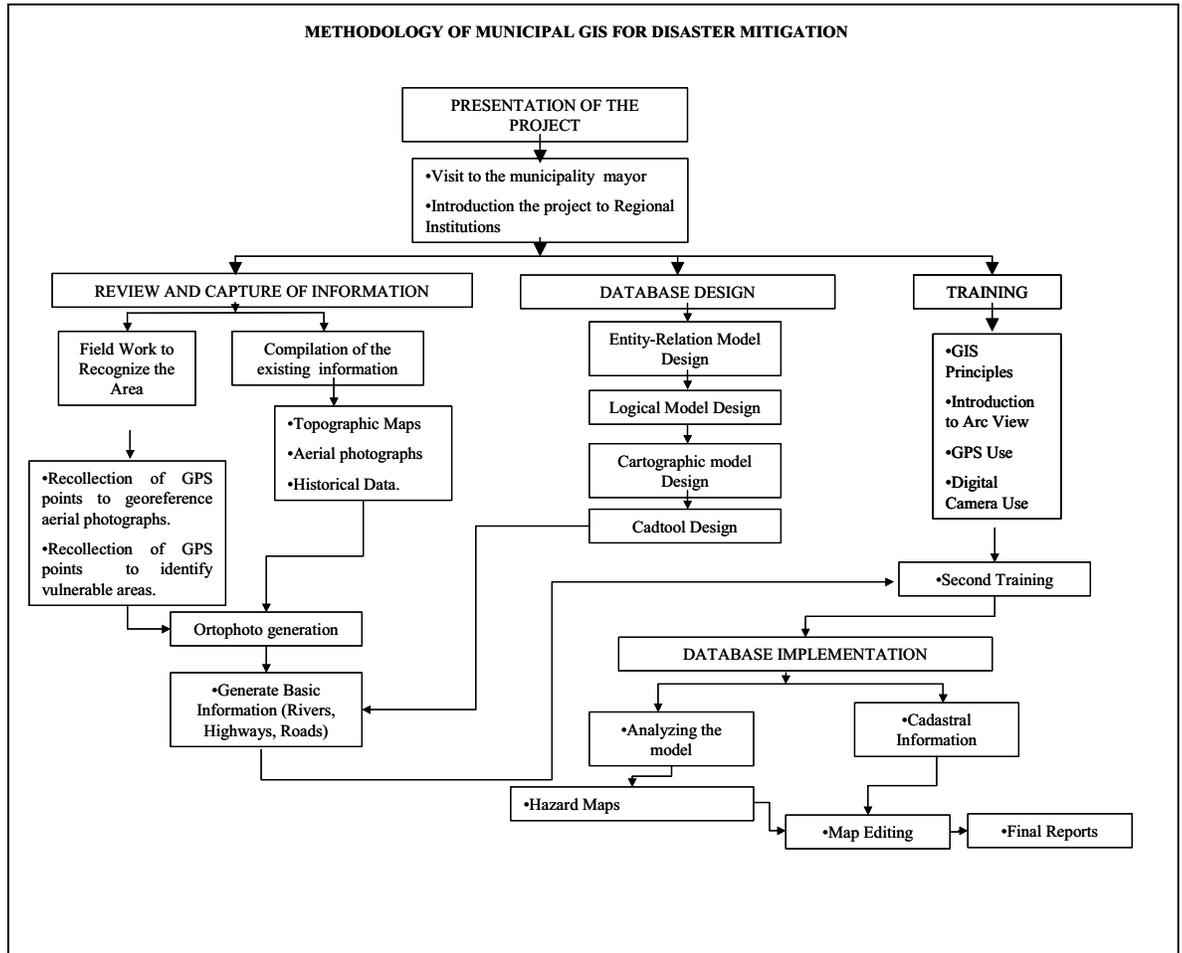
- **Critical Infrastructure and Urban Street Databases**

The streets, avenues and blocks of the urban areas in each Municipality were digitalized, using ortophotos as the base. Information related to the type of street, its materials, its name, viability, etc., was then added. Lastly, a map combining critical emergency infrastructure and road infrastructure was developed. Pending is only the cadastral database, since they were only provided and training with the Cad Tool interface, specifically designed for that purpose by the Reston staff.

- **Product Delivery and Info Integration**

At the end of the project, a meeting was organized in each Municipality, in order to deliver the information and products resulting from the process. In most cases, the same Councils and Committees that had been summoned earlier, in order to acquaint them with the project, were summoned this time.

They clearly recognized how much information had been generated by the members of their staff, and how many technical capabilities their staff had acquired. Some Municipal officials participated in the closing session that was held in December at INSIVUMEH, in which they



were able to present the major benefits that they had obtained from the project.

Additional Activities.

Because there were numerous activities implemented, some additional needs surfaced while executing the project. They were a good means of expanding and increasing benefits at a relatively low cost. Some of them were:

- A mini-training course at the technicians of the Municipality of Esquipulas (neighboring Concepción Las Minas) sponsored by the Agencia de Cooperación Española (Spanish Cooperation Agency), which also provided them with computers and the Arc View license.
- Direct support to the President's Executive Secretariat (training, GPS and Arc View license), specifically to the Commission on Seismic Hazard, which prepared an analysis of the vulnerability of public buildings in some of the Municipalities participating in the project.

- Training and technical support to the officers of the project's counterpart institutions: IGN, INSIVUMEH and CONRED, especially on topics such as digitalization and the zoning of natural- hazard areas using GIS.
- Training and technical support to CARE Guatemala, which was implementing a Risk-Management Program that included 30 communities in the area of Alta Verapaz.
- Training and technical support to the Ministerio de Energia y Minas (Energy and Mines Ministry) in the creation of their GIS office department.

Some Observations

- In almost all the municipalities the technicians had no college or university training. This caused difficulties in few cases for use cartography concepts.
- It is necessary to involve the Mayors and keep them informed of every activity in the process in order to have better results.
- Some municipalities in Guatemala have organizational entities called UTM (Municipal Technical Units). Municipalities with UTM's worked better than the others who do not have these units.
- When mayors and others with decision-making power were involved in the training, we observed that they learned how to use these tools for planning matters, and they were better equipped to work with the technicians in the municipalities.

Significance or Impact of the New Technologies

Municipal Governments have experienced a considerable technological leap in their efforts to solve many of their routine problems, since GIS is now being used by them for other purposes: inventorying and designing drinking water-systems; identifying flood hazard zones; urban planning, etc. Municipal officials have come to realize that there are new methodologies that will assist them in their work to solve the numerous problems faced by their Municipalities.

The GIS Municipal Project generated three substantial changes in the participating institutions, organizations and Municipal Governments.

- **Equipment:** 12 computers, with their corresponding printer; more than 15 Arc View 3.2 licenses; 12 digital cameras, and 12 portable GPS units were delivered in Guatemala. All this equipment is also being used for other purposes by Municipal Governments, especially to monitor the progress of their projects and to inventory their resources (drinking water, wells, sewage systems, etc.)
- **Digital information:** Approximately 20 Gb's of information was provided to Municipal Governments, especially ortophotos, topographic vectorial and raster information, maps and databases. This information will considerably increase decision-making and analysis capabilities of Municipal Governments.
- **Training:** More than 70 technicians were trained Guatemala, among them Municipal officials, governmental agencies, other organizations, etc. The type of training they received will enable them to use GIS for many other purposes within their Municipalities.

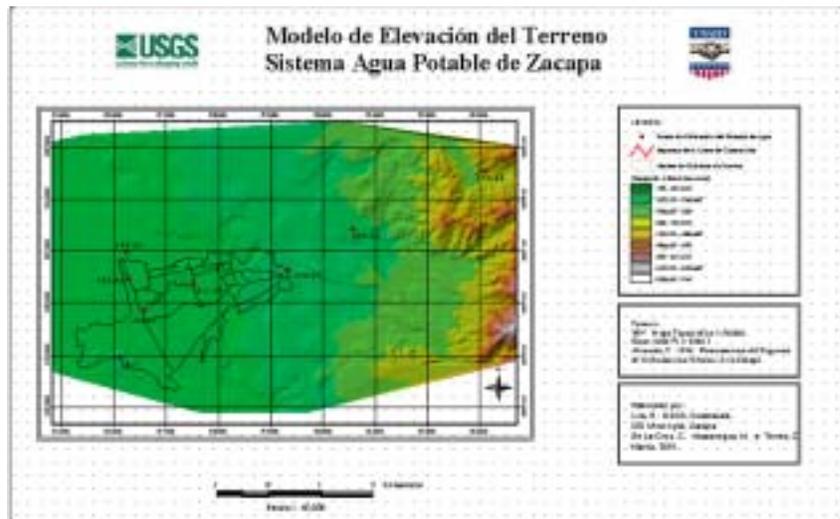
Measures to be taken to ensure that the investments are protected and maintained.

The Instituto Geográfico Nacional (National Geographic Institute--IGN in Spanish) provided the digital material that was needed to digitalize the 1:50,000 information (slides) and, at the end of the Project, it became the depository of the information that was generated and is now in charge of following up on the updating and validation activities.

In the Municipalities pending still is the Cadastral database, which will assist them in improving their land- and property-tax collection capabilities. They have already been provided with training and the necessary tools, and if they were provided with the funds they need to execute the required field work, the sustainability and operation of the Municipal GIS would be ensured.

Anecdotal Success stories.

Town of Zacapa – Successfully used the GIS system to decide on where to site water wells.



Town of Los Amates – Used the GIS to develop their own flood risk map and to upgrade their disaster response plan.

The Mayor of Los Amates was about to sign a contract for more or less US\$150,000, in order for a private firm to take aerial photographs of some municipal areas so that his Government could use them to execute development projects. When the Project was presented to him and he saw the type of orthophotos that he was going to receive (geo-referenced, high-resolution, etc.), he was very happy at not having contracted such a huge debt on behalf of his Municipality.



Collaboration with other agencies.

One of the major successes of the GIS Municipal Project was to involve all the institutions and organizations concerned with mitigating disasters in the areas in which Municipal Governments are working. CONRED played an important role when it utilized Municipal Emergency Committees as active tools in developing the Project, and their Departmental Delegates were always efficient in their efforts to remain in contact with Departmental Governors and Municipal Mayors.

Many NGOs also played important roles in the execution of the Project, especially the Agencia de Cooperación Española and CARE. The previous projects executed by Cooperación Española in the Northeastern area of the country (Puerto Barrios, Morales, Los Amates and Concepción Las Minas) established Municipal Technical Units (UTMs in Spanish) which later became the GIS operators in each Municipality. Conversely, CARE will use the municipal capabilities that have already been generated to execute its Risk-Management Program nationwide.

Program Budget

USGS HURRICANE MITCH PROGRAM - GUATEMALA	
Summary Budget	
Activity	Funds Expended
Digital Topographic Maps	\$115,182
Satellite Imagery & Aerial Photography	\$263,001
Hydrological data generated and made available	\$141,484
Internet Data Clearinghouse	\$176,645
Landslide & Volcano Hazard Assessments	\$406,243
Biological Assessments of Coastal Zones	\$175,306
Integrated GIS Products for Municipalities	\$189,215
In-country & HQ Management, Staff Support	\$328,600
Total	\$1,795,674

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