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RELIEF, PLANNING AND RECONSTRUCTION IN THE WAKE OF HURRICANE MITCH

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Invited paper

ABSTRACT

Hurricane Mitch was, from an economic perspective, the most destructive hurricane in the history of the western hemisphere. Soon after the disaster, the Honduran government requested mapping and technical aid from the U. S. Department of Interior. At the same time, the Office of the President of the United States formed the White House Reconstruction Task Force (WHRTF) to coordinate U. S. relief efforts in the affected Central American Countries. The U. S. Geological Survey (USGS) was asked to serve as the focal point for collection, integration and distribution of all types of information about the disaster. The information included not only typical map and geospatial data, but also statistical and non-graphical data sets key to the relief, planning and reconstruction efforts. USGS utilized GIS technology and on-going research and development work in the "Center for Integration of Natural Disaster Information" (CINDI) to respond to this challenge. The USGS CINDI laboratory employs a public-private cooperative approach with multiple government and private partners.

Response to a disaster of this magnitude requires the coordination of effort across multiple organizations. The planning and executing programs of this magnitude, as well as the affected countries' capability to absorb aid, is critically linked to a broad understanding of what has happened, is happening and may happen at local, regional and national levels across a wide range of concerns. Human health and basic infrastructure were the first and highest priority concerns. Basic map and future risk data are essential to decision-making at all levels of government. When effectively portrayed, these integrated data enable effective planning and recovery activities.

The major challenges addressed in the effort were the discovery, evaluation, integration and distribution of data about the disaster and Central America from a wide variety of sources in a wide variety of formats. While metadata existed for much of the data utilized, it varied widely in quality and completeness. The customer groups, their information needs, the strategies for information dissemination and the organization and relationship of the partner groups changed dramatically through the major phases of response. Policies for integration, documentation, eliminating redundant efforts and dissemination had to evolve as well.

This effort continues to successfully provide numerous products, technical service and assistance items including: an atlas, conventional and satellite image maps, aerial photography (from the Air Force Open Skies program), geographic informations systems CDROM data bases, computer software, advanced computer systems, and training. USGS scientists are also providing basic science in geography, hydrology, geology, biology and information science. GIS has been the core tool for this effort. Evolution of strategies and policies for data maintenance have been essential to the project's long term success.

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Note: The US government does NOT recommend software products or companies, any mention of specific companies or products in this article does not constitute an endorsement by the US government of said company or product. Any particular mention of specific companies or products is done purely to report the methodologies and tools used for the scientific work accomplished, to document the factual basis for reported results, and to allow independent verification of research results when desired.

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I. BACKGROUND

1. The Central American countries of Honduras, Nicaragua, El Salvador and Guatemala cover an area comparable in size to the state of California with almost the same population, over 28 million people. These countries have a primarily agricultural economy, but only 13% of the land is arable and less than half of that is being farmed. The western coast is one of the most seismically active areas in the world with a high incidence of earthquakes and vulcanism. They are, in general, characterized by narrow coastal plains and a rugged, mountainous interior much like the state of West Virginia. The Gross Domestic Product is only $2,177 per person per year and literacy runs at only 65%. Of the total population, over a third, 11.5 million, are less than 15 years of age.

2. From October 27th through November 1st of 1998, the most destructive hurricane in the history of the Western Hemisphere raged through Central America. Arriving from the north with 180+ mile per hour winds, it lingered off the north Honduran coast and then drifted south through the center of Honduras, and then moved west into and across southern Guatemala. The storm slowly lost intensity moving in a zigzag fashion across southern Mexico and east across the Gulf of Mexico and into the Atlantic.

3. Over 800 miles wide at its peak, the storm spread high winds and rain across most of Central America with cumulative measured rainfall amounts ranging from one to six feet over this five day period. While the northern islands and northern coastal areas suffered damaging high winds, the major damage suffered in Honduras, Nicaragua, El Salvador and Guatemala was due to very high rainfall and its resultant flooding.

4. In addition to the severe flooding, the saturated ground, soil and vegetation conditions and high slopes resulted in the widespread occurrence of landslides. The worst landslide occurred on the southern flanks of the inactive Casitas Volcano in western Nicaragua. A wall of mud and debris, initially moving at bobsled speeds, wiped out the small towns of Rolando Rodriguez and El Porvenor causing over 1900 casualities in this one event. The debris flow caused damage in the town of Posoletega, wiping out roads, the railroad and a bridge over 10 miles away from the start of the flow.

5. Some estimates indicate that more than 50% of the infrastructure of Honduras and Nicaragua were destroyed, leaving upwards of 2,000,000 people homeless. In addition to the destruction of homes, the transportation, communications and power networks were severed. Power transmission towers were toppled, bridges destroyed and roads buried by landslides or washed away by the floods.

6. Hurricane Mitch was also the deadliest Atlantic hurricane in more than two centuries, it has left a legacy of death as well as destruction across Central America. This storm left more than 11,000 dead and with another 13,000 still missing and feared dead.

II. DISCUSSION

7. In the days immediately following Hurricane Mitch's assault on Central America, the Minister of Interior and Justice of Honduras, Delmer Urbizo was named head of that country's relief efforts. He immediately contacted his counterpart in the US, Secretary of Interior, Bruce Babbitt. Minister Urbizo requested immediate assistance in the form of computers, GIS software, maps, imagery and data to assist in their relief efforts. The Honduran mapping and GIS capabilities were seriously compromised by the storm.

8. Minister Urbizo's staff reported that GIS was needed in country for numerous rescue and relief efforts. Relief efforts included finding and rescue of isolated people, distribution of food and medical supplies, tracking of disease, death, injury, construction of emergency housing, and critical bridge, airport, power plant and road repair, as well as documentation of the magnitude and extent of damage.

9. Employees of the U. S. Geological Survey's (USGS) **Center for Integration of Natural Disaster Information, CINDI**, were already working on gathering information on the tragedy as part of their standard research activities. USGS is a bureau of the Department of Interior and responded to Secretary Babbitt's request to assist the Hondurans. Upon receipt of the Honduran request, employees of the CINDI

began working 7 days a week preparing computers, satellite imagery, maps and GIS data bases of Central America.

10. CINDI is one of the USGS' research laboratories. It is focused on investigation of natural disasters with the goals of (1) developing and evaluating technology for improved information integration and dissemination, (2) performing research in data integration, analysis, modeling, and decision support, and (3) supporting the ongoing evolution of the USGS processing and delivery of natural hazards data. From the beginning the CINDI laboratory has been a joint public - private partnership activity involving multiple agencies of the Federal Government, as well as state and local governments. As our major private sector partner, ESRI has contributed significant GIS expertise to CINDI activities and their software is utilized on the CINDI's 60+ advanced computer systems.

11. Soon after the receipt of the Honduran request, all US Government agencies were asked to assist in preparing briefing materials for a US delegation to the affected Central American Countries to be led by Mrs. Gore. A briefing book and map atlas, prepared by the CINDI, were selected for the pre-trip briefing. Mrs Gore used these materials in her summary briefing to the President upon return of the delegation.

12. For the Hurricane Mitch response and recovery effort, the CINDI staff and partners built a comprehensive Geographic Information Systems (GIS) computer database of pre and post Mitch geographic and map data. This data has been published on multiple CD-ROMs. A CD-ROM product like this with integrated software and data would normally take 6 months to a year to produce, but in this emergency situation, USGS and ESRI personnel worked around the clock to deliver the first product in only a few weeks.

13. Called the "The Disaster Atlas of Central America," this first CD-ROM is a joint humanitarian effort of the public and private sector to collect and integrate geographic data over Central America to assist in the response to hurricane Mitch. The major partners are the U. S. Geological Survey, the Environmental Systems Research Institute, ESRI, and the Center for Tropical Agriculture, (Centro Internacional de Agricultura Tropical, CIAT). CIAT is a non-profit organization who contributed almost 90 layers of pre-Mitch detailed agricultural information over Honduras and Nicaragua. The National Oceanographic and Atmospheric Administration (NOAA) continues to be a major contributor of data and, as needed, has placed technical staff on-site in the CINDI to assist the GIS efforts.

14. The United States Geological Survey (USGS), headquartered in Reston, Virginia, provides the Nation with reliable, impartial information to describe and understand the Earth. This information is used to:
- minimize loss of life and property from natural disasters;
- manage water, biological, energy, and mineral resources;
- enhance and protect the quality of life; and
- contribute to wise economic and physical development.

15. The Environmental Systems Research Institute (ESRI), headquartered in Redlands, California, is the world leader in GIS and Mapping software.

16. The International Center for Tropical Agriculture (CIAT), located in Cali, Colombia, is part of the global agricultural research network known as the Consultative Group on International Agricultural Research (CGIAR).

17. Major partners are contributing proprietary data, software, hardware resources, integration and publication services and personnel. Other partners contributing to this effort include the U. S. Army Corps of Engineers (data), LizardTech (software), Silicon Graphics Corporation (hardware), Hewlett Packard (hardware), Microsoft (data), Ingenieria Gencial (data), Motorola (Iridium mobile Satellite telephones), MEDEA (university scientists' hydrologic analyses) and the Honduran Government (data). Public domain data is being used from the National Imagery and Mapping Agency, NIMA, NOAA, CNN and others.

18. The first shipment of data occurred in early November, soon followed (December 6) by the shipping of 10 boxes with four computers and monitors, ESRI ArcView software, GIS map databases and analyses, plotter supplies, maps and Landsat satellite imagery to Honduras. USGS has shipped a donation of four advanced Intel computer workstations with ESRI's latest GIS software and all of the Central America data to the Honduran emergency response team located in Tegucigalpa, the capital of Honduras . USGS

donated two of the computers and Hewlett Packard donated the other two. ESRI donated the GIS software and much of the proprietary data. ESRI placed a GIS expert on-site in Tegucigalpa to assist this team.

19. After receiving Mrs. Gore's summary of the extent of the devastation and suffering, Mr. Clinton formed the White House Reconstruction Task Force, WHRTF, with members from all major Departments of the US government. The WHRTF was formed to study the Hurricane Mitch impact on Central America and make recommendations on appropriate US action. Based on the success of the USGS CINDI data integration effort, the WHRTF tasked USGS with serving as information central for the relief and reconstruction efforts. The WHRTF tasked the U. S. Army Corps of Engineers (CoE) with estimating both the level of devastation and the anticipated cost of reconstruction in the aftermath of Mitch. US CoE staff utilized the CINDI data, integrated from a wide variety of independent sources, including in-country contributions as the initial data for their analyses. The WHRTF data played a key role in the successful budget request for relief for Central America. CINDI briefings were provided to many US Senators and Congressmen during November, December and January leading up to the successful relief appropriation for almost $1 Billion dollars of aid.

20. The first team of five USGS scientists arrived in Honduras in early December to assist in the set-up of the computers and to do field work on the geologic, hydrologic and biologic impacts and risks still facing Central America. USGS is continuing to do the science work so that reconstruction activities can proceed with minimal risk from future landslides and flooding and to support building disaster resilient communities and rebuilding out of harms way to the greatest extent possible for future natural disasters.

21. The CINDI research laboratory is continuing to provide mapping, GIS and analyses support not only for Central America but also for the US reconstruction effort including the White House reconstruction task force, USAID, the US Army Corps of Engineers and others.

22. The CINDI is operated by the USGS's National Mapping Division's Mapping Application Center, MAC. Dr. Darrell Herd, Chief Scientist for the USGS National Civil Applications Program, did the early coordination of the acquisition of aerial photography as well as data from the national technical means for this project. The LANDSAT satellite imagery mosaics and analyses have been accomplished at the USGS EROS Data Center, EDC, in Sioux Falls, South Dakota. Work is also being accomplished by ESRI in Reston and Redlands, CA. Geologists at the USGS were able to complete a landslide risk map for Honduras employing innovative scientific approaches to successfully complete the analysis and map in only a few weeks; normally such an analysis would take two years. Hydrologists and remote sensing specialists at the USGS are completing an initial hydrologic analysis of Central America that will be used to help place reconstructed facilities out of harms way for future floods, or permit engineers to rebuild bridges and other infrastructure that can withstand future events without damage. Scientists at the USGS Biological Research Division's National Wetlands Research Center in Lafayette, La. have prepared a simulation of Hurricane Mitch wind field speed and direction. MEDEA Scientist Dr. Douglas Way of Ohio State University utilized EarthSat Corporation under contract to assist in his preparation of hydrologic analyses and potential impacts.

23. The integrated data and donated GIS software is being utilized by the USGS, USAID, the U.S. Army Corps of Engineers, the Office of the Vice-President of the United States, the Canadian CARE organization, the World Bank, the State Department's Map Procurement Division, and the Center for Disease Control as well as by numerous other agencies and organizations responding to this disaster.

24. Version 2.0 of this CD-ROM with many new major data additions was completed in January 1999. The major additions to the data layers included the USGS LANDSAT mosaic over all of Central America. This approximately 6 gigabytes of LANDSAT mosaic was produced at our EROS Data Center and then compressed into only 86 megabytes using Lizard Tech's Mr. Sid wavelet compression technology while maintaining near 30 meter resolution, a technical miracle resulting from their unique advanced compression mathematics. This new CDROM set adds over 20 new layers from other sources as well as adding major updates to the existing road and stream network layers. Compressed digital 1:250,000 scale topographic maps from NIMA over all of Central America is included. A geologic map at 1:500,000 scale as well as a geologic landslide hazard risk map for Honduras prepared by the USGS' Geologic Division is also included.

25. A web site has been set up with information on this partnership and some of the atlas pages made from the CD-ROM data. This site is accessible through the USGS home page at "www.usgs.gov" or directly at "cindi.usgs.gov." An "ftp" site is also available that permits download of any of the data, it can be accessed as an ftp login from the same address "cindi.usgs.gov." Use the login name "anonymous" and the password is just your e-mail address. In addition, we have the capability to let users make maps of Central America on-line from selected layers of the CD-ROM data. It is accessed from the "Interactive Disaster Atlas of Central America" link on the CINDI web page (this capability built from ESRI's ArcView IMS software).

26. USGS continues to send teams in country to assist in the reconstruction efforts.

27. The products and data produced by this partnership effort include:

- Digital Atlas of Central America Version 1.1 (one CDROM dated November 1998),
- Digital Atlas of Central America Version 2.0 (two CDROM set dated January 1999),
- Disaster Atlas of Central America (11" X 17", bound paper atlas),
- Open Skies Aerial Photography of Selected Areas in Central America Affected by Hurricane Mitch (8 ½" X 11, bound report, 84 pages and one CDROM),
- Central America Geographic Informations Systems, GIS, database (Internet ftp site),
- CINDI Hurricane Mitch Information (Internet world wide web site),
- Open Skies Aerial Photography (rolls of film positives and negatives from 5 missions),
- Landinfo Digital Raster Maps of Honduras (17 CDROM set),
- For Offical Use Only (FOUO) Elevation (DTED) data and products derived from the DTED including Streams, watersheds and basins,
- National Imagery and Mapping Agency, (NIMA) 1:50,000 paper maps of Central American Countries,
- CIAT Spanish CDROM,
- Honduran and Nicaraguan Topographic Maps produced by those countries.

III. DATA DISCOVERY, ACQUISITION, INTEGRATION AND APPLICATION

28. Many studies have shown that effective decision-making in time of crisis is critically dependent on the right decision-maker having the right information, at the right time. A corollary to these results is that the decision-maker must have tools that permit him to rapidly integrate and visualize ("see") the data and its interrelationships. A Geographic Information System permits this integration and visualization.

29. During a time-critical, crisis response situation, the factors that are essential to geospatial data and GIS effectiveness are:

- rapid identification (discovery) of sources of relevant data, statistical and geospatial,
- geospatial data in a rapidly ingestible format,
- GIS capable of ingesting. creating and utilizing statistical data,
- application ready (computer friendly) geospatial data,
- documentation of data set accuracy and attributes in "metadata" (allowing for appropriate use assessments).

30. Note: almost all data has some geospatial relationship, i.e. the data can be related to a point, line or area on the surface of the earth. The ability to do this "georeferencing" permits the analyst to create a spatial picture of the data, normally in concert with other data – enhancing the rapid understanding and use of the data. Development of such "integrated" maps, simultaneously portraying many different data types often reveals relationships not easily seen in any other way.

31. Metadata is data about data, i.e. additional descriptive information about the spatial data included in the data file being described. In general, metadata includes not only accuracy and attribute definition, but also source material used, map projection or coordinate system, scale, date of source and producing agent among other, important data descriptors. The USA's Federal Geographic Data Committee, FGDC, has coordinated the development of a metadata standard that is highly recommended for its thoroughness and effectiveness. It is just beginning to be implemented within the US and, in general, no data utilized in the Hurricane Mitch response had FGDC compliant metadata. FGDC compliant metadata was generated for

much of the integrated data produced by USGS for the Hurricane Mitch response and is available from the USGS website.

32. The importance of GIS platform data ingest flexibility, and geospatial data and other data compatibility is most evident when trying to integrate data from across different computers, GIS software, scientific disciplines, data types, and government and civilian sources. The importance of GIS platform processing flexibility and display of analytical results is most evident when doing analyses that involves data from two or more types or scientific disciplines.

33. In the future, world-wide-web (www) based clearinghouses following the tenants and standards of the National (Global) Spatial Data Infrastructure, (NSDI, GSDI) will be the preferred method of data identification or "discovery." Unfortunately, this approach had not yet been widely utilized by the major data contributors and sources of importance to Hurricane Mitch response effort. For the Hurricane Mitch response, data discovery was facilitated in primarily two ways. First, for much if not most of the data utilized, standard web searches of existing www sites were used very effectively. For much of the remaining data utilized, word-of-mouth notification by knowledgeable and concerned third parties was the mechanism for discovering the existence and availability of relevant spatial data.

34. To ensure rapid ingestion of data within geospatial data applications software, the preferred format of the future will be the OpenGIS™ Consortium standards. These international, consensus-based, GIS interoperability standards are maturing rapidly and are already beginning to provide off-the-shelf commercial GIS products that will interoperate (or "exchange" geospatial data) transparently to the GIS user/decision maker. For the Mitch response, the existence and wide use of USA Department of Defense and defacto industry standards permitted, in most cases, the rapid ingestion of data from a wide range of sources. The easiest data to use was data in the defacto industry-standard formats; ArcInfo™, ArcView™, Dbase™ and Simple ASCII text. There was moderate difficulty in exploiting data in the USA's Department of Defense standard formats (DTED, DFAD, ADRG, and CADRG). The most difficulty in data ingestion and use was from drafting (or automated drafting/drawing) software, primarily because of a lack of data on map projection or coordinate system and similar metadata.

35. The best metadata existed for the US Department of Defense data, which was by far the most comprehensive and accurate data available to document the infrastucture prior to the disaster, making up in large part for the greater difficulty of ingestion and integration.

36. The best and most rapidly available imagery for documenting the agriculture and environment prior to the disaster was the Landsat multispectral data. In fact, the Landsat mosaic, formed from the "best available" cloud-free images over Central America was the most popular GIS backdrop across almost all of the early multidisciplinary efforts. This Landsat mosaic provided a rapid accurate, consistent, area-wide, historical coverage of all of the affected parts of Central America. The LizardTech Corporation's MrSid data compression technology reduced this multi-Gigabyte file to less than hundred megabytes. Compression in combination with its rapid decompression, "GIS plug-in" software made this multispectral, seamless area-wide coverage image readily accessible and useful to a wide range of scientific users across a wide range of computing platforms from laptops to high-end engineering workstations.

37. Later on, the release of USA Department of Defense 1:250,000 scale raster (digital), georeferenced color topographic maps provided a excellent documentation of medium scale topographic map detail (although somewhat out of date) for use in the GIS environment. Once again, the LizardTech Corporation's MrSid data compression technology reduced this collection of many, multi-hundreds of megabyte files to a single file only a few tens of megabytes in size. This single, compressed file in combination with its rapid decompression, "GIS plug-in" software made this single, seamless, color digital topographic map readily accessible and useful to a wide range of scientific users across a wide range of computing platforms from laptops to high-end engineering workstations. USA Department of Defense 1:50,000 scale color topographic maps were also provided to the USGS, but were not digital and were provided with limited distribution restrictions (they could only be shared within the country covered by the map – maps covering boundary areas could not be shared with either country).

38. For the country of Honduras, LandInfo Incorporated, had recently completed the scanning and georegistration of 1 to 50,000 scale topographic maps produced by Honduras. Landinfo provided the US

Government limited use of these data for the purpose of relief efforts only. No redistribution of this data outside of the US was permitted. The higher detail in these maps was very useful for many assessment activities.

39. The LizardTech MrSid compressed data was particularly useful because of their small size, portability, excellent detail, wide-area, seamless coverage, rapid decompression and integration into GIS software.

40. The best data available vector data for documenting the demographics and agriculture prior to the disaster was the CIAT (Center for Tropical Agriculture, Cali, Colombia) data.

41. At the request of the White House, in coordination with the US department of State and with the approval of the affected countries, the Open Skies Program of the Defense Threat Reduction Agency (DTRA) acquired imagery over Central America. Five missions accomplished soon after the event produced over 5,000 black and white, high resolution (20 Cm), aerial photographs and 15,000 video frames over Central America. These photographs had unparalleled resolution and represented the best documentation of the infrastructure damaged by Hurricane Mitch. About one hundred of these photographs were scanned into digital form and then compressed with the MrSid technology. The GIS software was used to simply rectify and georegister these photographs for use in the GIS analyses. These data are continuing to play a key role in the documentation of the damage to the affected countries.

42. The USGS' CINDI laboratory utilized ESRI GIS software as the basis for all Hurricane Mitch response activities. USGS selected the ESRI software through the "GIS II" competitive procurement. This procurement was based on almost a decade of use of GIS technology for a wide range of spatial science activities. This procurement was probably the most comprehensive and knowledgeable GIS procurement ever successfully attempted and completed by the US Government. This procurement included testing on real world data sets with real world applications. The result was the most versatile, flexible and powerful set of fully integrated GIS capabilities available from the market place at that time. An added benefit, not specifically requested or tested, was the broadest possible compatibility across the full range of national and international federal, state and local government, civilian partners and cooperators due to the continued market dominance of ESRI. Across the wide range of data sources and scientific disciplines, more data provided was in ESRI formats that in any other format; this greatly simplified the data ingestion and integration problems. ESRI's products are in a small group of commercially available GIS software that is already compliant with the OpenGIS™ Simple Features standard.

IV. OBSERVATIONS

43. Robust GIS technology is readily available for dealing with a wide range of information inputs across scales (resolutions) and types (point, line, polygon, grid, image, tables, text) of data. Tools for registration, geocoding, warping, coordinate transformation and symbolization are mature and easy to use quickly for this wide range of data types. Internet publication of data and the tools to find the data and metadata about the data exist and can be quickly learned. [Much of the data for the US, while available and extremely well documented, is not available quickly enough to be of use in emergency response. Government delivery systems that provide non-crisis access to national data bases, maps and satellite information need to be improved and localities should acquire this wide array of existing data and pre-stage and integrate it with their local data for use in times of emergency. The localities should work within a national framework of standards and procedures that permit sharing of these data and rapid access during emergencies.]

44. To respond efffectively to such disasters in the future, better systems and procedures are needed to evaluate the impact of major natural events on humanity and our infrastructure. While numerous remote sensing systems are available and local reporting is both quick and detailed, our ability to rapidly and appropriately integrate the massive amount of information coming in from these sources into a regional impact assessment is not there yet in other than a research environment (like the USGS CINDI laboratory). While local emergency response is immediate, the time from occurance of the event until there is a good understanding of the impact at a region, country or larger area is many days to many weeks. Also, the ability of local response teams to deal with most disasters is, in general, well practiced and rapid, but necessarily limited to their local resources. When a larger response is required, the time lag between what

can be handled locally and the larger response needed in many cases is delayed by the long time it now takes to process and integrate the data that helps form the broader perspective needed at the national level to make the decisions to commit additional resources. What are needed are dedicated resources; computer, telecommunications network capacity (voice and digital), software and trained personnel dedicated to such an information acquisition, integration and assessment functions. These resources are required at the national level to stage government data in ways that permit its easy and direct access and use. Resources are needed at the local level to access, integrate and pre-stage the national data with local, more detailed data sets. Timely access to time critical government data sets like weather needs to be assured at the local level by the agencies responsible for generating and delivering these data.

45. For Hurricane Mitch, finding out about, getting release and use of data from academia, the government, DoD, NIMA and others went more quickly and directly than anticipated due to the wide adoption of the www. But this data was not accessible as quickly as it could be, did not have uniform metadata and it was not in interoperable formats. Release and use of data from NGO's who had existing restricted use of Country data was very lengthy and in the case of CIAT, release to use some of the data in the response or reconstruction phases has still not been received. This problem seems to stem from the fact that no one anticipated the need to use this data in an emergency. The original uses anticipated for the Country data by the NGO did not include emergency response and sharing – and so their ability to release this data in a timely fashion was severely hampered.

V. CONCLUSIONS/LESSONS LEARNED

- Adoption of a GIS approach resulted in many expected and unexpected benefits (ease of generation of a wide variety of map projects, comparison of data from widely varying sources, facilitation of complex analyses involving many different data layers, visualization and display – greater ability to share data).

- Establishing a standard coordinate system and units was essential to the rapid integration of data sources. We used geographic coordinates, employing decimal degrees of latitude and longitude. This choice proved to be very powerful, because this unprojected data was then easily and quickly "projectable" into any desired map projection or working coordinate system by the GIS. Many of the engineers needed UTM or similar systems and working with the data in the coordinate systems of their choice was just a mouse click away.

- Rapid progress was based upon existence of a facility with trained personnel and advanced computer software, equipment and high speed, reliable Internet access.

- Progress was facilitated by existing partnership relationships between agencies and the private sector and numerous private donations of hardware, software and engineering support.

- Significant existing data was readily available from the private sector and government agencies.

- Robust local data sources and GIS expertise were found where the disaster occurred.

- Defacto industry standards have been adopted in the public and private sector that facilitated the finding and sharing of geospatial and disaster data.

- Due to the lack of a Global Disaster Information Network, GDIN, or similar capability, the Mitch response has been reduced to using CDROM and standard Internet technologies to accomplish data distribution. These approaches suffer from lower reliability and speed of delivery and update than is generally required during a crisis.

46. Due to all of these, a considerable amount of integration work was successfully accomplished by a small staff in a very short period of time; producing a data set that is proving to be very useful to a wide range of disaster response and reconstruction activities.

VI. Postscript

47. In the aftermath of this event, the scientific assessment of what natural forces triggered the widespread death and destruction is critically important. This assessment is underway and its results are being used to plan and rebuild so that both human and economic impacts of future natural disasters can be mitigated. Recognizing that floods and associated mudflows were the major source of death and destruction, studies are underway to develop a more complete understanding of the geomorphic and hydrologic processes that created the hazards, and to quantify the extent of damages for disaster planning and humanitarian relief. The damage to the ecosystems were severe and a preliminary ecological assessment including agricultural and livestock resources is underway that will assist in the long term restoration and protection of these unique ecosystems. Documenting and monitoring these processes and events are essential to providing a sound, defensible, scientific blueprint for the on-going reconstruction including resettlement, establishment of infrastructure, and future hazard mitigation. With knowledge of the areas and magnitude of the risk from natural hazards, reconstruction can proceed, placing people and infrastructure out of harms way or in disaster resilient communities.