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F I N A L R E P O R T

Integration of Remote Sensing and GIS with FEMA Flood Hazard Mapping

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Utah State University

Commercial Remote Sensing Program,
National Aeronautics and Space Administration

Affiliated Research Center
Final Report

Integration of Remote Sensing and GIS with FEMA Flood Hazard Mapping

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Preface

This project used the expertise of Sedona GeoServices (geographic information system (GIS), software, networking) and Utah State University (watershed science, GIS, remote sensing) to exploit, explore, and initiate the implementation of the GIS-based Flood Insurance Study/Flood Insurance Rate Map automated mapping process. Many people have made possible the successful accomplishments of this project, which involved private industry, education, and government. Of particular mention are Bruce Davis, Hugh Carr, Cliff Holle, John Beck, Paul Maughan, and Molly Macauly at the John C. Stennis Space Center; Doran Baker, Kimberly Olsen, Patric Patterson, Douglas Ramsey, Richard Spencer, and Thad Tilton of Utah State University; and Timothy Rimlinger and Eric Olsen of Sedona GeoServices. The sponsorship by the NASA Affiliated Research Center Program under Cooperative Agreement No. NCC13-18 is acknowledged and appreciated. An essential part for the proof of concept as a commercially feasible application of the automated mapping process was provided by Sedona GeoServices under the Memorandum of Agreement between Sedona GeoServices, Inc., and Utah State University dated January 8, 1998.

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Allan Falconer
Co-Principal Investigators

Executive Summary

The current method of creating Flood Insurance Rate Maps (FIRM's) primarily involves manually using paper maps and the discretion of the cartographer. The basic process starts with conducting a Flood Insurance Study (FIS), which may use one or several mathematical models to predict flood levels. The data generated with these models are used to plot 10-, 50-, 100-, and 500-year flood zones on a community base map. These maps are then used, in hard copy form, for making planning decisions and for determining flood insurance rates. Although models used to generate the initial data have been input into a computer, the process of transferring the results to a map remains manual and is therefore both labor intensive and prone to error. The automation of this process would minimize these problems as well as have the advantage of creating a FIRM data layer suitable for geographic information system (GIS) analysis.

The flood zones were calculated by evaluating potential water sources: (1) rivers, (2) streams, (3)ground water, (4) wetlands, (5) reservoirs, (6) canals, (7) public water lines, (8) lakes, and (9) the topography (slope) of the area. The topography was determined by Digital Elevation Models (DEM's) and potential water sources by a hydrology Digital Line Graph (DLG), groundwater, and well and spring data layers. In addition, replacing the community base map with an up-to-date, high-resolution digital orthophoto along with satellite imagery would make the process much easier and increase accuracy. This would revolutionize the use of FIRM's by making the recognition of individual buildings, dwellings, fields, rivers, streams, and other features intuitive.

The project provided the basis for a successful automated mapping program. However, in its present state it can perform only terrain analysis and identification of features.

1.0 Introduction/Objectives

The expertise of Sedona GeoServices (geographic information system (GIS), software, networking) and Utah State University (watershed science, GIS, remote sensing) was exploited to explore and initiate implementation of the GIS-based Flood Insurance Study/Flood Insurance Rate Map (FIS/FIRM) idea. Digital Flood Insurance Rate Maps (DFIRM's) and a data set were to be developed. Following the ARC program, the prototype would serve as the core software needed for the commercial development of the package as well as a suite of specialized tools needed to analyze DFIRM's. This report outlines the acquisition of a DFIRM data base and development of the tools that allow analyses. Environmental Systems Research Institute (ESRI) ArcView was the GIS software used for this project.

2.0 Methods

2.1 Coverages

During the first phase of this project, various data layers pertinent to characterizing landscape features were collected and integrated into a GIS:
10-meter resolution Digital Elevation Model (DEM)
90-meter resolution Defense Mapping Agency (DMA) elevation map
100-meter Triangulated Irregular Network (TIN)
1:24,000 Digital Raster Graphic (DRG)
30-meter Thematic Mapper (TM) satellite imagery
1:100,000 lakes and rivers Digital Line Graph (DLG)
wetland, ground water, spring, and well coverage from Utah County
Federal Emergency Management Agency (FEMA) Q3 flood zone map
survey grade roads map (DLG)
100-meter interval contour line map
facilities map
section map
forest boundary map
orchard location map
city boundaries
Utah County boundary

Because similar data were available for Utah County from a variety of sources, the quality of digital data was assessed and the highest-precision data were chosen. Data available from the Utah County GIS World Wide Web site was of higher resolution (in most cases) than data from the United States Geologic Survey (USGS) and was preferentially included in the data base. City boundaries and streets are "survey quality." High resolution (10-meter) DEM data were available for the urban area. The USGS DRG's for this area are also included. Redundant data sets were discarded; and all GIS data were projected into a Universal Transverse Mercator (UTM) projection and coordinate system. All coverages would overlay and be spatially correct, which is fundamental to analyses.

The flow accumulation and flow direction maps derived from the DEM were not completed because of a major restructuring of the Sedona GeoServices company. They ceased involvement on this project before it was completed.

2.2 Tools

The tools were developed using ESRI's ArcView Avenue programming language. The tools developed were (1) Line of sight, (2) General identification (Zone), elevation, and DRG map, (3) Map maker of the current View, and (4) Metadata.

The line of sight tool allows the user to draw a line on the map and to produce a surface profile of the topography by querying a (G)theme DEM and graphically displaying the chosen DEM according to the origin, direction, and length of the line. Elevation at each interval of the DEM and distance from the origin are indicated on the chart. This is used to analyze the areas prone to flooding because of water flowing into the area from higher ground. This tool also indicates those areas visible from the point of origin to the end of the line. The tool draws a color-coded line to indicate portions of the line that are visible (green) and not visible (red). The Spacial Analyst extension of ArcView is required for this tool.

This tool has been tested extensively by the National Environmental Database (NED) Project at Utah State University and at many locations around the Provo River.

The general identification tool requires the input of a point in the View; then the user chooses a feature from a list generated for the Table of Contents (TOC) of the View. If the Flood zones or Roads Small (small scale) is chosen, a FEMA flood zone or road name is displayed. A two-line written description of the flood zone or road name is displayed (if available). Any other feature that is selected in the view is displayed using the code for ArcView's identification tool. The user is then queried about whether to view the point elevation, which is displayed in meters and feet. Finally, the user is queried about whether to view a DRG Quadrangle map at a user-defined scale (user inputs the scale). A DRG is displayed at the user-defined scale along with a red dot indicating the chosen point. The DRG and DEM are available only for the urban corridor. This has been tested in many areas and performs adequately.

The Map maker tool produces a map of the features that are visible in the active view at the same scale. This tool makes a copy of the View and inputs a legend according to what is visible, and then adds a North Arrow, a Title, and a Sub-Title. The user is queried about whether to make the map in portrait or landscape style, and then the map is displayed on the screen. The map can be sent as a Post-Script (.ps), Encapsulated Post-Script (.eps), or Color Graphics Metafile (.cgm) to a printer or saved to a file to be printed later.

The Metadata tool allows the user to see a text file of metadata of the coverage or image. This script locates the path and file name of the active theme and looks for a .txt extension with the same file name. This is a Federal Geographic Data Committee (FGDC) approved Metadata file (text only).

3.0 Results

Graduate student Thad Tilton was assigned to work on the project in mid-January. His primary duties have been to gather and process digital data for the study area, to document Metadata for the project, and to coordinate with Tim Rimlinger at Sedona GeoServices.

Tim Rimlinger was responsible for the acquisition of flood insurance and FIRM data. However, Sedona GeoServices went through a major restructuring, and the company no longer produces data bases. The company now produces Java-based software. Sedona GeoServices has dropped its efforts on this program, leaving it up to the ARC to complete the program. Richard Spencer of Utah State University was assigned to finish the project and to produce a workable model with the data available.

Doug Ramsey and Richard Spencer analyzed all related tabular and spatial data. The DEM, potential water source (lakes and rivers), and flood zone data were necessary to analyze the flood potential. The line of sight and flood area identification tools were developed using the flood zone and DEM data for analysis and identification only. An analysis of flood potential is done by identifying a general area, zooming in to a selected area, using the ArcView zoom tool, selecting a spot using the roads coverage, and selecting the general identification tool. The user then selects a theme and clicks the mouse over the selected spot (indicates any FEMA flood zones in the selected spot). The user writes down the elevation and looks at the DRG to find any nearby water sources. Then, the user chooses the line of sight tool to get a surface profile of the area from any water source to the selected spot. If the selected spot is visible, then the spot is higher than the water source. The difference between the spot and water-source elevations is noted. This difference will be used to calculate the flood potential for any catastrophic rain event or dam break.

The other tools were designed to produce maps and to view metadata. These would be used for monitoring and producing up-to-date maps for clients.

4.0 Proof of Concept

Since Sedona GeoServices dropped out, the flow accumulation and direction maps were not produced, and the present project does not allow automated FEMA FIRM map production. The product (along with any addition of updated maps coverages produced) will be used for monitoring and analysis of the terrain. This data base and program can be easily modified and updated to meet all of the goals of the original program: (1) faster output and increased accuracy; (2) reflect optimum model changes; (3) augmentation with new overlays; (4) easily modified and/or updated to keep pace with the market; and (5) innovative in the use of 1-meter resolution data to provide image-based maps to meet client needs.

5.0 Conclusion

This concept has been given favorable feedback from the various players involved. We are investigating and will continue to investigate this concept. We are currently in discussions with Gateway Mapping of Orem, Utah, and hope to enhance the capabilities of this project.
There is a consistent opinion on development:
NASA and Utah State University have received favorable feedback.
We have been in contact with a national organization of state flood emergency managers who have indicated that such a product would have value.
We have contacted FEMA and they are interested and would like to review the concept.

We will continue to evaluate the market, and development will stop if a fatal flaw is found**.**

Business opportunities related to Digital FIRM data sets created from the Viability Information Program (VIP) (see also Table 1)**:**
FEMA is moving in the direction of integrated data sets with digital orthophoto quadrangles as the backdrop (based on Joe Foley's memo).
The timing of the new directives corresponds to the initiatives with FEMA programs being put into the FEMA FY99 budget.
The product will provide a multi-dimensional analysis of Flood Hazard Areas (FEMA model moving from a horizontal map to a vertical control).
We will provide data that are needed to augment models for determining flood hazards, damage assessments, and rate structures.

6.0 Addendum

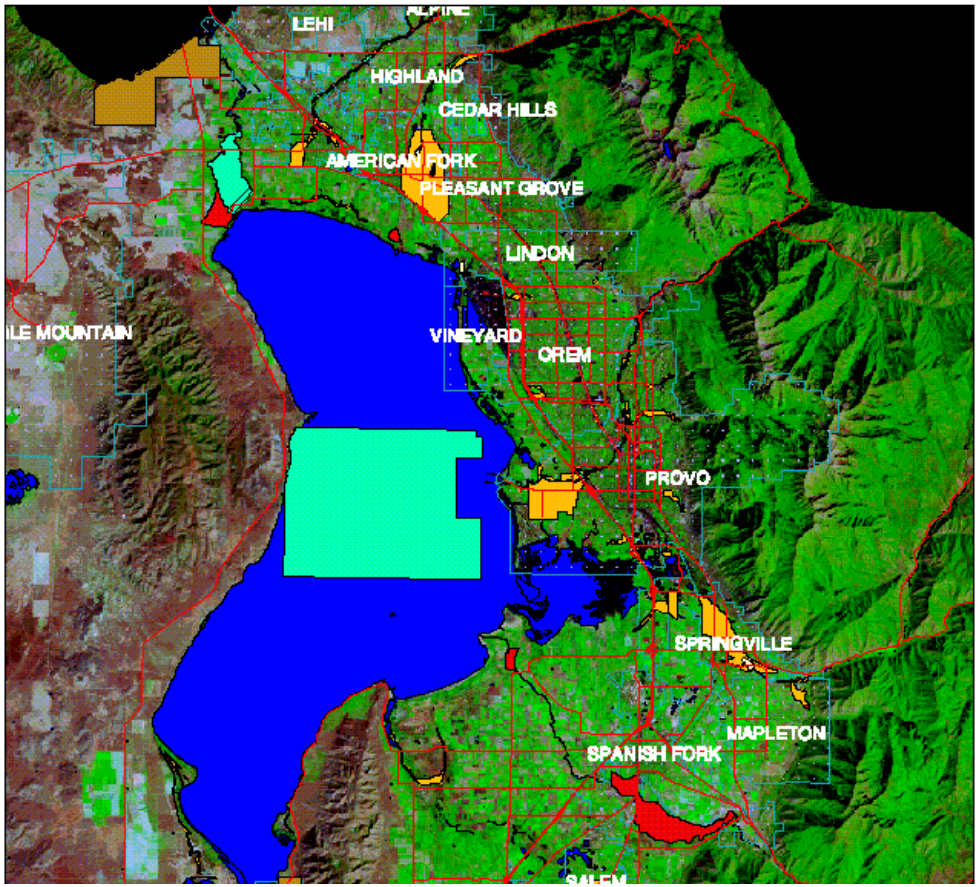
There is a known problem with the CD-ROM that Utah State University has produced. The ArcView program is operational and all functions are valid on the UNIX operating system. However, there can be erroneous values produced when elevation values are calculated and the CD-ROM is read from a PC. The CD-ROM performs well on certain PC's and produces errors on others. We have tried to fix the problem by checking elevation values generated by the Avenue script, but there don't seem to be errors in the calculations or theme queried. Since it performs well on certain PC's and UNIX systems but produces errors on others, we believe there may be a compatibility problem with the GIS software or there is a memory problem with the PC's.

Table 1. Potential users for VIP-developed data set.

Organization	Use
FEMA and FEMA Regional Offices	Emergency Planning, Federal Insurance
Insurance	Rate Determination, Post Event Analysis
Data Providers	Distribution Channels
County Planners	Sub-division Placement, Zoning, Infrastructure Planning
Local Government (Communities (i.e., Townships, Boroughs)) 20,400 took part in Flood Insurance Studies	Land Use/Planning/Management
Environmental Engineers	Land Use/Planning/Management
Civil Engineers/Architects	Site Planning (roads, bridges, buildings)
Soils Conservation Districts/Natural Resources Conservation Service (NRCS)	Farm Planning, Effects of Floods on Soils
Environmental Protection Agency (EPA)	Toxic Site Management, Flooding Predictions
State Environmental/ Natural Resources Agencies	Wetlands Conservation/Risk (may need National Wetlands Inventory (NWI)
Army Corps of Engineers	Evaluation/Design of Flood Projects and Models
National/State Park Service	Land Management and Planning
Public Utilities	Infrastructure Placement, Storm Recovery
Department of Agriculture/Farming	Fertilizer and Pesticide Runoff
Land Developers	Site Planning

Utah County

Urban Corridor



Roads Large

Floodzones

- A
- A0
- A1
- A10
- A14
- A2
- A3
- A4
- A5
- A6
- A9
- AH
- B
- C
- M
- City
- Lakes

N

Utah County

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