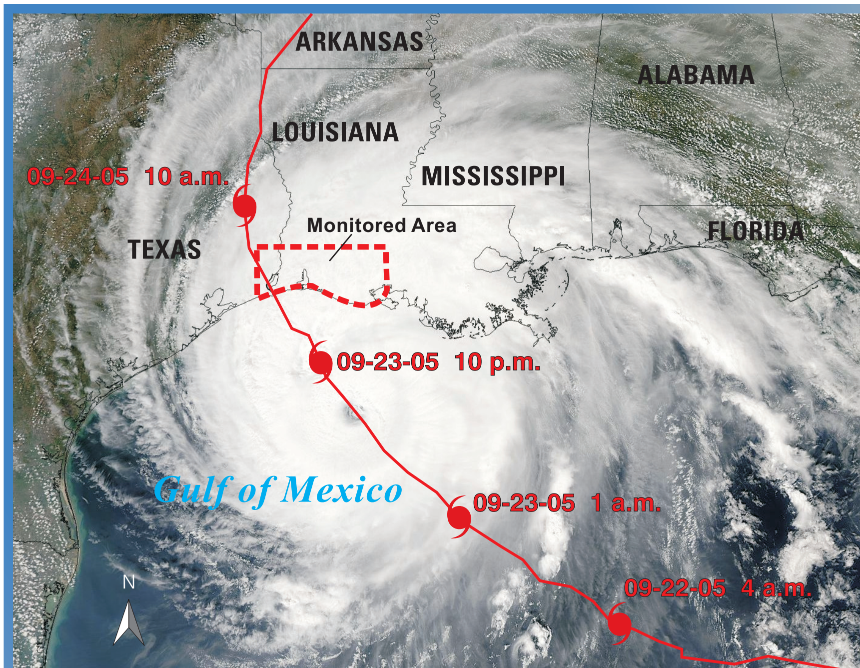
USGS
science for a changing world

Monitoring Inland Storm Surge and Flooding from Hurricane Rita

Preventing flood hazards from becoming human disasters requires an understanding of the relative risks floods pose to specific communities and knowledge of the processes by which flood waters arise, converge, and abate. Such understanding can lead to improvements in the design of levees, dams, bridges, and other infrastructure; aid the delineation of flood plain boundaries and evacuation routes; and serve as the basis for wise land-use planning.

Historically, study of coastal storm-induced surge was based on analysis of flood evidence such as structural damage, vegetative damage, debris piles, high-water marks, and eye-witness accounts. However, these sources rarely provide useful information about the timing of the inundation, nor do they facilitate reconstruction of the various flow paths by which surge waters penetrate inland areas, or provide information to assess natural or man-made factors, which may affect flooding.

In response to these needs, the U.S. Geological Survey (USGS) designed and developed an experimental monitoring network of pressure transducers (sensors) to document the timing, extent, and magnitude of hurricane storm surge. The network was deployed to areas of southwestern Louisiana and southeastern Texas (figs. 1 and 2) in the hours preceding landfall of Hurricane Rita in September 2005.



Hurricane Rita satellite imagery obtained from the National Aeronautics and Space Administration (2006).

Figure 1. Path of Hurricane Rita, September 22-24, 2005, and monitored area in southwestern Louisiana and southeastern Texas.

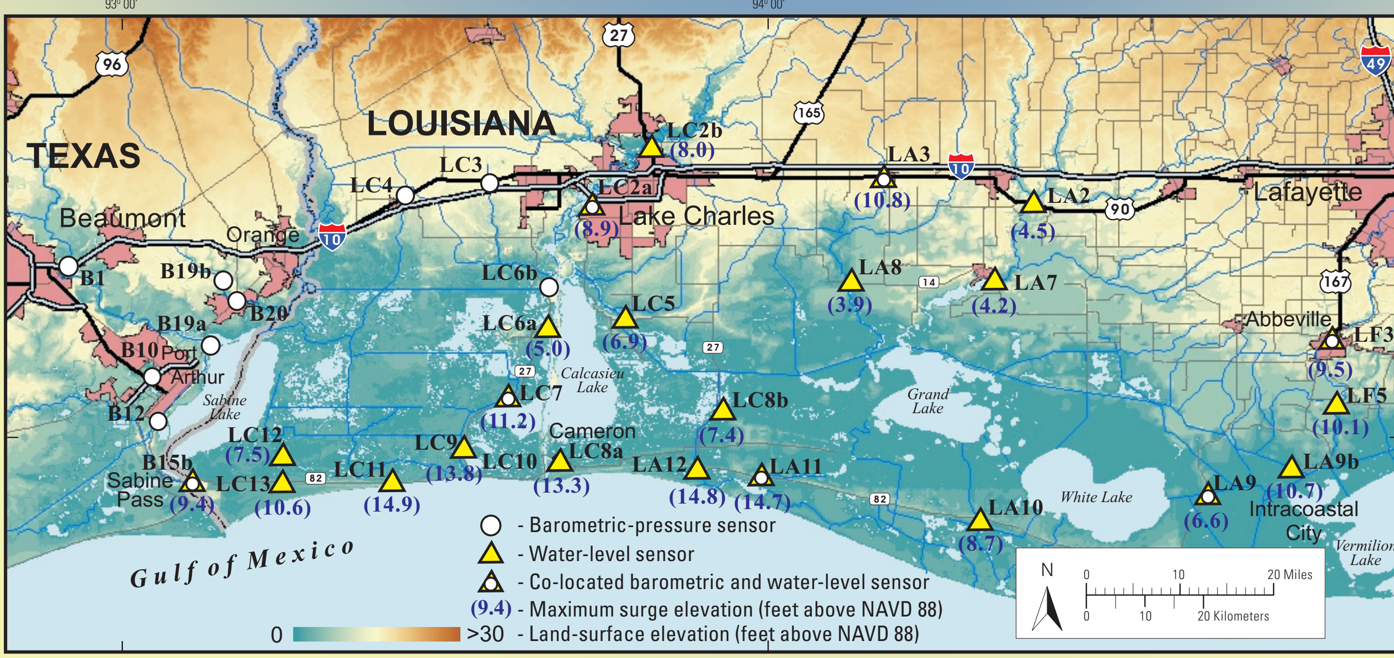


Figure 2. Location of data-collection sites and recorded maximum surge elevation.

The resulting water-level/barometric-pressure and related high-water mark data are described in USGS Data Series 220 and are available on the Internet at
http://pubs.usgs.gov/ds/2006/220/

Monitoring Storm Surge

As Hurricane Rita approached the coast, sensor sites were selected based on storm-surge forecasts, the location and accessibility of piers and bridges, and local topography. Sensors were deployed at 33 sites from September 22-23, 2005, along selected waterways and in coastal marshes from Sabine Pass, Tex., to Lafayette, La., at distances ranging from a few hundred feet from the coast to approximately 30 miles inland. Sensors (fig. 3) were programmed to measure and record date and time, temperature, and pressure every 30 seconds during the storm and for several days afterward. Sensor housings were fabricated of 1.25-inch diameter by 18-inch-long metal pipes and were deployed by strapping to permanent objects, such as piers and power poles (fig. 4A). Co-located sensors recorded water level and barometric pressure at 7 selected sites, and individual sensors recorded water levels at 17 sites and barometric pressure at 9 sites.

Figure 3. Sensor used to collect water-level and barometric-pressure data.

After the storm, the sensors (minus one that was destroyed) were recovered and the data downloaded and processed. Water-level data were corrected for changes in barometric pressure using data from a co-located or nearby barometric-pressure sensor. Water-level data also were corrected for salinity (water density). Corrections for salinity were based upon the location of the sensor in proximity to the coast, as either saltwater (density of 64.0 lbs/ft^3 [pounds per cubic foot]), brackish water (density of 63.1, lbs/ft^3), or freshwater (density of 62.4, lbs/ft^3).

To convert the water-level data from all the sensor sites to a common datum, temporary reference marks (fig. 4B) were established on permanent objects near each water-level sensor. Differential levels and graduated tapes (fig. 4C) were then used to relate the relative elevation of the temporary reference marks to that of the sensors, available high-water marks, and to the level of the water at the time the sensor was removed.

Global Positioning System (GPS) equipment and techniques were used to determine the elevation of the temporary benchmarks. The

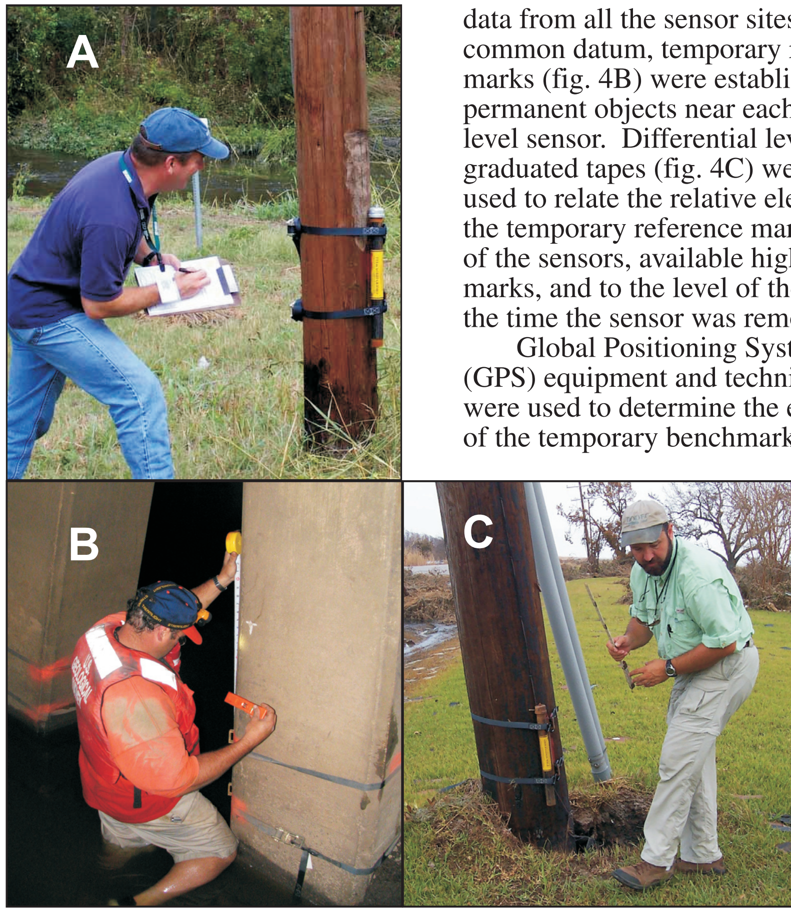


Figure 4. U.S. Geological Survey employees: (A) documenting site conditions during sensor recovery, (B) establishing a reference mark during sensor deployment, and (C) measuring the distance between the temporary reference mark and the sensor measuring point.

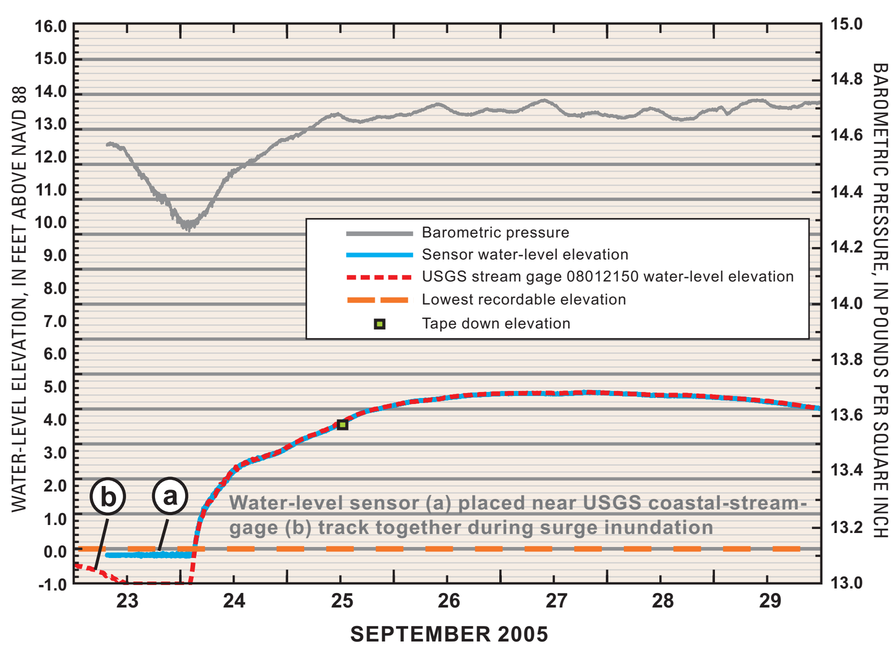


Figure 5. Hurricane Rita surge data at site LA2 west of Lafayette, Louisiana.

GPS data were processed using 2 first-order benchmarks and 6 National Geodetic Survey continuously operating reference stations (CORS) (National Geodetic Survey, 2006a) with Ashtech Solutions software (Ashtech Precision Products, 1999).

Quality Assurance

Quality-assurance procedures were used at selected sites to assess the variability and confirm the accuracy of the recorded water-level data. These procedures consisted of comparing water levels recorded by sensors to (1) water levels recorded by co-located sensors, (2) water levels recorded by nearby established USGS streamgages, (3) water-surface elevation of the water from which the sensor was recovered, and (4) field observed high-water mark elevations. Water levels recorded by the sensors at sites LF3 and LA7 were similar to water levels recorded by co-located sensors, and water levels recorded by the sensors at sites LA2 (fig. 5) and LA8 closely matched water levels recorded by USGS streamgages.

Water-level data were compared to the water-surface elevations of the water from which the sensors were recovered at seven sites: LA2 (fig. 5), LA3, LA9, LC2a, LF3, LC5, and LC8b. The data from the sensors matched the water-surface elevations within + 0.1 foot at all seven sites.

The highest water levels recorded at seven sites, including LA9b (fig. 6), LA12, LC2b, LC5, LC7, LC8a (fig. 7), and LF5, were compared to the elevation of the nearest high-water mark. In general, the highest water levels recorded by sensors were similar to nearby high-water marks rated as excellent; however, the highest water levels recorded consistently were higher than high-water marks rated as good, fair, or poor. For example, the highest recorded water level near site LA9b (fig. 6) was approximately 0.2 foot higher than the nearby high-water mark rated as excellent, and the highest recorded water level near site LC8a (fig. 7) was approximately 1 foot higher than the nearby high-water mark rated as good.

Storm Surge And Flooding

In general, the highest surge elevations were recorded near the coast, and lower elevations were recorded inland through the approximate latitude of Interstate 10 (fig. 2). Figures 5, 6, and 7 show water-level and barometric-pressure data before, during, and after landfall of Hurricane Rita. Analysis of these and the remaining data indicate that peak water levels over 14 feet above North American Vertical Datum of 1988 (NAVD 88) occurred at Constance Beach (LC11), Creole (LA12), and Grand Chenier (LA11), La., about 20, 48, and 54 miles respectively, east of Sabine Pass, Tex. (fig. 2). During the storm surge, water levels rose in excess of 5 feet per hour at many locations. Flooding at some locations near Interstate 10, such as sites LA3 and LA2, was increased by river flows in addition to storm surge.

The storm-surge data indicate the timing of flood waters as Hurricane Rita moved across the coast and inland. Approximate visualizations of these events can be created by interpolating water-level data between sensor locations and overlaying the results onto a digital-elevation model. For example, on September 24, 2005, 3:00 a.m., a flood wave (dark red

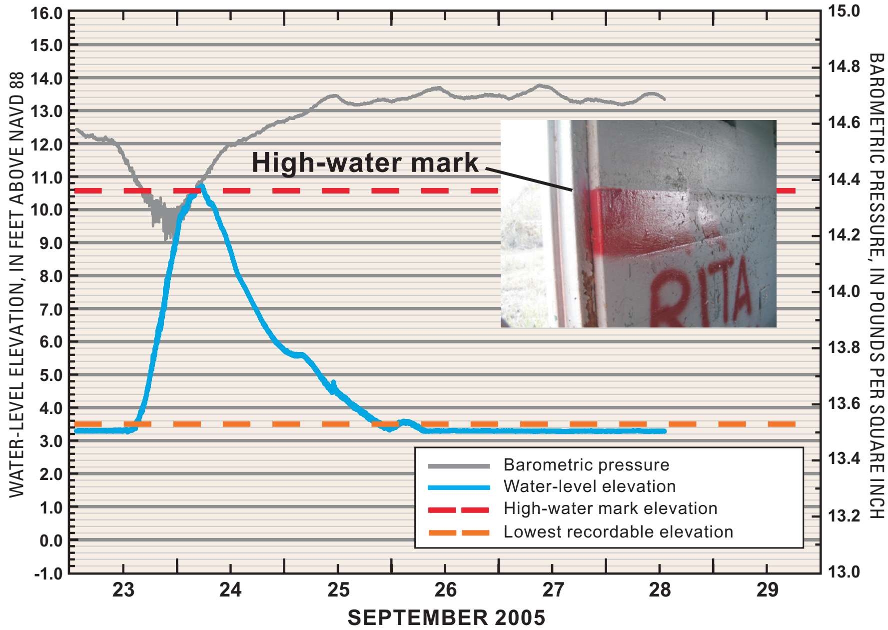


Figure 6. Hurricane Rita surge data at site LA9b near Intracoastal City, Louisiana.

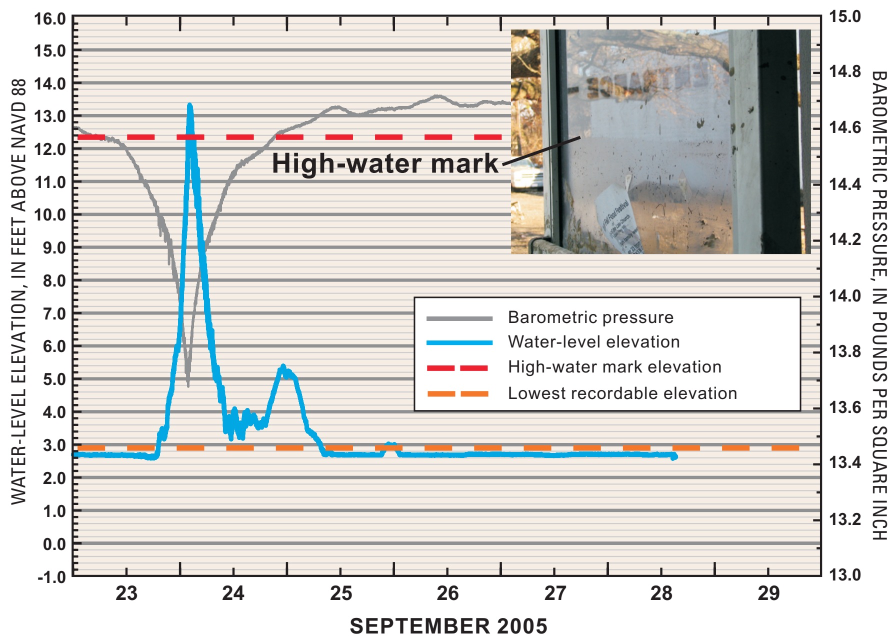


Figure 7. Hurricane Rita surge data at site LC8a in Cameron, Louisiana.

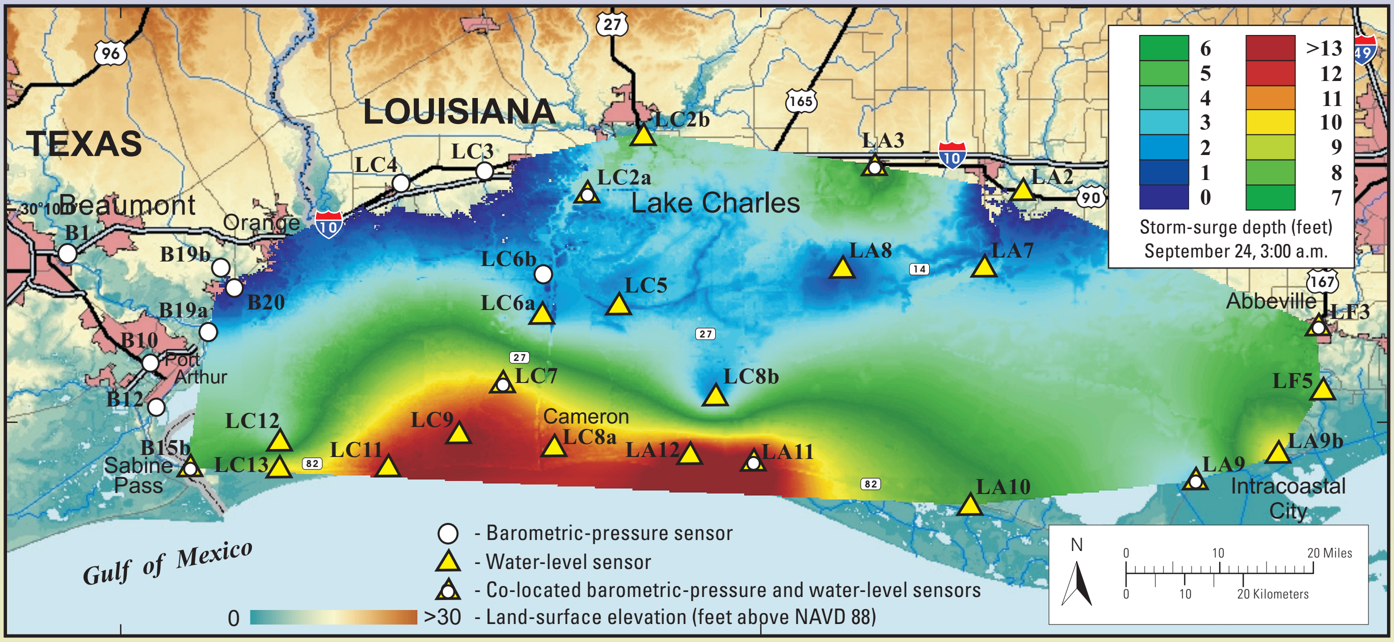


Figure 8. Simulation of surge from Hurricane Rita on September 24, 2005, 3:00 a.m., using water-level and barometric-pressure data from sensors (Dean Gesch, U.S. Geological Survey, written commun., 2006).

area in fig. 8) is shown inland of the coast and along Louisiana Highway 82 from sites LC11, LC9, LC8a, LA12, and LA11 (Dean Gesch, U.S. Geological Survey, written commun., 2006).

Maps also can be generated to display flood duration, times of surge arrival and retreat, and maximum depths. Overlaying that information on other visualizations of hurricane impact, such as beach erosion and housing damage, could ultimately enable scientists and engineers to better understand surge mechanisms and design more robust infrastructure. Future deployments may feature monitoring of salinity and may include real-time telemetry to help emergency officials respond when storm surge threatens coastal communities.

Acknowledgments

The authors wish to thank the following USGS personnel for their dedication and diligence in collecting, processing, and publishing data for this study: Wade H. Kress, Joe G. Beauchamp, Christopher L. Braun, Marcus O. Gary, Robin H. Gary, and Joseph Vrabel, Texas Water Science Center; Brenda K. Woodward, Nebraska Water Science Center; Christopher J. Rowden and Paul H. Rydlund, Missouri Water Science Center; and the employees of the Ruston Program Office, Louisiana Water Science Center.

Selected References

Ashtech Precision Products, 1999, Ashtech solution user's guide: Santa Clara, Calif., Magellan Corporation, 170 p.

McGee, B.D., Goree, B.B., Tollett, R.W., Woodward, B.K., and Kress, W.H., 2006, Hurricane Rita surge data, southwestern Louisiana and southeastern Texas, September to November 2005: U.S. Geological Survey Data Series 220.

National Aeronautics and Space Administration, 2006, Life on Earth-Looking at Earth: accessed May 16, 2006, at URL http://www.nasa.gov/vision/earth/lookingatearth/h2005_rita.html

National Geodetic Survey, 2006a, National Geodetic Survey continuously operating reference stations (CORS): accessed May 16, 2006, at URL http://www.ngs.noaa.gov/CORS/

National Geodetic Survey, 2006b, National Geodetic Survey datasheet retrieval page: accessed May 16, 2006, at URL http://www.ngs.noaa.gov/cgi-bin/datasheet.prl

National Oceanic and Atmospheric Administration, 2006, National Hurricane Center: Hurricane Preparedness, SLOSH model: accessed September 21, 2005, at URL http://www.nhc.noaa.gov/HAW2/english/surge/slosh.shtml

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

By Benton D. McGee, Roland W. Tollett, and Robert R. Mason, Jr.

For additional information contact:
Director
U.S. Geological Survey
Louisiana Water Science Center
3535 S. Sherwood Forest Blvd., Suite 120
Baton Rouge, LA 70816
Telephone: (225) 298-5481
Fax: (225) 298-5490
Email: crdemas@usgs.gov
Internet Home Page: http://la.water.usgs.gov