TESTING LARGE-SCALE DIGITAL LINE GRAPHS AND DIGITAL ELEVATION MODELS IN A GEOGRAPHIC INFORMATION SYSTEM

by

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ABSTRACT

In February 1988, the U.S. Geological Survey and the U.S. Environmental Protection Agency (EPA) entered into a cooperative investigation of the use of geographic information system (GIS) technology in the CERCLA (Superfund) Remedial Investigation process. EPA has over 28,000 sites in various stages of this process and is investigating mechanisms that can efficiently analyze the large amounts of spatial data that are associated with Superfund site investigations. The Old Southington Landfill in Southington, Connecticut, was chosen as a pilot site. This site is currently in the Remedial Investigation/Feasibility Study stage of the Superfund remedial process.

To evaluate the landfill's potential for contaminating the surrounding environment, a large-scale GIS data base was created. The data base included custom Digital Line Graphs (DLG's) generated from a digital analytical stereoplotter and coded in standard DLG format. Also under evaluation in this project were custom Digital Elevation Models (DEM's) and a unique site-feature data set compiled from historical aerial photographs.

Several application scenarios were tested and the results presented at EPA's Remote Sensing/Technical Support Symposium in May 1988 to demonstrate the advantages of incorporating remote sensing and GIS technology into the Superfund remedial process.

INTRODUCTION

Geographic information is of vital importance to the role of government in general and specifically to the mission of the Environmental Protection Agency (EPA). Most scientific disciplines are in some way concerned with spatially distributed phenomena and EPA studies nearly always involve multidisciplinary approaches. In The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and The Resource Conservation and Recovery Act (RCRA) site investigations, the majority of the data generated in the Remedial Investigation

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process is spatial in nature and is derived from such diverse sources as monitoring wells, utilities maps, political boundaries, ecological data, census tracts, and airborne remote sensors. The ability to process and analyze spatial information is central to the mission of the agency.

A geographic information system, or GIS, is a system of computer hardware, software, and procedures designed to store, analyze, and display spatial information. Spatial information is any information that can be mapped, or referenced "geographically." GIS technology has given us the capability to integrate and analyzes large amounts of spatial data that would not have been possible with analog techniques. GIS technology has emerged in recent years from the realm of research and development to one of application and is now rapidly becoming a new and powerful tool for integrating and analyzing spatial data.

The EPA has been investigating the use of GIS in various mission-related applications for several years. One such mission, Superfund site analysis, has been selected by the EPA's Advanced Monitoring Division (AMD) for evaluation by a GIS. This report will not deal with the complex modeling and site analysis that a potential hazardous waste site might be subject to during the CERCLA process, although GIS could assist those operations as well, but will concentrate on the design, production, and application of large-scale, site-specific digital cartographic structures.

EPA has long endorsed the use of historical imagery to fully examine the chronology of hazardous waste sites. Such a study has been done for the Old Southington, Connecticut, landfill. In order to more efficiently utilize this investigation, a pilot GIS demonstration was developed at the U.S. Geological Survey (USGS) incorporating spatial data from EPA, USGS, Soil Conservation Service (SCS), the State of Connecticut, and other sources.

The demonstration employed large-scale custom Digital Line Graphs (DLG's) in a GIS. The DLG is a standard digital mapping product of USGS and portrays spatial themes such as transportation, hydrography, and cultural features. However, at a scale of 1:24,000, the largest production DLG scale available, the standard product lacks sufficient detail and spatial resolution to address the thematic elements of information that are essential to large-scale, site-specific analysis. Additional spatial features, identifying site characteristics not found in standard DLG coding, needed to be implemented to assess the potential for contamination from the landfill. Also, large-scale Digital Elevation Models (DEM's) were compiled to better view the physical relief of the landfill during its operation.

THE REMEDIAL PROCESS

The CERCLA not only established funding mechanism for the cleanup of hazardous waste sites but also defined procedures for the study and evaluation of remedial options. To effectively study the complex issues surrounding most hazardous waste sites, a comprehensive strategy for data collection, processing, testing, sampling, and evaluation is required. This strategy is known as the Remedial Investigation/Feasibility Study. The final decisions must weigh the need to safeguard public health and environmental quality at a specific site against the ability to fund the process there and at other sites across the country.

The instrument of data collection in the remedial process is the Remedial Investigation and the instrument of analysis is the Feasibility Study. The Remedial Investigation emphasizes site characterization and investigation, while the Feasibility Study is directed at weighing options and providing the necessary analytical tools for making decisions.

SITE HISTORY

The Old Southington Landfill is a former municipal landfill located along Old Turnpike Road in Southington, Connecticut. Between 1920 and 1967, the landfill was utilized for the disposal of residential, commercial, and industrial wastes in both liquid and solid form. In 1971, the Town of Southington installed a municipal water well (No. #5) approximately 700 feet northeast of the landfill. In 1971, the well was closed due to elevated and unacceptable levels of trichlorethene, a common industrial solvent, which exceeded the Connecticut Department of Health water quality standards. Collateral data from the EPA and the State of Connecticut indicate that several types of industrial wastes, including those in drums, were accepted into the landfill during its period of operation. The site was predominately a wetland area prior to its becoming a landfill.

The closure of municipal well No. 5, in addition to two other municipal wells within the area, prompted EPA to request a historical aerial photographic analysis of the area by its AMD. To inventory past and present potential contamination sources within an approximately 3-kilometer radius of the closed wells, AMD asked its field station, the Environmental Photographic Interpretation Center (EPIC), to research, acquire and analyze all relevant historical aerial photography. Following the completion of this inventory study in January 1984, EPIC was requested to conduct a more intensive, site-specific aerial photographic analysis of the Old Southington Landfill. This report was completed in February 1988. The landfill is an EPA Superfund site and a potential responsible party in the contamination of well No. 5.

In March 1988, the landfill was selected for a pilot study to demonstrate the applicability of integrating remote sensing and GIS technology to support the acquisition, generation, and processing of site information essential to the Superfund remedial process. Information from the various remote sensing studies along with other relevant data generated by EPA, the State of Connecticut, USGS, and the Southington Chamber of Commerce were used to develop various data sets, models, and scenarios that would relate directly to the needs and requirements of the Remedial Investigation process.

LARGE-SCALE DLG/DEM PRODUCTION

One of the major drawbacks encountered in creating a large-scale GIS data base is the lack of large-scale digital map data. The largest scale data that is commonly available throughout the country is the 1:24,000-scale quadrangles of the USGS. However, for site-specific work, this scale is inadequate for the type of detail and accuracy that its necessary in Remedial Investigation activities. Often the only alternatives are to digitize an existing map of sufficient scale and detail or create a new one. Because there was no existing map deemed suitable by the GIS team, one was photogrammetrically created using a digital analytical stereoplotter and a quad-based control network.

The instrument used to produce the map was an Intergraph Corporation InterMap Analytic (IMA) photogrammetric workstation. The IMA is a first-order instrument that utilizes advanced analytical stereoplotter technology with interactive graphic capabilities that allow the operator to digitize, code, and create digital data structures in an interactive, three-dimensional environment.

Aerial photography acquired in 1986, as part of the standard historical site investigation was utilized for map compilation. The black-and-white photographs were standard 9 by 9 inche format and were acquired according to mapping cartographic specifications. The scale was approximately 1:12,000. Because time constraints did not allow for the establishment of surveyed control data, control was generated by digitizing selected photoidentifiable coordinates from a stable-base, 1:24,000-scale USGS color separate. The photogrammetric model was set using this control and followed standard model setup procedures (interior, relative, and absolute orientations). The final root mean square error for the production model was approximately 5 meters horizontally and 0.3 meters vertical.

Because the temporal aspects of this site spanned a considerable amount of time, the surrounding land use depicted on a current map base would not be sufficient for portraying historical development. To solve this problem, a second DLG was created from 1951 imagery to show the differences in the surrounding land use and to provide a more realistic base for the historical thematic overlays.

The DEM's were produced by using an OMI AS11A1GS analytical stereoplotter and standard profiling software developed by USGS. To capture the subtle changes in landscape and terrain that would be essential to large-scale applications, the sampling interval was reduced to approximately 5 meters instead of the usual 30 meters that is standard in DEM production. As with the DLG's, both 1986 and 1951 aerial photographs were used to create the data that showed the terrain profile differences in a historical setting.

CREATION OF A LARGE-SCALE CUSTOM DLG AND DEM DATA BASE

After processing the newly compiled large-scale topographic data set, the data were converted for entry into the GIS data base. Attribute information corresponding to the standard USGS DLG product was assigned to the topology and built into the relational data base management system. These attributes include topographic features such as roads, trails, streams, and wetlands. In addition, buildings were delineated and attributed as to their use, such as residential, commercial, or light industrial.

Because of the historical nature of the investigation, 1951 photographs were used to create an additional DLG and DEM to help analyze activities at the site during the course of its operation. The attribute coding for the historical DLG was identical to the present-day DLG.

This data set helped to reflect changes in the topographic, land use, and wetland characteristics found around the site while the landfill was active.

Once entered into the GIS, basic area and linear measurements were automatically calculated from the topology and became a part of the data base management system. The large-scale study area containing the custom DLG is approximately one square mile, while the full extent of the landfill is 15.75 acres. A quick GIS analysis of the two custom DLG's reveals that the closed landfill now contains four residential buildings and six commercial/industrial buildings and contains approximately 10 acres of wetland.

CREATION AND ANALYSES OF A SITE-FEATURE DATA BASE

Site features, compiled from historical aerial photographs, have been digitized and coded in the same manner as the topographic DLG's. Using the same instrument to produce the site-feature DLG, a data base of specific features associated with potential contamination sources was created to help document past activities attributed to the landfill. These potential sources of contamination were recorded from photography flown in 1941, 1951, 1957, 1965, 1967, and 1970, covering the entire existence of the landfill.

These features are especially important in developing data for the site history and characterization needs of the Remedial Investigation.

Because the standard DLG coding scheme relies on a unique set of feature attributes, a cross-over coding classification scheme (table 1) was implemented to take advantage of the standard DLG encoding system during digital compilation of the site-feature DLG.

A site-feature DLG was created for each year recorded during the photointerpretation phase of the EPIC investigation. A test was devised that would help identify the positions of these historical site features in relation to present-day topographic and cultural features. By selecting significant features or features that would automatically raise questions as to their potential threat to the surrounding environment and overlaying them with present-day topographic and cultural DLG's a graphic was produced that might produce questions and answers regarding the Remedial Investigation.

For example, the four homes in the extreme north of the landfill are built near a 5-acre debris field. By examining the historical site-feature DLG, it is noted that the debris field was active during the mid to late 1960's. Does the old debris field pose a health threat to the occupants of these homes? Another related issue might be, did the home owners know of the proximity of the debris field before their purchase? Farther south, within the landfill, a trench containing standing liquid appears on the 1951 site-feature DLG. This signature often indicates improper disposal methods and is usually investigated for a possible threat to the ground water. By observing the position of an existing building, the placement of a monitoring well or core sample site, which could determine the identity of the liquid, might be better located. Off site and northwest of the landfill, the 1970 site-feature DLG reveals a small area of less than a half acre containing drums, debris, and mounded material. This observation by itself might not be cause for great alarm, however, given the area's proximity to a known contaminated well (less than 100 meters) and the fact that an industrial building sits on top of this potential hazardous waste site, questions arise. Were these materials properly disposed of or are they now part of the present building's foundation?

Table 1.--Digital Line Graph cross-over coding classification scheme epic legend/DLG crossover coding - project pic 88084

[Environmental Monitoring Systems Laboratory Report TS-PIC-88031, site analysis, Old Southington Landfill, Southington, Connecticut]

EPIC[1] LEGEND (MEANING)	DLG CODE	(MEANING)
Auto junkyard	200.0423	(oil reservoir)
B (building)	200.0402	(church)
Berm	200.0211	(coke ovens)
C (containers)	200.0403	(school)
Cleared area	200.0406	(Post Office)
DB (debris)	200.0404	(municipal Building)
DK (dark-toned)	200.0601	(underground)
Discolored	200.0607	(chemical)
Drums	200.0451	(swimming pool)
E (equipment)	200.0405	(courthouse)
EX (excavation/extraction)	200.0430	(strip mine)
Fill area	200.0427	(mine dump)
GS (ground scar)	200.0445	(fairgrounds)
Graded area	200.0452	(ruins)
IM (impoundment)	200.0453	(recreation area)
LT (light-toned)	200.0603	(abandoned)
M (material)	200.0434	(storage bin)
MM (mounded material)	200.0436	(spoil bank)
Open trailer	200.0410	(town)
OS (open storage)	200.0450	(fort)
Pit	200.0432	(pit)
Pond	200.0421	(STP)
REV (revegetated)	200.0608	(covered)
Revegetated area	200.0447	(corral)
SL (standing liquid)	200.0433	(radio/TV facility)
ST (stain)	200.0454	(picnic area)
TR (trench)	200.0465	(pile, dolphin)
UC (under construction)	200.0602	(under construction)
V (vehicles)	200.0468	(sunken wreck)
Well	200.0307	(drilled well)
SYMBOLOGY ONLY		
--------------- Access road	200.0200	(conveyor)
_ . _ . _ . _ . Drainage	200.0201	(broadwalk)
_______________ Site boundary (solid line)	200.0206	(fence)
_-_-_-_-_-_-_ Historical boundary (long-short/long-short)	200.0422	(waterworks)
_______________ : : : : : : : : Sloped edge	200.0435	(levee)

[1] Environmental Photographic Interpretation Center, Environmental Protection Agency

PROPERTY OWNERSHIP

An important part of the Remedial Process is the determination of both the responsible parties and those potentially affected. As in many multipurpose cadastre issues, the importance of exact locations of property ownership boundaries is of paramount concern. For a quick assessment of property ownership, however, a property data base was extracted from county tax records and digitized and transformed to the baseline coordinates of the custom DLG.

This process allows an investigator to look at the chronology of ownership during the life of the landfill and to relate specific site characteristics to specific years of ownership. Because only those tax records that related to the years of photointerpreted site characteristics were used in the analysis, the results were not always be conclusive, but they helped to identify areas that required more information.

The property ownership investigation focused only on the landfill as it was identified in the photointerpretation phase. This meant that ownership boundaries were compiled for the landfill but not for surrounding areas. Even though early analysis of the actual landfill indicates less than full use of the area delineated as the landfill extent, all property boundaries within the site are defined. Also, to simplify site characterization within the property lines, a significant feature data set was extracted from the overall site-feature data base.

The initial photo analysis of the site utilized 1941 imagery that coincided with the beginning of activity in the landfill. Although only an isolated debris field is revealed, it is well within the property lines of the Town of Southington, operators of the landfill. Ten years later, 1951, a slight movement south of the initial debris field is evident; however, all landfill activities remain within the town's property lines. Analysis of the 1957 data reveals the first significant features, mounded material/stains, to be found off the town's property. Also, the development of an elongated debris field with a north/south orientation and curving west to stay within the town's property boundary is evident. The 1965 ownership/site-feature analysis produces some new ownership and possibly some new strategy in landfill debris collection. All major debris accumulation now occurring off the town's property, and the largest debris field, 1 acre, is located within the adjacent property to the north.

The change in location of landfill activity also coincides with a change in ownership of the northern parcel. Expansion of the debris field to 1.5 acres is detected within the northern parcel 2-years later, 1967, while landfill activities show signs of decreasing within the town's property lines and elsewhere. Termination of landfill activities is complete in 1970, although associated activities offsite have picked up, possibly because of the closing of the landfill.

DIGITAL ELEVATION MODELS APPLICATIONS

Large-scale DEM's were created from 1951 and 1986 aerial photographs to address several issues that typically arise in the Remedial Investigation. DEM's were created for the same square mile area that was mapped during the large-scale DLG production. After transforming the DEM data into ARC/INFO Lattice and triangulated irregular network formats, several application scenarios were developed.

First, the overall area was transformed into three-dimensional perspective views showing the topographical relationship between the landfill and the surrounding area. These perspectives not only give the viewer a better understanding of the topography of the overall area but are also detailed enough to show subtle drainage and runoff characteristics. When the DLG and other thematic overlays are draped over the three-dimensional image, the interrelationships among the various information elements can be better understood. This type of interrelated information is critical to network modeling, contaminant migration studies, and risk assessment, which are key issues in the Remedial Investigation process.

Second, the landfill boundary is extracted from the large-scale DEM for both 1951 and 1986, and volume calculations were performed for each year. The difference between the 1951 and 1986 volume theoretically shows the total amount of fill material that has been placed in the landfill during that period, which is roughly before and after landfill operations. This information can be used in a variety of Remedial Investigation scenarios, including cut-and-fill and other engineering applications.

Finally, an individual property was extracted from the DEM and the same volume calculations performed for that property. This information can be utilized as a quantifying factor for damage calculations and risk assessment.

SUMMARY

This pilot project demonstrated that custom large-scale DLG's and DEM's can be generated for use in a GIS. For those GIS applications that do not need custom baseline data sets existing DLG's, might be appropriate. However, if the requirement exists, such as in this Superfund site investigation, the capability to create the required unique data base is available.

In this case the need for custom large-scale data sets was directly related to the application. When areas to be examined are less than a few square miles and precise measurements are required, topographic and other features must be precisely positioned and existing data sets might not always be suitable for this purpose.

Concerning the issue of spatial accuracy USGS complies with National Map Accuracy Standards for its graphic maps and sets its digital standards from these stable-base cartographic products. If larger scale DLG's were systematically produced for use in analytical investigations, such as the one described here, then accuracy and coding standards must first be addressed. Questions regarding cartographic data bases, such as the USGS DLG, versus geographic data bases compiled from original source material, such as the custom DLG used in this project, are being addressed by USGS and other organizations.

As a result of the Old Southington GIS project, EPA and USGS are investigating accuracies and standards that will ensure the integrity of spatial data and multipurpose cadastre analysis of the remedial process. In December 1988, a Global Positioning System (GPS) survey was performed at the landfill site to determine the feasibility of using this technology for remedial investigations. The GPS survey will provide precise coordinates for stereocompilation of the large-scale DLG. A statistical spatial accuracy test is being performed as part of ongoing interagency research and will be reported on at a later date. The EPA has also initiated a study to standardize a coding scheme, such as the cross-over classification system used in this project.

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