Hurricane Public Health Research and Katrina Search and Rescue Mapping

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Abstract

The LSU Hurricane Public Health Center, Louisiana Geological Survey and LSU Coastal Studies Institute had consolidated over sixty layers of GIS data and imagery of New Orleans when Hurricane Katrina struck in 2005. This GIS framework had been incorporated into a web-based GIS portal utilizing ESRI ArcIMS. The intent of the data layers was to support cross-disciplinary research on hurricane public health vulnerability in New Orleans, and to be made available to emergency managers and requesting agencies via a password protected webpage.

This New Orleans GIS portal with associated data layers organized in ESRI ArcGIS was transformed into a mapping support tool for search and rescue missions in the weeks following Hurricane Katrina. Mapping of 911 calls, hospital evacuation, and military and Red Cross coordination were among the types of mapping support provided to every level of agency and organization. This paper will demonstrate some examples of how geospatial technologies enhanced public health and disaster management following Hurricane Katrina.

GIS Applications in Hurricane Public Health Research

The LSU Hurricane Public Health Center (HPHC)[1] was funded by the Louisiana Board of Regents (LA BoR) in 2002 to integrate multidisciplinary hurricane and public health research towards the study of complex disasters. Extreme rainfall events (1995) and Tropical Storms Allison (2001) and Isidore (2002) had caused widespread flooding in New Orleans. High resolution storm surge models, specific to southeast Louisiana and in development at the time, were showing an alarming increase in flood risk to New Orleans from even minor hurricanes.

These events prompted an initial pilot study to identify and mitigate public health impacts of a major hurricane strike or flooding event in the city. Following a number of preliminary research advances, Hurricane Katrina made landfall in southeast Louisiana in the fourth year of the project (29 August 2005).

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[1] Also known as the Center for the Study of Public Health Impacts of Hurricanes (CSPHIH).

In support of the New Orleans pilot study, researchers from the HPHC, Louisiana Geological Survey (LGS) and LSU Coastal Studies Institute (CSI) built an interactive, web-based geographic information system (GIS) portal in ESRI ArcIMS 4.0.

This GIS allowed for the integration of a large number of data layers, coming from the following providers, to be assembled:

Regional Planning Commission of New Orleans, New Orleans City Planning, Jefferson Parish Emergency Managers Office, Louisiana Geographic Information Center (LAGIC, http://lagic.lsu.edu/), Atlas: The Louisiana Statewide GIS (http://atlas.lsu.edu/), and Louisiana Oil Spill Coordinators Office (LOSCO).

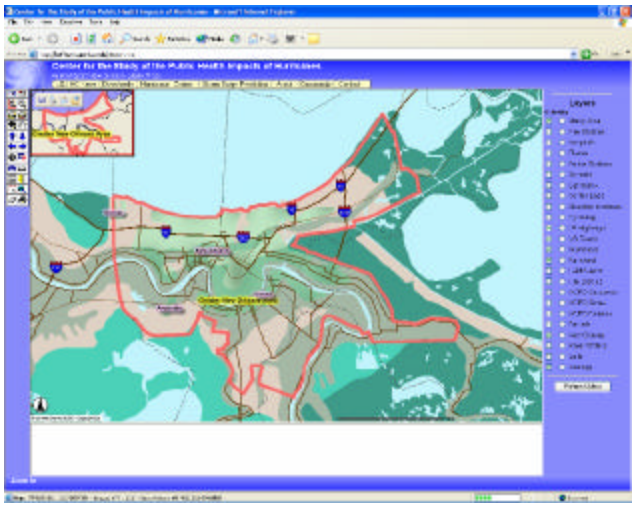

Figure 1. New Orleans ArcIMS portal (HPHC 2005).

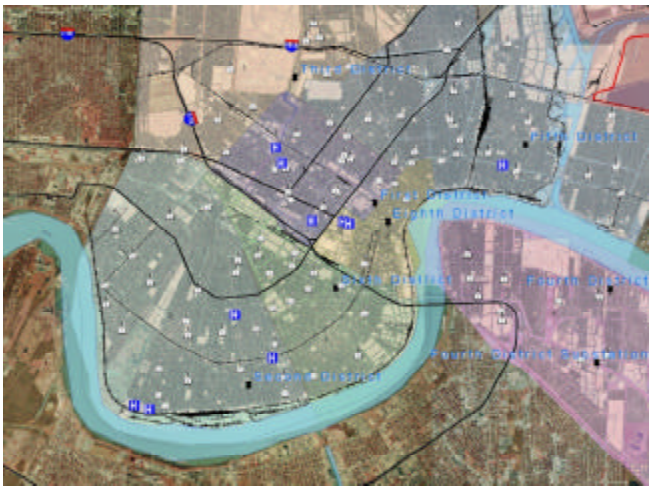

Figure 2. Hospital, school and district data overlaid on 2004 DOQQs (HPHC 2005).

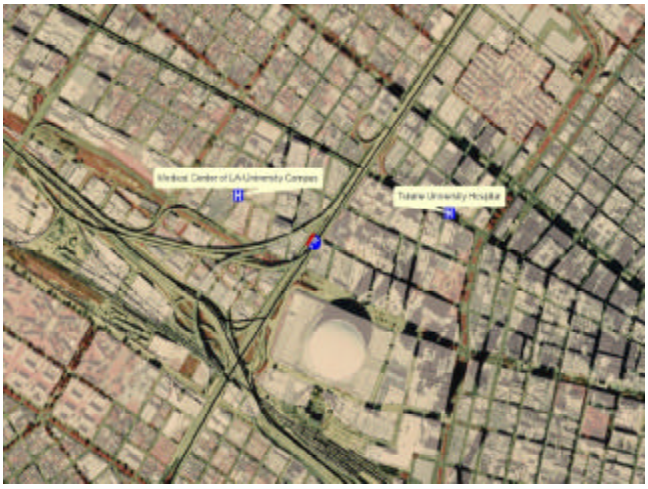

Figure 3. Hospital, parcel and roads data over high resolution panchromatic aerial photography (HPHC 05).

These data included layers such as parish boundaries, census data, Tiger Roads 2004, and 2004 DOQQs, high-resolution LIDAR mosaics and topographic data, the latest high-resolution (including 1 foot and reprojected panchromatic) aerial photography and satellite imagery for the study area, and individual data layers from project researchers, such as outer levee boundary layers (Feng, LGS) and restricted-access petrochemical pipeline data coverage (Peele and Paulsell, LGS).

The web-based GIS portal was made available to project researchers, emergency managers and center partners beginning in 2003 through a secure logon and password-protected web page (http://hef-hurricane.lsu.edu, Figures 1-3).

ArcIMS for Research Integration

The ArcIMS GIS framework is based on a three-tiered client-server web map server architecture; namely, presentation, business logic, and data storage tiers. Utilizing customized java client, the framework communicates between four major components of the current web map server system through ArcXML codes.

The presentation tier consists of customized java connector implementation, which provides a wide range of operations such as editing of existing data layers, creating new data layers, or importing of ADCIRC output data. The business logic tier consists of four major components: Web Server, ArcIMS Application Server, ArcIMS Application Connectors, and ArcIMS Spatial Server. The data storage tier is composed of the sources of data and data server. The current implementation is distributed among three servers.

This client server approach provides flexibility in Web Map Server implementation with different levels of interactivity, connectivity, and functionality among the system components, thereby allowing for the integration of the latest in hurricane research and modeling.

Pre-Katrina LIDAR-derived levee heights (Yang, LSU Hurricane Center); fate and transport/water contamination modeling (Pardue, LWRRI); air dispersion modeling (Sajo, LSU Physics), and storm surge and associated wind vector modeling (Mashriqui, Kemp, van Heerden, HPHC and Westerink, UND), are among the desired research layers[2] to be integrated and viewed in a GIS environment with other critical data layers, such as roads, hospitals, fire and police stations, hazardous chemical and waste site locations.

Additional features of the ArcIMS framework include facilitated data sharing between project investigators via downloadable layers,[3] which can be acquired for use in individual GIS labs; and the ability to conduct basic geospatial analysis from any configured laptop[4] with an internet connection.

Geotechnologies Integrating Disaster Planning and Public Health

Much earlier than 2005 and Hurricane Katrina, geotechnologies have supported post-emergency disaster response in the US. Examples include emergency response mapping for the September 11th terrorist attacks at the World Trade Center (Kant 2002), space shuttle debris mapping (Brown et al 2003), and mapping response for the 2004 Florida Hurricanes (Geoplace 2004), among others. However, the significant need to integrate disaster preparedness and planning with public health planning is increasingly recognized.

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[2] Incorporation of these data layers and model outputs into the ArcIMS is a part of ongoing research. These research layers were not yet accessible online when Hurricane Katrina hit in 2005.

[3] This downloadable feature is still in development.

[4] Database access must be requested and approved by the Lead Project Investigator (van Heerden) and individual computer information such as computer domain and name, IP address, etc. must be provided to the network administrator (Binselam) prior to access attempt, to bypass data security firewalls.

Particular to hurricane research, as highly vulnerable, densely populated coastal populations face decades of increased hurricane activity, scientists are finding value in Remote Sensing (RS) and GIS to quantify realistic impacts and elucidate major concerns. Public health challenges rise to the top. Typically, modern prediction technologies afford at least a 72-hour window before a hurricane strike. This provides a unique opportunity to develop effective strategies for resident, medical patient and nursing home evacuations and sheltering, among many other public health applications for utilizing RS/GIS.

Prior to Katrina, the LSU Hurricane Center and HPHC had been testing project geotechnologies (e.g. in support of evacuation and sheltering decisions) in a number of ways. Experimental surge models and mapping products were made available to the Louisiana state Office of Homeland Security and Emergency Preparedness (LOHSEP) during Tropical Storm Isidore and Hurricane Lili (2002), Hurricane Isabel (for the East Coast, 2003), and other storms, as well as for state training exercises.

The New Orleans project GIS was made available to state agencies and LOHSEP during Hurricane Ivan, and for the Hurricane Pam exercise (2004) in support of the development of a catastrophic hurricane functional plan. The HPHC had tested the functionality of the New Orleans GIS on multiple occasions at the Louisiana state Emergency Operations Center (EOC) in Baton Rouge, after having been issued a network connection within the Southern Regional Climate Center (SRCC) and LSU Earth Scan Lab (ESL) work spaces, and resolving firewall issues, optimizing connection speed, etc.

Research GIS Goes Operational

Built for research, the New Orleans GIS portal and associated project data layers organized with ArcGIS 9.1 were transformed into mapping solutions for search and rescue missions in the weeks following Hurricane Katrina, 1-16 September 2005.

Realizing the magnitude of Hurricane Katrina's impact to the state, the project sponsor (LA BoR) temporarily authorized project researchers to redirect their efforts in support of the most relevant Katrina response activities. Although never funded to build a GIS for operational response, project researchers with RS/GIS backgrounds and expertise nonetheless found themselves applying the New Orleans project data and research layers to hurricane response efforts in an intense operational environment. This introduced significant challenges.

As GIS professionals will agree, to properly construct an operationally functional and effective GIS to support state-wide disaster response mapping would require time, personnel, and resources - of months if not years. At a minimum this would require the proper hardware/software, storage, high network bandwidth, printing capability, system/library for data management (e.g., versus an ArcIMS system for data storage) ensure projection compatibility,[5] etc.

[5] although ArcGIS 9.1 alleviates some of these issues with an "on-the-fly" projection feature.

Data and Maps Save Lives in Disasters

While Federal agencies such as DHS/FEMA (GIU), USGS, DOD, NGA and NOAA have considerable RS/GIS capability, they also have numerous support functions in disaster response, and could not be available to all of the Louisiana State, local agencies, incoming military/DOD personnel and incident command partners who requested immediate data and mapping support in the days following Katrina.

Throughout Hurricane Katrina, these agencies were producing massive amounts of data and map products; but the overwhelming nature of the disaster, the magnitude of requests, issues with connectivity and location, and other factors created a significant need for a supplementary, on-site mapping solutions resource within the EOC to assist any organization that was not getting the solutions that they needed, for whatever reason.

In the most urgent search and rescue operations, such as those requiring point location mapping for the thousands of 911 calls, the coordinates of hospitals to be evacuated and/or evaluated, or reconnaissance imagery for critical helicopter missions or to determine impassable roads, most emergency responders had precious little time to spare, while communication and resources were at the same time being seriously delayed.
In these cases, on-site geotechnologies such as the HPHC New Orleans GIS, and the knowledge, expertise and resources of various LSU scientists in the EOC and at LSU Center Labs, demonstrably helped to save lives.

Katrina Search and Rescue Mapping: The first week

Hurricane Katrina made landfall in southeast Louisiana on Monday 29 August 2005. Project advisory board members at the CDC had requested a 27 August conference call with the HPHC to discuss potential public health impacts of the hurricane, and also for CDC logon access to be reestablished to the project GIS, as it "would be very helpful in our planning." It was later learned that the project GIS, and experimental storm surge prediction webpage, were frequently referenced at CDC headquarters in Atlanta.

Many hurricane researchers who stayed in Baton Rouge throughout the storm had been providing storm briefs to emergency managers at the EOC in the immediate days of the storm, while others who had evacuated Baton Rouge returned a few days later, once family and home matters were stabilized and roads had been cleared of downed trees and power lines. Many returned to LSU even though the university was closed, in order to provide support for the emergency response efforts.

Thursday, 1 September 2005

Following preliminary discussions among the HPHC, the developers of the database at LGS and CSI, and the SRCC and ESL (who accommodated the group in their EOC work space), the state EOC arranged access for the project group to set up interim GIS capability on-site (Figures 4a,b). By this time, additional requests had been received from LOHSEP, DHS/FEMA, and the Secretary's

Office of US DHH for access to the New Orleans project database.

That afternoon, S. Ahmet Binselam and Kate Streva, HPHC and R. Hampton Peele, LGS set up an operational GIS, amidst the numerous representative agencies within the EOC, using the available project hardware and software they had brought from LSU; namely two computer workstations, an external storage hard drive, a set of GIS data disks, and a laser printer.

This initial team remembers a moment of hesitation before stepping into the fray - like so many who experienced Katrina, wanting to contribute, but questioning if and how they might be of assistance - while weaving through many high-level, decorated officials, military, and emergency responders, with media interviews of these and other famous personalities taking place outside.[6] However, the uncertainty of this initial team of project researchers was allayed as they were immediately barraged with data and mapping requests. They were soon assisted by Robert Paulsell, LGS; Ezra Boyd, HPHC; Henrike Brecht and Carol Friedland, LSU Hurricane Center.

Requests poured in from numerous sources (Table 1). While providing mapping solutions, constantly acquiring additional data, and continuing to build GIS capabilities, the team sought out GIS reinforcements and resources from the greater LSU and Louisiana GIS community.

Figures 4a,b. The first days of the Hurricane Katrina Emergency Mapping Response at the LA EOC. Above: Pictured clockwise from left are R. Hampton Peele, Brandon Ellis, Andrew Augustine, Ezra Boyd and Kate Streva. (HPHC, 2005)

Figures 4b. LA EOC (HPHC, 2005)

From the onset of the response, Josh Kent and Craig Johnson of LAGIC made all relevant GIS data layers available, and provided additional laptops for deployment to the EOC as well as links to download additional statewide geodatabases from the LAGIC server.

[6] Besides President Bush, Vice President Cheney, Secretary of Homeland Security Chertoff, and then-FEMA Director Mike Brown, GIS mappers also mingled with James Lee Witt, CNN and Fox News anchors, senators, congressmen, Jesse Jackson, and Al Sharpton (Rumors also swirled that Brad Pitt showed up at the EOC, but this was never verified…)

Table 1. Agencies and organizations requesting map products (estimated number of requests)

Federal:	DHS-FEMA (3)/Emergency Operations Branch/Menlo Park Fire Protection District, ESF #3/FEMA, Earl K. Long Army Medical Center, NSAR & Federal Highway Administration, Centers for Disease Control and Prevention (CDC) New Orleans, US Geological Survey, US Environmental Protection Agency, US Dept. of Agriculture & Forestry (2), US Dept. of Health and Human Services (US DHHS), Pelican Task Force, National Weather Service, NOAA, FBI.
DOD/ Military:	5th Army, Standing Joint Force Headquarters (SJFHQ), Civil Air Patrol (2), Louisiana Army National Guard (LANG)(4), AVN 82nd Airborne Division (2), 35th Division, Kansas Air National Guard, US Army Corps of Engineers Civil Engineering & Construction Division (3), US Public Health Service (2), Disaster Medical Assistance Team (DMAT), US Air Force, US Army/ 75th DCE/PEO EIS, US Navy NAV/MAR UAV, Army National Guard (2), AVN, National Guard Bureau.
State:	Governor's Office (8), EOC Command Team (2), LOHSEP/Disaster Recovery(4), Office of State Parks/Dept. of Culture, Recreation & Tourism, Louisiana Board of Regents (4), Louisiana Wildlife and Fisheries/Enforcement (13), Louisiana State Police (LSP)(7), Louisiana Department of Health and Hospitals (2), Louisiana Department of Natural Resources (LA DNR) (3), Louisiana Attorney General's Office (2), Louisiana Department of Environmental Quality (LA DEQ)/Emerg. Resp. (2), Louisiana Department of Transportation & Development (4), Louisiana Public Service Commission (2), Louisiana Geological Survey, Louisiana Legislative Black Caucus, Louisiana Hospital Association (2), LOSCO
Regional:	Regional Planning Commission, Texas Forest Service (3), Railroad Liaison, American Red Cross (4), Entergy
Local:	St. Bernard Parish, City of New Orleans, EMS, New Orleans Sewerage & Water Board
LSU:	LSU Ag Center (3)
Partnering States:	COHSEP, ATS-Tulsa FI, Port Authority NY & NJ (2), NY Fire Department, California Highway Patrol, US Border Patrol/California Border Patrol, Michigan State Police, Electronic Messaging Assistance Center (EMAC)/A-Team
Private:	Cingular Wireless, Vanguard Technologies, C&C Technology, Lafayette, E-Team (2), SCC Technologies
International:	Japanese Embassy (New Orleans)
Media/ Journals:	Wall Street Journal, National Geographic, CNN, other various
Personal Requests:	(a few)

Craig fielded numerous requests for data and mapping support from LOHSEP and Federal Agencies, as Josh geo-rectified a 31 August Digital Globe natural color image (2' resolution) of a portion of the New Orleans area (with some clouds, but where flooded and non-flooded areas could be discerned).

NOAA also provided some of the first digital imagery of the New Orleans flooding,[7] as the LSU ESL, including Dr. Nan Walker, Ric Haag, Shreekanth Balasubramanian, S.A. Hsu, and students passed on a high-resolution SPOT Image (from U. Miami CSTARS, for internal use only) 31 August. ESL sent additional satellite imagery, applied geo-correction and analysis, and soon after acquired Radarsat-1 Synthetic Aperture Radar (SAR) imagery (1 and 2 September) of New Orleans flooding.

DeWitt Braud, CSI and his team also worked to acquire, filter through, consolidate, and geo-correct for the mapping teams the vast amounts of remotely-sensed satellite imagery that soon poured in. Assisted by Rob Cunningham, Emily Hyfield, LSU School of the Coast and Environment Special Programs, and Elaine Evers, Coastal Ecology Institute, this team applied geo-rectification and enhancement, among other remote-sensing applications, to the best (free of cloud cover) imagery, providing high-resolution mapping and analysis of flooded areas. Their efforts included the processing of IKONOS imagery (e.g., 2 September) and LIDAR mapping of flood depths provided to FEMA on a quick turnaround. On 1 September, John Johnston and Reed Bourgeois, LGS were working with National Geospatial-Intelligence Agency (NGA) personnel to set up a forward deployment computer center and mobile command post at LGS, to capture and provide high-resolution satellite imagery and FEMA initial damage assessment data (produced by NGA).

Following discussions with Louis Halbert, NGA, in anticipation of huge amounts of high-resolution satellite imagery coming from the DOD WARP system, Hampton Peele alerted the LSU team that a large amount of dedicated disc storage space would soon be needed by the LSU Katrina response GIS team.

John Snead offered the services of the LGS Cartographic Section to provide large format hardcopy plots on demand as needed. He would later prepare oversized Provisional Base Maps of the Hurricane Katrina (and later Rita) impact areas for use by planning and public information teams. Robert Paulsell, LGS and Karl Morgan, Louisiana Department of Natural Resources (LDNR), provided restricted access to Louisiana oil and gas pipeline and wells data for use in oil spill mapping applications.

Friday, 2 September 2005

Hampton, Ahmet and Kate remained in the EOC, providing mapping solutions, cataloguing available data, fielding and tracking initial requests, troubleshooting hardware, software and connectivity issues,

[7] http://www.ngs.noaa.gov/katrina/

and initiating volunteer coordination. Ahmet uploaded current satellite imagery of flooded New Orleans to the HPHC flood prediction web site (http://hurricane.lsu.edu/ floodprediction/) as the first requests for New Orleans street maps came in from the Louisiana State Police (LSP).

Ahmet and Carol Friedland, LSU Hurricane Center, would later work through the night at the EOC to construct a New Orleans Street Atlas with alpha-numeric reference grids (Figure 5), to be printed on letter-size paper for use by LSP troopers. This street atlas[8] would become an invaluable base template for other mapping solutions (e.g., LA DEQ and US EPA among many others) as additional requests mounted. Grid cell size was constructed based on the amount of coverage area possible by each rescue team, to allow for maximum efficiency and minimum redundancy in force deployment.

The locations of actual 911 calls, routed through DHS/FEMA and LSP (one of the north shore 911 call centers having been damaged), were soon provided by the LSP, DHS and other search and rescue/recovery agencies. Call locations were geo-coded by the USGS (USGS 2005) and others, and subsequently mapped with the overlays of New Orleans streets and other requested layers by the HPHC team. This atlas was updated each night for release to the LSP by 6:00am the following morning.

[8] Hampton Peele later developed an elaborate, new statewide search and rescue reference system for use during the Hurricane Rita search and rescue effort, when called upon by LWF.

This task involved coordination of efforts between the HPHC GIS team in the EOC, the LSP, DHS, USGS, Louisiana Department of Wildlife and Fisheries (LWF) and LGS. The geocoded locations of 911 calls were provided by Bill Slavin, a USGS contractor in Delaware.

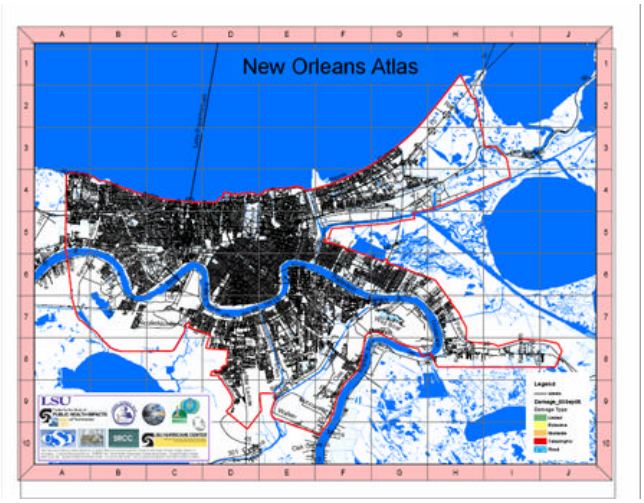

Figure 5. The New Orleans Atlas, with street names and FEMA damage assessment layers over an alpha-numeric grid. Viewed as black on the image are hundreds of zoomable street names. Damage assessment colors are viewable upon closer zoom. Bottom left shows an integrated logo of the many GIS teams who supported the EOC in the Hurricane Katrina data and mapping effort.

In parallel to the HPHC EOC GIS effort, John Barras's GIS team at the USGS National Wetlands Research Center, Coastal Restoration Field Station, assisted by Reed Bougeois, Thomas Van Biersel and Jeanne Johnson of LGS and others, were working around the clock to provide thousands of color plots of 911 call locations over DOQQs (one-meter aerial photography) to the LWF, for deployment to the field emergency rescue teams in boats.[9]

[9] LWF is the lead agency in Louisiana charged with the coordination of search and rescue efforts.

Alternately, the LSP wanted only streets with names and 911 call locations with attached database printouts of 911 call details. The tremendous efforts of the LSP personnel, along with their collaborative colleagues in other law enforcement agencies, who were involved in the preparation of this crucial database, asked to remain nameless, but will not be forgotten. Later, in coordination with the LGS and LWF to match the call location symbology of the USGS maps, Jason Knowles, LSU Geography & Anthropology (G&A), provided valuable assistance in creating the LSP New Orleans 911 Atlas (associated 911 map figure has been requested not to be published).

Some of the data supplied on 2 September and in high demand for the response (e.g., to determine impassable roads) included FEMA damage assessment shapefiles. These were produced and supplied daily by the NGA under contract to FEMA.

In addition to various requests for New Orleans street maps, additional data and mapping requests (listed below in agency/request format) included:

- 5th Army/high-resolution post-Katrina imagery of the New Orleans Convention Center and River Front;
- LA BoR/aerial photos of LSU System properties, including maps of college campuses with lat/long, imagery, and roads for locating potential staging areas;
- LA DOTD/high-resolution color, hard surface vs. flooded derivative products;
- LWF/New Orleans City maps in PDF format and large format plots (a dedicated large format plotter had been provided in the EOC by the LSU WHOCC);
- Governor's Office/the latest imagery of the coast affected by Katrina;
- Louisiana Army National Guard/data and imagery to locate a high-rise building in New Orleans to deploy a communication tower on;
- Texas Forrest Service/GIS transportation data (roads and railroads) and DOQQs for SE Louisiana for planning locations for DOP sites;
- Cingular Wireless/large format plot of Cingular facilities and resources in the impacted area for facility evaluations.

Saturday, 3 September 2005

By 3 September 2005, HPHC Advisory Board agencies were notified of the team's presence at the EOC and to the availability of data and mapping support. Similar to many other Katrina initiatives that had been sparked at LSU[10] there was an overwhelming response by the university

[10] Among other campus outreach during Katrina, LSU had worked with LA DHH to set up a Special Needs Shelter in the Field House; converted the Pete Maravich Assembly Center (PMAC) into a treatment facility and hospital; and established a temporary 400-bed hospital on the nearby grounds (O'Keefe 2005). The LSU Vet School, AG Center and others had partnered to set up a Hurricane Katrina Emergency Animal Shelter at LSU's John M. Parker Coliseum; LSU had also organized a campus-wide volunteer effort, housed several federal agencies in temporary offices, and relocated UNO and LSU Medical School offices.

community in support of Katrina emergency RS/GIS needs as well.

The HPHC project database and team became just one component of many in a greatly expanded, campus-wide and community-wide effort to provide data and emergency response mapping for search and rescue.

Through requests from Dr. Ivor van Heerden, HPHC, and under the coordination of Dr. John Pine, LSU G&A, the effort immediately branched out to include LSU faculty researchers and volunteer graduate students operating from the LSU CADGIS lab, the G&A Spatial Lab, LSU World Health Organization Collaborative Center (WHOCC) for Remote Sensing and GIS (http://whocc.lsu.edu/), the LGS Cartographic Section and other LSU research labs and facilities.

Dr. Andrew Curtis, WHOCC and LSU G&A, dedicated the full support of his lab and research staff[11] to the effort. Jason Blackburn, WHOCC would prove to be an invaluable asset not only in advanced mapping solutions, but in various technological aspects of EOC and LSU lab team connectivity, software installation and troubleshooting.

Curtis and Blackburn, along with Sarah Hinman, WHOCC and Dr. Jacqueline Mills (covering numerous shifts at the EOC from the first days, and highly proficient in geo-applications), provided numerous rapid response mapping solutions, and were central to acquiring state health data layers, providing hospital lat/long coordinates to emergency responders, working closely with the Red Cross, coordinating with the LSU labs, and providing map request tracking and volunteer coordination support as well (see also, Curtis et al 2006).

John Anderson, LSU G&A, led and expanded the GIS volunteer effort, while coordinating task request assignments and providing necessary maps from the extensive map collection of the LSU Cartographic Information Center in the weeks that followed.

The 'GIS-Store' Network Access Storage system was installed 3 September in the LSU Frey Computing Center, and accessed by Cisco Virtual Private Network (VPN) client software via remote access. Brian Ropers-Huilman, LSU High Performance Computing (HPC), secured the generous support of Panasas, Inc. to acquire the 20Tb disc. Sam White, HPC, was the primary implementer of this new hardware. Andy Waggenspack and his team, LSU Information Technology Support (ITS), integrated the disc into the central campus Microsoft Active Directory.

This new resource provided the online storage space required to handle the anticipated large amounts of imagery and data. A VPN connection was established between the EOC and the LSU Campus by Jason Blackburn, WHOCC, allowing the GIS support effort to expand production capacity by involving more resources at

[11] The WHOCC team had already been working from the onset of the disaster with Dr. Pine from LSU to provide mapping support to FEMA.

LSU. Once the VPN connections were made, all project and acquired data were ported to the GIS-Store for access by the LSU based personnel.

Farrell Jones of the LSU CADGIS Lab, and research staff including Ramesh Ramani and Amit Kulkarni, coordinated and managed the data stored on the newly installed "GIS-Store," and provided GIS solutions from the CADGIS Lab, Farrell simultaneously maintaining his role as 'Atlas' Webmaster. Barrett Kennedy, CADGIS lab, instituted a Blackboard site for initial project request tracking[12].

Example map requests from 3 September included requests from LOHSEP for large plot maps of the affected region, and DHH requests for New Orleans below sea level elevations data.

Sunday, 4 September 2005

By 4 September, numerous LSU researchers and graduate student volunteers from G&A and departments across the campus were manning GIS workstations at the EOC, as well as in their own campus labs to prepare digital and hardcopy maps in support of state and federal agencies.

During one shift at the EOC, Brandon Ellis, G&A recalls taking a request from a Chinook helicopter pilot who needed imagery to help him avoid antennas when flying in supplies. With available satellite imagery, Kate Streva and Jason Knowles were one early morning asked to demonstrate estimated depth of flooding of New Orleans areas for Louisiana Attorney General Charles Foti. During some of his extended hours providing mapping solutions in the EOC, Andrew Augustine met (and got a photograph with) President Bush (see also, Figure 6).

Additional volunteers at the EOC and LSU labs included Stephanie Pedro, Chris Pennington, and Bretton Somers among others, with LSU RS/GIS experts Dr. Tony Lewis and Dr. Nina Lam, G&A, consulting with team members.

GIS partnerships and collaboration also included the wider local, state & Federal GIS effort, as well as the assistance of many private companies within the Louisiana GIS community who provided a cache of resources.

Figure 6. President and Laura Bush departing the LA state EOC (September 2005, HPHC).

[12] Initial requests for data and mapping products were taken in hard copy, and later entered in database format. However this method was not efficiently relaying or organizing the requests; Blackboard was a second attempt to manage requests and was subsequently superseded by the SRCC PRTS (following pages)

Central to the data and mapping effort were John Barras, Brady Couvillion, Karen Eldridge, and Christina Saltus of the USGS; Matt Farlow, Mike D. McDaniel, and Steven Burr of LOHSEP; Rebecca Storey, Ron Landhelm, Doug Bausch, and Rich Hansen of DHS/FEMA; Louis Halbert, NGA; Sal Bonaccorso; Texas DHS (collaborating with Ahmet Binselam and Jason Blackburn to provide access to Google Earth Pro); and Doug Albert, LWF.

Companies such as HP, Google, Image America[13], and many others asked how they could assist the effort, and provided resources and available imagery.

By 4 September, the combined teams had mapped FEMA damage assessment data over SPOT imagery for operational response. Data and mapping requests (again listed by agency/request) included:

- LSU Ag Center/updated state-owned land and property shapefile;
- LSP/high quality coordinate 911 call overlays on the New Orleans Atlas and large plots of the New Orleans area with streets for search and rescue;
- 82nd Airborne Division of the Louisiana National Guard/general maps with shaded relief of the flooded regions of Orleans
- LWF/available software for the impacted area to query locations via laptop, in the field, and the FEMA Damage Assessment Areas shapefile;
- LA Attorney General's Office/maps of court house location with associated Lat/Long coordinates for records retrieval;
- USACE/inundation map of New Orleans and surrounding areas;
- FEMA/basic "E" size pdfs of states w/state boundaries, names, and labels for planning purposes;
- 35th Div. UEX of the Kansas Air National Guard/large format plots of New Orleans DOTD street maps
- Red Cross/Road closure data

Monday, 5 September 2005: A week later

In the days that followed Hurricane Katrina, offers to assist with mapping support came in from the UCGIS, URISA, Louisiana GIS Council, and GISCorps; yet, coordination of mapping volunteers amidst the ongoing response had already proven difficult, and it is unclear if these valuable mapping resources were ever fully utilized.

By 10 September, a formal, web-based task Project Request Tracking System (PRTS) had been modified to meet team needs and implemented by the Southern Regional Climate Center, headed by Drs. Kevin Robbins and Barry Keim, with Bob Leche, Kalyan Jammigumpula, and David Sathiaraj. The modified PRTS allowed mapping task requests to be entered, assigned, monitored, updated, and tracked from any network computer. When FEMA assumed full management of GIS and mapping requests 16 September 2005, LSU had taken and processed nearly 150 task requests.

[13] On 5 September Image America provided LSU with high-resolution DVD imagery of 2 September New Orleans and vicinity, with a one-foot resolution seamless single-file MrSID mosaic.

Among the many advanced datasets that resulted from the mapping response, ESL had processed RADARSAT-SAR Imagery from NOAA NESDIS of the substantial oil spills due to Katrina.

Some of the later types of data and mapping requests after 6 September included (listed in agency/request format):

- Governor's Office/maps of all state owned lands on "E" size plots
- National Institute of Health/GPS coordinates for 6 hospitals for helicopter reconnaissance missions
- US Air Force/ Lat/Long coordinates for mile markers on I-10
- FEMA/maps of EMC operations bases
- 82nd Airborne Division and LSP/911 New Orleans Atlas with inundation map overlays
- US Navy/digital imagery of the New Orleans and St Bernard area with flooded areas and landmarks for reconnaissance
- LA DOTD/pumping station maps
- Attorney General's Office/latest image showing the breach of the 17th St. Canal, West End
- ATS Tactical/plots of the highest 3 points of elevation between New Orleans and Baton Rouge for establishing communication relay stations
- US Army 75th DCE/ inundation map
- LA BoR, Governor's Office, FEMA, and Red Cross/geocoded shelter locations for broadband access, populated by Lat/Long
- Governor's Office/high-resolution satellite imagery of 17th St. Canal breach
- ESF #3/pumps and levees over satellite imagery with a Lat/Long grid;
- LA DHH/state map with deceased victim recovery locations;
- SWBNO/System map of sewerage and water systems, council districts, and flood levels;
- NYFD/Lat/Long coordinates for helicopter supply pick-up and drop-off to feed Kansas Firemen
- LSP/map of New Orleans w/hotspots of hostile activity over areas still inundated
- EPA /copies of LSP Search and Rescue Atlas
- FEMA Emergency Operations Branch, Urban Search and Rescue/daily 911 calls update, maps and table hard copies, digital .dbf file
- Governor's Office/FEMA map plot: "Water Depth Analysis-Downtown New Orleans"
- Red Cross/Map of railroads, shelters, kitchens, disaster warehouses, parishes, and maximum flood;
- Governor's Office/Plot of provided PDF of shelters and State Lands
- National Weather Service/Plots of FEMA and Corps of Engineers maps
- FBI/Printed 911 tables by police district and a "E' size map of the whole N. O. area
- LOSCO/Shapefile of 6K grid of Louisiana for indexing the incoming ADS40 digital orthographic imagery from Emergency NASA Missions

Disaster Response GIS Lessons Learned: The following list of recommendations to be considered in future planning for disaster response and Operational GIS are offered by the authors, based on lessons learned.

Location: The location of the GIS Disaster Response Team should not be isolated in one location, even if that one location is the Command EOC. The vast resources of potentially available GIS talent cannot be utilized most effectively in only this one location. A web-based network of GIS responders, all working from their own familiar facilities is required in order to provide the maximum potential mapping resources. However, the Command EOC should always have Operational GIS Resources within the building capable of providing mapping solutions for essential emergency response efforts for the following reasons, made clear in the Katrina and Rita response experience.

Power and communications are subject to failure during disasters, and without both, a network of GIS responders will be unavailable to the Command EOC.

During such times when either power or communications are compromised for the networked mapping resources, the members of the GIS Disaster Response Team located within the Command EOC must be prepared to continue to provide mapping solutions to all of the agencies, both governmental and non-governmental, that maintain a presence there.

Resources: Wherever members of the GIS Disaster Response Team are located, they should be equipped with all of the resources that they will require in order to produce the mapping solutions that they are called upon to provide.

These resources include: hardware such as computers with sufficient memory, printers, plotters, scanners, sufficient redundant digital storage such as local external hard drives and/or additional networked hard drives, flash drives, etc.; the latest versions of necessary software already installed and fully functional; ample plotter and printer paper, printer toner, plotter ink/dyes; and portable digital media such as blank CDs and DVDs and portable hard drives.

All necessary disaster response resources should be made available prior to hurricane season or any impending disaster. The GIS personnel should have access to everything they will need in the setting most familiar and comfortable to them. This is essential for GIS personnel to be prepared and to train in advance.

Communication Systems, Sending and Receiving Data: Operational GIS data sharing and mapping requires extensive communication systems with a central data repository, and the ability to send and receive data through all available means. When planning Operational GIS support for disaster response broadband, satellite, land line, cell phone, internet, fax, e-mail and operable electricity all of course need to be available, primarily at the EOC.

A comprehensive emergency contact list of essential professionals should be created well in advance of emergencies and updated regularly. Such a list should include disaster managers for the entire region, mapping team members, critical data providers, Information Technology support personnel, hardware and software vender technical support as well as management personnel.

Create a contact list of members of the mapping team, critical data providers, Information Technology support personnel, etc., including emergency numbers.

Funding: Obviously sufficient funding should be in place for dedicated disaster response personnel and all their needs. This funding should be regularly evaluated to be certain that such funding will be adequate for a major disaster.

That which is not obvious, is the funding needs of those mapping personnel, that are not dedicated disaster response personnel, who are assisting in the event of a major disaster, such as Katrina or Rita. It would be ideal to have a system for financial reimbursement for GIS/mapping support in place prior to a disaster. Agencies with limited budgets can be reluctant to expend those critical operating funds with no mechanism in place to assure reimbursement. After the Katrina and Rita responses, many agencies found themselves unable to get reimbursed by FEMA or any other financial entity, for that matter.

Management: Identify a central contact person at the emergency agency and establish points of contact for the division of labor based on knowledge, technical skills, and available data sets (e.g., imagery analysis, vector data, etc.). A chain of command should be established well in advance for optimal coordination.

EOC GIS shift briefings, based on mapping task requests in progress and the experience of the GIS personnel on duty during the last shift, are essential for sustaining an institutional memory of the mapping tasks that are in progress, on-going negotiations of new mapping requests, and any changes in operational procedures. Such briefings should eliminate much of the confusion and help to avoid duplication of effort. These briefings would be most efficient and effective by overlapping shifts by thirty minutes.

Request Tracking: Develop or implement a user-friendly, web-based (mobile), map request tracking system, capable of being sorted by date, requesting agency, priority level, GIS personnel who worked on the requested task, and status of task (in progress, complete, etc.). The system should be able to generate reports as well as store data sources (or document their storage locations), final map file names, map file formats and their storage locations used in the map solution.

This request tracking system should have both the ability to cache tracking information while off-line and a batch uploading and downloading capability. The upload function would allow a quick upload of request tracking data from the

off-line cache. This would allow uninterrupted tracking of the map requests during times of network outages with automated updates to the request tracking system database when communications are restored. The download capability would also allow for a quick and efficient migration of the tracking system database from one server to another.

The value of the proposed Map Request Tracking System would increase tremendously by having a number of well trained operators, one of which would be available at all times to interface with the operational GIS managers. This would enhance the ability of GIS managers to monitor progress of the mapping efforts.

Data Structure/Library: Advanced planning is extremely important concerning the projection, datum, and file format that critical data layers are stored in. Therefore, methods and procedures for data access and storage, file formats, projection and datum standards, and metadata creation and cataloging should be established well in advance of any disaster. Filing systems, password access, and data back-up procedures should be implemented, tested, and updated regularly.

During emergencies, in an operational GIS environment is not the time or place to be converting, transforming, or translating large GIS data layers, especially raster data. Different agencies have different data format requirements for compatibility with their systems. For example, Louisiana state agencies are required by law to utilize NAD83 datum as are Federal agencies, while the US military employ WGS84.

Data Sharing and Acknowledgement Protocols: As is always the case, data comes with requirements; and protocol is very important. If the data are fully within the public domain, they should be accompanied by their corresponding Federal Geographic Data Committee (FGDC) compliant metadata records. These records should contain any restrictions on the use and distribution of the data. Even in the urgency of an emergency operational GIS environment adherence to these restrictions are important. If however, the situation requires exceptions to be made, the metadata records should contain the contact person authorized to make such an exception, or to notify that an exception was taken. Sometimes the metadata records clearly state that no exceptions will be permitted. These data are usually very difficult to get access to.

If the data are not within the public domain they may not be accompanied by FGDC compliant metadata records. Quite often restricted data such as medical records, strategic facilities, 911 caller records, proprietary data, and research data in development, will not include metadata records. Therefore, operational GIS personnel must have a way of restricting access to such data, even among themselves. The best way to do this is to ensure standard FGDC compliant metadata records be created for any restricted data immediately upon receipt of such data. These data should then be stored in

restricted locations that only authorized personnel can access.

The FGDC compliant metadata records will assist in the acknowledgement of all data providers for their invaluable assistance in the emergency response.

Acknowledgement of these contributions is often the only recognition that data providers get for their valuable assistance in the disaster response. Therefore, as a rule, whenever data is being provided, check to see if FGDC compliant metadata files accompany the data. If not, create the metadata records upon receipt of the data.

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