HAZARDOUS WASTE DISPOSAL SITE SELECTION USING INTERACTIVE GIS TECHNOLOGY

Calvin Van Zee
Ebasco Services, Inc.
10900 NE 8th St., Bellevue WA 98004

John E. Lee
QC Data Collectors, Inc.
777 Grant St., #111, Denver, CO 80203

ABSTRACT

Site selection for disposal of hazardous waste requires consideration of numerous geographic factors. Use of a Geographic Information System (GIS) can facilitate examination of interaction between site-related factors. The IBM PC AT-based GIS STRINGS(tm) was used to cartographically model and identify potential landfill disposal sites for hazardous waste on the US Army's Rocky Mountain Arsenal in east-central Colorado. A digital database was created from multi-source maps of topography, hydrography, geology, transportation, utilities, land use/status, and man-made features. Several data themes were derived using reclassification, compositing, proximity, and polygon overlay analysis techniques. A cartographic model was built to identify potential sites based upon user-defined criteria. Interactive computer sessions with technical experts were used to further refine the model and test site alternatives. The "slide" function of the GIS allowed rapid interactive viewing of site-related factors. Executive decision makers were able to identify and choose between site alternatives in 3 1-hour computer sessions that might otherwise have taken months using manual cartographic methods.

INTRODUCTION

Disposal of hazardous waste has become a pressing environmental concern. Selection of a disposal site requires consideration of numerous geographic features and their interaction, and usually involves numerous governmental agencies with varied siting criteria. U.S. Army scientists at the Rocky Mountain Arsenal (RMA) near Denver, Colorado studied the feasibility of different hazardous waste disposal options. One possibility which was considered was on-site landfill. Factors which were considered in selecting a landfill site for disposal of these wastes included topography, transportation, utilities, land status, hydrography, geohydrology, and man-made features. Consideration of all of these factors was an enormous task, even on the relatively small area of the RMA (17,000 acres).

Use of a (GIS) permitted editing, analysis, and display of more site selection criteria combinations than would have been possible with hand-drafted methods. In addition, interactive computer sessions with the GIS database allowed executive decision makers to quickly modify criteria and identify site alternatives on a real-time basis. Producing these site alternatives with traditional engineering drafting methods would have taken months of manpower effort.

METHODS

Hardware/Software

The STRINGS(tm) GIS was used for this project. STRINGS (GeoBased Systems, Inc., Research Triangle Park, NC) is a topologically-structured (arc/node) vector-based GIS package with digital data capture (map registration and digitizing), attributing (primary and multiple), element editing (interactive and batch), database management (edge-matching and rubber-sheeting), polygon formation (with island identification), display (interactive and hard-copy), reporting (query and hard-copy), and cartographic analysis (reclassification, overlay, and distance) capabilities.

STRINGS operates on IBM AT (or compatible) personal computers under MS-DOS. This study used a Sperry IT CPU with 640 KB RAM, a 30 MB hard disk drive and 1.2 MB floppy disk drive, an 80287 math co-processor, serial/parallel ports, a monochrome text monitor, a high-resolution (1024 x 1024) color (RGB) 19" graphics monitor with Vectrix Pepe graphics controller, and a MicroSoft Mouse.

Map digitizing was accomplished using a high-resolution (0.005") large-format (48 x 60") Calcomp 9100 digitizing tablet with power stand, backlighting, and magnifying (5x) 16-button cursor. Hard-copy plotting was accomplished using a high-resolution E-size Calcomp 1073 4-pen plotter.

Database Creation

Several source maps were used in preparation of the geographic database for the RMA. These maps were at various scales, on different media, and containing various types and amounts of information. The first step in database creation was to identify the data themes to be captured, as follows:

- Topography (elevation contours at 5′ intervals)

- Public Land Survey (township, range, and sections)

- Ground Water (ground water contours at 10′ intervals)

- Bedrock (bedrock contours at 10′ intervals)

- Land Status (exclusions due to ownership/development)

- Hydrography (lakes/basins, creeks, and ditches)

- Flood Plains (100-year flood plain outline)

- Transportation (paved and gravel roads, and railroads)

- Electricity (main and distribution electrical lines)

- Pipelines (oil and gas pipelines)

Data for each of these themes was captured separately and stored in a separate map file. Only data within the boundary of the RMA was captured, thus the boundary acted as a common border for all map themes. A primary integer attribute code was also assigned to each feature within a theme.

All data was captured in Colorado State Plane Coordinates (SPC) due to their suitability for engineering applications and anticipation of new surveying data being incorporated in the digital database. Maps were registered to the digitizing tablet using up to 16 points with known State Plane coordinates. Where no known points were available, USGS 7.5' quadrangle maps were registered and used to determine State Plane coordinates for points in common between the USGS map and the source map. These points were often section corners, road intersections, or stream confluences.

After the maps were registered to the digitizing table, an operator digitized the data as either lines or polygons. For example, streams were captured as lines and the flood plain was captured as a polygon. After digitizing, the data was topologically structured and polygons were formed.

All data derived from separate and adjacent map sheets were edge-matched to ensure topological and attribute continuity. After edge-matching, the maps were merged to produce one seamless map of the study area.

After merging, all data were rubber-sheeted to known SPC's. State plane coordinates for section corners on the RMA were obtained from a surveying firm and then compared to the section coordinates determined through digitizing. The database was then rubber-sheeted according to a least squares transformation to yield a more accurate coordinate database across the entire study area.

<u>Database Analysis</u>

Once the database was complete, several data themes were derived using cartographic analysis techniques; reclassification, overlay, proximity, and compositing.

The map database was reclassified according to geographic viewing windows and primary attributes. For example, hydrographic and man-made features data were combined to create an exclusion area theme.

Overlay analysis was performed between topographic contours and ground water contours to produce a depth-to-ground water map and also between topographic contours and bedrock contours to produce a depth-to-bedrock map. These products were then overlayed to determine difference between groundwater and bedrock depth and produce a saturated alluvium theme (i.e., ground water elevation higher than bedrock elevation).

Proximity analysis was performed to determine 1000′, 0.5 mile, and 1 mile buffers inward from the RMA boundary.

Compositing (map merging) was used to produce final map displays of more than one data theme.

For editing and site selection previewing, hard-copy plots and interactive graphics monitor displays were developed. For each map product, a legend identifying attributes and codes; a title identifying participating agencies and companies, map source, map number, and approvals; and a map title, bar scale, and north arrow were added. Then colors were assigned to lines and text, and solid fill or shading assigned to polygons. Pen plots in black and white, and color, were produced on paper and mylar at different scales. Graphic monitor displays were produced interactively and also saved as "slide" files for faster display at a later time.

The Cartographic Model

A GIS lends itself to the solution of cartographically related problems through construction and solution of a cartographic model. Typically, the desired end product is identified first. Next, the steps and data required to reach this end product are identified. Thus, a tree-diagram or flow chart is constructed from final product (left) to beginning products (right) and then a GIS executes this model from right-to-left.

The end product was to identify a potential landfill site for hazardous waste disposal on the RMA. Siting criteria included:

- a maximum depth-to-ground water
- a minimum depth-to-bedrock
- at least 1/2 mile inwards from the RMA boundary
- location outside of the 100-year floodplain
- a minimum size of 1,000 acres
- away from existing infrastructure (roads, pipelines, buildings, etc...)

Several intermediate map products were necessary to reach a decision on a proposed site and were derived through analysis, as described previously.

RESULTS

As the cartographic model was executed, interactions among the siting variables necessitated a trade-off among criteria to define multiple potential sites. Interactive computer sessions were held with technical siting experts and executive decision makers and alternatives and trade-offs in the criteria were tested.

Six potential sites were defined during these interactive sessions. Criteria which were varied included distance from the RMA boundary, depth-to-groundwater, and depth-to-bedrock. Criteria which were deemed to be inviolate included floodplain, exclusion area, and site acreage. Users then ranked each site based upon their assessment of the priority of each criteria.

Once potential sites had been identified the GIS "slide" function was used to save the screen displays for future high-speed viewing by other decision makers. Thus, during interactive computer sessions, executive decision makers were able to identify and choose between site alternatives. Using traditional engineering drafting methods, this process might have taken months. Use of the interactive GIS slide function allowed rapid viewing of alternatives and recommendation of the preferred potential hazardous waste landfill site.

When this project began in May 1986, STRINGS was one of the only PC-based vector GIS' with an arc/node data structure facilitating complex polygon overlay analysis. Other PC-based GIS' are now available. While this paper is not an endorsement of, or a comparison between, systems, several lessons were learned on this project. The STRINGS package proved to have an efficient and user-friendly data entry, analysis, and display system. The database for this project had to be compiled, edited, and analyzed, and display products created within 2 months. Use of STRINGS facilitated this task. All project deadlines were met and executive decision makers were generally pleased with output products.

The slide function of the STRINGS GIS proved particularly useful in interactive sessions. This function allows screen graphics displays to be built and then stored as an image file for rapid viewing at a later time. Thus, complex displays could be created by an operator and then viewed by decision makers without having to wait for graphics processing to be accomplished by the GIS. These images were repeatedly displayed to compare pros and cons of alternate sites. If new slides were requested during an interactive session, executive decision makers would take a break while analysts prepared a new slide file for review. This new slide would then be compared with previous slides until decision makers were satisfied that all site alternatives had been evaluated and that trade-offs between sites were fully understood. In this way, a preferred site was determined in 3 1-hour interactive computer sessions versus months of manpower effort which would be required using traditional engineering drafting methods.

CONCLUSION

This paper has attempted to demonstrate how a GIS can be used to identify potential landfill sites for hazardous waste disposal. By utilizing STRINGS, geographic data was effectively captured, stored, edited, analyzed, and displayed using an IBM AT-based GIS. Here, base map data on the RMA was captured digitally, analyzed through a cartographic model, and finally the map products and cartographic model solutions were displayed in plots and screen images. Use of interactive computer sessions allowed executive decision makers to rapidly identify alternatives and trade-offs and further refine the cartographic model.