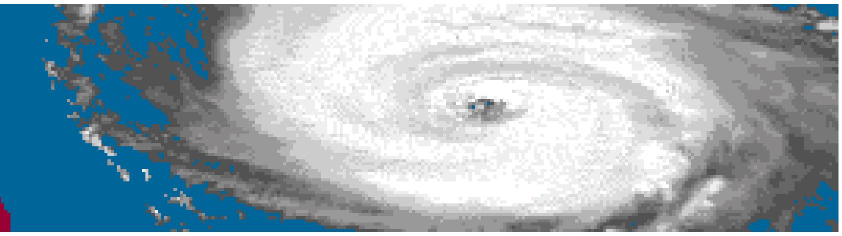
BACK



Activities in Honduras In Support of the Hurricane Mitch Reconstruction Program

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

by the

U.S. Geological Survey

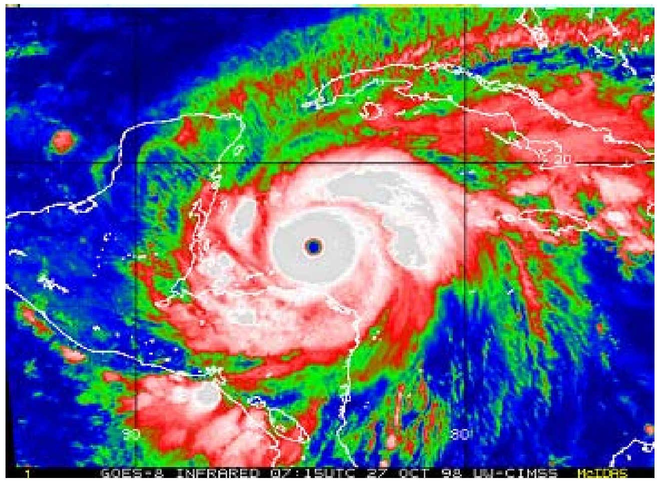
May 2002

Table of Contents

Overview

Jeff Phillips

On October 21, 1998, a tropical depression formed in the southern Caribbean Sea. One day later, the storm became a tropical storm and was given the name "Mitch". Tropical Storm Mitch moved very little over the next few days, drifting to the northwest, and gathering strength. On October 24 Atlantic Tropical Storm Mitch was upgraded to a hurricane that developed into one of the strongest and most damaging storms to ever hit the Caribbean and Central America. At its height on October 26 and 27, the hurricane had sustained winds of 180 mph and dumped heavy rains over Central America. The image to the right, taken by the NOAA GOES satellite shows the position of Hurricane Mitch on October 28, 1998.



Although the winds diminished as Hurricane Mitch traveled inland over Honduras on October 30, the storm continued to produce torrential rains, reaching a rate of more than 4 inches per hour, which caused catastrophic floods and landslides throughout the region. After its slow, destructive march north and west across Honduras and Guatemala, Mitch dissipated over southeastern Mexico but briefly regained tropical storm strength as it moved northeasterly across Mexico's Yucatan Peninsula, the Gulf of Mexico and southern Florida. By November 5 all tropical storm warnings were discontinued as Mitch's remnants tracked out into the Atlantic.

IMPACT

Hurricane Mitch struck Central America with such viciousness that it was nearly a week before the magnitude of the disaster began to reach the outside world. Hurricane Mitch will be remembered as the most deadly hurricane to strike the Western Hemisphere in the last two centuries. Not since the Great Hurricane of 1780, which killed approximately 22,000 people in the eastern Caribbean, was there a more deadly hurricane.

Honduras suffered the brunt of Hurricane Mitch. After being stalled for more than two days off the country's northern coast, the storm traveled inland during October 30 and 31. Extensive wind damage occurred along the northern seaboard, and rain-induced landslides and flooding caused incredible devastation nationwide. As of November 10, the National Emergency Committee of Honduras (CONEH) reported that 6,600 persons were killed,

8,052 were missing, 11,998 were injured, and approximately 1.4 million were left homeless. The U.N. Office for the Coordination of Humanitarian Affairs (OCHA) estimated at least 70,000 houses had been damaged. Critical food, medicine, and water shortages were prevalent throughout the Country. Hunger and near-starvation was widespread in many villages. Fever and respiratory illnesses widespread, and epidemics of malaria, dengue, and cholera were feared in many parts of Honduras.

The majority of the country's bridges and secondary roads washed away. USAID/OFDA initial reconnaissance teams estimated that more than 92 bridges had been damaged or destroyed. An estimated 70 - 80 percent of transportation infrastructure was destroyed. Even airports were under water. In outlying areas, over 25 small villages in the northern part of the country were swept away, and the city of Morolica in southern Honduras was completely destroyed. Helicopters were required to take supplies to areas cut off by floods and landslides.

At least 70 percent of the Country's crops were destroyed, including 80 percent of the banana crop. Crop losses were estimated at $900 million. Large warehouses and storage rooms for coffee were flooded. The shrimp industry (located on the delta of the lower Choluteca River) was devastated.

In addition to the human and economic losses, intense landslides scarred the Honduran landscape. The environmental impact began in the upper watershed areas, perhaps due to watershed mismanagement, but definitely due to the intense and high amounts of rainfall, geology, and relief or mountainous terrain of Honduras. Thousands upon thousands of landslides occurred throughout the country, devastating homes and infrastructure in the vicinity of the slides, but perhaps worse contributing incredible amounts of sediment to river channels and lower valley areas. As a result of intense landslide activity throughout the country, heavy sediment loads were deposited exacerbating Mitch flooding, and raising water levels for subsequent highflows that have occurred since Mitch. No significant channel geometry data was available prior to the Hurricane, but officials and local engineers estimate approximately 1 to 2 meters of sediment aggradation in river channels throughout Honduras as a result of sediment brought down from upper basins. Hydrologic and geomorphologic processes throughout the country likely will be affected for many years. Honduran officials estimated that Hurricane Mitch destroyed 50 years of economic development.

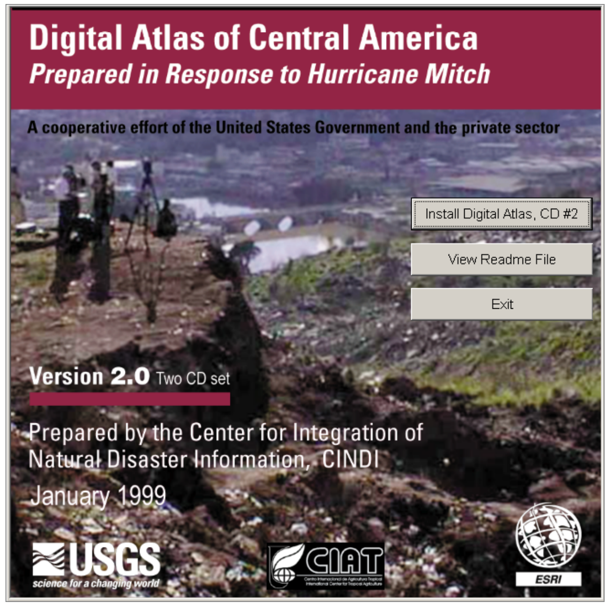
RESPONSE

Immediately after Hurricane Mitch struck, the US Government (implemented by USAID) provided more than $27.8 million in immediate disaster and recovery assistance, including the repair of damaged water and sanitation systems that most threatened an outbreak of disease. $42.5 million of emergency food assistance was released, and USAID redirected an additional $33 million to initiate reconstruction activities prior to passage of the Supplemental Reconstruction appropriation. In May 1999, Congress passed the Emergency Supplemental Appropriations Act, creating the Central American and Caribbean Emergency Disaster Recovery Fund (CACEDRF), which contained a total of $621 million in reconstruction assistance. Although USAID was the primary implementer and coordinator of all CACEDRF programs, approximately $110 million of these resources were passed to other US Government organizations that include US Department of Agriculture, Army Corps of Engineers, National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, US Department of Housing and Urban Development, and US Geological Survey.

Immediately in the wake of Hurricane Mitch, it became clear that a wide variety of data, information, expert analyses, capacity building and technical assistance were needed to successfully implement the massive recovery and reconstruction effort facing Honduras.

Detailed maps, aerial photographs of key areas, damage inventories, and continued assessment of potential flood, landslide, and other hazards needed to be made available not only to plan the reconstruction efforts, but also to mitigate the human and economic impacts of future natural disasters. Immediately following Hurricane Mitch, therefore, the USGS mobilized to gather available earth science and remotely sensed data.

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.



As part of the initial response, on December 8, 1998, the USGS mobilized and sent a multi-divisional team of scientists, including a geologist, two hydrologists, a biologist, and a computer/geographic information systems specialist, to Tegucigalpa, Honduras. The purpose of the effort was to provide scientific and technical expertise, including fieldwork surveys on geologic, hydrologic, and biological impacts and risks still facing Central America.

"Even as the humanitarian effort continues, the Central American nations devastated by Hurricane Mitch are beginning the reconstruction process and planning for the future," said U.S. Interior Secretary Bruce Babbitt. "The technical support and scientific assessments that the USGS team is conducting will enable those working on the reconstruction effort to make informed decisions as they rebuild and will help ensure that communities will be less vulnerable to natural hazards."

Following the initial reconnaissance trips, USGS and other federal agency staff were asked by USAID to participate in two field reconnaissance trips to Honduras to evaluate potential housing relocation sites for displaced population. The sites were assessed with respect to possible future landslide and flood potential, as well as accessibility and potable water supply. Then in March of 1999 USAID again requested USGS assistance. A fulltime liaison was subsequently stationed in Tegucigalpa, Honduras, and the USGS engaged in several short-term activities intended to assist Hondurans to rebuild and better prepare for additional landslide and flood activity. These short-term programs ended about the same time President Clinton signed the disaster relief supplemental for Central America on May 21, 1999.

USGS RECONSTRUCTION PROGRAM IN HONDURAS

The USAID-led reconstruction effort focused on economic reactivation, public health, educational opportunities, housing environmental and disaster mitigation, and municipal development. The USGS component of the massive US Government program crossed over into many of these sectors, but primarily focused on disaster mitigation, natural resource management, and municipal development.

From the outset of post-Mitch efforts to enhance natural resource management, disaster mitigation, and physical infrastructure repairs, it was recognized that decision makers and other participants were hampered by a lack of integrated information on natural resources, particularly information in a geographically consistent format and in useful and easily understandable forms. Accordingly, as part of a broad, US Government interagency effort to respond to the needs of organizations involved in the reconstruction of Honduras, the USGS conducted a multi-disciplinary program to generate useful natural resource and disaster mitigation information, and to institutionalize the capacity to generate and effectively utilize such natural resource information within a network of local institutions.

The USGS program in Honduras, appropriately titled, “Natural Resources and Hazard Mitigation Information Generated and Applied,” was the result of discussions and planning following USAID and USGS initial recovery efforts. The program consisted of the following primary components:

1) **Development of Digital Topographic Maps**

2) **Acquisition and Distribution of Satellite Imagery and Aerial Photography**

3) **Development of an Internet Data Clearinghouse**

4) **Landslide Hazard Assessment**

5) **Flood Hazard Mapping**

6) **Biological Analysis of Coastal Resource Damage and Recovery**

7) **Assessing Damage and Recovery of Coral Reefs**

8) **Development of a Ground Water Database**

9) **Hydrologic Data Collection and Management**

10) **Municipal GIS Development**

The USGS program also involved substantial capacity building through purchase of equipment and software for counterpart agencies and both formal and on-the-job training of specialists from counterpart agencies.

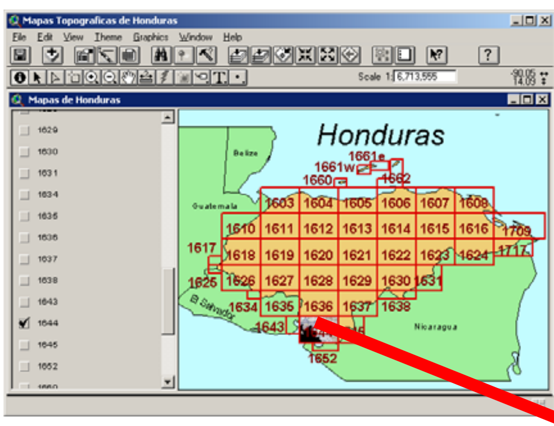
Digital Topographic Maps

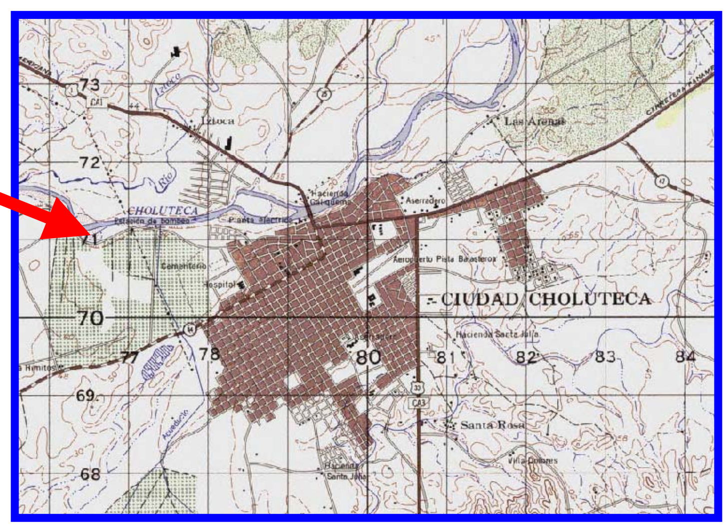
Sharon Hamann and Cassandra Ladino

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 El Salvador 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 El Salvador in making these maps publicly available.

Activities: The USGS, working through the U.S. National Imagery and Mapping Agency (NIMA), compiled and packaged digital maps for El Salvador at scales of 1:250,000 and 1:50,000. The equivalent of approximately 40 individual map sheets were mozaicked and indexed.

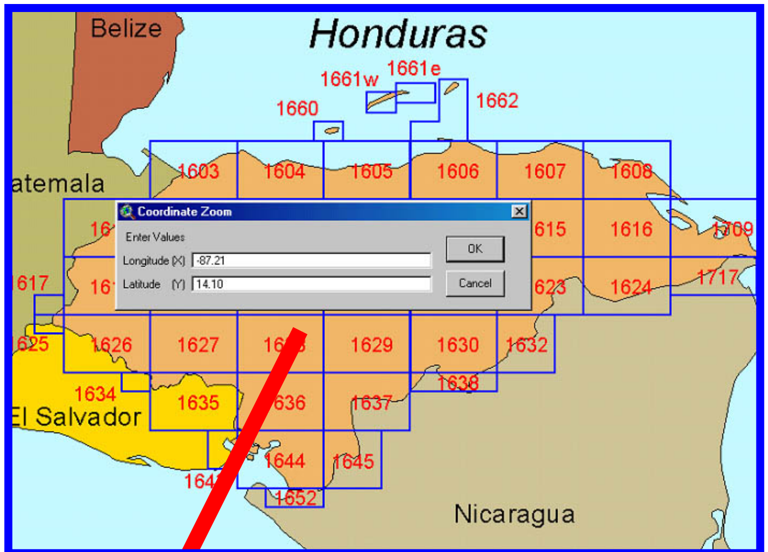


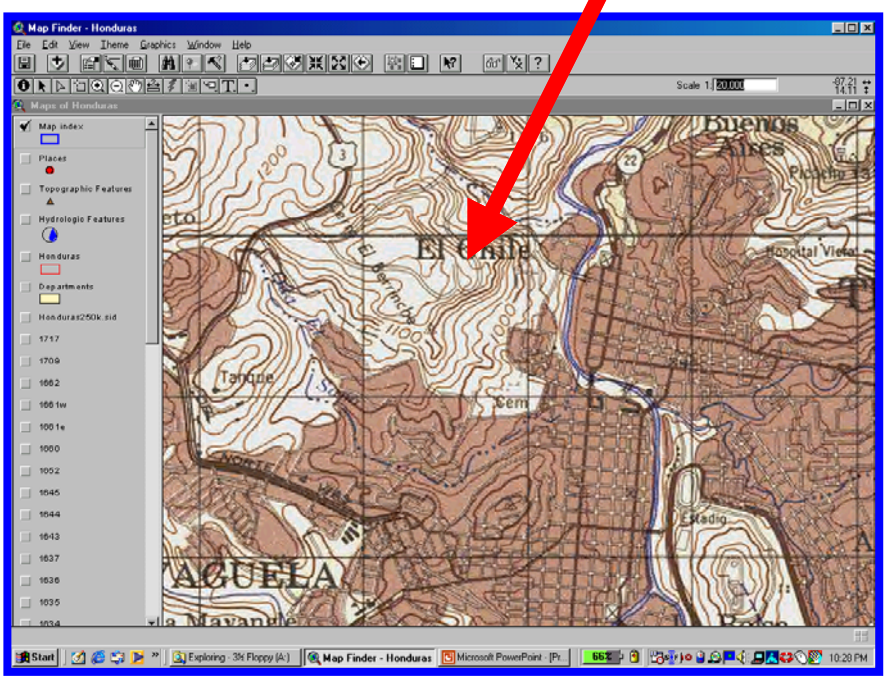


The maps were digitally compressed and packaged on a single CD-ROM together with GIS software to view the maps, make measurements, and print copies of selected areas..

These maps have been delivered to the Honduran Instituto Geografico Nacional, who will assume responsibility for their distribution These products will significantly increase access to large-scale topographic maps for Honduran 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 Honduras, and are also serving a host of other applications, including risk assessments, road building, watershed analysis, and urban development.

One example of the usefulness of these maps to disaster response and mitigation is a custom software application developed by a specialist at the Honduran IGN in cooperation with the Honduran Disaster Preparedness agency COPECO. By simply entering a set of coordinates (which might be collected using GPS by a field crew or municipal staff), this software queries the user for the scale he wants the map displayed at and then zooms to the location.





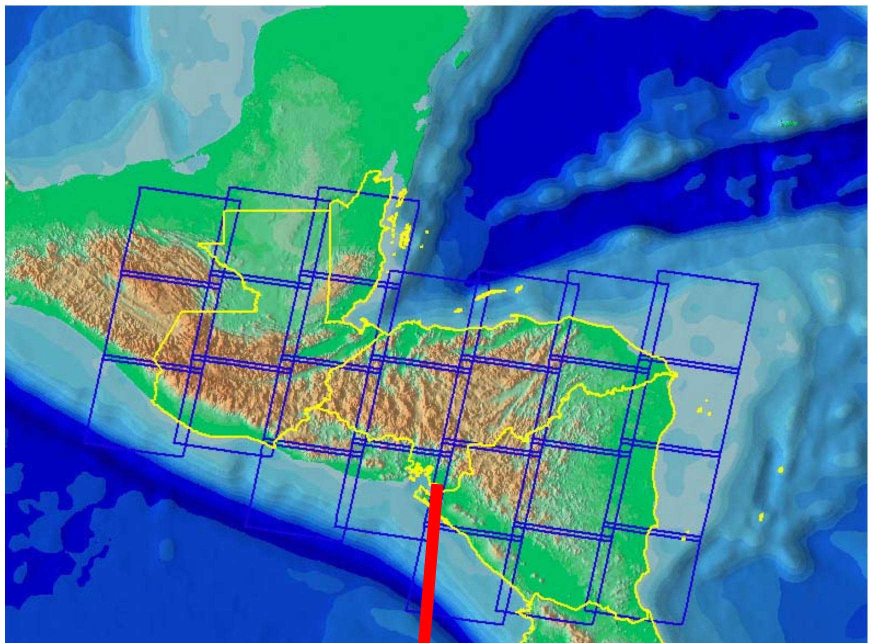
Although simple in concept, this tool will help speed the response to events by allowing much quicker and efficient evaluation of base maps than was previously possible.

.

Satellite Imagery and Aerial Photography

Mike Crane

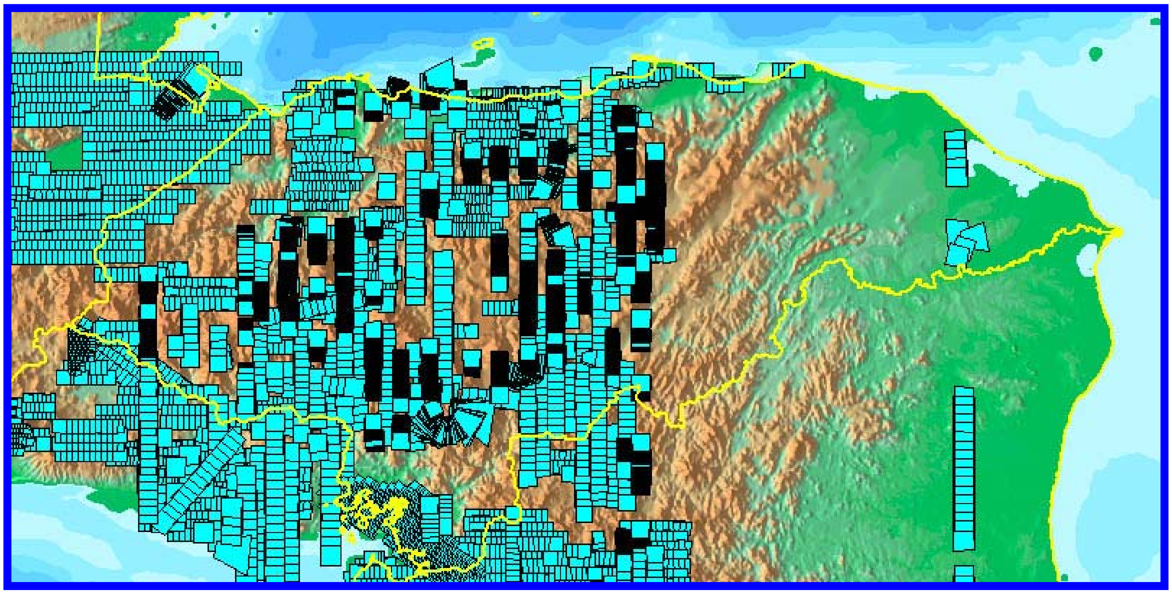
Although topographic maps are essential for providing a geographic frame of reference, the information they contain is only as current as their dates of publication. The best alternative to doing extensive observations on the ground is acquiring imagery of priority areas from satellites or aircraft.



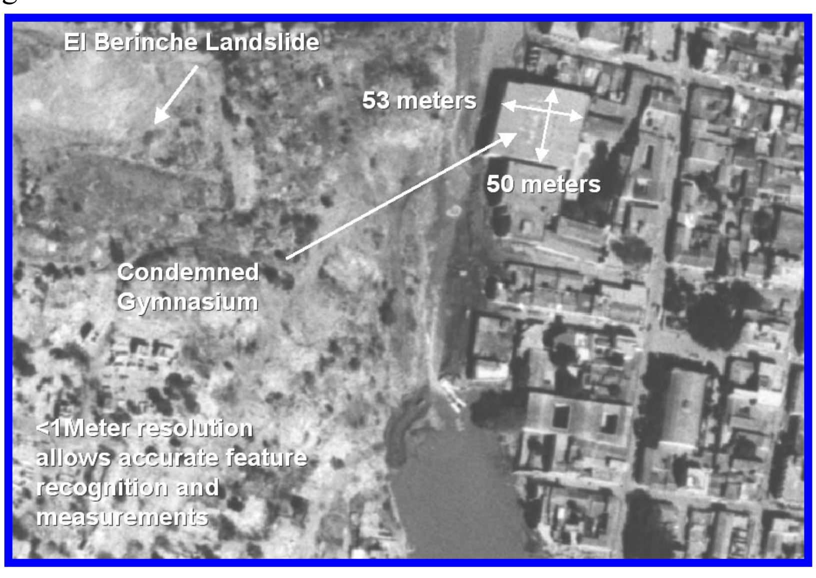
Landsat satellite imagery provides 15-30 meter resolution and the ability to detect subtle differences in vegetation and land cover. The figure to the right shows the location of individual Landsat images (scenes) covering the Mitch-affected countries. The USGS compiled and mozaicked complete Landsat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

The sample Landsat image to the right shows mangroves, shrimp farms, and cultivated areas bordering the Gulf of Fonseca on the Pacific Coast of Honduras. Landsat mage products were provided to U.S. and Honduran counterpart agencies participating in USAID-funded Hurricane Mitch relief activities, and are also now 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 several thousand frames of black and white, color, and color-infrared aerial photography over Honduras (see figure below). 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 40 Honduran 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 aerial photo to the right shows the dramatic effects of the El Berinche landslide in Tegucigalpa. The landslide, which was triggered by the torrential rains during Mitch, effectively dammed the Choluteca River. Since Tegucigalpa has no advanced sewage treatment, this event caused a serious and immediate health hazard. Photography like this was used in initial assessments of landslides and flooding throughout Honduras. Most of the aerial photography flown over Honduras 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.



Internet Clearinghouse and Data Distribution Network

Diego Pedreros

The USGS activities in the reconstruction program for Honduras were aimed at producing a great amount of geographic and hydrologic data. This created the need to have a distribution system to facilitate the utilization of the data by national agencies in Central America. Also it was important to make sure that the local personnel would be able to understand and manipulate the data to provide useful information to the decision makers. Responding to these needs USAID selected the Universidad Tecnologica Centroamericana to work along with the USGS to meet these needs. This document presents the tasks undertaken and the results achieved during the two years of the project.

Activities

The following items were key activities that the USGS and designated counterparts had to accomplish to adequately meet one of the USAID Intermediate Results as outlined in RP2.3.

Data Centers and User Network Established and Utilized

- *Integrated database developed using GIS*
  Responsible parties: Diego Pedreros, John Walkey and UNITEC

- *Data center established*
  Responsible parties: Diego Pedreros and UNITEC

- *Network of users established*
  Responsible parties: Diego Pedreros and UNITEC

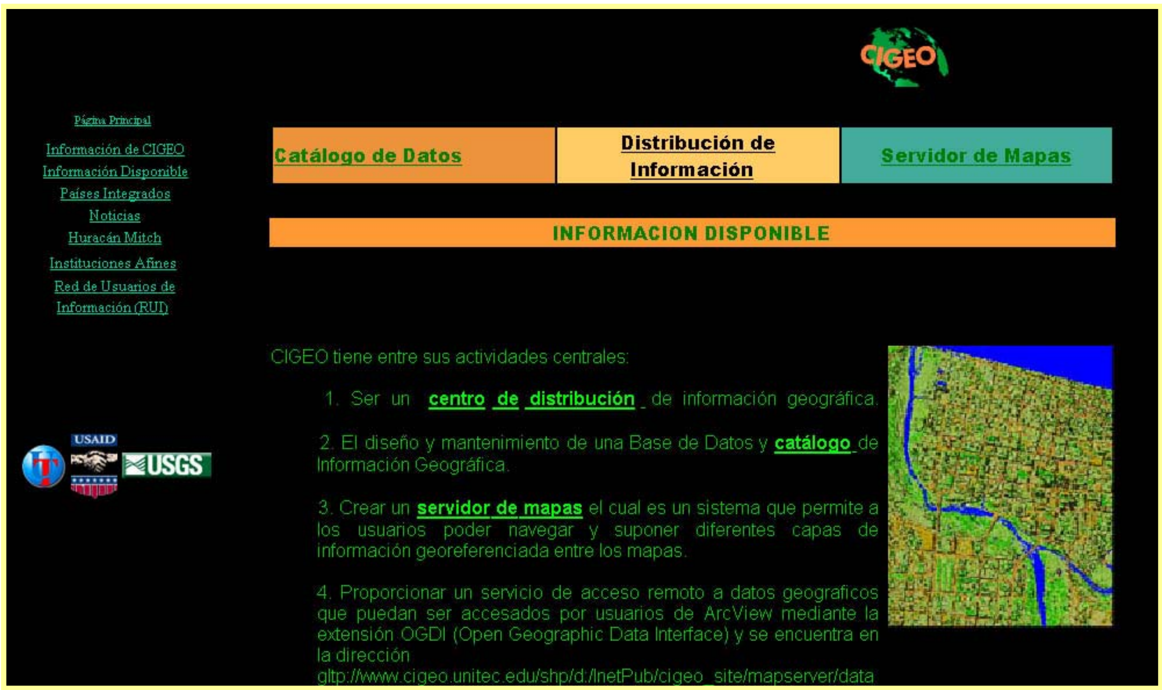
- *Technical assistance and training*
  Responsible parties: Diego Pedreros and UNITEC

Description of Activities and accomplishments

Integrated database developed using GIS

A national spatial database was developed using a GIS. Available topographic maps, aerial photography, and satellite imagery, provided by the USGS, were integrated into a database. This information then was available to water-resource managers, emergency response personnel, municipal planners, and engineers engaged in the reconstruction effort. GIS products integrated into the database will include landslide inventory and susceptibility maps and flood risk maps. GIS products for coastal assessment and watershed management will also be featured. The database resides at CIGEO-UNITEC with copies of most of the information available at COPECO and FUNDEMUN.

Data center established
The USGS assisted in the development of a data and GIS products distribution center (Centro de Informacion Geografica, CIGEO) at UNITEC. The center was in charge of coordinating activities such as training, data distribution and technical support. Through CIGEO, the USGS and UNITEC provided access to the topographic maps, aerial photography, satellite imagery, and derived products. Data were distributed in different forms: cd-rom, diskettes, via FTP and paper. An Internet map server was installed to facilitate access at www.cigeo.unitec.edu. A popular product was the set of topographic maps scanned and provided on CD-ROM, with software to view and print the maps. During the life of the project, data were distributed to 142 people from 76 institutions



Some tasks were developed prior to the creation of the Center. UNITEC and USGS staff began renovation and construction of the Data Center facilities. Equipment and software, for both the CIGEO and the counterparts, were identified and organized to facilitate the procurement.

Network of users established
A primary activity was the establishment of a network of spatial data users. The network is now composed of NGO's, government agencies, private sector firms, academic institutions and municipalities. This group of institutions is linked together by the CIGEO web site. Main participating institutions like the National Geographic Institution (IGN), the Minister of the environment (SERNA) and the Fundacion para el Desarrollo Municipal (FUNDEMUN) are interconnected by a dedicated line provided by UNITEC and funded by the project. Other participants were given a dial up connection by UNITEC. Some of the members of the network are UNITEC, SERNA, FUNDEMUN,

UNAH, ESNACIFOR, COHDEFOR, Zamorano, FHIS, SOPTRAVI, COPECO, SANAA, ENEE, CEVS, UNAT, UNAH, SAG.

An important accomplishment was the promotion of open data sharing and distribution between all users. A series of meeting were conducted to promote the development of a **National Spatial Data Infrastructure (NSDI)**, which is a structured national system for managing geographic information. NSDI encompasses the policies, technologies, standards, laws, and institutional organization for facilitating the acquisition and access to geo-referenced information. Several national institutions created an NSDI national committee for the coordination of activities and the development of policies. The committee organized two seminars to evaluate the current situation and challenges facing geographic data management in the country. Additional committees were created to discuss topics such as data interoperability, copyrights and pricing. A product of these seminars was a proposal to the Interamerican Development Bank requesting support for continuing these tasks. The proposal has been approved and funding is to be available the first quarter of 2002.

Another important task under the network of users was the implementation of the FGDC metadata standard to document geographic data. An FGDC-compliant data catalog was implemented in the **Metadata Clearinghouse Node**. Support for documenting metadata was provided to the main geographic data producers such as IGN (who collected 180 records), SERNA (50 records), SANAA (40 records), FUNDEMUN (50 records), ESNACIFOR (50 records), ZAMORANO –(50 records). Two Clearinghouse nodes were established, and it is expected that other institutional nodes will be created in the near future - such as the IGN.

Technical assistance and training

A training program in geographic data management and analysis was developed to include personnel from the participating agencies and municipalities. The program included classes in basic computer knowledge such as Windows and Internet. Also a series of courses on basic Geographic concepts, Arcview, ArcInfo, ERDAS Imagine, Orthobase and GPS computer network management were provided, for a total of 39 courses during the two years project. Overall CIGEO provided training to 1100 staff members of 70 public and NGO agencies.

Left: UNITEC's graduation of first class of students trained in basic map applications, September 13, 2000. Thirty eight students completed the training required for a diploma

Technical assistance was provided to other USGS projects, as well as counterpart agencies and municipalities. Personalized data vectorizing training was given to personnel from the IGN GIS unit. This unit produced the vector layers needed to produce the Digital Elevation Models used in the USGS municipal GIS project. The IGN Technical Archiving Unit received training needed to improve the search and distribution of their data. Support in additional topics such as Web development, metadata documentation and publication was given to institutions such as SANAA, FUNDEMUN SERNA and UNAH.

Lessons learned

- One of the lessons learned relates to the right approach necessary to identify the right partner able to undertake different activities. For example, UNITEC turned out to be an appropriate partner for conducting the training activities, but on the other hand lacked experienced personnel needed to undertake GIS activities under its aegis.
- Problems have to be addressed early on. A clear example of this is UNITEC, where it could be argued that USGS personnel waited too long before resolving certain pressing problems.

Conclusions

Part of the success of the project is based on a strong sense of trust created between the USGS project personnel and staff at partner institutions. Also, the work done provided a sense of project ownership to locals partners, helping to develop a personal pride on the work accomplished.

Landslide Hazard Assessment

Edwin L. Harp

Introduction

The effects of Hurricane Mitch left Honduras not only with major loss of life and property due to flooding but also left a legacy of damage to property, infrastructure, and people due to landslides. The rainfall from the hurricane triggered in excess of 500,000 landslides throughout the country, damaged over 70% of the countries road network, and caused approximately 1,000 fatalities. Efforts of the U. S. Geological Survey Landslide Hazards Team was to document the landslides, assess their current and ongoing hazards, and to produce maps and provide training to agency personnel and scientist counterparts in Honduras so that the hazards could be understood, evaluate, and dealt with through a combination of evacuation, relocation, avoidance, slope protection measures, and other mitigation methods.

Studies of landslides and landslide hazards in Honduras as a result of the rainfall from Hurricane Mitch have concluded with the publication of three U. S. Geological Survey Open-File reports that include 19 landslide inventory maps at a scale of 1:50,000 of selected parts of the country where high landslide concentrations were triggered, 1 landslide inventory map of the capitol city at a scale of 1:15,000, a landslide susceptibility map of the capitol city (1:15,000 scale), and a landslide hazard map of Tegucigalpa at 1:15,000 scale. Numerous workshops and training seminars have been held in Honduras to transfer data and expertise among the various agencies concerned with existing and future landslide hazard as well as an intensive training exercise in GIS and landslide hazard mapping techniques in the U. S. Incidental hazard assessments were made in Honduras both to review the feasibility of proposed relocation of housing and at times of heavy rainfall when renewed landslide movement raised issues of evacuation or mitigation.

Landslide Inventory Maps

U. S. Geological Survey Open-File Report #02-061 describes the landslide occurrence throughout the country of Honduras as a result of Hurricane Mitch and documents the types, sizes, and distribution of landslides in those areas of Honduras where there were high concentrations of landslides and where an ongoing landslide hazard exists. For those portions of the country where the landslides contribute a significant part of the sediment that is being transported within the stream and river network, estimates of sediment volume due to landslides are tabulated. A typical landslide inventory map is shown in figure 1.

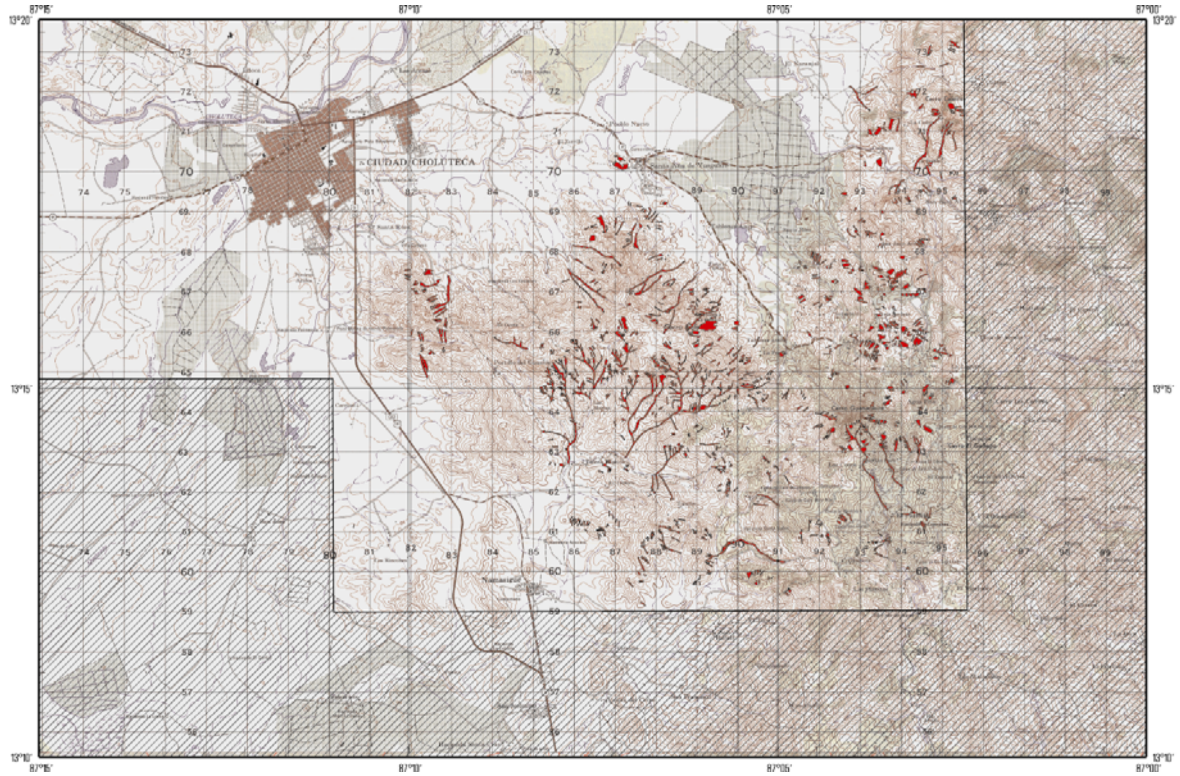


Figure 1. Landslide inventory map of the Choluteca area in southern Honduras.

This report contains 20 oversize plates consisting of 19 landslide inventory maps and one index map. The quadrangles covered include: La Ceiba, Pico Bonito, El Progreso, Villa Nueva, Las Flores, La Libertád, Ojojona, San Buenaventura, Yuscarán, Sabanagrande, Nueva Armenia, San Lucas, Nacaome, Soledad, Morolica, San Lorenzo, Orocuina, and Choluteca.

Landslide Inventory Map of Tegucigalpa

The distribution of landslides that occurred in the metropolitan area of Tegucigalpa was documented through the use of aerial photography taken by the U. S. Air Force at a scale of 1:40,000 and additional aerial photography at a scale of 1:20,000 taken by a local contractor. The inventory was initially mapped onto 1:10,000-scale topographic maps of the city produced by the Instituto Geografico Nacional. The final landslide inventory is displayed on a mosaic of these base maps at a scale of 1:15,000. The accompanying report (USGS Open-File Report 02-33, figure 2) describes the landslides, their distribution, the various landslide processes at work during their occurrence, and the four largest landslides that produced the greatest impact on people and property.

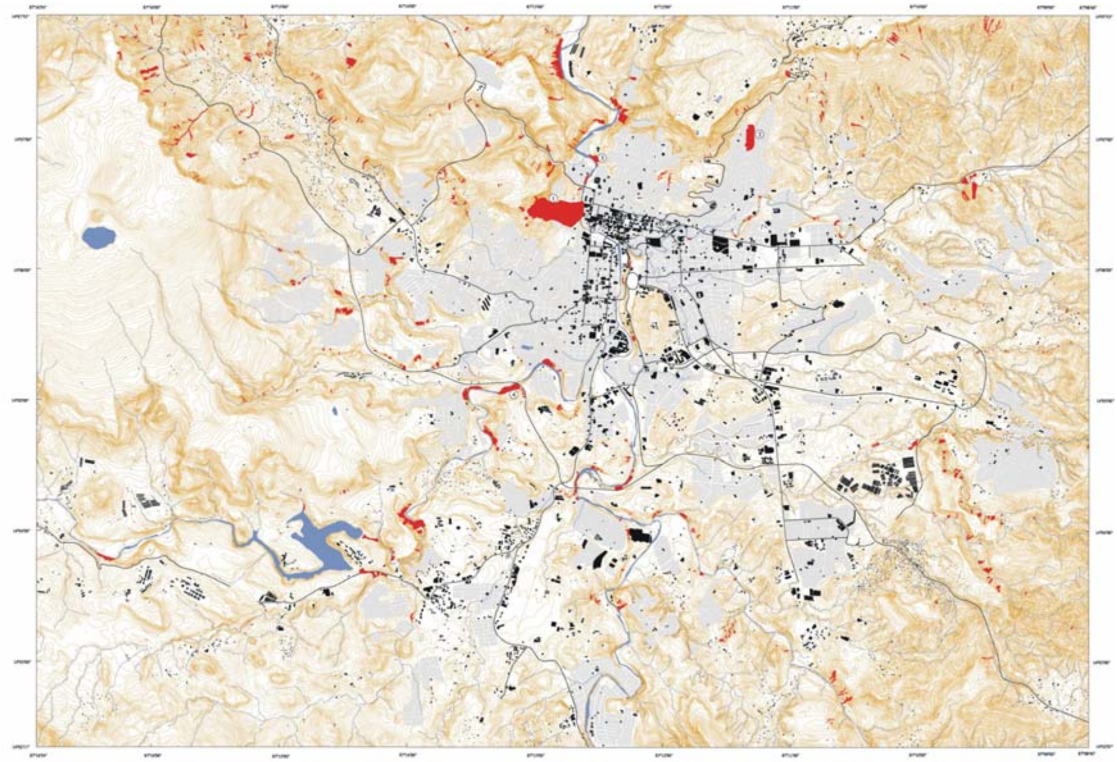


Figure 2. Inventory map of landslides triggered by Hurricane Mitch in Tegucigalpa, Honduras. Red polygons are landslides triggered by the hurricane.

Landslide Hazard Map of Tegucigalpa

With the landslide inventory map of Tegucigalpa to use as comparison, we have constructed a landslide hazard map of the capitol city. We have estimated the shear strengths of all of the geologic units using the recent geologic map made of the Tegucigalpa area by the Japanese International Cooperative Agency, we have prepared a slope map from the recent contour map made by this same agency, and we have used these data as input into an infinite slope analysis that calculates the factor of safety for every slope cell on the map. The resulting map is a factor-of-safety map, referred to as a susceptibility map. Comparing this map to the actual landslides triggered by Hurricane Mitch, we have constructed a probabilistic landslide hazard map for the Tegucigalpa area. This map (figure 3) estimates the landslide hazards for the occurrence of debris flows triggered by an extreme event such as Hurricane Mitch. However, even for a lesser event, the relative hazard from debris flows will be the same as the probability density function that relates factor of safety to landslide occurrence will be of the same form.

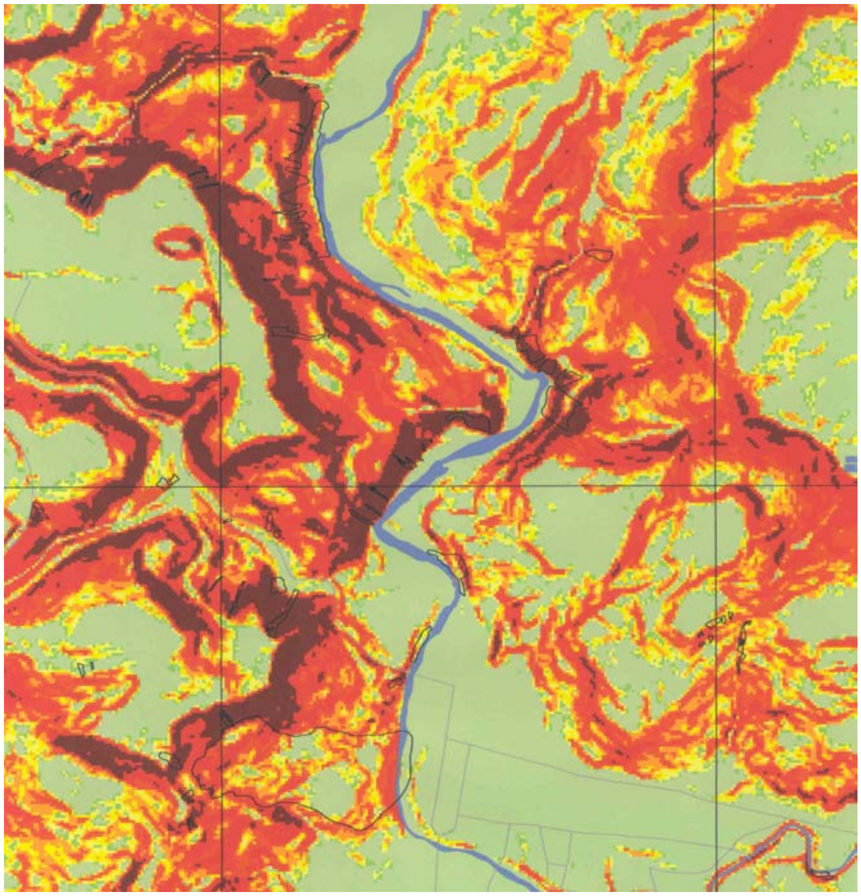


Figure 3. Example of landslide hazard map of Tegucigalpa. Red=high hazard, orange=moderately high hazard, yellow=moderate hazard, and green=low hazard. Outlined polygons are landslides triggered by Hurricane Mitch.

To facilitate data and capability transfer, we have held several training seminars in Honduras and have sponsored several weeks of training in the U. S. to teach the techniques of GIS landslide hazard analysis to Honduran agency personnel. Together with the hardware and software made available to the government of Honduras at UNITEC, a private university in Honduras, the ability to manipulate the data and do basic GIS hazard analysis should now be within the capability of the technical staff at UNITEC and available to those agencies and municipalities in Honduras who have need of the inventory and hazard products that we have prepared.

Flood-Hazard Mapping

Mark C. Mastin

Introduction

In late October 1998,Hurricane Mitch, a category 5 hurricane, struck Honduras and other countries in Central America. Several days of intense rain from this tropical cyclone caused devastating floods and landslides throughout the affected area. In Honduras, 7,000 people died, and 33,000 homes and 95 bridges were destroyed, and 70 percent of the road network was damaged. A top priority identified by the U.S. Agency for International Development (USAID) was the need for reliable maps of areas of flood hazard in Honduras to help plan the rebuilding of housing and infrastructure. USAID requested that the U.S. Geological Survey (USGS) develop these maps and document the method used to produce them.

It was recognized that a systematic method of defining areas of flood hazard was required that eventually can be applied to the country as a whole. However, to guide the rebuilding that is currently underway, rapid determination of flood hazard was needed for selected municipalities. Therefore, the flood-hazard mapping method was applied in these municipalities first. USAID considered 41 municipalities in Honduras for hazard mitigation, but not all of them sustained flood damage during Hurricane Mitch. After visits to a number of the municipalities, 15 of the 41 were selected as most in need of flood hazard mapping: Catacamas, Choloma, Choluteca, Comayagua, El Progreso, Juticalpa, La Ceiba, La Lima, Nacaome, Olanchito, Santa Rosa de Aguán, Siquatepeque, Sonaguera, Tegucigalpa, and Tocoa.

The flood design criterion selected for the program's flood mapping effort was the 50-year flood recurrence interval, or 50-year flood discharge —the discharge that is equaled or exceeded on average once every 50 years and has a 2-percent probability of occurring in any one year. This selection was based on discussions with staff of USAID and the Honduran Public Works and Transportation Ministry. The 50-year flood discharge is the most common discharge used for flood-design purposes by domestic and foreign agencies working on the recovery effort in Honduras (Jeff V. Phillips, U.S. Geological Survey, written commun., 2001).

Determining and mapping flood-hazard areas in Honduras involved three steps. (1) A regional regression equation was developed to estimate the 50-year flood discharge in a river as a function of drainage area and annual precipitation in the basin, and a geographic information system (GIS) was used to estimate the 50-year flood discharge for any location on the river. (2) An airborne laser terrain-mapping system was used to obtain high-resolution digital-elevation models (DEMs) of the river floodplain, from which elevation cross sections were determined along the river profile. The cross-section data were applied in a numerical, one-dimensional, steady-flow step-backwater model to estimate the corresponding water-surface profile of the 50-year flood discharge. (3) The water-surface profiles and floodplain DEMs were used in a GIS to produce maps of the area and depth of inundation of the 50-year flood for that area.

Objectives

The objectives of this project were to (1) develop a methodology to estimate the 50-year flood discharge for areas throughout Honduras, (2) describe a methodology to produce area and depth of inundation maps for the 50-year flood, (3) produce maps of the extent and depth of flooding expected from the 50-year flood at 15 municipalities, and (4) transfer the flood-hazard mapping technology to engineers and planners in Honduras.

These objectives were intended to provide tools to assist planners in the rebuilding of Honduras for both the short-term and long-term. In the short term, flood-hazard maps would be created for those municipalities with an urgent need for flood-hazard maps. It would be too time consuming and too expensive to provide flood-hazard maps to all the municipalities in need within the time and money constraints of the project. 15 municipalities was a workable number of sites that would provide a good start for a national program of flood-hazard mapping. In the long term, the methodology documented in the reports could be used to develop flood-hazard maps throughout Honduras. In order to perpetuate the program, the final objective, technology transfer, was achieved with hands-on training of Honduran engineers and planners with the software used to create the flood-hazard maps along with in-country seminars or meetings to advertise the project and the flood-hazard maps.

Methods

Flood-hazard maps for individual municipalities were developed by (1) estimating the 50-year flood discharge for each major river in the selected municipality, (2) constructing a hydraulic model of the river reaches within the municipality based on cross sections from topographic information, and (3) plotting water-level profiles, simulated with the hydraulic model, and area-and depth-of-inundation maps over topographic maps.

At municipalities where long-term records exist from nearby streamgaging stations, the 50-year flood discharge is estimated from the streamflow record using statistical procedures established for the United States (U.S. Water Resources Council, 1981). At municipalities with no long-term streamflow records, the 50-year flood discharge was estimated on the basis of a regression equation developed for the entire country by analysis of all the available long-term, annual peak-discharge records for Honduras and drainage basin characteristics.

A GIS program, HEC-GeoRAS (U.S. Army Corps of Engineers, 2000), was used to create cross sections of floodplain elevations from a DEM of the selected municipality acquired from a high-resolution, airborne laser terrain-mapping system survey conducted as part of this project. A hydraulic model embedded in the HEC-RAS software program (U.S. Army Corps of Engineers,1998) performed the hydraulic calculations to estimate water levels at the cross-section locations. HEC-GeoRAS was used again to process the hydraulic model results to create maps of the areas and depths of inundation for the municipalities.

The high cost of the airborne topographic surveys limited the study to flood-prone areas with a high population and (or) densely spaced structures. The surveyed areas were generally adjacent to river reaches within or near cities. Many of the municipalities that were visited were subjected to local flooding of small creeks or failed and (or) undersized drainage networks during Hurricane Mitch. This localized flooding was outside the scope of the project. The extents of the study areas at the select municipality were defined by the extents of the airborne topographic surveys and varied in size from 4.9 square kilometers (km^2) at Sonaguera to 54.2 km^2 at Tegucigalpa (fig.1 and table 1). The contributing drainage basins to the downstream end of the study areas vary from 45.4 km^2 at Catacamas to 10,579 km^2 at Santa Rosa de Aguán. The area of the topographic survey at Tegucigalpa extended away from the river into the foothills because data from the survey also were used for a concurrent landslide study.

	Municipality	**River**	**Area of topographic survey (square kilometers)**	**Area of contributing drainage (square kilometers)**
1	Catacamas	Catacamas	8.4	45.4
2	Choloma	Choloma	7.2	89.5
3	Choluteca	Choluteca, Iztoca	37.1	7,080
4	Comayagua	Humuya	20.9	1,542
5	El Progreso	Pelo	14.7	47.4
6	Juticalpa	Juticalpa	6.4	431
7	La Ceiba	Cangrejal	10.9	498
8	La Lima	Chamelecón	33.6	3,757
9	Nacaome	Nacaome,Guacirope,Grande	10.4	2,478
10	Olanchito	Uchapa	5.2	97.1
11	Santa Rosa de Aguán	Aguán	6.4	10,579
12	Siguatepeque	Selguapa,Celán,Guique, Chalantuma,Calán	12.1	139
13	Sonaguera	Sonaguera, Juan Lázaro	4.9	72.7
14	Tegucigalpa	Choluteca,Guacerique, Chiquito,Grande	54.2	804
15	Tocoa	Tocoa	7.4	204

Table 1. Characteristics of 15 municipalities selected to demonstrate the flood-hazards mapping methodology developed for Honduras

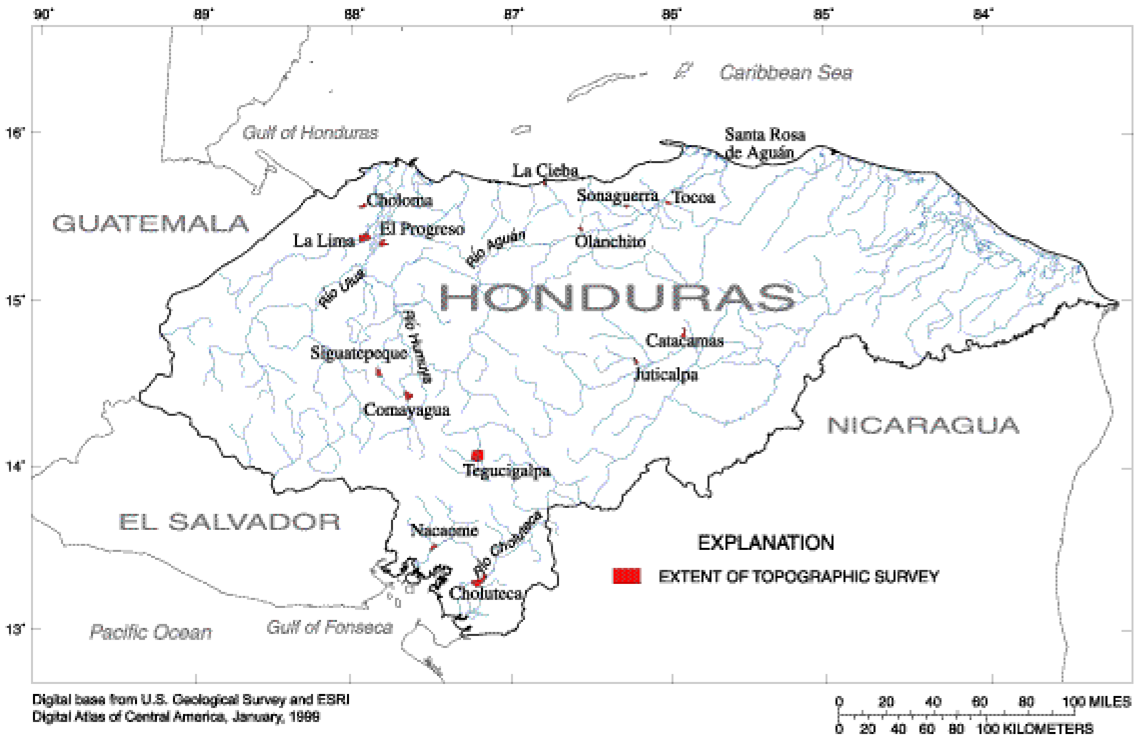


Figure 1. Flood-hazard areas mapped by airborne topographic surveys, Honduras.

It was discovered after conducting the airborne topographic surveys that the surveyed areas in the municipalities of Santa Rosa de Aguán and La Lima did not include the entire areas that would be inundated by a 50-year flood. The area and depth of inundation maps for the site report for Santa Rosa de Aguán are based on the elevation of the estimated 50-year storm tide. Also an additional map of wave-hazard in areas exposed to the sea was included. For La Lima, the site report describes the maximum streamflow discharge that the main channel can convey without overtopping levees and natural river banks in the city, as computed from trial-and-error model simulations. The La Lima report does not include a map of the extent of inundation for the 50-year flood.

Accomplishments

The accomplishments from this project include a variety of products: elevation data, GIS shape files, reports, and various outreach activities. These are briefly discussed or listed below.

Data and Maps

One of the primary sets of data collected specifically for this project was high-resolution elevation data acquired using a laser terrain-mapping system (LIDAR). These data were filtered to remove vegetation and retain buildings and resampled into a DEM with a 1.5-meter cell resolution (figure 2). These data were used to construct cross sections of the floodplain that became input to the numerical, hydraulic models used to estimate the water surface profiles of the 50-year flood. The DEMs have potential use in other applications such as landslide analysis. The data are available on the Internet at the Flood

Hazard Mapping Web page http://mitchnts1.cr.usgs.gov/projects/floodhazard.html , a part of the USGS Hurricane Mitch Program Web site.

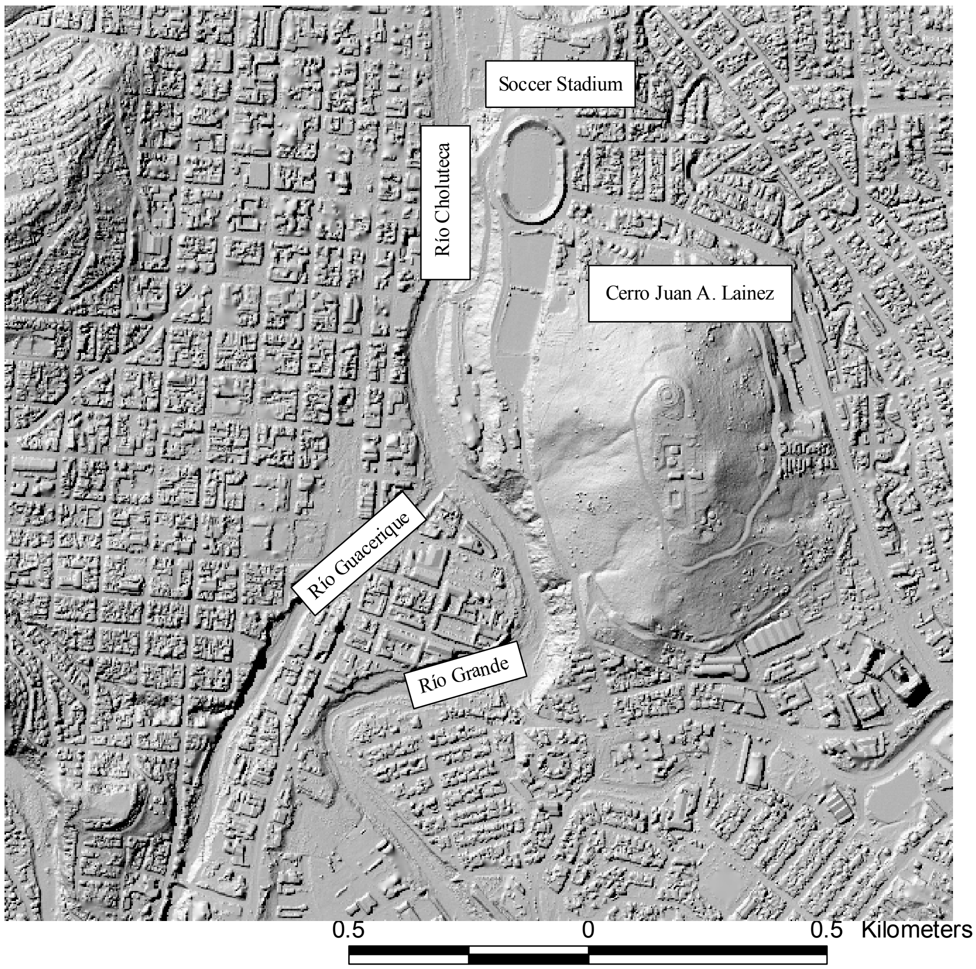


Figure 2. Shaded relief image in Tegucigalpa, Honduras of the LIDAR DEM filtered to remove vegetation.

The primary products from this project are the flood-hazard maps (fig. 3 and 4). These are presented formally in the site reports. However, to support the concurrent Municipal GIS project and provide users of the products flexibility in viewing the products, the cross section location, area of inundation, and depth of flooding used for the flood-hazard maps were compiled as GIS shapefiles for each of the 15 municipalities. These shapefiles allow users with a GIS such as ArcView to view the areas in detail and overlay them over other GIS themes. The Municipal GIS project is suppling municipalities with ArcView software and training and the flood-hazard shapefiles. Also, as an aid to similar, future projects, a shapefile was developed that estimates the 50-year-flood discharge anywhere in the country for 50-year floods greater than 100 cubic meters per second. The shapefiles are available on the Internet at the Flood Hazard Mapping Web page

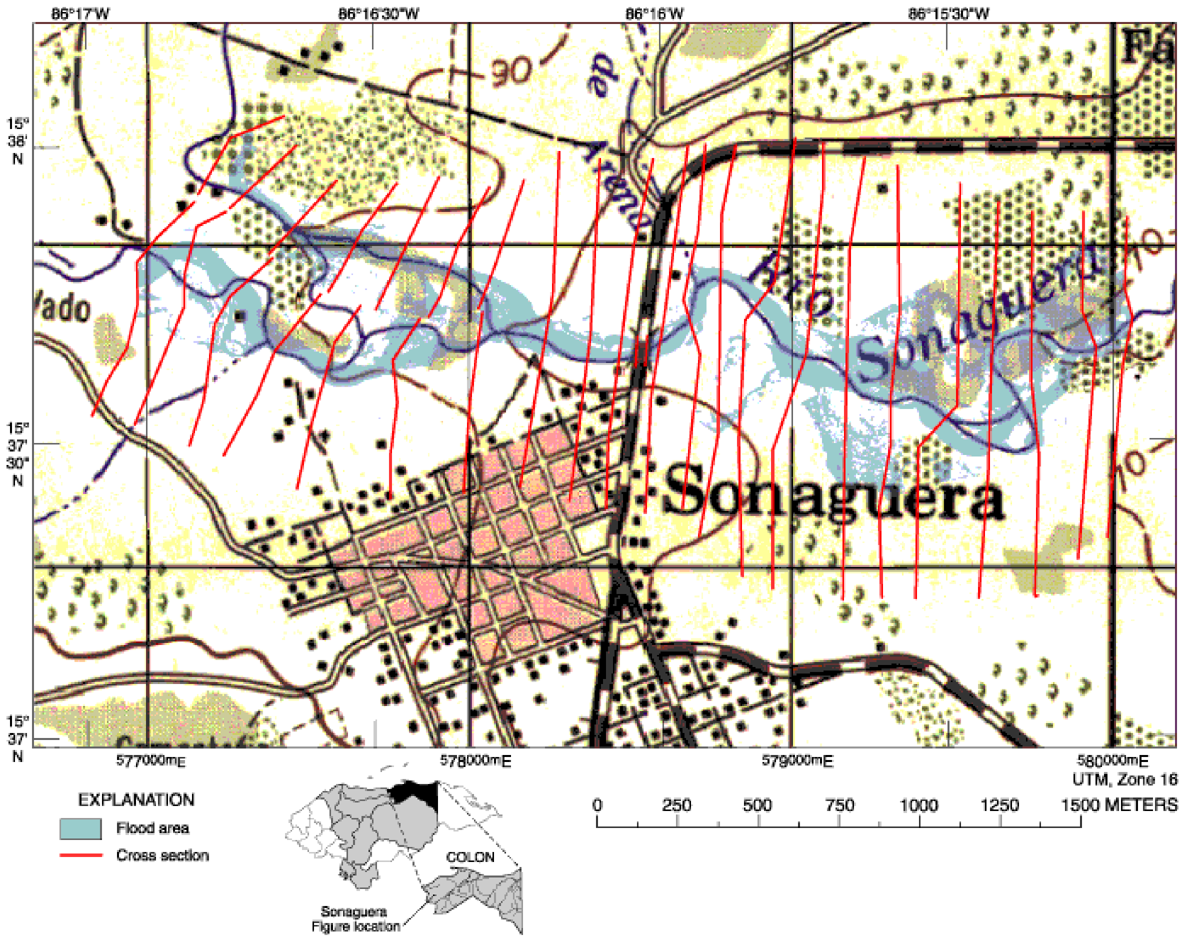


Figure 3. Extent of inundation for the 50-year flood and location of cross sections at Sonaguera, Honduras

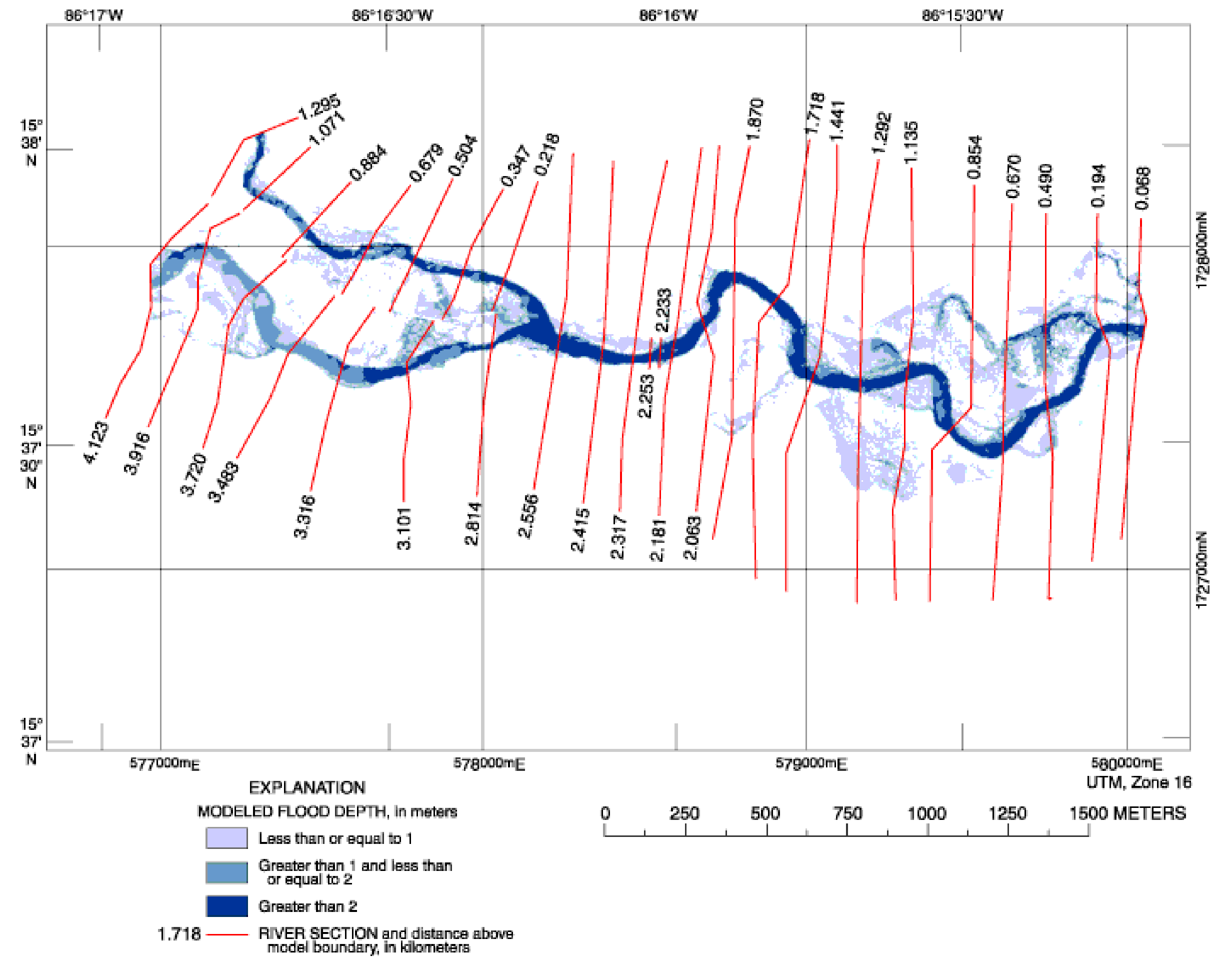


Figure 4. Depth of inundation for the 50-year flood and location of cross sections at Sonaguera, Honduras.

Reports

Sixteen reports were generated from this project. One report, "Flood-Hazard Mapping in Honduras in Response to Hurricane Mitch," (Mastin, 2002) will be published as a USGS Water Resources Investigation Report. It contains a detailed description of the methodology and data used to develop the flood-hazard maps for the 15 municipalities. 15 short site reports will be published as USGS Open File Reports. They will contain the estimates of the 50-year-flood discharge, any particular site data that affects the hydrology and hydraulics of the area, the area and depth of inundation maps, and graphs of water-level profiles. These reports will be distributed to the normal USGS distribution centers, to the 15 municipalities, and they will be available on the Internet at the Flood Hazard Mapping Web page.

<u>Outreach Activities</u>
Outreach activities included a one-week workshop held in Tacoma, Washington, meeting with the mayors of most of the municipalities, and a number of public meetings in

Honduras that were held to advertise the project and promote the use of the flood-hazard maps.

The one-week workshop in Tacoma, Washington on October 1-5, 2001 was titled, "Flood-Hazard Mapping Workshop" and was co-sponsored by the World Learning Center. Four students from Honduras attended to learn about the project, about some fundamental concepts in hydrology and hydraulics as they applied to flood-hazard mapping, and about topical issues from several guest speakers. They gained hands-on experience with using the LIDAR data, the GIS pre-and post-processing software, and the numerical hydraulic model.

Figure 5. Flood-Hazard Mapping Workshop, October 1-5, 2001, Tacoma Washington. (from left to right: Dave Kresch, USGS-Instructor; Migual Vásquez, student; Santos Damas, student; Mirna Gonzalez, USAID training coordinator; Karla Valle, student; José Hernandez, student; Mark Mastin, USGS-Instructor; Luis Fuste, USGS-Interpreter; and Theresa Olsen, USGS-Instructor)

During the first reconnaissance trip to Honduras in October 1999 most of the mayor's offices of the 15 municipalities were visited and an explanation of the project was given.

The Flood-Hazard Mapping was a feature subject at three project public meetings:

Tegucigalpa	April 25-27, 2001	Seminar titled, "Fortaleciendo la Infraestructura de la Informacion en Mitgation de Desastres y Recursos Naturales de Honduras" sponsored by USAID and USGS
Tegucigalpa	December 7, 2001	Presentation at UNITEC

San Pedro Sula December 10, 2001 Presentation at CEVS

Collaboration

The project's primary Honduran organization for collaboration is the Fundación para el Desarrollo Municipal (FUNDEMUN), the Honduran Federation of Municipalities. The collaboration with FUNDEMUN began with informal meetings with Thelma Cabrerra of FUNDEMUN and an initial two-week joint reconnaissance field trip with Roberto Rivera Moran of FUNDEMUN and USGS personnel. Ms. Cabrerra was later assigned to other tasks and Mr. Moran, who was on contract with FUNDEMUN, did not have his contract renewed. On a later USGS field trip, Santos Damas and Miguel Vásquez of FUNDEMUN were present for a demonstration of the field-survey techniques used to survey bridges. Later they attended one or more of the public meetings in Honduras, and attended the one-week workshop in Tacoma, Washington. Mr. Vásquez has since move to a different agency, Cumunidad Hábitat Finanzas.

While the collaboration with FUNDEMUN has not been as strong as planned largely because of personnel changes at FUNDEMUN, the project has informally collaborated with CEVS, Comision Ejecutiva Valle de Sula. Karla Valle of CEVS (now working for the municipality of San Pedro Sula) attended the one-week seminar in Tacoma, Washington; Luis DaCosta of CEVS join us during our reconnaissance trip in the Sula valley; and Humberto Calderon of CEVS hosted one of our public meetings and co-presented with Mark Mastin at a seminar in Tegucigalpa.

Collaboration is important for the continuation of the program because the existing flood-hazard maps may need revision in the future and many more municipalities need to plan for floods. As floodplain geometry changes because of scour or fill, the river changes course, or bridges are built, the flood-hazard maps may need to be revised. This would probably require field surveys and a knowledgeable engineer to make the changes. The existing numerical models and digital elevation products produced by this project provide most of the tools to make the updates. For new sites to be mapped, however, the major cost--the topographic survey either LIDAR or traditional aerial photogrametry--will probably be prohibitive to any of the national government agencies or local municipalities without some outside aid.

Continuation of the flood-hazard maps program needs support at the local level within the municipality offices and at the professional level with accurate, available data. Rather than visit with every municipality that may have a need for flood-hazard planning, FUNDEMUN was chosen to be a collaborative organization for this project because they assist municipalities with planning issues throughout Honduras. But the resources of FUNDEMUN seem to be limited; therefore collaboration with other organizations and more financial resources may be necessary to continue the program. Other organizations such as CEVS and SOPTRAVI, the national public works and transportation ministry, would be good candidates for future collaboration. At the professional level, the project provided a good foundation of documented methods and hydrologic data to support a program of flood-hazard mapping. However, all the maps and publications are in

English, and they may not be understood by Honduran professionals not fluent in English. Translation of the reports into Spanish might be a reasonable future expenditure to maintain the program. Another worthwhile expenditure would be the support of the streamgaging program to continue collecting quality data. Long-term streamflow data is essential for good hydrologic analysis.

References

Mastin, Mark C., 2002, Flood-hazard mapping in Honduras in response to Hurricane Mitch: U.S. Geological Survey, Water-Resources Investigations Report 01-4277. *Available online* at http://water.usgs.gov/pubs/wri/wri014277/index.html

U.S. Army Corps of Engineers, 1998, HEC-RAS, River Analysis System hydraulic reference manual version 2.2: Hydrologic Engineering Center, Davis, California, 237p.

———2000, HEC-GeoRAS, An extension for support of HEC-RAS using ArcView user's manual: Hydrologic Engineering Center, Davis, California, 96p.

U.S. Water Resources Council, 1981, Guidelines for determining flood flow frequency: U.S. Water Resources Council Bulletin 17B, 28p, 14 appendixes.

Biological Analyses of Coastal Resource Damage and Recovery

Edward Proffitt

Project Objectives

The U.S. Geological Survey (USGS) biology projects in Honduras were developed at the request of USAID and Honduran government agencies responsible for shrimp aquaculture and tourism, two of the major components of the Honduran economy. The USGS coastal resource damage and recovery projects had three primary objectives: (a) analyses of damage and recovery in Gulf of Fonseca shrimp farms and the important estuarine resources (water quality, mangrove forests, natural shrimp populations) that are integrally tied to the shrimp aquaculture industry, (b) evaluation of the degree of destruction caused by Hurricane Mitch to coastal and marine resources (mangrove forests, seagrass beds, shallow soft-coral reef flats) of the Bay Island, rates of recovery, and needs for active restoration, and (c) providing aerial photography-based mapping of damaged coastal areas and selected municipalities.

To meet these objectives we involved a number of USGS biological scientists (mostly from the National Wetlands Research Center [NWRC]), a collaborator from the National Park Service, and faculty and, in some cases, graduate students from the University of Louisiana at Lafayette, Auburn University, the University of Texas, and Western Washington University.

Accomplishments

Gulf of Fonseca - We provided initial surveys of natural resource damage in coastal areas and inland agricultural fields by sending a small team of biologists and two single engine, amphibious airplanes (one piloted by USGS T. Michot and the other by US Fish and Wildlife Service F. Roetker) just 8 weeks after Hurricane Mitch. Reports from these aerial damage surveys were delivered verbally (as well as by written trip reports) at meetings with various Honduran ministries and USAID. This team also met with many individuals from resource management agencies, Honduran universities, and non-governmental organizations (NGOs) to discuss damages to coastal, aquaculture, and agricultural resources and to develop the in-depth course of activities to follow.

During Hurricane Mitch, the Choluteca River changed course and destroyed a large area of estuarine mangroves through flooding and sediment deposition. Early surveys indicated that in some locations over a meter of sediment had been deposited in intertidal estuarine areas, which affected the existing forest, increased elevation in areas and which subsequently retarded recovery, and provided a reservoir of sediment in the estuary that could possibly be remobilized in ensuing rainy seasons or by future storms thereby producing secondary effects. USGS scientists completed projects that determined the degree of sedimentation (Cahoon and Hensel) and the effect of this sedimentation on the mangrove forest structure (Proffitt and Hensel) and soil chemistry (McKee). Damaged, undamaged, and aquaculture wetland and upland areas around the municipalities of San

Lorenzo, Nacaome, Amapala, and Choluteca were mapped (base maps and aerial photos are provided in tif format), and habitat data were placed in ArcInfo format. These USGS data will be distributed on compac disks (Handley).

Project scientists from Auburn University and the University of Texas completed assessments of riverine and estuarine water quality in the Gulf of Fonseca to determine if washout from shrimp farms caused by Hurricane Mitch increased levels of nutrients and if subsequent farm recovery and operations produced effluent that exceeded the water quality (mainly dissolved oxygen [DO] and biological oxygen demand measurements) carrying capacity of the San Bernardo and El Pedregal estuary systems. In addition, a transport model for salinity and DO was developed for both wet and dry season inflows, which will allow resource agencies to further evaluate the interaction between continued shrimp farm operation and development and estuarine water quality.

In addition to understanding the links between shrimp farms and their impacts on water quality through discharge of water laden with effluent, Honduran natural resource managers and aquaculture officials recognized the highly integrated nature of shrimp populations (and thus shrimp aquaculture) and mangroves which serve as habitat for various life history stages of shrimp and, through photosynthesis and production of plant leaves and eventually detritus, support the natural shrimp population food web. Constructing and operating shrimp ponds to avoid or minimize impacts to the mangrove ecosystems is of paramount importance, although in many regions of the world these interests are in conflict. Project scientists (Twilley and Rivera-Monroy, from the University of Louisiana at Lafayette [ULL]) worked in collaboration with experts from the shrimp farm industry association (D. Martinez, ANDAH) and the Aquaculture/Fisheries Center at the University of Arkansas-Pine Bluff (D. Valderrama) to develop a system by which the rehabilitation of estuaries and shrimp farms following Hurricane Mitch could be integrated with ecological processes of mangrove ecosystems. They estimated the total area of mangrove forests for the entire Gulf of Fonseca via remote sensing techniques, as well as the area and distribution of mangroves and shrimp ponds in the southern gulf where the industry is focused. They also collaborated with Green (Auburn University) and Ward (University of Texas) to employ the latter's long-term data on water quality to understand current levels of fertility in coastal waters. These data were used in models developed to determine the capacity of mangrove forests to assimilate excess nitrogen and phosphorus in the water. They also propose mangrove:shrimp pond ratios that could remove excess nutrients from the pond effluent and present this as a strategy for integration into suggested Best Management Practices.

Shrimp viral diseases began to show up in the Gulf of Fonseca for the first time a few months after Hurricane Mitch had caused nearly complete loss of the current shrimp crop through washout and sedimentation, both of which can be devastating to the industry. USGS scientists Jenkins (with ULL collaborator Dankert) and Travis analyzed different aspects of the shrimp and viral disease problem. Dankert and Jenkins worked to develop a quick test kit for the viral disease "white spot" by which post-larval shrimp caught in the gulf and destined for use as shrimp pond stock could be tested for the virus. This is necessary since the virus can be present but does not produce visible effects at this shrimp life history stage. They demonstrated that the enzyme phenoloxidase (PO) can be coupled with a simple color indicator system (i.e., requiring no sophisticated equipment to test) and will react with white spot extract. This has promise as eventual use as a simple, but powerful, test and suggests that other similar tests can be developed for other shrimp viral diseases. Travis analyzed the problem of how viruses might be introduced from infected stock released from shrimp ponds into the natural shrimp, and other crustacean, populations in the Gulf of Fonseca. His genetic work showed that releases of live shrimp or larvae from ponds are a regular occurrence, as shown by his finding that their specific signatures can be picked up in the natural populations of nearby estuaries via DNA fingerprinting.

Bay Islands and Caribbean Mainland – Unlike the Gulf of Fonseca where flooding and sedimentation was the main problem, at the Bay Islands and portions of the mainland, wind and wave damage were rampant in some locales. Our initial analyses showed that nearly all mangroves on the island of Guanaja had been destroyed, and that portions of the eastern end of Roatan were impacted as well. Also, upland forests on Guanaja had been essentially eliminated by the extremely high winds that affected the island. Because of reports from locals and the extent of damage to mangroves that was visible early on, damage to biological resources important to tourism (e.g., coral reefs, soft coral/seagrass flats) was also suspected but was undocumentable from the surface and from initial aerial scans.

The USGS research team of Proffitt and Hensel quantified the impacts to mangrove forest structure and recovery rates, to soil chemistry (McKee), and to soil elevation collapse associated with root decay (Cahoon, Hensel, Rybczyk, and Perez). Michot (USGS) and a colleague from the National Park Service (J. Burch) assessed status of soft coral/seagrass flats just offshore of mangrove areas. Doyle (USGS) analyzed wind patterns and related these to mangrove and upland tree wind-throw and developed a model of this hurricane effect. Based on the high rate of elevation loss in interior portions of mangrove forests on Guanaja and the relative isolation of this island from other sources of mangrove propagules, the research team recommended active restoration of portions of this forest.

Resulting Benefits

The field, lab, and mapping results of these projects provide important, first-order information that not only applies to Hurricane Mitch recovery efforts, but also can be used in overall management of natural resources. The base maps and aerial photographs provided by our work will be a useful tool for both government and private natural resource managers.

The establishment of working relationships and close data integration between mangrove ecologists and shrimp farmers is an important outcome of our projects in the Gulf of Fonseca. In many regions of the Tropics, these two groups do not cooperate and are even antagonistic to one another at times. In the USGS Hurricane Mitch project in the Gulf of Fonseca, shrimp farmers and their association were specifically included in planning and were integrated into studies of water quality, planning better inclusion of mangroves in shrimp farm design, and linkages between farms, estuarine pollution, and conservation of natural shrimp populations. Initiating and maintaining these relationships will provide a framework for future sustainable management of natural coastal and estuarine resources in the Gulf of Fonseca.

Local officials and environmental managers in the Bay Islands now have a basis for assessing not only the effects of and recovery from Hurricane Mitch, but for predicting the effects of future major hurricanes. In addition, our finding of sediment collapse from root decay has demonstrated the importance of planting mangrove seedlings on Guanaja. Without restoration plantings, the soils will erode which will preclude any future establishment by mangrove seedlings that might wash in to the area, which, in turn, may lead to the mangrove forest being lost possibly for decades or centuries.

Success Stories

Training Honduran natural resource managers is of paramount importance to the continued wise use and conservation of the many magnificent coastal living resources of Honduras. We worked closely with several environmental officials, foresters, and NGOs so that our methods and scope of studies would be understood and could be used in future analyses where necessary. One natural resource manager, Adrian Oviedo, worked very closely with several of our projects, and in the Fall of 2001, we invited him to attend and be a co-presenter of a talk about one of the shrimp projects at the international Estuarine Research Federation symposium (in St. Petersburg, FL). He learned the importance of symposia, formal discussions, and informal talks in interacting with biologists and other natural resource managers.

As mentioned, the development of close working relationships and collaborations between estuarine and mangrove ecologists and the shrimp farm industry may lead to better integration of shrimp farms into the coastal zone, more sustainable yields coupled with less impact on natural shrimp populations or their habitat, and reduced inputs of effluent into rivers and estuaries.

Primary Collaboration Efforts

Bay Island projects were coordinated with coral reef studies performed by USGS-Geologic Discipline. Work was coordinated with National Oceanic and Atmospheric Administration scientists to ensure non-overlap and more useful data and products. Projects were also coordinated with local counterparts (ANDAH, etc.), some of whom played critical roles in day-to-day activities of some of the projects. Complete lists of contacts and collaborations are given in the individual technical reports of the projects.

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.

Dankert, J. R. and J. Jenkins. 2002. Assessment and development of immunological methods to determine viral infection of shrimp: U.S. Geological Survey, draft report.

Doyle, T. W. , T. C. Michot, F. Roetker, J. Sullivan, M. Melder, B. Handley, and J. Balmat. 2002. Hurricane Mitch: Landscape analysis of damage forest resources of the Bay Islands and Caribbean coast of Honduras: U.S. Geological Survey, draft report.

Handley, L. R., J. L. Tibodeaux, J. L. Dugas, and K. Mouton. 2002. Hurricane Mitch: Mapping coastal habitats: 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 adn 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.

Rivera-Monroy, V., R. R. Twilley, and E. Castaneda. 2002. Integrative management and rehabilitation of mangrove resources to develop sustainable shrimp mariculture in the Gulf of Fonseca, Honduras: U.S. Geological Survey, draft report produced in collaboration with A. R. Alcanara-Eguren, D. Aragones, D. Martinez, and D. Valderrama

Travis, S. E. 2002. Hurricane Mitch: Shrimp population assessments in the Gulf of Fonseca, Honduras: U.S. Geological Survey, draft report.

Ward, G. And B. W. Green. 2002. Effects of shrimp farming on the water quality of El Pedregal and San Bernardo estuaries, Golfo de Fonseca, Honduras: U.S. Geological Survey, draft report.

Figures

Figure 1. Dr. Philippe Hensel (USGS – National Wetlands Research Center) measuring sediment elevation in a dead mangrove forest on the Bay Island of Guanaja.

Figure 2. Aerial photograph of shrimp farm and mangrove shoreline in the Gulf of Fonseca taken from the USGS amphibious airplane (T. Michot, Pilot).

Figure 3. Mangrove shoreline in the Gulf of Fonseca showing severe damage from flooding and sedimentation resulting from Hurricane Mitch.

Assessing the Damage and Recovery of Coral Reefs

Christopher D. Reich, Robert B. Halley and T. Donald Hickey

OBJECTIVES

Investigations of coral reef damage and recovery in Honduras from Hurricane Mitch involved: (1) assessing the amount of coral breakage and displacement that occurred as high waves and strong currents impacted the reef and (2) identifying the effects of increased coastal sedimentation and nutrient-enrichment, which resulted from flooding after Mitch moved onshore. Monitoring and evaluating the damage to the reefs from Mitch involved installing instruments around Cayos Cochinos and Roatan as well as photo documentation of coral disease, algae abundance, physical damage to corals, and overall reef health. Very little coral reef data exist for Cayos (e.g., Guzman, 1998), so the data presented here are considered to be some of the first collected throughout the region. Two instruments recording water salinity, temperature, and light intensity (PAR) were installed on a shallow reef (17 feet) at Cayos Cochinos and Roatan. In addition, three sites throughout Cayos (Lions Head, Pelican Point and a shallow reef near the field station; red dots on Figure 1) were selected to house instruments measuring temperature only. These temperature loggers were placed on the reef in 17-feet and 66-feet water depths to measure upwelling events that might occur as a result of meteorological or oceanographic changes and to measure extreme sea-surface temperatures on a shallow reef (3 feet).

While working with the Honduras Coral Reef Fund (HCRF) in their 184 square mile Cayos Cochinos Natural Monument we became aware of their vulnerabilities. They were lacking vital information for coral reef health. Continuous monitoring of water quality at the basic of levels was absent, but is necessary as this region is influenced by coastal runoff at a local and, more importantly, regional scale. Roatan, on the other hand, has less vulnerabilities/data gaps as there are other agencies conducting water quality, reef quality and fisheries studies. A few of those institutions/agencies that have been involved or are currently involved in these studies are: 1) Roatan Institute of Marine Science (RIMS), 2) Societe Anonyme Francaise d'Estudes et de Gestion (SAFEGE) and 3) Global Vision

International (GIV). We chose Roatan as our control site for this reason as well as for its distance away from the mainland.

BACKGROUND

Reef corals from around the world were severely affected from bleaching by the El Niño event in 1997-1998. Mass bleaching events occur when prolonged high sea-surface temperatures stress corals, causing the expulsion of symbiotic zooxanthellae (plant-like organisms living within the coral tissue). Extended periods of bleaching may lead to an increase in coral mortality. It is estimated that ~16% of the worlds corals were destroyed from this one bleaching event in 1998 (Wilkinson, 2000). Unfortunately, coral reef environments along the north coast of Honduras were about to face additional problems. On October 25, 1998, Hurricane Mitch had formed into the fourth strongest Atlantic hurricane on record; a category 5 hurricane with wind speeds over 180 mph and estimated wave heights of 45 feet. Mitch turned out to be the deadliest hurricane since the great hurricane of 1780 (http://www.ncdc.noaa.gov).

Mitch lost energy and became a category 4 hurricane on October 27 as it began to interact with the mountains on the Honduras mainland. Mitch passed over Roatan, Guanaja, and Cayos Cochinos on October 27 & 28 (Figure 2) with 130-mph winds that caused severe damage to buildings and onshore habitats. Mitch dropped over 6 ft of rain on the mainland causing severe flooding, landslides, and mudflows. In response to this devastation, the U.S. Geological Survey (USGS) received supplemental congressional funds through the U.S. Agency for International Development (USAID) to establish a network of early detection systems (stream gages, maps of landslide-prone areas, etc), assess impacts to potable water quality, and assess damage to coastal resources such as coral reefs, sea grass beds, and mangrove forests. This study focused on the impacts that Mitch had on the coral reef ecosystems of Cayos Cochinos and Roatan, Honduras.

SITE DESCRIPTION

Cayos Cochinos Natural Monument served as the primary study site with secondary efforts in the Roatan Marine Reserve (WestEnd). Cayos Cochinos is located on the continental shelf approximately 12 miles off the northern coast of Honduras and 18 miles south of Roatan in the Caribbean Sea. A deep trough (1400 ft) separates Cayos and Roatan. Fringing coral reefs circumvent the coasts of all the Bay Islands thereby providing shoreline protection from storms and shelter to hundreds of species that make coral reefs their home. This protection allows a tourism-based economy, supplemented by sustenance fishing for the local indigenous people. Though the reefs of Roatan and Cayos Cochinos share many similarities, there are important differences. Historically, Roatan has been bathed in clear water (100+ ft visibility), which is a result of relatively strong oceanic currents that sweep past the island. However, during the past decade poor land-use practices and development have resulted in increased runoff and sediment deposition on the reefs (Mehrtens, C.J. and others, in press). Cayos Cochinos, on the other hand, is located on the shallow continental shelf and is persistently influenced by runoff from mainland rivers that result in salinity, temperature, turbidity and water-quality fluctuations. Land clearing and deforestation on the Honduras mainland has accelerated sediment loading, nutrient content, and frequency of flood events that eventually impact the marine environments around Cayos Cochinos, and to a minor extent, other Bay Islands.

KEY ACCOMPLISHMENTS

Physical damage to coral reefs from Hurricane Mitch may have been kept to a minimum because the reefs in this area are composed primarily of robust head coral species such as brain coral (*Diploria* sp.) and star coral (*Montastarea* sp.). Sedimentation and freshwater runoff from the mainland most likely caused more damage to corals than did waves and currents. Divers observed widespread coral disease such as black band, white pox, and bleaching and an abundance of algae during the initial visit to Cayos in October 1999 (Figure 3). The occurrence of these diseases and algae are thought to be a combined result of stress induced from of pre-hurricane, high sea-surface water temperatures and post-hurricane, high sedimentation and nutrient influx from the mainland. SeaWiFS (Sea-viewing Wide Field-of view Sensor) satellite imagery (Figure 4A) taken November 1, 1998 and Space Shuttle photograph (Figure 4B) taken November 3, 1998 show a large plume of sediment-laden river water flowing from the engorged Aguan River Valley directly to Guanaja. Portions of this large plume eventually inundated the Cayos Cochinos region. Coral reef communities typically thrive in clear, low-nutrient oceanic water and therefore are affected when subjected to water that has lower-than-normal salinity, increased sedimentation and additional nutrients. Cayos Cochinos is regularly influenced by all of these factors.

It is probable that Hurricane Mitch prevented further bleaching damage to the corals throughout the Bay Islands (Roatan, Guanaja, Utila, and Cayos Cochinos) during the fall of 1998. Upwelling of deep oceanic water lowered the surface temperatures by 4^{o}F as Hurricane Mitch passed over the Bay Islands (Jennifer Keck, pers. comm.; Figure 5). The drop in surface temperature had a positive effect by reducing the severity of coral bleaching and prevented further coral mortality. In addition, during the past two years (1999-2001), summer-time sea surface temperatures throughout the Caribbean have not exceeded the coral bleaching threshold temperature of 86^{o}F (Hoegh-Guldberg, 1999) for any length of time (Figures 6 and 7). Hence, there have not been any widespread coral bleaching events in this area since 1998.

Coral reefs at Cayos Cochinos have displayed fewer diseased corals during each of the subsequent visits. This is an encouraging sign that the corals are recovering from the stresses induced by Hurricane Mitch. However, widespread turf and fleshy algae are still widespread throughout the Bay Island archipelago. Observations by previous researchers (Guzman, 1998) suggest that coral disease and algae were present prior to Mitch but are not well documented. On the other hand, algal persistence around Cayos has been well documented and may have resulted from repeated nutrification of surface waters, whether from land clearing and agricultural runoff on the mainland, or from local human sources (Guzman, 1998). River discharge as well as local runoff can be monitored by looking for low salinity spikes and/or decreased light levels in surface waters (Figure 8). Continued monitoring of these parameters is essential in understanding the long-term impacts that sedimentation, nutrification and low-salinity events may have on coral reef health within the Cayos Cochinos Natural Monument. Human impacts, such as over fishing, poor sewage disposal practices, and coral mining, though not investigated in this study, may also lead to the deterioration of coral reef environments.

In October 2001, Hurricane Michelle formed over Honduras and moved northward. In its path it rained significantly and raised the Aguan River by 3 to 4 meters. This was valuable information in that we were able to pick up the Rio Aguan's discharge signal by our instruments at Cayos Cochinos (Figure 9). USGS stream gages located at Olanchito on the Rio Aguan showed two major discharge pulses that look to be discernable in the salinity record at Cayos Cochinos. If this is true, then all of this work is an attempt to take what we see in our data and predictively forecast what the impacts of a larger event (e.g. Hurricane Mitch) might have on the water quality and health of coral reef.
This project has resulted in several products. Two US Geological Survey Open-File Reports have been published on our work, one in English (OFR 01-133) and one in Spanish (OFR 01-214). Both of these reports can also be found at http://coastal.er.usgs.gov/publications/ofr/01-133/. Additional data and information about the project is located on the Hurricane Mitch Clearinghouse website at http://mitchnts1.cr.usgs.gov/projects/coral.html. A short documentary movie (unpublished) about our work has also been placed on a website for viewing. The movie can be found at http://coastal.er.usgs.gov/education/mitch-movie/.

FUTURE DIRECTIONS

As a result of our study we were able to provide training to personnel at the lab on Cayos Cochinos. This training will hopefully ensure that our instruments are properly taken care of and that the data collected will be used for the benefit of future scientific studies and for the management of the Cayos Cochinos Natural Monument. At the end of the project we were able to provide grant money to the HCRF to continue our work for another two years. The grant also will allow HCRF and Cayos Cochinos Natural Monument to expand some of our work to include analyzing for additional water quality parameters (e.g., nutrients) as well as mapping benthic habitats throughout the Cayos archipelago and conducting additional coral reef surveys.

ACKNOWLEGMENTS

Much of this work could not have been accomplished without the assistance of several people: Carlos Garcia-Saez, Adoni Cubas and others at the Honduras Coral Reef Fund; Elias Aguilar and others at the Cayos Cochinos Natural Monument; Jennifer Keck at the Roatan Institute of Marine Science; and Frank Mueller-Karger and Serge Andrefouet at the University of South Florida in St. Petersburg.

REFERENCES

Guzman, H.M., 1998, Marine-terrestrial flora and fauna of Cayos Cochinos Archipelago, Honduras, *Rev. Biol. Trop.,* 46, Supl (4), 200p.

Hoegh-Guldberg, O., 1999, Climate change, coral bleaching and the future of the world's coral reefs, *Mar. Freshwater Res*., 50, 839-866.

Mehrtens, C.J., Young, R.S. and Rosenheim, B. (in press) Reef morphology and sediment attributes:

Roatan, Bay Islands, Honduras. *Journal of Coastal Research*.

Wilkinson, C., 2000, Status of coral reefs of the world: 2000, Global Coral Reef Monitoring Network (GCRMN),

http://coral.aoml.noaa.gov/gcrmn/Status_2000.pdf.

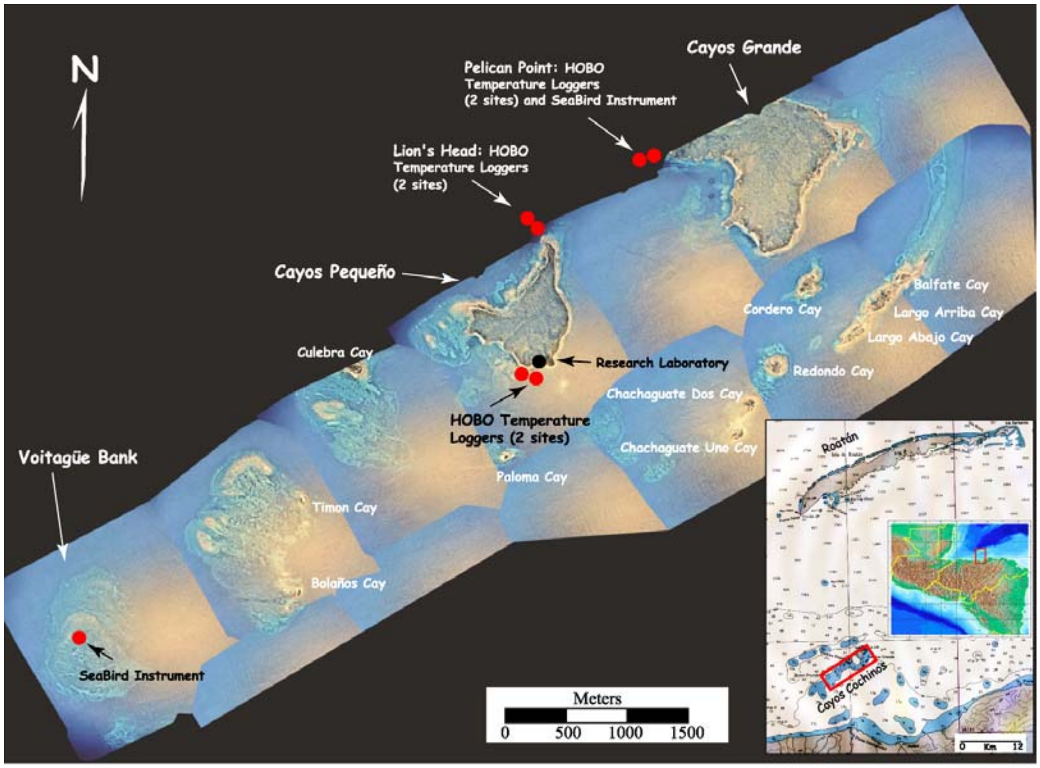


Figure 1. Photo mosaic of the Cayos Cochinos archipelago and its proximity to the Honduras coastline (inset). Red dots depict the locations of both the SeaBird Instruments and the HOBO temperature loggers. The research lab is located on the southern shore of Cayos Pequeño.

Figure 2. Index map showing location of Cayos Cochinos and Roatán, Honduras and the path of Hurricane Mitch in October 1998.

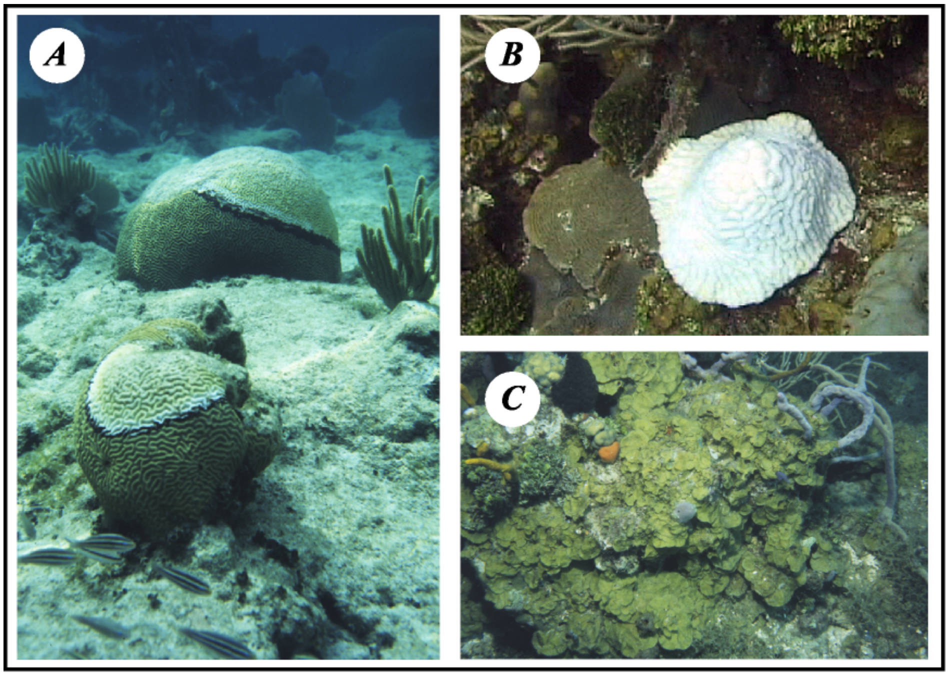


Figure 3. Photographs of (A) Black Band Disease on brain coral (*Diploria* sp.), (B) bleached *Meandrina* sp. coral, and (C) typical algae (*Lobophora* sp.) overgrowth along the reef crest.

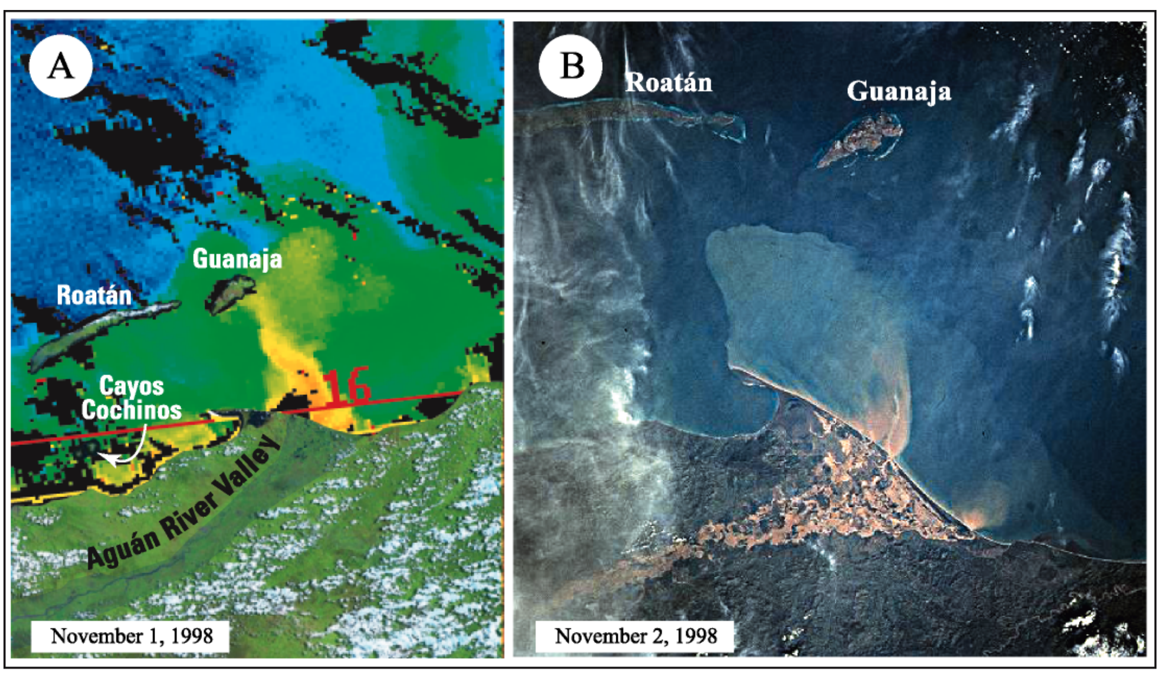


Figure 4. (A) Color-enhanced satellite image (SeaWiFS) and (B) NASA Space Shuttle photograph (STS-095-711-71) showing the extent of the fresh water plume as a result of the intense rainfall produced by Hurricane Mitch. SeaWiFS image courtesy of ORBIMAGE and the University of South Florida. Space Shuttle photograph courtesy of NASA Earth Sciences and Image Analysis, Johnson Space Center.

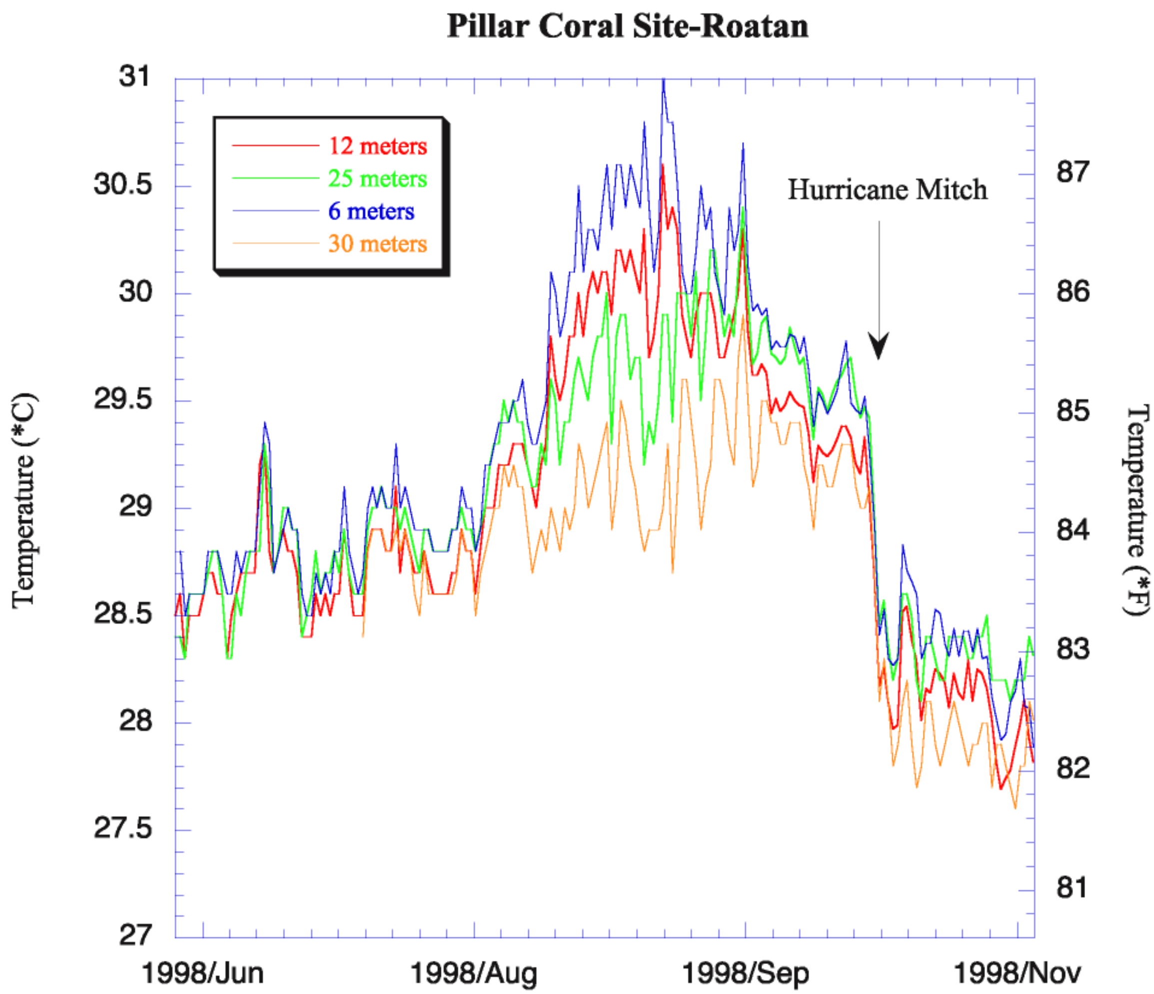


Figure 5. Temperature record at various depths on Pillar Coral Reef located off Sandy Bay, Roatan. It is apparent that Hurricane Mitch had an overwhelming affect on lowering sea surface temperatures at this site. This graph also shows the temporal extent of the high sea surface temperatures that lead to mass mortality of corals throughout the Caribbean from coral bleaching.

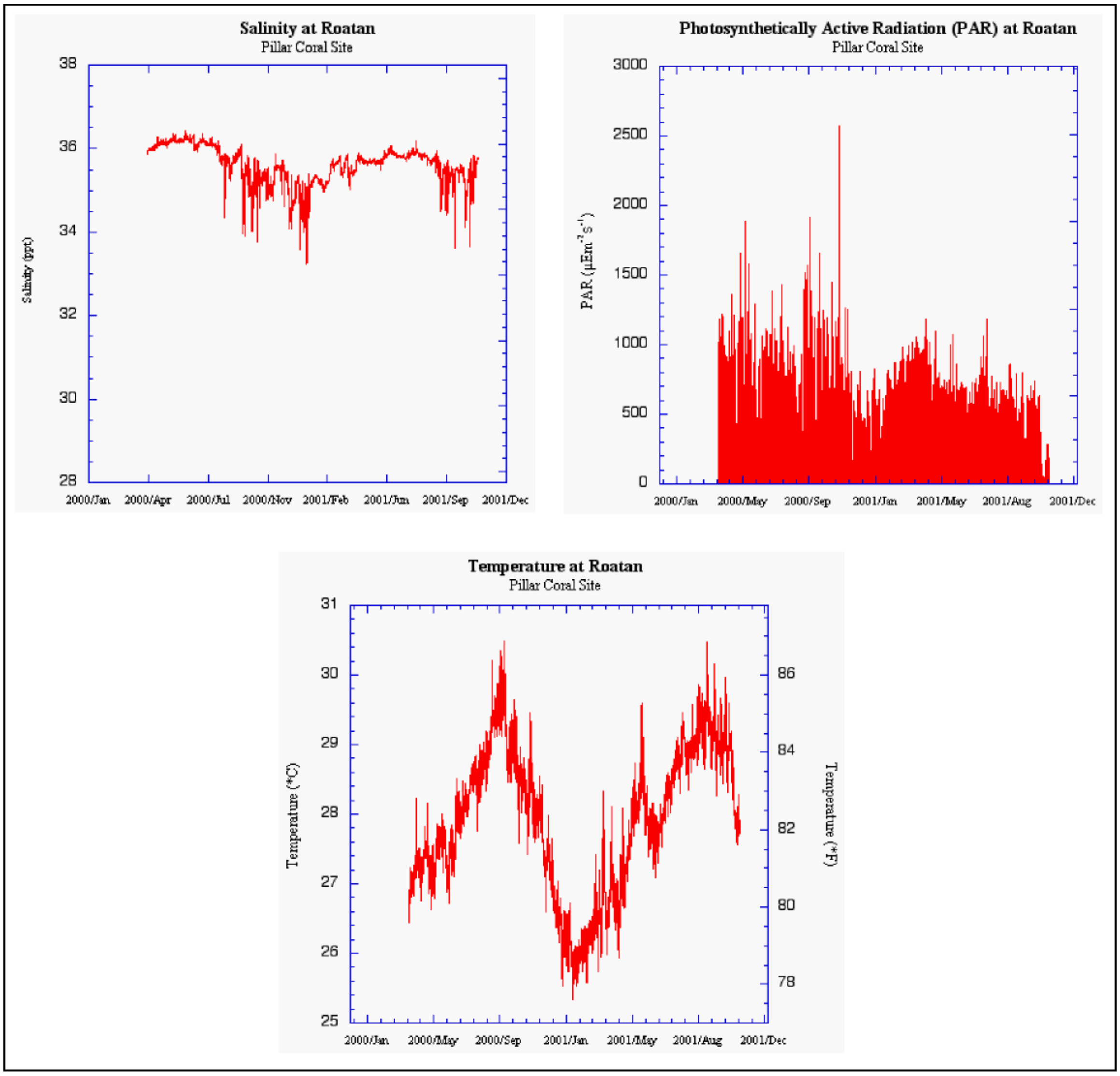


Figure 6. Data collected by SeaBird electronic instrument moored in 17 feet of water at Pillar Coral Site located off Sandy Bay, Roatán.

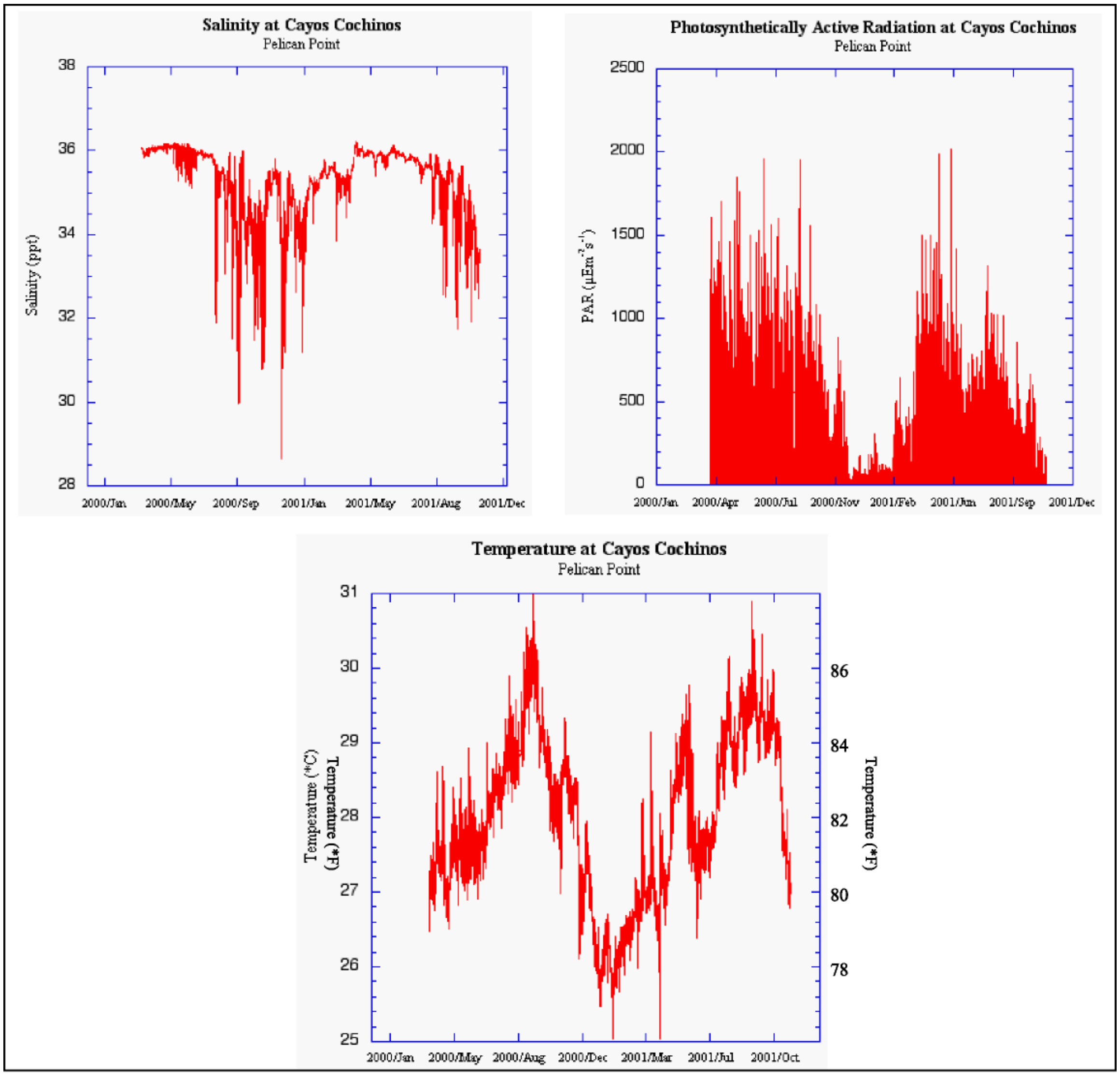


Figure 7. Data collected by SeaBird electronic instrument moored in 17 feet of water at Pelican Point located off Cayos Cochinos Grande.

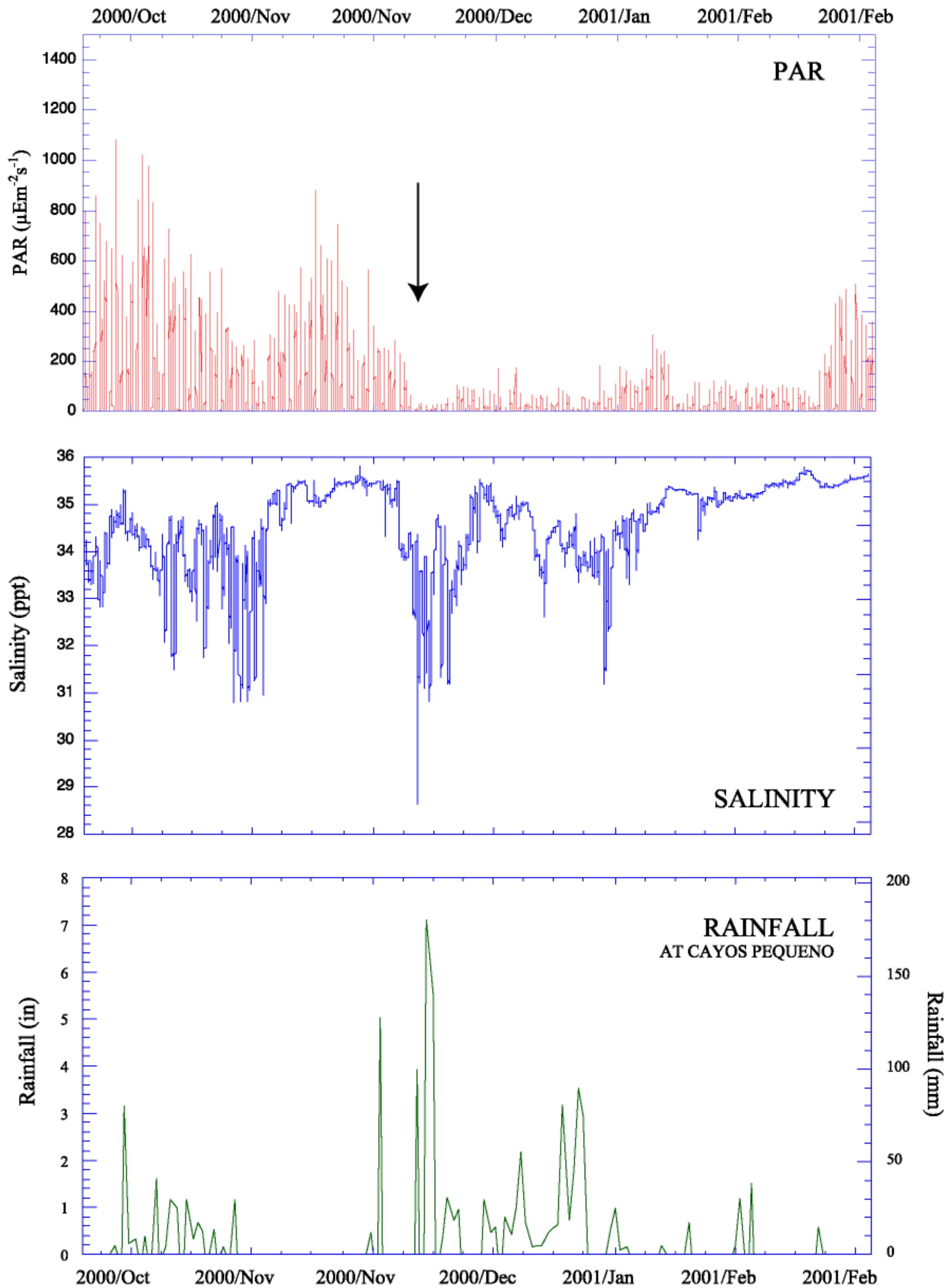


Figure 8. Data from Cayos Cochinos showing the relationship between Rainfall, Salinity and Photosynthetically Active Radiation (PAR). Local rainfall events, in addition to fresh water inputs from the mainland, can be detected in the salinity and PAR data as shown here. Typically, rainfall increases particulate material (sediments) in the seawater thereby decreasing the clarity and hence the light penetration.

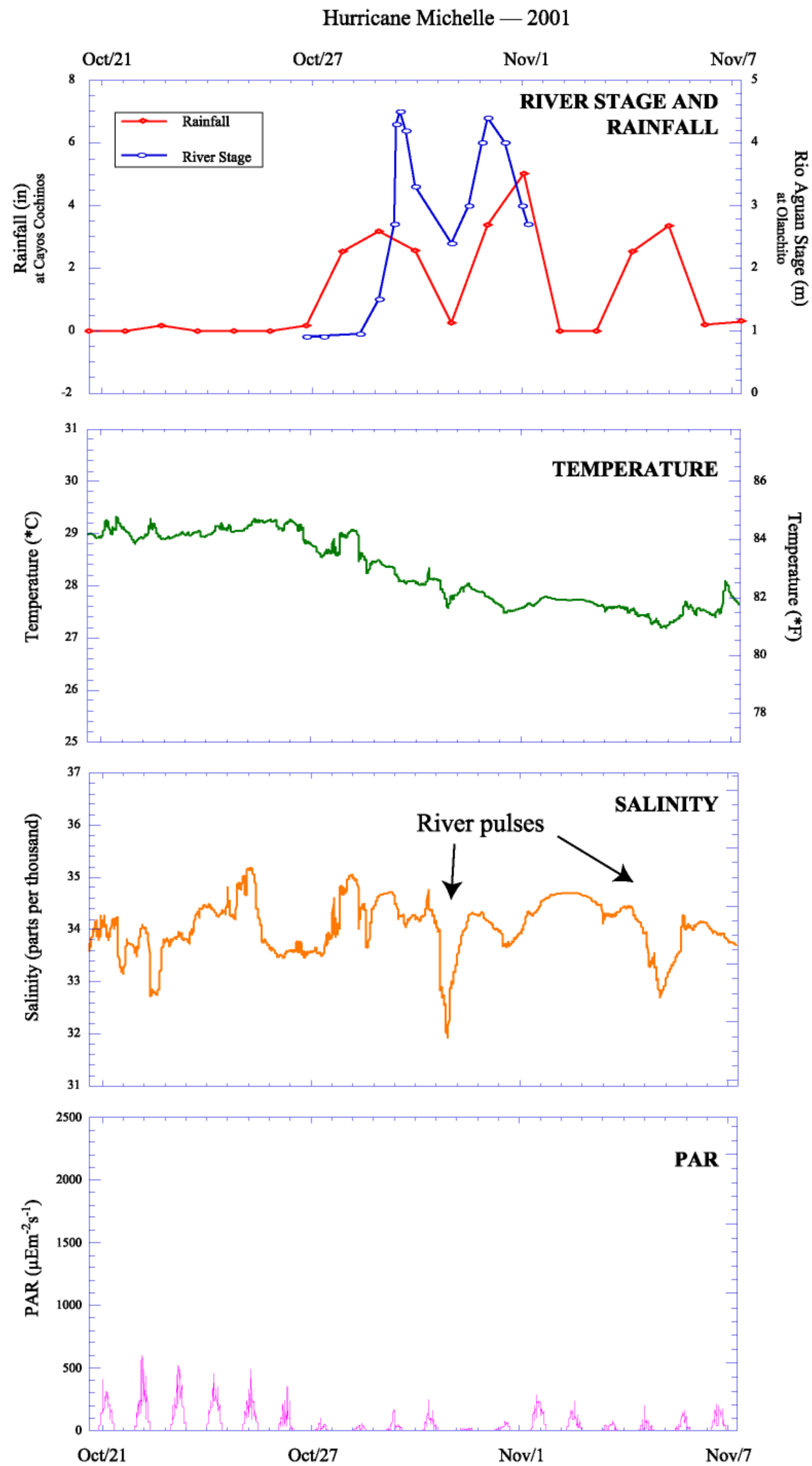


Figure 9. Data collected at Cayos Cochinos during the fall of 2001 when Hurricane Michelle was heavily raining on the Honduras mainland. Sea surface temperatures began to drop as a result of the rainfall and the salinity record shows two sharp decreases that can be correlated to the two pulses recorded on the Rio Aguan at Olanchito.

Development of a Ground Water Database

Wes Meehan

INTRODUCTION

The U.S. Agency for International Development (USAID), at the request of the Government of Honduras, initiated a program to evaluate the current status and future development potential of the ground-water resources of Honduras. This study was designed to contribute to the ability of Honduras to manage its own ground-water resources after the program expired, and had both national and local perspectives.

Honduras has relied on ground water for many of its domestic, agricultural and industrial water-supply needs. As the nation's population grows, the need to monitor and manage ground-water resources is becoming a critical issue. The historical use of surface water as a means of transport and disposal of untreated wastes from agricultural, municipal, industrial and domestic sources has rendered most surface water in the country unfit for human consumption. This places a greater importance on the assessment, monitoring and development of ground water as a feasible water source. Water-level and water-quality data are needed in order to monitor changes in ground-water conditions, to identify current trends and predict future trends, and to support management decisions necessary to maintain the quality and quantity of water needed. Previous attempts to monitor the availability and quality of ground water have been limited to specific geographic areas, or were of temporary duration, or were based on limited scientific methods and/or computer technology.

Objectives

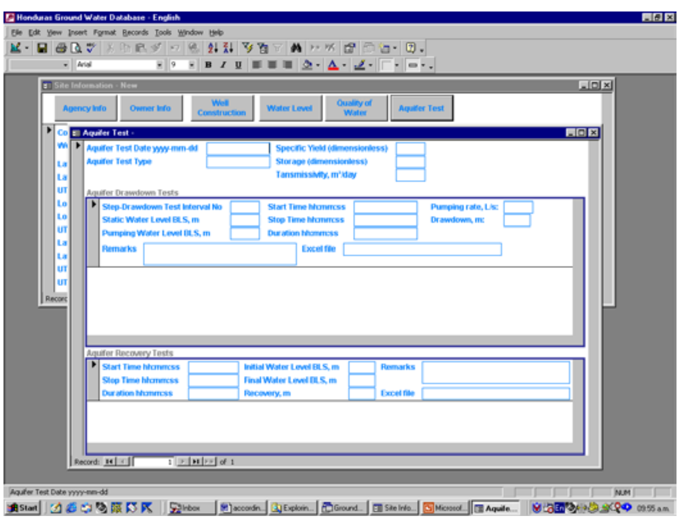
The first objective was to establish a ground-water data repository in Honduras consisting of a library and a database. The library was to comprise a collection of available reports related to ground water in Honduras. A digital national ground-water database, managed at the same location, was to contain available data for wells in Honduras. This database would continue to be maintained and updated by Honduran personnel trained as part of this program, and would be the first step in serving the data needs of current and future ground-water investigations.

The second objective was the enhancement of the capacity of Honduras to manage its own ground-water resources. This would be accomplished through training and development programs designed to increase the technical and administrative management skills of in-country staffs. Separate training for technicians would emphasize the need for the ability to collect high-quality, consistent data throughout the country.

Accomplishments

The program assembled existing data and reports pertaining to the ground water of Honduras, and oversaw the collection of new data, the design of new investigations, the development of ground-water resources based on all available information, and the training of Honduran personnel. This program was designed and managed with the understanding that future operations and improvements would be the responsibility of Honduran agencies and individuals, and that the program within Honduras would not end with the termination of USGS involvement.

Three Honduran engineers from DIMA, FUNDEMUN, and DIAT/SANAA were introduced to relevant aspects of data collection, data base management, complex ground-water investigations, and sustainable development of ground-water resources. This training took place in October 2000 at the USGS offices in Tucson, Arizona. Additional training courses were conducted in Honduras for groups of managers, engineers, technicians and support personnel. These training sessions targeted each group's needs with respect to ground-water data collection, data management, and project management.



A computer data base was developed using Microsoft™ Access and was populated with all available ground-water data. The data base was distributed, with training, to designated counterpart personnel as well as to representatives from other agencies and municipalities, to NGO's associated with ground-water resources, and to private individuals interested in ground-water monitoring. The CD's containing the data base also contain a complete data-base operating manual, a Microsoft™ Excel spreadsheet containing all available ground water data for users without Microsoft™ Access, several forms usable to guide collection of field data, and a list of contact information for all persons involved in Honduras ground-water resources.

USAID and USGS provided DIAT/SANAA with nearly $30,000 worth of computers, office equipment, field equipment, GPS units, and software. Training and support were included.

At the end of the USGS's involvement in this program, each designated Honduran counterpart was capable of operating their part of the ongoing program with minimal oversight. Other interested individuals and groups within Honduras are now able to understand and support efforts to develop ground water as a sustainable resource.

During this program USGS personnel were asked to consult to numerous other agencies, municipalities, NGO's, and relief organizations concerning pressing local water-resources issues. Agencies assisted included ESNACIFOR, SERNA, and the CUENCAS group within SANAA. Assistance also was provided to Comayaguela, Amarateca, Villa Vida Nueva, Utila, Choluteca, San Pedro Sula, La Lima, El Progreso, Nuevo Limón de la Cerca, Colonia Grácias a Diós, Colonia Marcelino Champagnac, Colonia Unidas, Acción Contra el Hambre, DIMA, and FUNDEMUN. An Excel spreadsheet containing a complete list of participating agencies is attached.

Observations

At the beginning of this program, most Honduran agencies and individuals had limited skills for collecting or using ground-water data. A few of the larger municipalities were collecting ground-water data, but had little or no ability to effectively use the data as part of a ground-water monitoring and development program. Communication between the various water-resources agencies within Honduras was almost nonexistent. A few local agencies shared data, but differences in data collection and storage methods produced inconsistencies when data from different agencies were compared.

Periodic meetings were held with water-resources personnel from throughout Honduras. These meetings were intended to involve Hondurans in the develoment of the data base. A second intent was to create an environment of cooperation and communication between these individuals that would last beyond the term of this program. During this program USGS personnel established working relationships with 76 personnel representing 40 agencies or groups.

Most wells that have been visually inspected in this program have no access ports for water-level measurements or for water-sample collection. Few have flow meters. Also, some local agency representatives seem to be unfamiliar with the locations and characteristics of wells within their own cities, and often do not have the proper keys to gain access to the wells. These factors are not amenable to maintaining a system for ground-water monitoring.

Because there are few actual monitoring wells, most ground-water information has been collected from production wells. Water-quality samples usually can be collected from the pump discharge pipe; these are adequate for many samples but not for detection of volatile compounds. Where these compounds are suspected, other methods must be considered. In some cases it might be necessary to install monitoring wells in areas of suspected contamination. These wells are of simple construction, need no permanent pump, and are less expensive than standard production wells.

Reports from field personnel indicate that many municipal production wells are pumped for 18 to 24 hours each day. It is difficult to gain accurate water-level measurements because of the times required for water levels to recover to static conditions. Static water-level information is needed to monitor long-term water-level changes. Two methods should be considered, depending on local conditions. First, monitoring wells can be installed that penetrate the pumped aquifer. For unconfined aquifers, these wells would need only to penetrate the upper part of the saturated zone. Alternatively, pressure transducers could be inserted into production wells and connected to data loggers. These units can be programmed to collect data for several days, through several cycles of drawdown and recovery. The resulting data can be used to construct extrapolated recovery curves, which could be used to estimate the hypothetical static water-level of the fully recovered aquifer. Although not as precise as other methods, this procedure will at least give an approximation of the water table at full recovery.

Hydrologic Data Collection, Storage, and Analysis

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 Honduras. 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 worked closely with several Honduran agencies involved with hydrologic data collection and analysis, including:

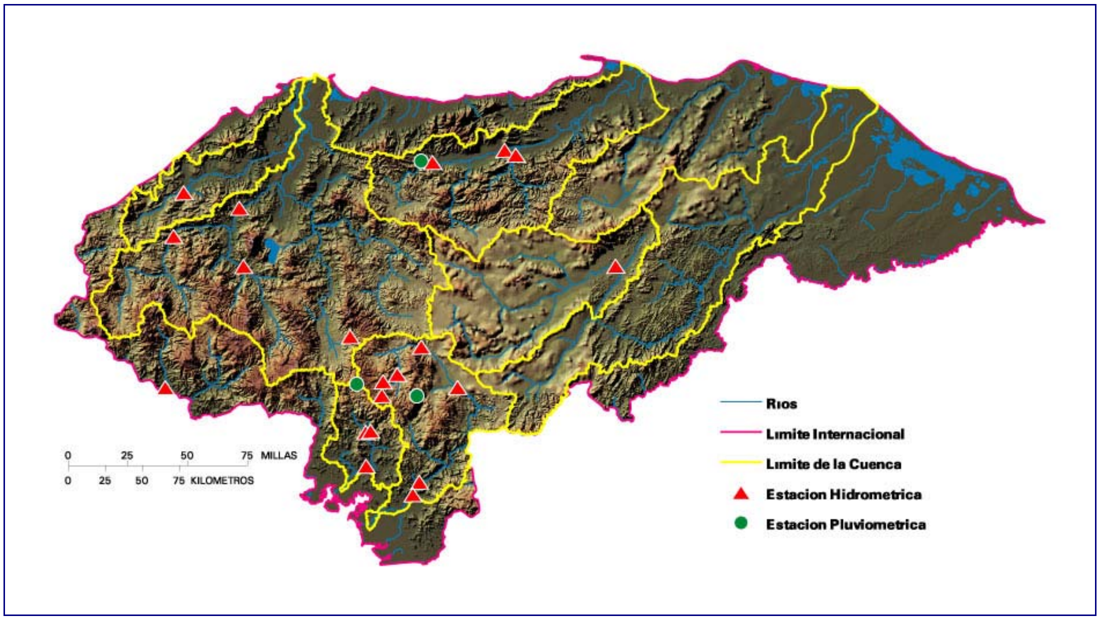
- Secretaría de Recursos Naturales y Ambiente, Dirección General de Recursos Hídricos (SERNA/DGRH)
- Empresa Nacional de Energía Eléctrica (ENEE)
- Comisión Ejecutiva Valle de Sula (CEVS)
- Servicio Meteorológico Nacional (SMN)
- Servicio Autónomo Nacional de Acueductos y Alcantarillados (SANAA)
- Universidad Tecnológica Centroamericana (UNITEC)

SERNA/DGRH is the GOH agency primarily responsible for maintenance of the nationwide hydrologic monitoring network and storage of hydrologic data in Honduras. The USGS worked closely with SERNA/DGRH in providing equipment, training, and technical support to implement the surface-water hydrology program in Honduras.

National Hydrologic Monitoring Network

The streamflow monitoring network in Honduras suffered severe damage as a result of Hurricane Mitch. Monitoring stations were in desperate need of repair if they were to be useful in early-warning systems and in planning for disaster preparedness and mitigation. To address this need, the USGS worked closely with counterpart agencies (and with other USG agencies such as NOAA) to identify critical areas where stream flow data are needed to mitigate future damage and deaths from flooding and to enhance management of water resources.

USGS and Honduran counterparts installed a total of 23[1] state-of-the-art hydrologic monitoring stations – 20 streamflow stations (each equipped with satellite telemetry and rain gage) and 3 telemetric rainfall stations – in 7 basins throughout the country (fig. 1).



While satellite-transmission technology was not entirely new to Honduras (ENEE has a network of stations equipped with satellite telemetry), implementation of this technology on a national level as a standard for hydrologic data collection was unprecedented. Hydrologic monitoring stations installed in Honduras are the same as those 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 Honduras 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 Honduras is shown in Figure 2. Table 1 at the end of this report shows a complete listing of hydrologic monitoring stations that were installed in Honduras as part of the USGS program.

[1] Three of these streamflow-monitoring stations were installed under a 1999 PASA (prior to implementation of Hurricane Mitch Supplemental Funding).

Figure 2. Streamflow monitoring station Río Choluteca at Colonia Apacilagua, installed in May 1999.

Stage-Discharge Relations at the Streamflow Monitoring Stations

Accurate stage-discharge rating curves, which translate river level (stage) into an equivalent discharge, are needed by hydrologists, engineers, and water-resources planners in Honduras to enhance flood-warning capabilities and to implement water-resources development and basin management activities. The USGS and counterpart personnel conducted cross-section surveys at 12 of the streamflow-monitoring stations, in order to develop theoretical stage-discharge rating curves at those sites. Personnel from SERNA/DGRH, CEVS, and ENEE accompanied USGS surveying teams during field data collection – counterpart personnel received training in the use of sophisticated surveying equipment (SERNA/DGRH received an electronic total station and full set of accessories as part of this program component), and in the basic hydraulic methods for conducting these analyses.

Hydrologic data from the telemetric monitoring stations are being used by many agencies, municipalities, and private interests involved with flood warning, disaster mitigation and water-resources planning in Honduras. The USGS cooperated closely with NOAA/NWS and its contractors in developing the hydrologic monitoring network. Hydrologic data from the monitoring stations are being used by NOAA/NWS in the Choluteca, Aguán, and Lempa River basins. Stage-discharge ratings for stations in the Choluteca River basin are being used by NOAA/NWS and SERNA in the development and calibration of the Choluteca River Forecast System. Accurate river stage and flow data are critical to the accuracy of river-basin forecasting models used by NOAA/NWS.

Problems and future needs

As a result of intensive formal and on-the-job training, counterparts at SERNA/DGRH, CEVS, and ENEE are highly 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.

However, program continuity and maintenance of trained technical personnel within each agency will be critical to continued success of this program. Adequate operating budgets for maintenance of the monitoring network (vehicles, fuel, staff perdiem, and routine repair costs) need to be established and maintained within each agency. Currently, the operating budget for hydrologic monitoring at SERNA/DGRH is inadequate, and is subject to wide fluctuation. Based on an analysis of operating costs by USGS and SERNA personnel, the estimated net annual cost (not including staff salaries) to operate and maintain the telemetric monitoring network in Honduras is $25,000.

Centralized Hydrologic Database

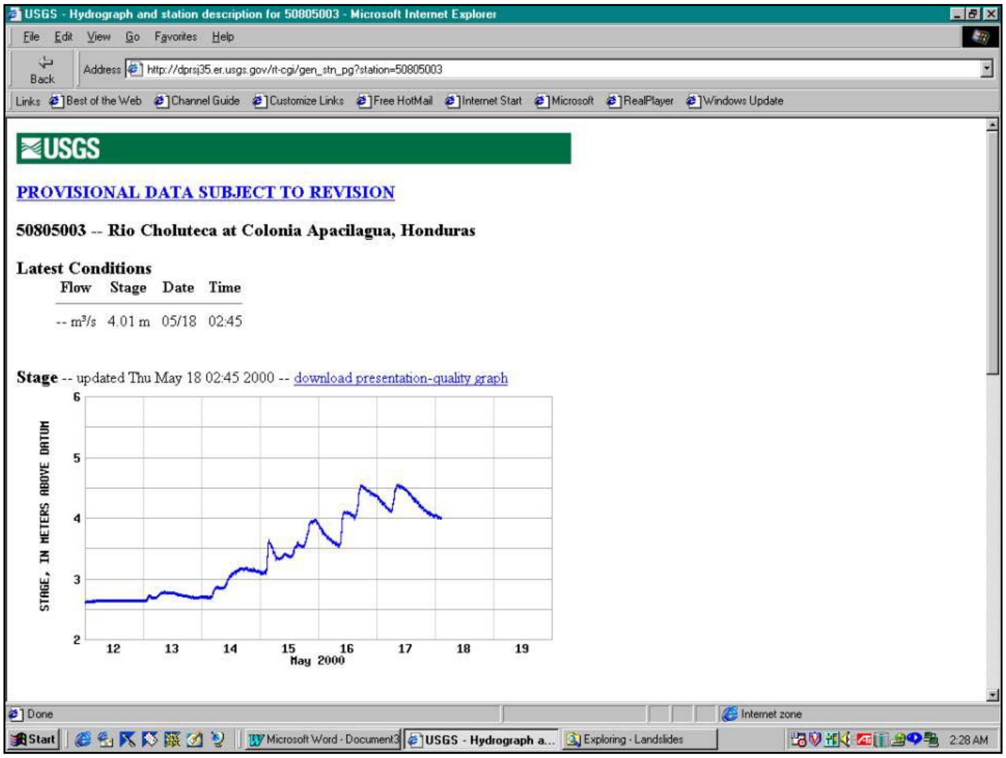
Several agencies in Honduras (including SERNA/DGRH, ENEE, SANAA, and CEVS) historically have collected hydrologic data from more than 70 streamflow gaging stations and 140 precipitation gages. Each of these agencies has used different methods for data collection and quality assurance, and stored the collected data in its own offices. 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.

To this end, the USGS worked with counterpart agencies to compile historic hydrologic data and to make it available in a central location. The USGS encouraged the formation of a hydrologic working group, comprised of the key Honduran agencies involved with hydrologic data collection, flood forecasting, and water-resources planning. The group met on a regular basis and included participation by both the USGS and NOAA/NWS – the meetings were very useful in addressing the concerns of all the agencies.

The USGS provided SERNA/DGRH with a powerful SUN workstation (housed at UNITEC) and advanced hydrologic-analysis software (NWIS/ADAPS) used by the USGS in the United States. Systems administrators at UNITEC are responsible for maintenance of the computer system, while SERNA/DGRH hydrologists are primarily responsible for data entry, analysis and storage using the NWIS/ADAPS system. Other cooperating agencies (such as ENEE and CEVS) also will have access to the system via modem to manipulate data for selected stations, or simply to view the hydrologic data. Real-time data from each station are stored in NWIS/ADAPS and displayed via the World Wide Web at sites in Tegucigalpa and Puerto Rico at the following URLs:

http://www.cigeo.unitec.edu
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 small satellite receiving stations for SERNA/DGRH and ENEE. 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.

EMWIN can be used for primary data reception, or as a backup if information from the receiving station at Toncontín Airport in Tegucigalpa is not accessible. The 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 SERNA/DGRH, CEVS, and ENEE 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, a number of factors hindered the effectiveness of this program component:

1. As a result of procurement delays, the Sun workstation and NWIS/ADAPS system were not installed until April, 2001. Although training was ongoing, the

installation delays meant that analysts were unable to implement skills and techniques learned during the training courses.
2. Limitations of the telecommunications system in Tegucigalpa delayed (until December 2001) installation of a communications line at SERNA/DGRH for modem access to the Sun workstation installed at UNITEC. This delay adversely affected the ability of SERNA/DGRH technicians to utilize the system.

Systems administrators at UNITEC are capable of maintaining the Sun workstation; it will be critical that trained personnel at UNITEC continue to be available to support the computer system and hydrologic database. Other recurring costs to maintain the database will be salary for the data analysts at SERNA/DGRH, and service costs to maintain the phone line and modem connection between SERNA/DGRH and UNITEC.

Counterpart Training

USGS personnel conducted on-the-job training of SERNA/DGRH, ENEE and CEVS counterparts (hydrologists and technicians) during each visit to Honduras. As of December 31, 2001 counterpart personnel were well-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 accomplishment 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 on a regular basis in Honduras; counterparts from the cooperating agencies participated in all formal courses presented by the USGS. Personnel from SERNA/DGRH, CEVS, and ENEE 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 Honduran counterparts is shown in Table 2 at the end of this report.

Program Successes

The hydrologic monitoring program already has been successful in providing early flood warning and mitigating flood-related damages. To the right is the text of a letter sent to the USGS, acknowledging the value of real-time streamflow data in the Choluteca River basin to mitigate damage to agriculture operations during flooding of September and October, 1999:

Mr. Rodriguez (USGS):

Azucarera la Grecia is located on the following coordinates 13.18' and 87.15' near a village called Marcovia, right now we have 19,000 acres planted with sugarcane.

As you can see we are under the direct influence of the Choluteca River and we have cane crops planted all around the river.

Last year as a direct effect of the flooding of the Choluteca River, we lost 275,000 tons of sugar cane that were ready for harvesting in mid November.

This year, thanks to your system, we could prevent some of the damages that the river made due to the flood we had on September 24 and

During the passing of Tropical Storm Michelle in October 2001, real-time data from the streamgages in northern Honduras (Ulua and Aguan River basins) were monitored closely by Honduran emergency management agencies, by SERNA/DGRH, and by the USGS. Early warning provided by streamflow and rainfall stations across northern Honduras allowed for the successful evacuation of at-risk residents and the mitigation of flood-related damages in affected areas. The following summary was written by Humberto Calderon, Deputy Director of CEVS:

Comisión Ejecutiva Valle de Sula

UTILIZATION OF STREAMGAGES

"During the recent flood event on October 28 – November 1, in the north coast of Honduras and specifically in the Sula Valley, which was caused by tropical depression 15 (then Hurricane Michelle), various government and private institutions relied on information produced from the different stream-gaging stations on the Ulúa and Chamelecón Rivers.

At critical times before, during and after peak discharges which caused extensive flooding in the city of La Lima, the access to real time data from the telemetric stations was very valuable and allowed the authorities such as CEVS, COPECO and Municipality to alert the people located in areas of risk. Also CEVS was able to better coordinate emergency works and repairs of levees, and time theses works in relation to the fluctuations of the river water-level and discharge.

At a certain moment the information from the telemetric stations was the only data available, due to the loss of radio communication with the observers at the stations operated by the Sula Valley Executive Commission, CEVS.

It is considered of up most importance that the institutions involved in managing and operating the telemetric stations maintain close ties with the USGS for guidance and support to assure the continuity of the benefits obtained from the stream-gages."

TABLE 1. Hydrologic Monitoring Stations in Honduras (December 31, 2001)

Number	Station	Type	Lat N (dec deg.)	Long W (dec deg.)	Date Operational
	CHOLUTECA RIVER BASIN				
50805001	Rio Grande above Concepcion	Streamflow, Rainfall	13.9967	87.3072	May 1999
50805002	Rio Guacerique above Los Laureles	Streamflow, Rainfall	14.0800	87.3005	August 2001
50805024	Rio Choluteca near Tegucigalpa	Streamflow, Rainfall	14.1222	87.2107	July 2001
50805005	Rio Choluteca at Paso la Ceiba	Streamflow, Rainfall	14.2866	87.0611	February 2000
50805006	Rio Choluteca at Ojo de Agua	Streamflow, Rainfall	14.0431	86.8353	January 2000
50805003	Rio Choluteca at Col. Apacilagua	Streamflow, Rainfall	13.4769	87.0744	May 1999
50834025048	Rio Choluteca at Markovia	Streamflow, Rainfall	13.2718	87.2959	December 2001
50805004	Linaca	Rainfall only	13.9942	87.0889	August 1999
	ULUA RIVER BASIN				
50805505	Rio Ulua at Chinda	Streamflow, Rainfall	15.1178	88.1989	August 1999
50834025026	Rio Jicatuyo at S. de Posta	Streamflow, Rainfall	14.9464	88.6111	November 2000
50834025034	Rio Ulua at S. Fco. de Ojueras	Streamflow, Rainfall	14.7680	88.1723	November 2000
50834025046	Rio Zenon above Coyolar Dam	Streamflow, Rainfall	14.3499	87.5052	August 2001
	CHAMELECON RIVER BASIN				
50805018	Rio Chamelecon at La Vegona	Streamflow, Rainfall	15.2078	88.5481	April 2000
	NACAOME RIVER BASIN				
50805010	Rio Nacaome at Las Mercedes	Streamflow, Rainfall	13.5742	87.4061	March 2000
50834025042	Rio Grande de Reitoca at Los Amates	Streamflow, Rainfall	13.7755	87.4075	August 2001
50834025044	Rio El Verdugo at Santa Cruz	Streamflow, Rainfall	13.7823	87.3775	August 2001
50805170	Lepaterique	Rainfall only	14.0648	87.4640	August 1999
	AGUAN RIVER BASIN				
50805014	Rio Aguan at Sabana Larga	Streamflow, Rainfall	15.3917	86.9878	April 2000
50834025038	Rio Aguan at Olanchito	Streamflow, Rainfall	15.4644	86.5356	January 2001
50834025040	Río Mame en Puente Mame	Streamflow, Rainfall	15.4344	86.4650	January 2001
50805016	Agua Caliente	Rainfall only	15.4000	87.0600	April 2000
	GUAYAPE RIVER BASIN				
50834025028	Rio Guayape at Paso del Burro	Streamflow, Rainfall	14.7658	85.8442	December 2000
	LEMPA RIVER BASIN				
50805020	Rio Mocal at La Virtud	Streamflow, Rainfall	14.0407	88.6579	August 2000

TABLE 2. Summary of Formal Training Provided by the USGS

Course	Location	Dates	Participants
Station Operation and Maintenance			
Streamflow Measurement Techniques at Gaging Stations (High Flows, Bridge Measurements)	Río Chamelecón, Valle de Sula	September, 1999	SERNA/DGRH, ENEE, CEVS
Workshop in the Use and Maintenance of the Price Current Meter	SERNA/DGRH, Tegucigalpa	27 August, 1999	SERNA/DGRH, ENEE
Installation and Operation of Electronic Monitoring Equipment (Sutron and Design Analysis) Used in the Gaging Stations	SERNA/DGRH, Tegucigalpa	8-9 June, 1999	SERNA/DGRH, ENEE
Concepts in Hydrology and Hydraulics			
Basic Concepts of Hydrology and River Hydraulic Analyses	INSIVUMEH, Guatemala	13-17 August, 2001	SERNA/DGRH, ENEE, CEVS
Hydraulic Concepts for the Indirect Measurement of Discharge	UNITEC/SERNA, Honduras	27 October, 2000	SERNA/DGRH, ENEE, CEVS
Compilation and Analysis of Data using NWIS/ADAPS			
Computation of Hydrologic Records and Analysis of Discharge	UNITEC/SERNA, Honduras	3-7 December, 2001	SERNA/DGRH, ENEE, CEVS
Computation of Hydrologic Records and Analysis of Discharge	INSIVUMEH, Guatemala	20-24 August, 2001	SERNA/DGRH, ENEE, CEVS
Computation of Hydrologic Records and Analysis of Discharge	UNITEC/SERNA, Honduras	14-18 May, 2001	SERNA/DGRH, ENEE, CEVS
Introduction to the Computation of Hydrologic Records (Review)	UNITEC/SERNA, Honduras	11-15 December, 2000	SERNA/DGRH, ENEE, CEVS, SMN, SANAA
Introduction to the Computation of Hydrologic Records	USGS: Guaynabo, Puerto Rico	31 Jul - 11 Aug, 2000	SERNA/DGRH, ENEE, CEVS

Municipal GIS Program

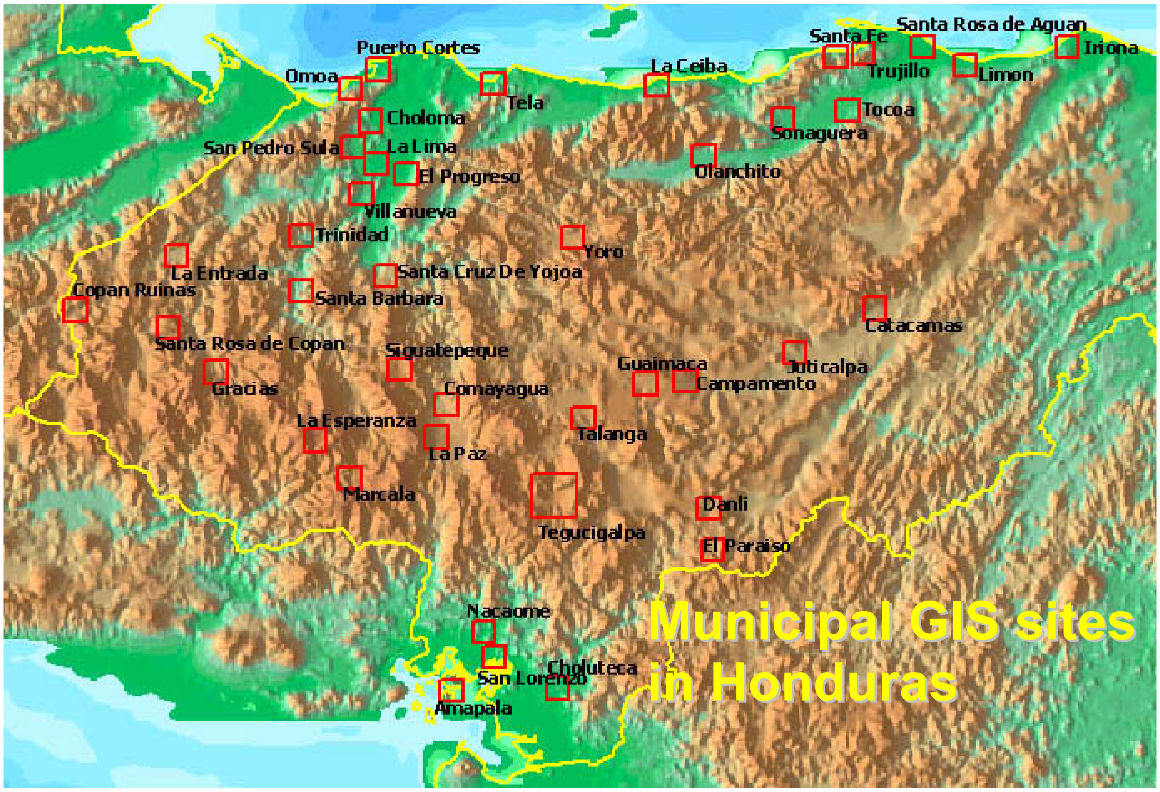
John Walkey and Peter Chirico

Introduction

Hurricane Mitch was a devastating event at a regional scale, however the initial responses to it were at a local level. Municipal governments were typically the first to know about individuals stranded on rooftops during flooding, the destruction of bridges and the damages wrought by extensive landslides and debris flows. Accordingly, they were frequently the first to attempt to respond to these emergencies with the little resources that they had available at the time.

The USGS response to Hurricane Mitch centered on the collection, dissemination and use of natural resource and hazard information for mitigation and disaster response. While many of the counterpart agencies were national government institutions, there was a need to ensure that municipal governments would be able to make use of the data collected by the USGS and its local counterparts for future response, mitigation and improved day-to-day management of local resources.

Towards this end the USGS was requested by USAID to collaborate with the Foundation for Municipal Development (FUNDEMUN) to increase the capacity of municipal governments to use spatial technologies, such as Geographic Information Systems (GIS) and Global Positioning Systems (GPS). This activity was incorporated into the Municipal GIS component of the USGS Mitch Honduras Program.



Objectives

The objectives of the Municipal GIS Program were:
1. To provide to the municipalities with which FUNDEMUN works the relevant data of the other conmponents of the USGS Mitch Program in a form that could be used by the municipalities in their future planning and mitigation activities.
2. To increase the capacity of the municipalities to make use of GIS and GPS technologies for their future use, to improve response during times of emergencies and to improve their daily execution of normal responsibilities, such as cadastral management, taxation, environmental management and land use planning.
3. To increase the capacity of FUNDEMUN to provide continued technical assistance to the municipalities in the field of GIS and GPS use at the municipal level.

Activities

The activities of the Municipal GIS Program included:
1. The delivery of a computer (including CPU, monitor, UPS and printer), GIS software (ArcView 3.2), GPS unit (Garmin 12) and digital camera (Sony Mavica) to 37 municipalities.
2. The provision of relevant USGS data sets and reports to the FUNDEMUN municipalities.
3. The creation and provision of digital orthophoto maps of the urban areas of the municipalities.
4. The training of municipal staff in the use of the above equipment including the integration of digital field photos, GPS-collected points and field observations into a GIS environment.
5. The training of and technical assistance to FUNDEMUN staff for future maintenance of the systems installed in the municipalities*:*

Items donated to 37 municipalities




Desktop Computer & Peripherals | ArcView License | Garmin 12 GPS Unit | Sony Mavica Digital Camera

Methodology

Data Collection

USGS Project Data

Within the context of the other components of the USGS Mitch Program the following data were collected: landslide locations and susceptibility, inundation zones within the urban areas of 15 municipalities, lidar elevation data, the national topographic map series (1:50,000) in digital form, groundwater data, locations of hydrometeorological stations, and biological resources impact studies. Where relevant these data sets were provided to the municipalities.

USGS Orthophotography

Specifically for the needs of this project aerial photography was flown over selected locations of Honduras. While some photography was used to delineate landslide locations, many other frames were used in the development of orthophotography of 40 municipalities. The municipalities involved in the project were:

Copan Ruinas	Santa Rosa de Copan	Trinidad
Santa Cruz de Yojoa	Villanueva	El Progresso
La Lima	Choloma	Omoa
Puerto Cortes	Tela	Yoro
La Ceiba	Santa Fe	Trujillo
Limon	Iriona	Santa Rosa de Aguan
Tocoa	Sonaguera	Olanchito
La Paz	Marcala	Gracias
Siguatepeque	Comayagua	Intibuca
La Esperanza	Tegucigalpa	Talanga
Guaimaca	Campamento	Juticalpa
Catacamas	Danli	El Paraiso
Choluteca	San Lorenzo	Amapala
Nacaome		


GPS Ground Control Survey

After acquisition of aerial photography, field crews collected horizontal ground control for each site. Field crews varied from local Honduran counterparts (Instituto Geografico Nacional) under supervision of the USGS Municipal GIS Project Coordinator, to USGS field crews from the United States under the supervision of the Coordinator, to a contract with a local engineering firm (Ingeneria Gerencial), to field training sessions for various Honduran counterparts (COPECO, FUNDEMUN, UNITEC, IGN). Horizontal ground control was differentially corrected to accuracies under a meter, and in most cases well under half a meter. This was achieved through the use of either CORS base station data after field collection or in real time using a beacon reference station where available. All data and accompanying field forms and field photography were finally sent to USGS in Reston, Virginia.

Vertical control was derived from the 1:50,000 topographic map series of the IGN. Under the supervision of the USGS Clearinghouse Coordinator, mylar map separates of elevation contours (20 meter intervals, 1:50k scale) were scanned, vectorized and attributed. These elevation vectors were then sent to the municipal GIS team in Reston, Virginia, where these data were edited, stitched together and transformed into Digital Elevation Models for the development of the orthophotos which also took place in Reston.

Municipal Staff Training

Formal training of at least one technical staff member from 37 municipalities was coordinated through the Center for Geographic Information (CIGEO) established at UNITEC by the USGS Mitch Project. Three weeks of training was provided by CIGEO staff, the USGS Municipal GIS Coordinator and FUNDEMUN staff. The course series covered: an introduction to computers and the Internet, basic geographic concepts, spatial metadata and clearinghouses, ArcView use, GPS concepts and use, and GIS data integration for municipal applications.

Municipalities were given the option of sending additional trainees to the training sessions, an opportunity of which many municipalities took advantage. The municipality of Tegucigalpa (Distrito Central) actually received formal technical assistance (donations of equipment, data and training) to 3 separate units within the municipality: Catastro, Metroplan and the CODEM. Additional follow-up training was provided to many of the municipalities at their offices by USGS and FUNDEMUN staff.

Equipment Donations:

Field visits to 37 of the 41 municipalities were made by USGS, FUNDEMUN and UNITEC/CIGEO staff in order to deliver and set-up the computer systems and software.

Typically this involved a review of many of the concepts covered in the training sessions and a brief training session on the proper care and maintenance of the computer equipment where needed. In the vast majority of the cases the equipment was donated to Cadastral Departments, however in those municipalities where the cadatsral unit was already well equiped the Environmental Unit received the equipment. All donations were documented by letters of transfer signed by the mayor and USGS representative.

The four municipalities not to receive computer equipment were:

Santa Fe   Santa Rosa de Aguan   Iriona   Limon

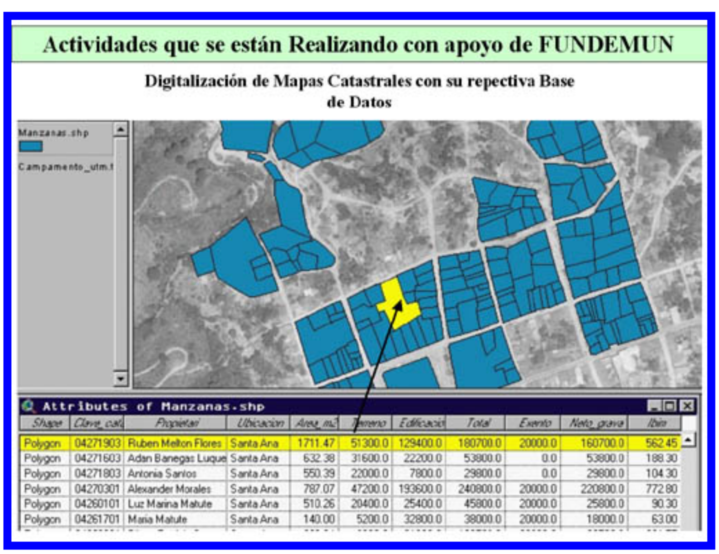
With the advice of FUNDEMUN and USAID staff, it was decided that these municipalities were at a developmental state that would not greatly benefit from the equipment. It had been decided to provide more useful VHF radio equipment to these municipalities, however, due to procurement delays within USAID these radios were not provided.

Results

Municipalites

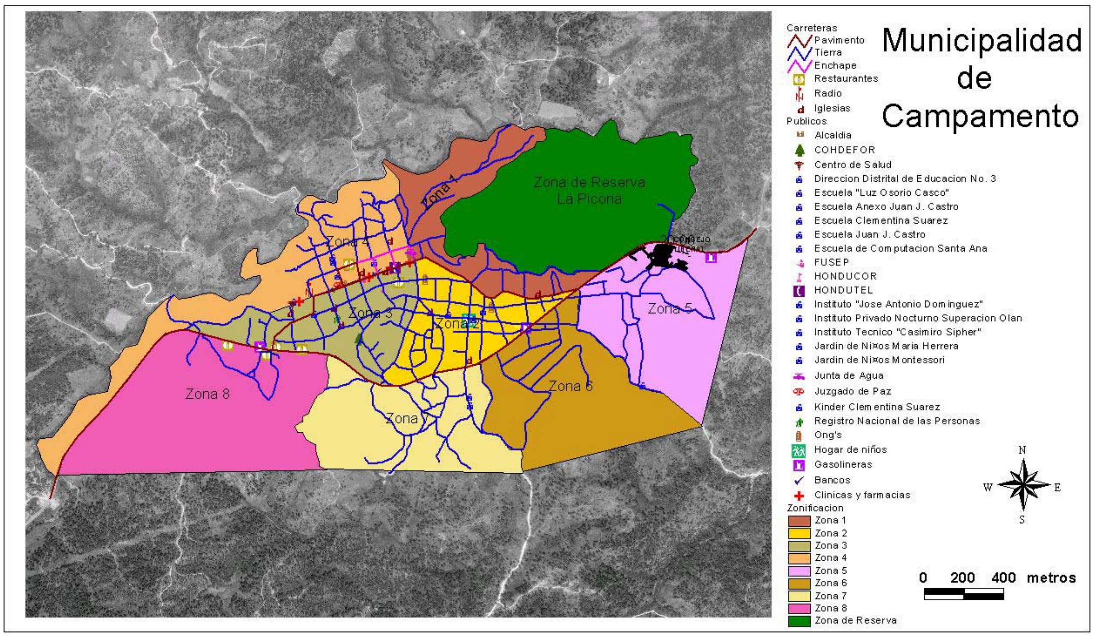
The USGS Municipal GIS Program in Honduras achieved its goals to varying degrees in each municipality and overall can be considered an unqualified success. Contrary to initial preconceived notions of the mayors' level of understanding of GIS and related technologies, they quickly grasped the utility of the technology for meeting their daily information management needs. In many cases the introduction of GIS to the municipality was something for which the local authorities had been planning and waiting.

GIS project staff meeting with mayor of Santa Rosa de Copan



Left - Development of a cadastral database for tax assessment and tax-related information management.

Wherever possible the Program activities were broadened to include other projects and activities on-going in the municipality that would make use of the equipment andf assist in the promolgation of the use of the technology. Volunteers from the Municipal Development Program of Peace Corps were included in the training sessions and made use of donated equipment to collect data for their work within the municipality. Accomodations were made to make better use of project resources in coordination with other donor projects, such as the European Union’s Proyecto Jicatuyo and the programs of the United Nations (UN Development Programme and UN Population Fund). This project coordination helped to increase the impact of the project on the municipalities.



Above – GIS of the town of Campamento. This system was utilized for a variety of applications, including cadastral development, tax assessment, and urban planning.

FUNDEMUN

The USGS Municipal GIS Program had a profound impact on the future programs of this important Honduran NGO. Prior to the USGS Program FUNDEMUN had little experience in GIS and GPS and the little digital mapping that had been done was in a CADD system by outside consultants. Chiefly thanks to the quality of the consultant retained for the USGS Program, FUNDEMUN now has a GIS division within its newly established Land Use Plannning Division (Ordenamiento Territorial, previously Catastro). A GIS computer lab was established at FUNDEMUN through the Program, including 6 desktop computers, all running ArcView and extensions, 2 laptop computers, large format plotter, GPS units and printers. This lab has been used for follow up training sessions with municipal representatives, as well as for the use of FUNDEMUN consultants on other projects.

The FUNDEMUN consultant contracted for the USGS Program has been retained by FUNDEMUN in the permanent position of GIS Coordinator. FUNDEMUN's workplan for the next fiscal year, approved by USAID, contains a GIS component which will provide further technical assistance to those municipalities showing the most interest and investment in the technology. To date that has included over 15 municipalities.

The tasks for future work will include the integration of GIS within the administrative structure of the municipality, primarily through linking the Municipal GIS database to the Integrated Municipal Information System (SIIM) promoted by the information division of FUNDEMUN. Initial tests of this in the municipality of Siguatepeque have been very fruitful. Additionally, the digitization of the cadastral plat maps of the urban areas of the municipalities will also be a primary task for FUNDEMUN and its clients.

Conclusion:

Prior to Hurricane Mitch no more than a handful of Honduran municipalities had been involved in any GIS projects and of those that had been, only 2 or 3 had made steps towards integrating the technology into its daily workings. While many mayors were aware of the technology and its potential benefits for their offices, they lacked the resources and understanding to attempt to implement these systems. Additionally, many previous projects approached these mapping endeavors as something done by outside experts and handed over to the municipalities in the end. This lead to municipal "GIS's" that consisted of no more than a cd of data and nothing resembling a truly integrated system.

The USGS Hurricane Mitch Program in Honduras was able to not only provide the basic tools and training for 37 municipalities, but also a vision for how GIS could become a backbone for their daily information management needs. In large part this was achieved due to the benefits received by working with an agency that has built up over 12 years of trust with these municipalities. In return FUNDEMUN received a technical capacity it did not have before and now crucially needs in order to continue to meet its clients' needs.

Program Budget

USGS HURRICANE MITCH PROGRAM - HONDURAS	
Summary Budget	
Activity	**Funds Expended**
Digital Topographic Maps	$275,237
Satellite Imagery & Aerial Photography	$902,046
Internet Data Clearinghouse	$513,635
Streamflow Monitoring Network and Hydrological Databases	$1,608,299
Groundwater Database	$342,122
Flood Hazard Assessment	$837,726
Landslide Hazard Assessments	$510,900
Biological Assessments of Coastal Zones	$584,493
Integrated GIS Products for Municipalities	$674,831
In-country & HQ Management, Staff Support	$1,529,469
Total	$7,778,758

Contact Information

Program Coordinator – **Paul Hearn**; Reston, VA; 703-648-6297; phearn@usgs.gov

Associate Coordinator – **Verne Schneider**; Reston, VA; 703-648-5230; vrschnei@usgs.gov

In-Country Manager – **Jeff Phillips**; West Valley City, UT, 801- 908-5048; jvphill@usgs.gov

Project Contacts:

***Digital Topographic Maps* – Sharon Hamann;** Reston, VA; 703-648-4128, shaman@usgs.gov

***Satellite Imagery and Aerial Photography* - Mike Crane;** Sioux Falls, SD; 605-594-6041, mpcrane@usgs.gov

***Internet Data Clearinghouse* – Larry Tieszen;** Sioux Falls, SD, 604-594-6056; tieszen@usgs.gov

Landslide Hazard Assessment* – Ed Harp*; Golden, CO, 303-273-8557; harp@usgs.gov

Flood Hazard Mapping – **Mark Mastin;** Tacoma, WA; (253) 428-3600 X2609; mcmastin@usgs.gov

Biological Analysis of Coastal Resource Damage and Recovery* – Edward Proffitt*; Lafayette, LA; 337-266-8509; *Edward_proffitt@usgs.gov*

Assessing Damage and Recovery of Coral Reefs – **Christpher Reich**; St Petersburg, FL; 727-803-8747 x3032; creich@usgs.gov

Ground Water Database – **Wes Meehan**; Tucson, AZ; (713) 718-3655 X38, wdmeehan@usgs.gov

***Hydrologic Data Collection and Management* – Mark Smith,** Fort Collins, CO; 303-236-4882 ext 255, huascafe@yahoo.com

Municipal GIS Development – Peter Chirico; Reston, VA; 703-648-6950
pchirico@usgs.gov