Carcass Disposal: A Comprehensive Review

National Agricultural Biosecurity Center Consortium
USDA APHIS Cooperative Agreement Project
Carcass Disposal Working Group

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Chapter

15

Geographic Information Systems (GIS) Technology

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Abbreviations

CAFO	confined animal feeding operation
FEMA	Federal Emergency Management Agency
FMD	foot and mouth disease
GADER	GIS for animal disease and emergency response
GIS	geographic information systems
GPS	global positioning system
POTW	publicly owned treatment works
PRV	pseudorabies virus
SSURGO	soil survey geographic

Section 1 – Key Content

Geographic information systems (GIS) should play a significant role in the management of mapped or spatial data prior to, during, and after carcass disposal events. At the simplest level, GIS can provide maps, while at the more complex level can serve as a decision support capability. This chapter contains an overview of GIS and its applications. Examples of how GIS has been used in recent livestock disease and carcass disposal efforts are also provided.

The site requirements for specific carcass disposal technologies vary, as do their site-specific impacts on the environment. GIS can play a significant role in the analysis or screening of potential sites by considering the requirements of carcass disposal technologies and identifying and mapping locations within a region that meet these criteria. For example, burial sites should be some distance from surface waters and various cultural features, should not impact groundwater, may require certain geologies, and may have other site requirements. The result of analysis of these requirements in a GIS is a map or series of maps that identify sites where carcass disposal technologies would likely be suitable. Further on-site analysis of locations would be required prior to actual site-selection for carcass disposal.

GIS data layers are critical to determining the appropriate use of carcass disposal technologies. This chapter expands on the GIS data layers that would be useful. Checklists describing the data layers that can be used to refine the selection of the specific GIS data layers are included. Note that it is important to collect, organize, and preliminarily analyze data prior to a carcass disposal event due to the time required for such efforts.

Web-based GIS capabilities have improved significantly in the last few years. The creation of web-based GIS capabilities to support carcass disposal efforts could overcome some of the access and other issues related to desktop GIS and make mapped information available to decision-makers and field personnel in real time.

GIS are important in the application of environmental models to address environmental concerns associated with carcass disposal. GIS can provide the data required by these models and can provide visualization of the modeled results in map form.

Section 2 – Introduction

Recent advances in information technology–including hardware, software, and the Internet–have provided capabilities to potentially enhance problem solving in areas that require information processing. Among several information technologies that have been incorporated with other areas, Geographic information systems (GIS) are one of the most popular tools to be utilized in decision making. GIS have had a profound effect on decision support system development, especially environmental modeling and model development, because GIS can supply functionality for dealing with spatial information that is required in most decision-making processes.

Fire, flooding, or a disease outbreak can suddenly result in a large number of dead livestock, presenting a challenge in the disposal of carcasses. Carcass disposal should be handled correctly and quickly because various environmental impacts may result on surface water, groundwater, soil, and air. A massive carcass disposal effort requires careful analysis of carcass disposal site selection and transportation issues.

GIS can play a significant role in carcass disposal in several areas including site selection, transportation planning, and environmental evaluation due to its spatial information processing and data query capabilities. For example, spatial information

processing can assist with disposal site selection using layer overlay operations, map algebra, and buffering, while road map queries and routing can be used to assist with identification of carcass transportation routes.

Maps can also be a valuable tool to help epidemiologists identify spatial patterns of disease as cases occur. Perhaps one of the best known examples of this was the observation by John Snow, a physician working in London in 1854, who demonstrated a spatial association between cholera cases and a single water supply (Freier, 2003). Eliminating public access to the contaminated water supply brought an end to the outbreak (Snow, 1994).

Carcass disposal and treatment sites are usually environmentally vulnerable, because large numbers of carcasses present difficulties in removing potentially harmful sources, such as pathogens, liquids, and organic material. Spatial information that is pre- and post-processed in GIS also can assist with environmental impact assessment before and after carcass disposal.

This document overviews how to utilize GIS capability for responding to an emergency outbreak requiring disposal of a large number of carcasses, carcass disposal site selection, and environmental assessment. It also provides a short overview of GIS to provide essential knowledge in using the spatial information and processing capabilities of GIS.

Section 3 – Strategic Use of GIS

3.1 – Role of GIS Task Forces in Decision Support Strategy Using GIS

To use GIS as a spatial information tool in carcass disposal processes, specialized GIS task forces should be organized with team members that are familiar with GIS functionalities (Figure 1). Human resources are a key component among the five GIS project components that include hardware, software, data, human resources, and methods. GIS task forces should be composed of a manager, developer, and data manager, with each having a specific role.

3.2 – GIS Role for Animal Health Issues

Spatial database construction

Spatial data collection and database construction is important to ensure the GIS provides appropriate information to decision makers, because the data quality in the database affects secondary information quality. A well-prepared database can make analysis fast and efficient and provides versatile support in carcass disposal decision making. Data collection through site investigation, for instance using Global Positioning System (GPS), and collection of spatial data from a clearinghouse or other sources such as federal, state, or local government agencies, are typically necessary for spatial database construction. In most instances, it is desirable to develop a spatial database prior to a carcass disposal event, since the development of such a database can require a significant level of effort and time.

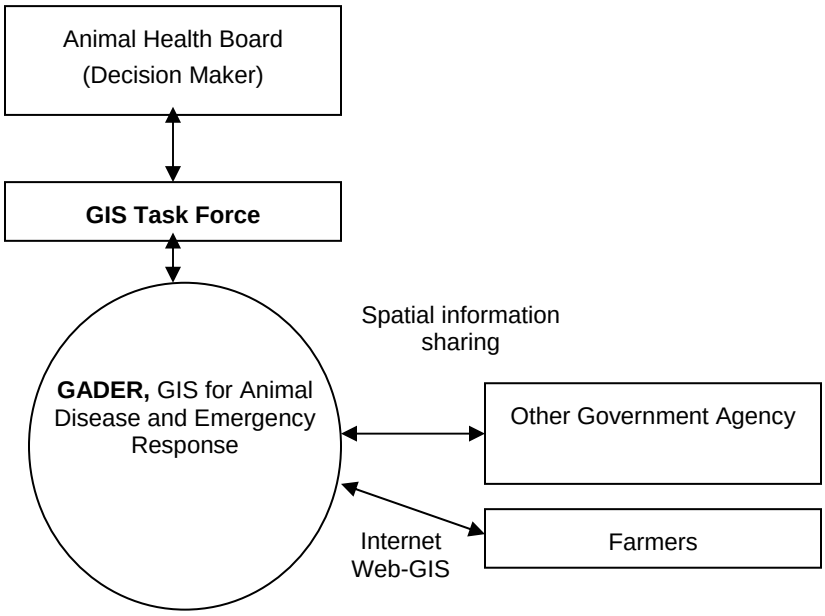

FIGURE 1. Schematic diagram of spatial information sharing among agency and people related with the animal disease outbreak using GIS.

Historical/spatial transaction and surveillance for animal health issues

Time series analysis and GIS-derived spatial statistics based on observations of disease spread can be helpful to animal disease propagation analysis efforts. Such analyses can provide information key to preparation for an animal emergency. Spatially tracking animal health issues and creating digital maps showing animal disease outbreak cases can provide an opportunity for optimal decision making in preparing for an emergency.

GIS and spatial analysis are especially well-suited to farm-level, environmental, and epidemiological applications. The first steps in GIS may involve collecting data in the real world and converting this to a series of representative objects within the GIS to create mathematical representations of landscape features. Once the spatial components have been assembled, various visualization tools, exploratory data analysis methods, and model-building techniques can be applied. GIS provides a powerful means of managing data related to a disease outbreak, especially in designing surveillance strategies and monitoring spatial-temporal trends as cases are reported.

Although GIS methods offer a data-organizing mechanism that can be used to enhance knowledge about how infectious agents are maintained and spread, there are many challenges to overcome in spatially referencing information about an epidemic, as well as protecting the confidentiality of data. While many aspects of emergency management can benefit from GIS use, each phase is likely to have different goals and specialized needs that must be satisfied. Unfortunately, GIS is interpreted by many to be simply the making of maps. It is important that emergency managers have a better understanding of the planning, surveillance, analysis, and modeling tools available within GIS. Finally, if GIS is going to be used effectively in emergency management, it is critical that response plans incorporate spatial methods from the beginning.

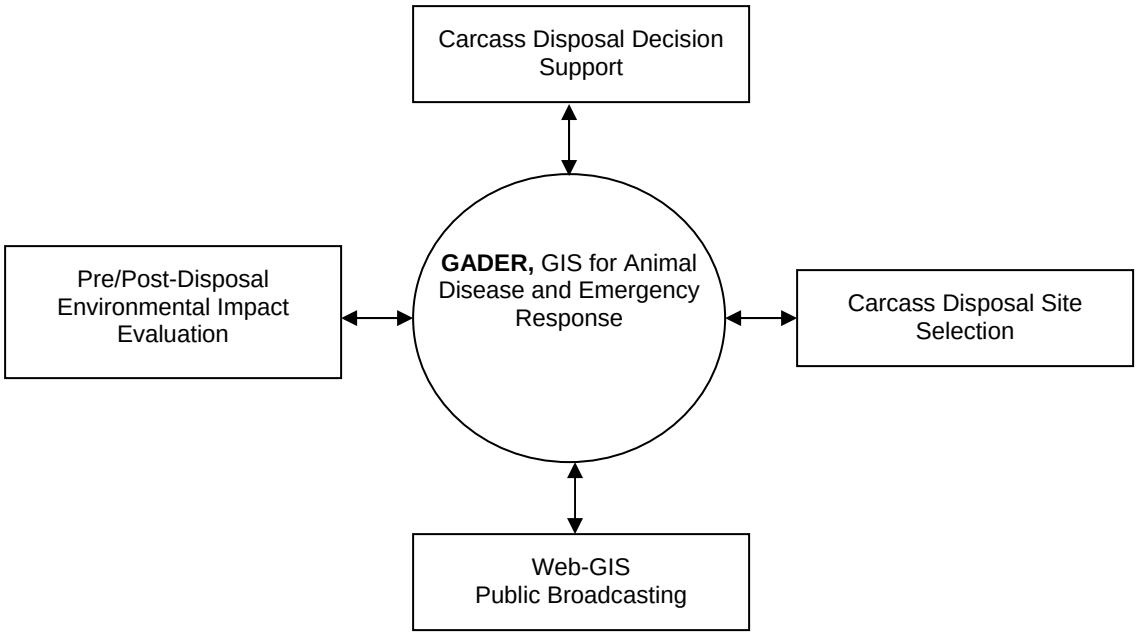

FIGURE 2. GIS tasks while disposing of carcasses.

Before a carcass disposal event, it is vital that certain essential information be available about administrative boundaries, roads, terrain, watersheds, and vegetation. In addition, a national spatial infrastructure regarding livestock and poultry movement is needed, as well as established partnerships with data providers to obtain appropriate population and environmental information to help prevent disease spread.

Organizing data in a GIS for use in epidemiological studies presents several challenges. The most vexing of these challenges are: (1) representing exposure in spatial terms that can be used in statistical analyses, (2) showing activity spaces (e.g. home ranges), (3) incorporating residential histories of animals, and (4) modeling the social environment. In addition to showing exposure, activity spaces, residence, and interaction models, one of the most important decisions to make is that of scale. The scale level should be appropriate for the issues being investigated in an analysis; otherwise, the results will not be meaningful and may be misleading. Finally, a major challenge when working with farm-level information is the problem of data confidentiality. These challenges are receiving significant attention by the ever-growing number of health workers utilizing GIS methods. The animal health community will benefit greatly by becoming actively involved in finding solutions to these challenges associated with gathering spatial data (Freier, 2003).

3.3 – GIS Support Categories for Carcass Disposal

Map production and spatial information sharing

GIS can strategically support carcass disposal staff through a variety of map products created from spatial databases. During eradication of an emergency animal disease, maps from spatial analysis provide an important communication and planning aid which can be useful in defining the location and extent of the disease and spatial relationships between properties within and adjacent to the affected areas. Maps provide two major management advantages. The ability to encompass the incident within boundaries gives better definition

and visualization of the tasks and advances the probability of their achievement. Progress can be instantly recognized; for example, the change of status from "red" to "blue" can be a powerful stimulus for encouragement (AUSVETPLAN, 1999). Maps can be shared with users ranging from decision makers to farmers through Web-based GIS capabilities as shown in Figures 1 and 2. A GIS task force might operate GIS for animal disease and emergency response (GADER), and provide decision support materials including maps and tables. The GADER component could also provide Web-based GIS maps to the public and other government agencies involved in the emergency.

Role of GIS during carcass disposal site selection

The spatial analysis functionalities of GIS can be applied to select carcass disposal sites considering the site characteristics required for various disposal technologies and the potential for environmental impact, transportation accessibility, and secondary infection of nearby livestock. Incorporating GIS analysis in the decision-making process can minimize environmental, social, human, and economic impacts. The GADER concept depicted in Figure 2 can also be used for preliminary carcass disposal site selection before an emergency, in the selection of an actual carcass disposal site during an emergency, and in follow-up environmental evaluation and monitoring of disposal sites. Spatial information and post-visualization functions in GADER can be integrated with environmental impact evaluation models to assist in site selection. Preselection or some level of screening of carcass disposal sites can accelerate response during carcass disposal, because emergency response staff can more quickly identify appropriate disposal locations. Possible GIS output for supporting animal carcass disposal tasks are described in Figure 3.

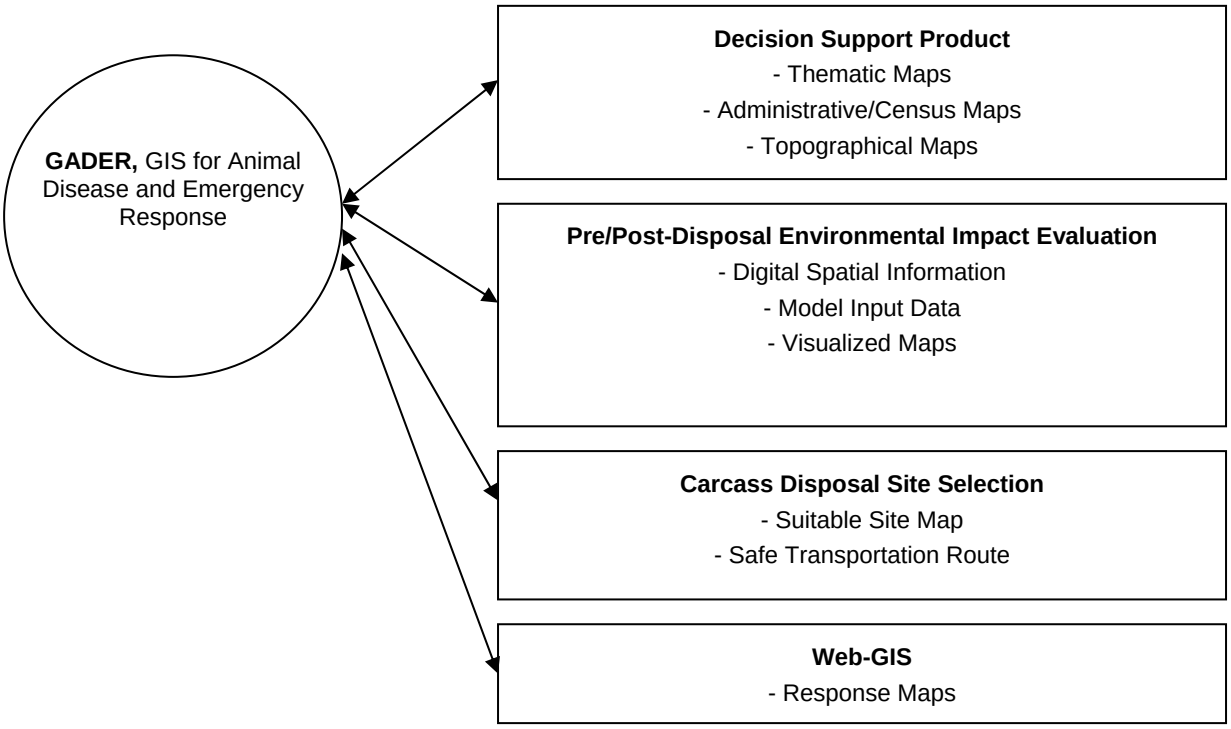

FIGURE 3. GIS output for supporting animal carcass disposal tasks.

Several examples were implemented to show how GIS can assist in the carcass disposal process and are appended at the end of this chapter. The examples presented are as follows:

- Preliminary carcass disposal site selection in six Indiana counties (Appendix A).
- Web-based GIS and airborne disease propagation example (Appendix B).
- Disposal site layers ranking system (Appendix C).

Decision support strategy using GIS

Reaching a final decision in many areas including carcass disposal often includes quite complicated processes; for optimal decision making, information from various sources is required. Spatial information is essential to address animal health and carcass disposal issues during an emergency situation. Due to several distinct capabilities, GIS has been commonly included in decision support systems to provide spatial information and analysis capability.

The Federal Emergency Management Agency (FEMA) has defined an emergency response cycle include preparation and prevention, disasters and emergencies, and response and recovery. By reflecting on the response cycle steps, a strategic use of GIS diagram is presented in Figure 4.

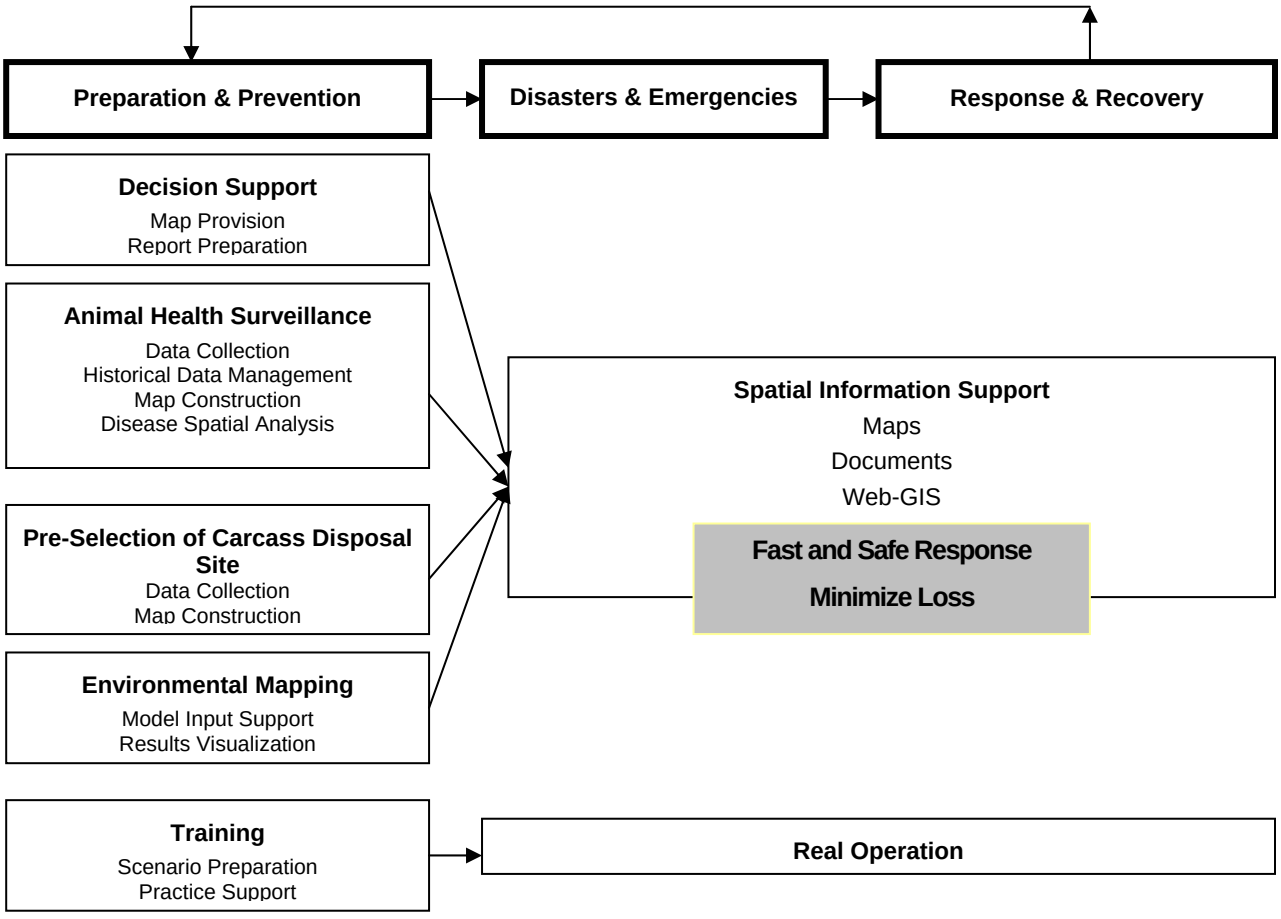

FIGURE 4. Decision support strategy using GIS following FEMA's emergency response cycle for animal health issues.

During the preparation and prevention stage, GIS can assist with several tasks in animal health and carcass disposal management including:

- Decision support
  - Map provision
  - Report preparation
- Animal health surveillance
  - Data gathering
  - Historical data management
  - Map construction
- Preselection of carcass disposal site
  - Data gathering
  - Map construction
- Environmental mapping
  - Model input support
  - Results visualization
- Training
  - Scenario preparation
  - Practice support

Those jobs during the preparation and prevention stage using GIS can promote the next two stages for emergencies and response in terms of safety and speed. Visualization of data and trained staff can improve emergency response. It may also minimize losses, prevent disease propagation into other places, and increase efficiency of resource use.

Section 4 – GIS Application

4.1 – Map Making During a Disaster

During an animal disease outbreak or carcass disposal event, several maps can be created to assist response efforts. These maps can be distributed to staff involved in responding to the emergency. The maps can include:

- Preselected carcass disposal sites.
- Transportation routes.
- Disease development and propagation status.
- Evacuation area and contagious possibility.
- Farm/industry/public facilities inventory.

The preselected carcass disposal site map can be prepared before the disaster by a GIS task force using GADER to respond quickly to an animal disease outbreak or carcass disposal event. The map can assist decision makers in identifying appropriate places to dispose of carcasses safely and efficiently. Transportation route maps can be useful to find safe routes to transport contagious material. Disease development and propagation status maps, evacuation area and contagious possibility maps, and farm/industry/public facilities inventory maps can be useful for predicting the disease spread trend and sanitizing the places likely to be contaminated. GIS also can be used to prevent propagation of the disease by setting control lines based on the map of the disease movement and can help identify the possible evacuation area.

4.2 – Spatial Data and Analysis for Disposal Site Selection

Analysis methods

A common task in GIS analyses is to rank a group of layers which affect a process, then sum the rankings to display where something is impacting the process. In such a fashion, GIS processes may be used to create exclusion zones where an activity such as

carcass burial is inappropriate, unsuitable, or less desirable. The simple concept of an exclusion zone where something is forbidden (for example, the typical practice of forbidding home building in 100-year floodplains) can be modified to show levels of suitability, or a suitability ranking, where an activity is increasingly less appropriate based on the physical characteristics of the site.

To define exclusive or inclusive areas, a buffering technique is frequently adapted. Buffering is a typical spatial function in GIS to define a zone of a specified distance around coverage features such as roads as shown in Figure 5. For instance, both constant- and variable-width buffers can be generated for a set of roads based on each road's attribute values, like pavement or number of lanes. The resulting buffer zones form polygons-areas that are either inside or outside the specified buffer distance from each feature. Buffers are useful for proximity analysis (e.g., find all stream segments within 300 feet of a proposed carcass burial area). Map algebra and data overlay is another spatial analysis function to sum the rankings to display where something is impacting the process. Figure 6 is a prototype approach for carcass disposal site selection procedures using GIS spatial analysis. Refer to Appendix B for additional information.

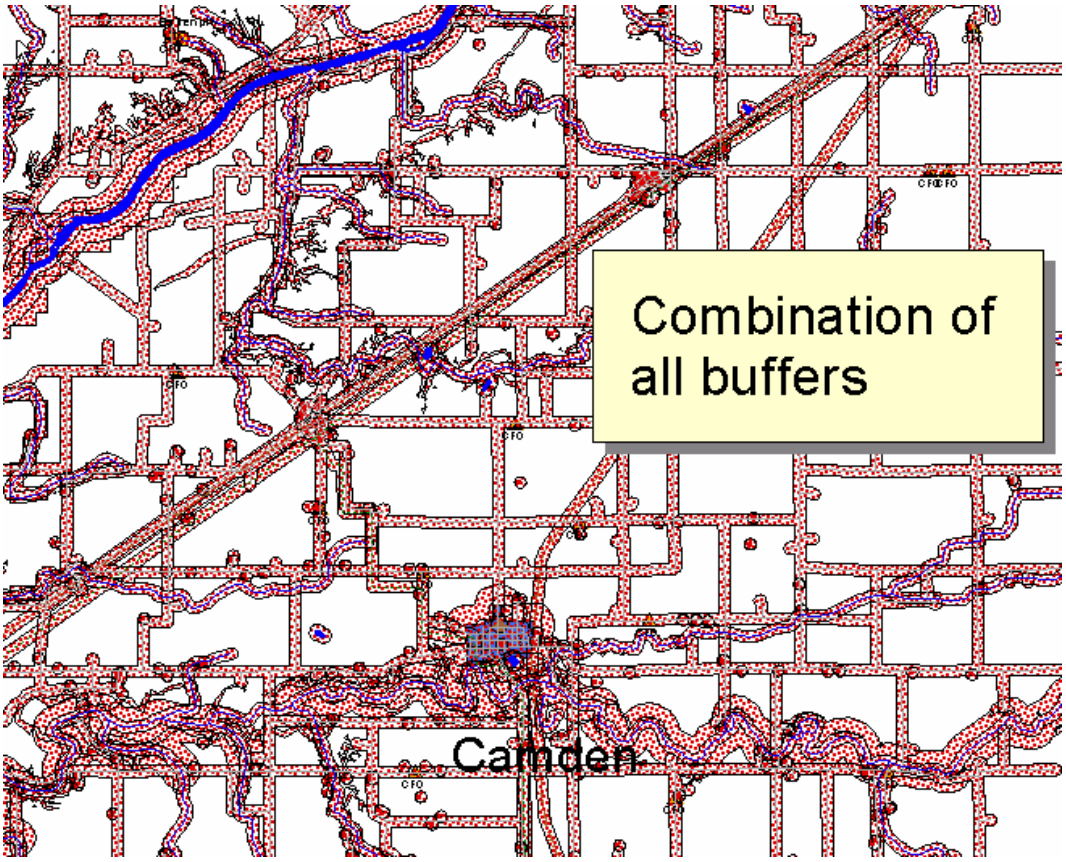

FIGURE 5. Map overlay of road, well, and stream buffering.

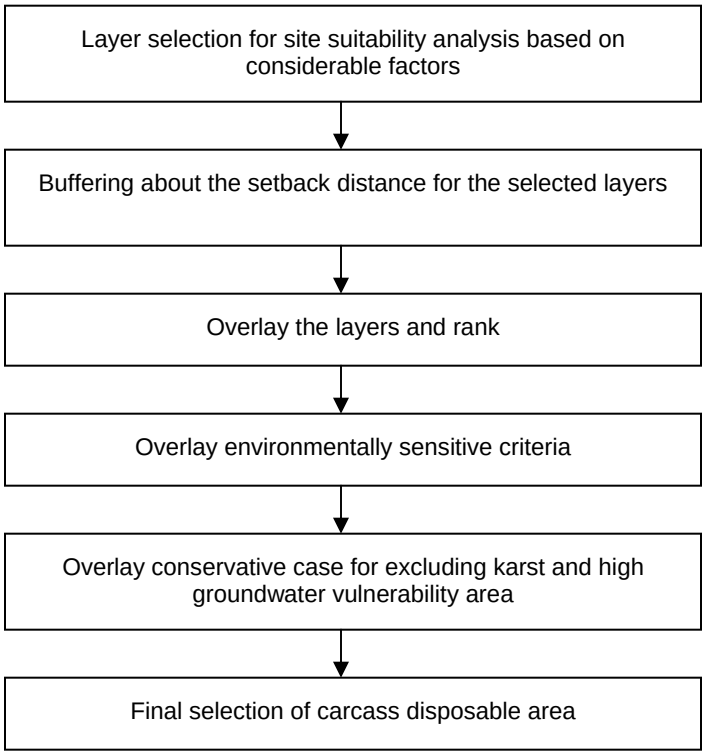

FIGURE 6. Carcass disposal site selection procedures using GIS spatial analysis approach.

Data layers

For the carcass disposal site selection analysis, seven layers were selected and analyzed to define an exclusive or inclusive area as follows.

- Forbidden
  - Soil with slope > 6%
  - Karst areas
- 300-foot setback
  - Roads
  - Private wells
  - Streams, lakes
  - Property lines (No detailed GIS layer exists, so this was not implemented in the model.)
- 1000-foot setback
  - Public water supply wells

These layers are intended to create a ranking system for estimating the appropriateness of a site for large-scale carcass burial. The basic model is designed from the approach taken to site a manure lagoon as shown by the sample ranking in Table 1. Other, more regional, considerations are added to improve the way the ranking considers groundwater features.

When summed, the layers will create a ranking where 3 is forbidden, 2 is a concern at a county scale, 1 is a possible local concern, and 0 is not a concern. It would be appropriate to establish that rank 1 and 2 should be evaluated on site.

TABLE 1. Sample layer description for the ranking.

Layer	Buffer (ft)	Burial rank	Description	Rule
Basic Themes				
Roads	300	3	Roads that can be used to "geocode" a street address, placing it at a specific location on the map.	Manure lagoon
Streams and rivers	300	3	National Hydrography Database, medium resolution (USGS digitized from 1:100,000 maps)	Manure lagoon
Lakes and Rivers	300	3	Polygons from NHD	Manure lagoon
Wetlands	300	1	This layer contains the National Wetlands Inventory (NWI) developed by the US Fish and Wildlife Service.	Polygon
Private wells	300	3		Manure lagoon
Public wells	3000	1	Wells for non-community public water supply systems, from 2001	WHPA
Public wells	1000	3	Wells for non-community public water supply systems, from 2001	Manure lagoon

Section 5 – Utilizing GIS for Animal Disease Cases

GIS has frequently been considered a tool that has potential to be utilized in several aspects of animal related disasters. Through several different examples, GIS has shown its applicability for improving disaster response efficiency by supplying maps and spatial analysis capabilities. Examples introduced in this section are typical applications for utilizing GIS in animal disease cases.

5.1 – North Carolina Department of Agriculture Veterinary Division

In North Carolina, the North Carolina Department of Agriculture Veterinary Division developed a GIS for use in animal health programs during the late 1980s. They have utilized GIS for animal health issues since that time during mitigation and disease response processes (McGinn et al., 1996, McGinn et al., 1998, McGinn, 2002).

GIS was used with pseudorabies virus (PRV) outbreaks in Duplin County, North Carolina to display 12 swine herds circulating PRV and a one-mile buffer around each circulating herd. In Figure 7, buffers of three, four, and five miles are shown around the cluster of circulating farms and their neighbors. Quarantine disease status, farm type, and ownership are displayed on the map and ghost circles are used to show where the virus has stopped circulating. This information is important in the containment of the virus and in epidemiological investigations. As preparation for an emergency, the use of GIS in the situation allowed decision makers to develop a containment and elimination plan in a timely manner via a conference call. It also provides directions and medical herd/area history to investigators, such as foot and mouth disease (FMD) diagnosticians (McGinn et al., 1998).

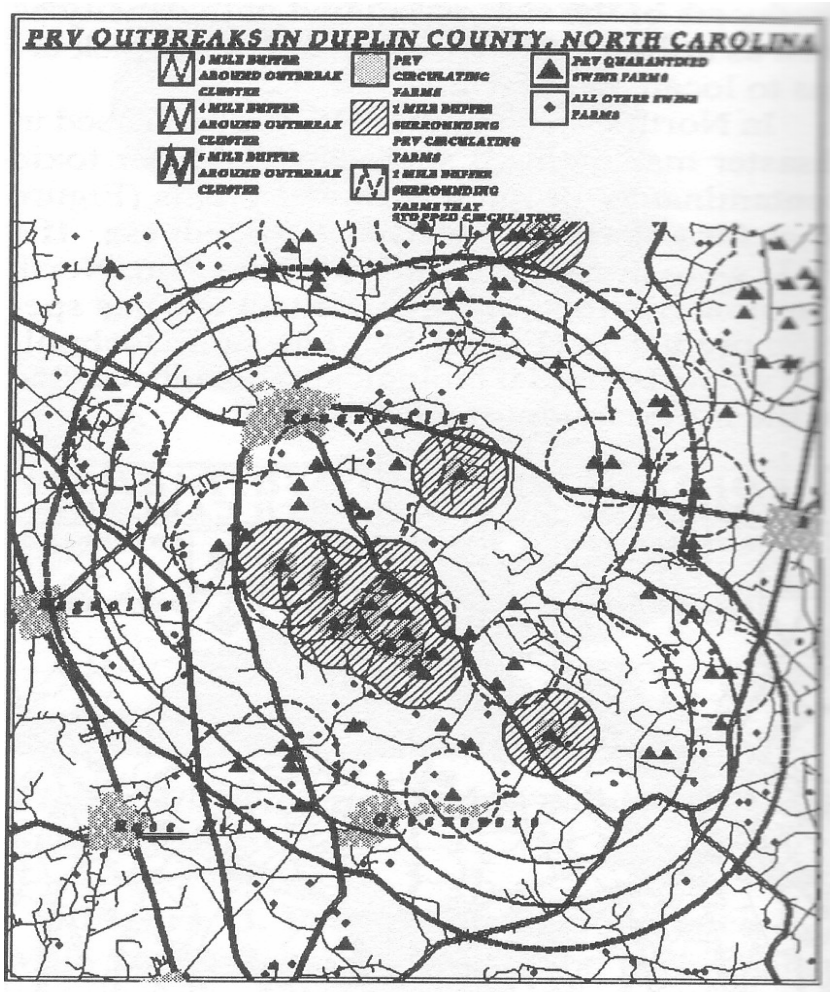

FIGURE 7. Pseudorabies virus outbreaks in Duplin County, North Carolina, and buffers (McGinn et al., 1998).

Routing applications enhance biosecurity for farms by controlling which truck(s) visit each farm, decreasing cost of operations, and shortening training period for new drivers (Figure 8). Computerized truck routing allows management to make better decisions for preventing the spread of disease such as pseudorabies in swine and the corona virus in turkey operations. Computer-aided truck routing enables companies to immediately update farm information such as disease status and quickly change routes and directions to reflect the new information. In an emergency or a disaster situation, routing applications aid in reducing exposure to noninfected animals by quickly moving the infected animals on a minimized path to a disposal site. Management overall has more information in which to make better decisions (McGinn et al., 1998).

5.2 – Animal Health Surveillance in Alberta, Canada

Agri-Food Surveillance Systems Branch, Agriculture, Food and Rural Development, Alberta, Canada, has considered a GIS for animal health surveillance. Renter (2002) indicated in the Animal Health Forum that "a GIS can be a valuable tool in addressing animal health and food safety issues. Maintaining the

confidentiality of producers (and other information sources) and assuring the accuracy of the data are essential when using a GIS. When used correctly, a GIS can help identify clusters of disease, manage and predict disease outbreaks, identify risk factors, assess sample and population distributions, and supplement other areas of food safety and animal health surveillance and research (Figure 9).

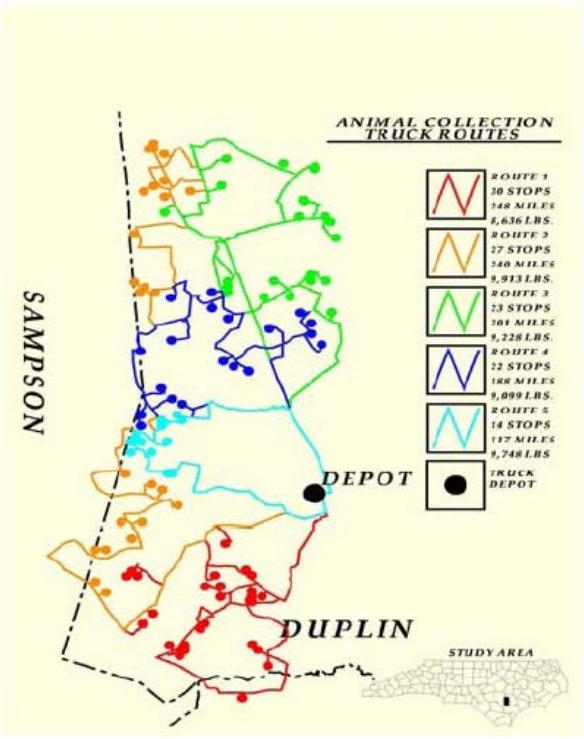

FIGURE 8. Truck route map from GIS for animal carcass collection (McGinn et al., 1998).

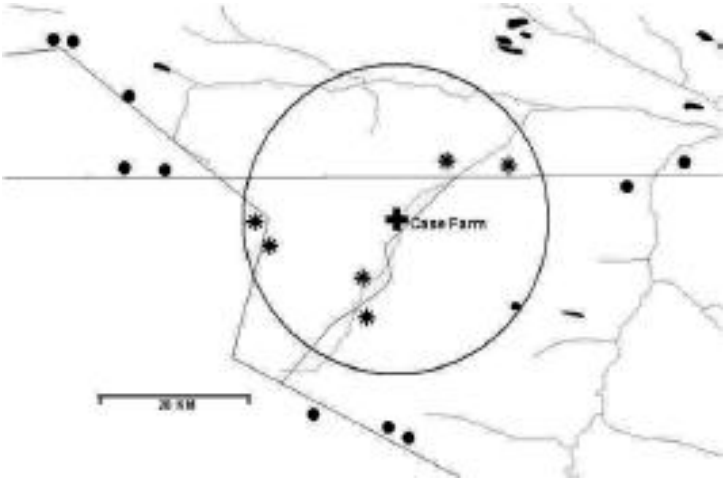

FIGURE 9. A simulated GIS map that could be generated for disease response. When a disease is diagnosed, the case farm (**+**) is displayed and all farms (*****) within a specified zone (circle) can be identified. Roads, waterways, and farms outside the zone (·) are also shown (Renter, 2002).

5.3 – Foot and Mouth Disease Outbreak in Great Britain, 2001

Although the FMD disaster in Great Britain in 2001 was a great stress on people who were involved, they learned several lessons from the disastrous outbreak (Scudamore and Harris, 2002). Among the lessons were the usefulness of GIS and its role in an animal health emergency response process. Scudamore and Harris (2002) noted in their article: "The value of a geographic information system (GIS), already recognized during the classical swine fever outbreak, was confirmed by use during the FMD epidemic at both local and national levels. The GIS provided location data and allowed separate databases to be combined to provide graphical representations of disease status. The production of high quality and specific maps greatly helped the effort to deal with the disease and to explain the process to others. The GIS is a data handling tool that will play an increasing role in any future disease outbreak and resources are being made available to ensure such a tool is available."

5.4 – Debris Recovery Effort for the Shuttle Columbia

While it is difficult to find published examples of the use of GIS in carcass disposal projects that are national in scale, there are a few examples, primarily the English response to FMD. Certainly one example of the use of GIS in a national catastrophe that has serious implications for carcass disposal is the recent debris recovery effort for the Shuttle Columbia (Brown et al., 2003).

How is this related to the carcass disposal effort? There were teams of thousands of responders, untrained in GIS or GPS, who were performing coordinated actions across five states as rapidly as possible. The activities of thousands of small groups were coordinated using GIS. Several lessons can be learned as reported in the recent article by Brown et al. (2003). The sheer scale of this operation makes it similar in size and complexity to a multi-state outbreak of FMD in the US

As the shuttle debris field was spread across state borders, multiple federal, state, and local organizations mobilized large numbers of small mapping parties. These parties had GPS receivers to create a location for use in a GIS, but no previously agreed-upon mapping standards existed between local, state, and federal authorities. This resulted in maps made with different units; for example, county surveys often use feet, federal agencies may use meters, and some organizations used degrees of longitude and latitude. The latter can be collected in two different formats, which results in the coordinating groups receiving map data in at least four different types of data units, requiring conversion before they can be incorporated into a map used for the following day's coordination (Brown et al., 2003).

The authors conclude that the numerous agencies involved should coordinate on mapping standards and data formats in advance. They further stated: "Even a simple 1 hour instruction on how to use a GPS receiver for data collection, navigation, and coordinate system configuration would have saved countless hours in data conversion" (Brown et al., 2003).

The authors report that in Central Texas, the effort by the University of Texas San Antonio provided GIS support for approximately 4000 field personnel, mobilizing daily with fresh maps printed showing progress and search areas. "At any given time, there were three to four GIS personnel making needed maps to support the recovery efforts. Unfortunately...printing was excruciatingly slow." The authors conclude advance procurement of the highest speed postscript plotters with expanded memory is critical to future efforts (Brown et al., 2003).

The most important lesson here for carcass disposal is that prior coordination of resources and data formats would greatly leverage scarce resources during a disaster.

Section 6 – Critical Research Needs

The following research needs have been identified based on the review of materials related to the use of GIS in carcass disposal events, activities completed as part of this effort, and the authors' experiences in application of GIS to various issues.

1. A set of decision rules to select the best carcass disposal technology for a particular location and situation are needed. These decision rules will need to be created in a manner that can be implemented within GIS. GIS should play a critical role in the development of resulting decision support tools to identify the likely suitability of locations for carcass disposal.
2. A site analysis decision support tool is needed that will allow prescreening of sites to identify whether they are likely suitable for carcass disposal. The decision rules from recommendation #1 combined with spatial data in GIS can be used to create maps that depict areas to be considered further for carcass disposal. Such a tool will also require use of environmental models.
3. Further analysis of the GIS data layers required for carcass disposal management is needed. Once the key data layers are selected, these should be assembled in a common format and integrated for use in the event of an emergency. There will not be sufficient time to assemble these data during an emergency.
4. Web-based GIS capabilities should be developed to provide some of the key data assembled within recommendation #3. By making the data available within a Web-based GIS, the amount of training of decision makers and field personnel can be reduced and the data can be made widely and quickly available.
5. A range of training materials on the use of GIS for carcass disposal are needed. For example, materials that would provide simple and rapid training to field personnel on the use of simple capabilities such as those provided within WWW-GIS are needed. More comprehensive GIS training materials are also required that would target personnel in central coordinating locations.

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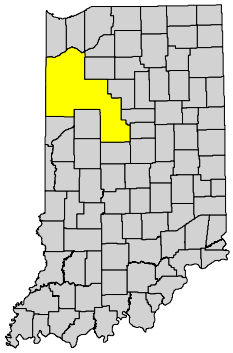
Appendices

Appendix A – GIS: Multicounty Exclusion Model

This appendix describes the creation of a six county carcass disposal site exclusion zone model. In this analysis, an exclusion zone was created where carcass burial is not deemed appropriate. The object of this exercise is to provide a quick reference map (prepared in advance) to emergency responders which can guide their decision-making in choosing disposal options, and disposal locations.



This example is based on detailed geographic information for a multi county area of north-central Indiana. The area includes the counties of Benton, Carroll, Clinton, Jasper, Newton, and White.

Total area 1715100 acres.

This is a fairly level, till-plain topography with a large animal agriculture base. The area is mostly rural but also includes some medium–sized cities.

For step one, the GIS team used current Natural Resource Conservation Service manure lagoon criteria to eliminate areas that would not be acceptable for manure lagoons. The basic assumption is that a carcass burial site is as environmentally sensitive as a manure lagoon. The manure lagoon management criteria for Indiana include the following:

- Forbidden: soil with slope > 6%
- Forbidden: Karst areas, a region in Southern Indiana which is underlain by limestone that has been extensively eroded, forming an interconnected network of sinkhole, springs, and limestone caverns with flowing water. A legal definition of Karst extent was created by the Indiana Department of Environmental Management (IDEM) using Indiana Geological Survey (IGS) data for the management and licensing of confined animal feeding operations. This map layer is used for the model.

- 300-foot setback:
  - Roads
  - Private wells
  - Streams, lakes
  - Property lines (No detailed GIS layer exists, so this was not implemented in the model.)
- 1000-foot setback:
  - Public water supply wells

This model was created using a 300-foot buffer around all private wells from the 2003 IGS database, and 1,000-foot buffer around all public wells (2001 database from IGS). This first buffer layer, water wells, represents 119,513 acres excluded. Using 300-foot buffer around general streams and waterbodies creates a buffer of 271,690 acres. Using 300-foot buffer around all roads represents 532,236 acres excluded (overlap is not removed from these numbers yet).

We also created a buffer for the 6% or greater slope area. This was created from 30-meter by 30-meter cells (the National Elevation Data Digital Elevation Model layer), so it is a measure of where general slope averages greater than 6%. It will include local areas of lesser slope. These high-slope areas are generally around the river valleys. The calculated area for this is 9,133 acres. This part of Indiana does not have Karst topography.

Additional environmentally sensitive criteria:

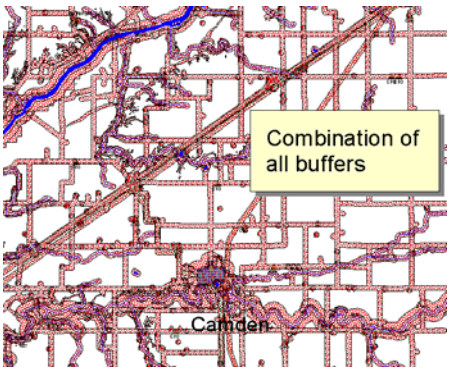
We then increased the buffer from 300 feet to 1000 feet around these water features:

- Legally designated "Scenic" or "Exceptional use waters."
- Legally designated "Impaired waters."
- Public Recreation Water Bodies (from an Indiana Department of Natural Resources database of sites with public access to water recreation).

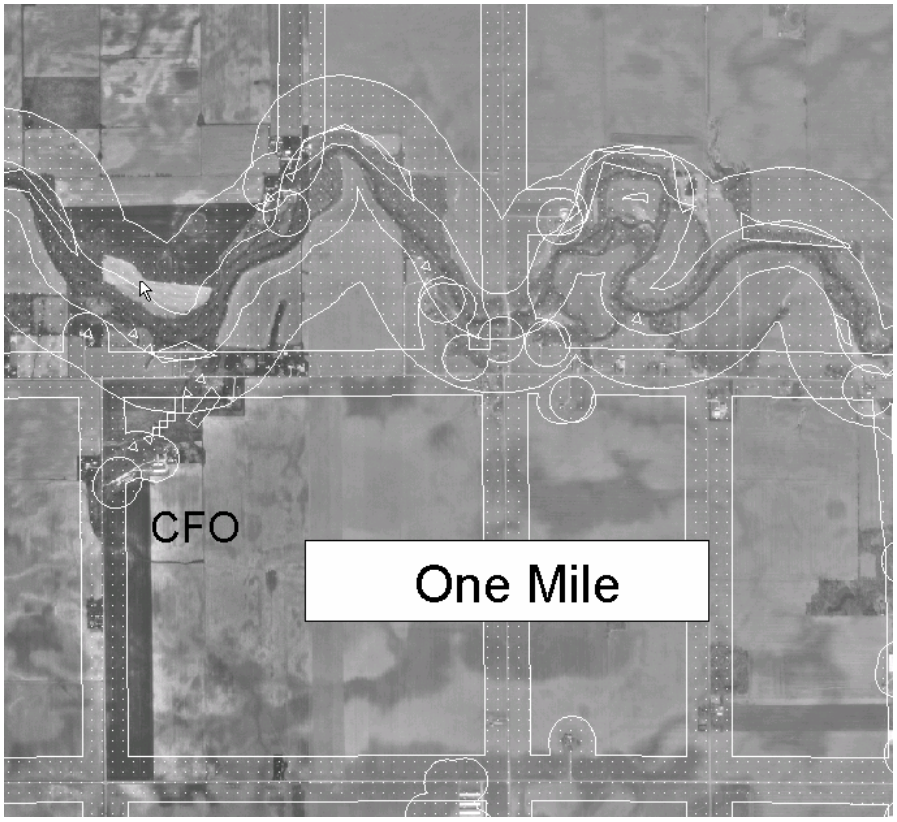
This increased the water body buffer to 518,171 acres for mapped water features.

We assigned a 1,000-foot buffer to Census Urbanized Areas and urban clusters; these two map layers from the US Census Bureau include Defined Places (towns and cities) and also include suburbs where population density is judged to be more than 5,000 per mile. So this area is slightly larger than the actual town limits. In some areas, it is quite a bit larger than actual town limits. This created a buffer of 132,927 acres. These numbers still include overlap.

We assigned 300-foot buffer to pipelines, major power lines, schools, cemeteries, churches, fairgrounds, petroleum wells, hospitals, and underground storage tanks. This created a buffer of 190,201 acres (much of which is inside the town buffer map layer). A representation of what this looks like on the ground also follows.



Total exclusion zone without "high Drastic" is 718,134 acres (from a total of 1,715,100 acres); thus 42% of the total area is excluded in advance of a disaster, 58% is available for consideration by local responders.



Exclusion zones are displayed with a white hachured area.

This rural area displays zones mainly around streams, roads, and wells.

Large areas remain which are outside the exclusion zones.

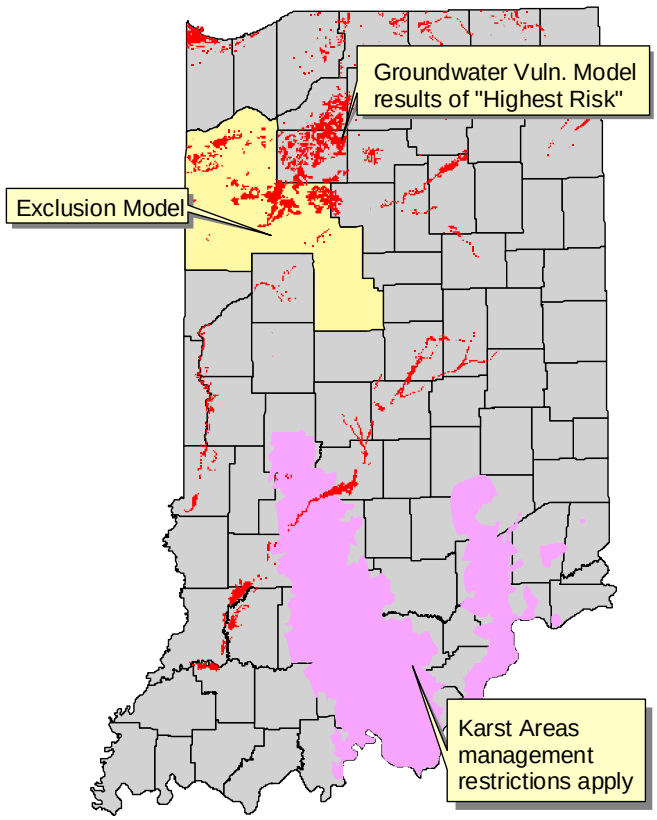
The model assumes local responders will choose the most appropriate or accessible sites from the non-excluded areas.

Most conservative case

We created a buffer for the areas designated by the Indiana Groundwater Vulnerability Study to be at "Highest risk" of nitrate loss (Grid value 4). This area is extensive where it is present, and is the only rating factor besides Karst topography which eliminates large chunks of entire counties. Excluding this factor, but with all the other factors, a suitable site remains within a mile or so of any operation. This should be carefully considered before employing this particular factor (Highest risk from DRASTIC model) on a large scale.

This DRASTIC model Highest-risk area is 346,366 acres. That number includes overlap with other factors.

Total exclusion zone including the "Highest-risk vulnerability to Nitrates" area is 801,160 acres, or 47% of the available land (in the six-county test area) in the more conservative case.



This figure illustrates the extent of two agricultural practice management restriction areas.

The red illustrates the “Highest risk to Nitrate contamination” area from the Indiana Groundwater Vulnerability Study. This map layer is used in pesticide use management.

The pink illustrates the extent of the “Karst area” as defined for Confined Animal Feeding Operations(CAFO) management by IDEM.

Appendix B – Prototype of Airborne Disease Propagation Based on Web-GIS

To show the applicability of Web-based GIS in dealing with animal health issue, a prototype Airborne Disease Propagation system based on Web-GIS has been developed.

1. Web-GIS and Interface Development

   The MapServer Web-GIS tool was selected as the Common Gateway Interface (CGI) engine for developing the Web-GIS map user interface. MapServer was originally developed by the University of Minnesota ForNet project in cooperation with NASA and the Minnesota Department of Natural Resources (MNDNR) (http://mapserver.gis.umn.edu). The CGI, running on the server side, provides a “light weight” page for the client. Thus, if the server is powerful enough to control the processes from multiple connections within a reasonable time, it is the preferable choice to support potential users, since concerns regarding client side computer capability and connection speed are minimized.

2. Exposure zoning

   Airborne propagation simulation with wind direction, wind speed, and duration from an outbreak was programmed to display exposure zoning on the Web-GIS interface. Using the input data from the HTML form map interface, an exposure zone can be delineated as a cone shape boundary. The cone shape boundary is used to extract the information for school locations, public recreation areas, and public water supply locations from the database.

The Web-GIS also has several functions like coordinate conversion from latitude and longitude to Universal Transverse Mercator (UTM) and printable page preparation.

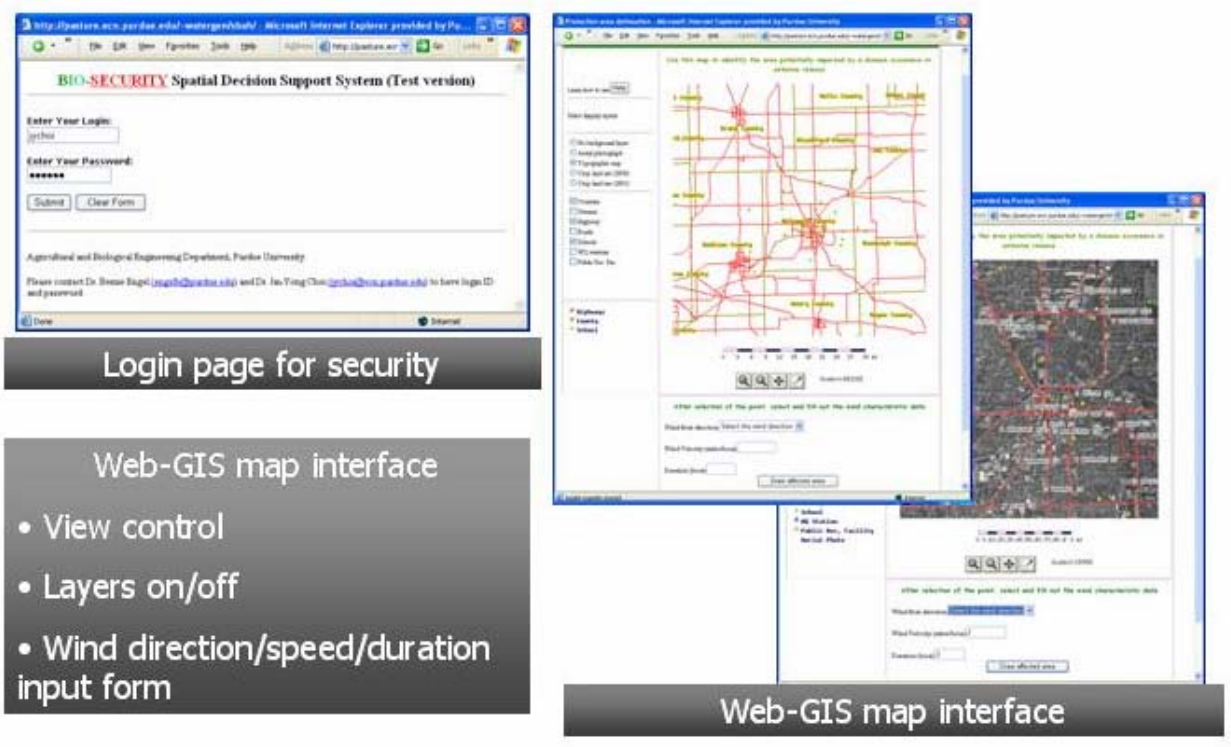
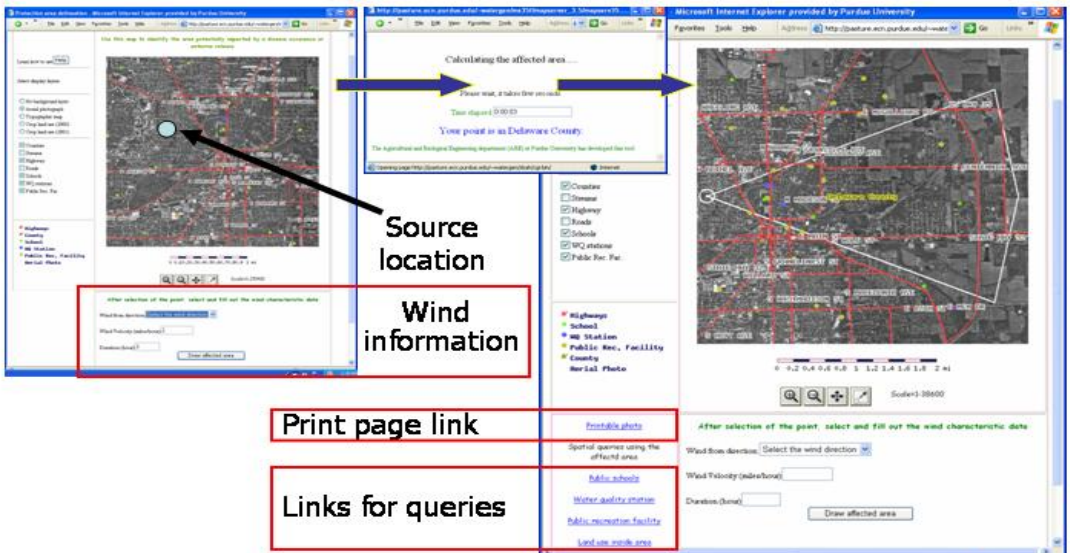


FIGURE B1. Login page and map interface of the airborne disease propagation simulation Web-GIS.



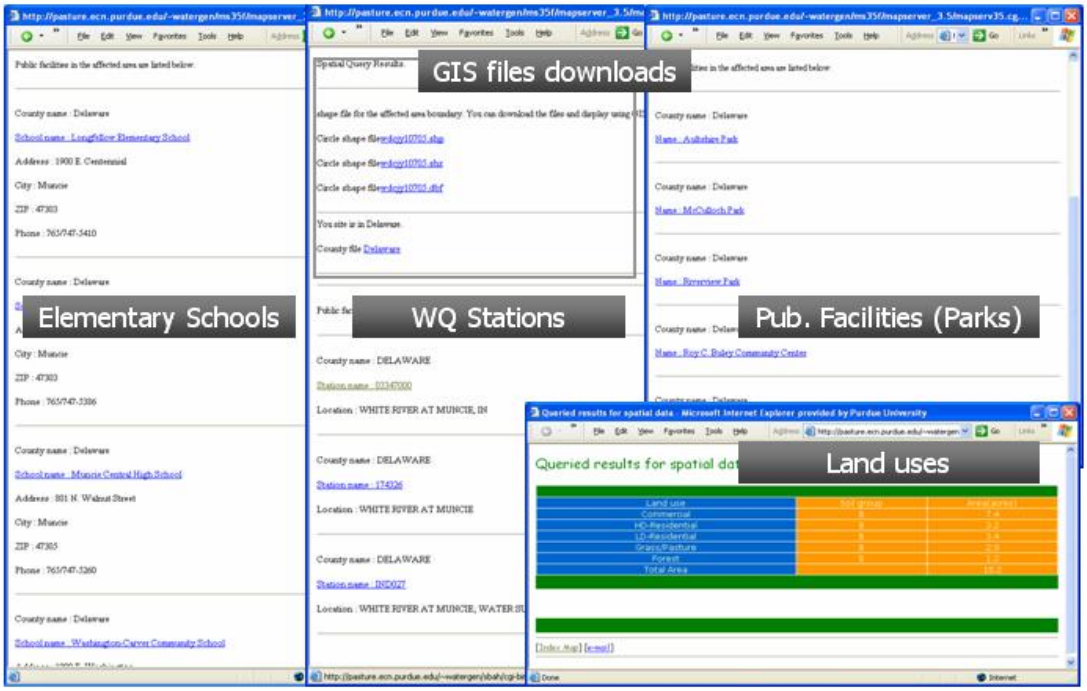


FIGURE B2. Airborne disease propagation simulation and result display on the Web-GIS map interface.

Appendix C – Layers Ranking System

Information Request, US Department of Agriculture (USDA) Carcass Disposal Working Group (CDWG), GIS subcommittee

Discussion

This subcommittee of the CDWG is requesting an evaluation of GIS data layers which relate to the decision-making process in carcass disposal operations.

For each of the disposal operations (e.g. burial, burning, etc.) under consideration by various teams, we have identified GIS layers which may aid in the process of deciding which mechanism to employ and where to employ it. Establishing this foundation of decision support data would enable individual states to make recommendations or guidelines for site suitability and technology selection in advance of an emergency.

The GIS planning group envisions state-level planning using both pre-emergency screening techniques and post-emergency decision support. Typical actions include:

- Pre-disposal evaluation of suitable sites and technologies.
- Decision support during an emergency.
- Post-disposal evaluation of site.
- Monitoring and observation after carcass disposal if required.

The function of the questionnaire is to prompt discussions among the various technology teams. Using the questionnaire to develop a list of useful data layers, or expose incorrect assumptions in the GIS planning strategy, becomes a process of creative strategic design as experts in various technologies are exposed to the GIS planning groups assumptions.

For example, in meetings at Purdue with the chemical digestion team, the concept was put forward that employing digestion technologies that produce liquid waste would benefit from a map layer (list) of publicly owned treatment works (POTW). The plan would be to send the liquid fraction of the digestion output to sewage treatment plants, perhaps after buffering the pH.

Ideally the person in command could quickly organize the shipment of liquid waste to POTWs working from a map layer showing nearby POTWs with phone numbers. This idea led to further discussions with faculty who have expertise in that issue. In Indiana, there is a map layer of POTW facilities with phone numbers and capacities included. However, some clarification will be required before it is useable in carcass disposal scenarios.

This liquid digestion waste material is statutorily banned from disposal in some communities, and many POTW no longer are equipped to handle large trucks. The material will probably need to be sent to tertiary treatment plants for several reasons (basically, large cites). In fact, preapproval is strongly suggested here. It became apparent that this would be very useful data layer to have in advance, but it will require some work on the ground to make it happen. This is an important result of this discussion process.

Another aspect of GIS planning data needs that came to light during this discussion was the need to arrange for refrigerator trucks to store carcasses as well as tankers to move digestion products. Because of the slow throughput, the digestion technology would also need refrigerator trailers to store carcasses till the digesters(s) could handle them. Planning to acquire these trailers can be done in advance and would benefit from being spatially arranged. (One strategy would be to assume it will pay to locate sources of trucks near the densest areas of livestock.)

In an infectious disease scenario, the amount of truck and trailer type equipment which will repeatedly be disinfected becomes significant, even in an on-site chemical digestion scenario. As reported elsewhere, in England the widespread and copious use of disinfectant on barns and equipment had a negative impact on shallow groundwater supplies.

Therefore, operational planning would benefit from a map layer displaying areas where shallow groundwater or drinking water aquifers or reservoirs are particularly vulnerable to surface spills of disinfectant. Such a map layer has been produced already for several states such as Indiana and Texas,

and location of that map data in advance of the emergency is good planning.

In a similar fashion, discussing the usefulness of various GIS layers with the composting team brought out the usefulness of creating or finding planning layers such as pallet suppliers (because shredded pallet debris can be a compost amendment). The sheer volume of amendment needed for composting large numbers of carcasses strongly supports the need for advance planning to locate nearby supplies. The discussion of which map data is useful in planning seems to quickly bring up requests for map data which is not commonly used, but not impossible to come by. Working in advance of emergencies, these data layers can be constructed or, more frequently, tracked down where they already exist in obscure state agencies.

Conclusion

To support this strategic planning discussion, each operational disposal technique has a list of specific map layers that may or may not be useful (in your opinion) to implementers dealing with an event. GIS support for these screening efforts will include collecting existing data layers as well as determining what new layers should be created.

In addition to the list for the specific disposal technique, there is a Basic Planning Layer list which includes layers that may or may not be useful to pre-disaster response planning.

We would like you to look over the GIS data layer list and rate the layers in regard to usefulness to the disposal techniques you are considering. Add any layers you feel are useful that do not appear on the list.

Executive summary

For each of the disposal operations (rendering, biodigestion, incineration, composting, burial, and chemical digestion) under consideration by various teams, we have identified GIS layers which may aid in the process of deciding which mechanism to employ and where to employ it. Establishing this foundation of decision support data would enable individual states to make recommendations or guidelines for site suitability and technology selection in advance of an emergency.

The GIS planning group envisions state-level planning using both pre-emergency screening of techniques and post-emergency decision support. Typical actions include:

- Pre-disposal evaluation of suitable sites and technologies.
- Decision support during an emergency.
- Post-disposal evaluation of site.
- Monitoring and observation after carcass disposal if required.

The function of this questionnaire is to develop a list of useful data layers, or expose incorrect assumptions in the GIS planning strategy.

Each operational disposal technique has a list of specific map layers that may or may not be useful (in your opinion) to implementers dealing with an event. GIS support for these screening efforts will include collecting existing data layers as well as determining what new layers should be created.

In addition to the list for the specific disposal technique, there is a Basic Planning Layer list which includes layers that may or may not be useful to pre-disaster response planning.

We would like you to look over the GIS data layer list and rate the layers in regard to usefulness to the disposal techniques you are considering. Add any layers you feel are useful that do not appear on the list.

We seek input from your group as to whether each specific layer is:

5 – needed, and present in your state

4 – needed, and could be constructed

3 – needed, but the basic data probably does not exist

2 – useful, but not needed

1 – not applicable in my state

0 –not useful in any case

Disposal Option 1 Rendering

Basic planning layers for carcass movement

Layer	Uses	Rating 0 - 5
FEMA flood zones, county-level	Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts, during storm emergencies.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Census designated places (2000 updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, local jurisdictions.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, etc.	
Transportation buffer	Used with a CAFO database to alert the CAFO operators within a fixed distance of the highway systems that carcasses capable of airborne contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.	
Military bases, especially National Guard and training grounds	May be used as burn or burial sites. “Points-on-a-map” rather than lists may speed planning process. Armories may be used as equipment marshalling areas.	
Street-address type roads layer	Allows the GIS to make a “dot-on-the-map” for any street address. In rural areas this may be difficult to do, and should be prepared in advance.	

Disposal Option 1 Rendering

Layer	Uses	Rating 0 - 5
Location of possible render processing sites.	Transport of carcasses long distances into undiseased areas may preclude use in some cases.	
Location of current rendering pickups	With some diseases render pickup points outside disease area may need to be closed to minimize spread. Use with road layer and CAFOs layer to map contamination warnings	
Transportation buffer	CAFO or animal owners can be alerted to movement of carcass to render pickups. Useful with airborne contamination possibility.	
Trucking contractors	May need refrigerator trailer trucks to hold carcasses till pickup.	

Disposal Option 2 Biodigestion

Basic planning layers for carcass movement

Layer	Uses	Rating 0 - 5
FEMA flood zones, county-level	Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts, during storm emergencies.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Census designated places (2000 updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, local jurisdictions.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, etc.	
Transportation buffer	Used with a CAFO database to alert the CAFO operators within a fixed distance of the highway systems that carcasses capable of airborne contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.	
Military bases, especially National Guard and training grounds	May be used as burn or burial sites. “Points-on-a-map” rather than lists may speed planning process. Armories may be used as equipment marshalling areas.	
Street-address type roads layer	Allows the GIS to make a “dot-on-the-map” for any street address. In rural areas this may be difficult to do, and should be prepared in advance.	
Land application permits	Areas where “sludge” is licensed for application. (A sludge material is also a digestion by-product in some technologies.)	
Soil map	Useful for screening sites that will use large amounts of disinfectant on trucks, tractors, and digesters.	
Water table depth	Useful for screening sites that will use large amounts of disinfectant on trucks, tractors, and digesters. Groundwater contamination by disinfectant was an issue in England.	
POTW locations	Public water treatment plants. To be useful for disposal of digestion liquids, this list needs to be prescreened for tertiary treatment plants, plants with truck unloading facilities, and plants not statutorily forbidden from accepting off-site waste.	
Landfill locations	Dry residue product of some technologies could be landfilled if burial is not an option.	
Schools, hospitals layer	With some technologies odor will be a problem.	

Biological digestion on site

Layer	Uses	Rating 0 - 5
Census designated places (updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning where the smell of digestion might preclude its	

	use.
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning where the smell of digestion might preclude its use.
CAFOs location maps	With species, size, and contact info, this database becomes an aid in planning where to move carcasses. Also useful to track the disposal sites in the future.
Corn oil and other agricultural process facility locations	Contact for “bio-solids” supply for filler.
Trucking contractors	May need refrigerator trailer trucks to hold carcasses till digesters have capacity on site.

Biological digestion at collection points

Layer	Uses	Rating 0 - 5
Location of possible render / digestion processing sites	Transport of carcasses long distances into undiseased areas may preclude use in some cases. Makes decision easier if determined in advance no site is within reach.	
Location of current rendering pickups	With some diseases render pickup points outside disease area may need to be closed to minimize spread. Use with road layer and CAFOs layer to map contamination warnings.	
Transportation buffer	CAFO or animal owners can be alerted to movement of carcass to render pickups. Useful with airborne contamination possibility.	

Disposal Option 3 Incineration

Basic planning layers for carcass movement

Layer	Uses	Rating 0 - 5
FEMA flood zones, county-level	Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts, during storm emergencies.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Census designated places (2000 updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, local jurisdictions.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, etc.	
Transportation buffer	Used with a CAFO database to alert the CAFO operators within a fixed distance of the highway systems that carcasses capable of airborne	

	contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.
Military bases, especially National Guard and training grounds	May be used as burn or burial sites. "Points-on-a-map" rather than lists may speed planning process. Armories may be used as equipment marshalling areas.
Street-address type roads layer	Allows the GIS to make a "dot-on-the-map" for any street address. In rural areas this may be difficult to do, and should be prepared in advance.

On-site pyre incineration

Layer	Uses	Rating 0 - 5
Lumber yards	Untreated timber for pyre construction fuel.	
CAFOs location maps	Useful to track the burial sites in the future.	
Census designated places (updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning where the smell/smoke/particulates of burning might preclude its use.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning where the smell/smoke/particulates of burning might preclude its use.	
County-level Soil Survey Geographic (SSURGO) map	Useful for excavation suitability and soil drainage ratings.	
FEMA flood zones, county-level	Useful to eliminate unsuitable excavation sites due to flooding or saturated soils. Also useful to distinguish sites where it may be impossible to recover or move carcasses.	
Pallet sales and manufacturing locations	Shredded or scrap pallets can be used as fuel.	

Incineration pyres at collection points

Layer	Uses	Rating 0 - 5
Lumber yards	Untreated timber for pyre construction fuel. "Points-on-a-map" rather than lists may speed planning process.	
Straw sources	Bales/bulk straw/hay for pyre construction. "Points-on-a-map" rather than lists may speed planning process.	
Wholesale coal suppliers	Fuel for pyre construction. "Points-on-a-map" rather than lists may speed planning process.	
Municipal/industrial incinerators or kilns	May be used as burn site. "Points-on-a-map" rather than lists may speed planning process.	
CAFOs location maps	With species, size, and contact info, this database becomes an aid in planning where to move carcasses for pyres. Also useful to track the burial sites in the future.	
Military bases	May be used as burn site. "Points-on-a-map" rather than lists may speed planning process.	
Municipal landfills	May be used as burn site. "Points-on-a-map" rather than lists may speed planning process.	

Coal mines/reclamation areas	Excavated or “clinker” beds may be used as a burn site.
Transportation buffer	Used with a CAFO database to alert the CAFO operators within a fixed distance of the highway systems that carcasses capable of airborne contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.
Census designated places (updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning where the smell/smoke/particulates of burning might preclude its use.
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning where the smell/smoke/particulates of burning might preclude its use.
Schools and outdoor recreation areas	These layers are environmentally sensitive and are useful for planning where the smell/smoke/particulates of burning might preclude its use.
Public drinking water reservoirs	These layers are environmentally sensitive and presence in a smoke plume area might preclude use as a pyre collection point.
County-level SSURGO map	Useful for excavation suitability and soil drainage ratings.
County-level stream and water-body layers	Useful in states where there is a “minimum distance rule” or buffer established for burial or burning operations near still or moving water. Also useful for planning environmental impact of burning by pyre or burial.
County-level aquifer or aquifer-sensitivity maps	Useful to eliminate unsuitable excavation sites based on groundwater contamination possibility.
FEMA flood zones, county-level	Useful to eliminate unsuitable excavation sites due to flooding or saturated soils. Also useful to distinguish sites where it may be impossible to recover or move carcasses.
Extended flooding vulnerability maps	Layers extending the flood zone to encompass additional low-lying areas that are possible inundation areas, outside floodplains in unusual storms or high-water conditions. Aids in planning where burial might not be appropriate or where it may be impossible to recover or move carcasses.

Air curtain burning at collection points

Layer	Uses	Rating 0 - 5
Census designated places (updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning where the smell/smoke/particulates of burning might preclude its use.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning where the smell/smoke/particulates of burning might preclude its use.	
FEMA flood zones, county-level	Useful to eliminate unsuitable collection sites due to flooding or saturated soils. Also useful to distinguish sites where it may be impossible to recover or move carcasses. Useful in some situations to map where flood debris may provide fuelwood. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and	

	viaducts.
CAFOs location maps	With species, size, and contact info, this database becomes an aid in planning where to move carcasses for burial. Also useful to track the burial sites in the future.
Bulk fuel depots	Contact and location of source of diesel fuel for fire. (For example, 500 swine would use 200 gal of fuel.)
Transportation buffer	CAFO or animal owners can be alerted to movement of carcass with airborne contamination possibility to burn sites pickups.
Wholesale lumber yards	Untreated timber for fire fuel. (For example, 500 swine would also use 60 tons of wood.) Display of timber supply as "points-on-a-map" rather than lists to speed planning process.
County-level SSURGO map	Useful for excavation suitability and soil drainage ratings.
Straw sources	Bales/bulk straw/hay for fire construction. "Points-on-a-map" rather than lists may speed planning process.
Military bases	May be used as burn site. "Points-on-a-map" rather than lists may speed planning process.
Municipal landfills	May be used as burn site. "Points-on-a-map" rather than lists may speed planning process.

Disposal Option 4 Composting

Basic planning layers for carcass movement

Layer	Uses	Rating 0 - 5
FEMA flood zones, county-level	Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Census designated places (2000 updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, local jurisdictions.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, etc.	
Transportation buffer	Used with a CAFO database to alert the CAFO operators within a fixed distance of the highway systems that carcasses capable of airborne contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.	
Military bases, especially National Guard and training grounds	May be used as burn or burial sites. "Points-on-a-map" rather than lists may speed planning process. Armories may be used as equipment marshalling areas.	
Street-address type roads layer	Allows the GIS to make a "dot-on-the-map" for any street address. In rural areas this may be difficult to do, and should be prepared in advance.	

On-site composting

Layer	Uses	Rating 0 - 5
Census designated places (updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning where the smell of composting might preclude its use.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning where the smell of composting might preclude its use.	
CAFOs location maps	With species, size, and contact info, this database becomes an aid in planning where to move carcasses for burial. Also useful to track the burial sites in the future.	
Transportation buffer	Used with a CAFO database to alert the CAFO operators, within a fixed distance of the highway systems, that carcasses capable of airborne contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.	
Pallet sales and manufacturing locations	Shredded or scrap pallets can be used as filler.	
Recycle paper wholesalers	Contact info on supply of filler for compost piles. “Points-on-a-map” rather than lists may speed planning process.	
Lumber yards	Untreated sawdust for filler. “Points-on-a-map” rather than lists may speed planning process.	
Straw sources	Bales/bulk straw/hay for filler. “Points-on-a-map” rather than lists may speed planning process.	
Bulk storage (fertilizer) facilities	May need “starter” fertilizer for composting with wood products.	
Corn oil and other ag process facility locations.	Contact for “bio-solids” supply for composting filler.	
County-level SSURGO map	Useful for excavation suitability.	
County-level SSURGO map	Useful for soil drainage ratings.	
County-level SSURGO map	Useful for soil type/series ratings.	
County-level SSURGO map	Useful for soil texture ratings.	
County-level slope maps	Useful to eliminate unsuitable excavation sites (due to steep slopes).	
County-level aquifer or aquifer-sensitivity maps	Useful to eliminate unsuitable excavation sites based on groundwater contamination possibility.	
County-level water well maps	Useful to eliminate unsuitable excavation sites due to drinking water contamination issues.	
Street-address type roads layer	Allows the GIS to make a “dot-on-the-map” for any street address. In rural areas this may be difficult to do, and should be prepared in advance.	
County-level aerial photos	Useful for planning.	
Land application permits	Areas where “sludge” is licensed for application (compost product may be considered a sludge in some states.)	
Schools, hospitals layers	With some technologies odor will be a problem.	

Disposal Option 5 Burial

Basic planning layers for carcass movement

Layer	Uses	Rating 0 - 5
FEMA flood zones, county-level	Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts, during storm emergencies.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Census designated places (2000 updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, local jurisdictions.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, etc.	
Transportation buffer	Used with a CAFO database to alert the CAFO operators within a fixed distance of the highway systems that carcasses capable of airborne contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.	
Military bases, especially National Guard and training grounds	May be used as burn or burial sites. “Points-on-a-map” rather than lists may speed planning process. Armories may be used as equipment marshalling areas.	
Street-address type roads layer	Allows the GIS to make a “dot-on-the-map” for any street address. In rural areas this may be difficult to do, and should be prepared in advance.	

On-site burial

Layer	Uses	Rating 0 - 5
County-level SSURGO map	Useful for excavation suitability.	
County-level SSURGO map	Useful for soil drainage ratings.	
County-level SSURGO map	Useful for soil type/series ratings.	
County-level SSURGO map	Useful for soil texture ratings.	
County-level slope maps	Useful to eliminate unsuitable excavation sites (due to steep slopes).	
County-level aquifer or aquifer-sensitivity maps	Useful to eliminate unsuitable excavation sites based on groundwater contamination possibility.	
County-level water well maps	Useful to eliminate unsuitable excavation sites due to drinking water contamination issues.	
Extended flooding vulnerability maps	Layers extending the flood zone to encompass additional low-lying areas that are possible inundation areas outside floodplains in unusual storms or high-water conditions. Aids in planning where burial might not be appropriate or where it may be impossible to recover or move carcasses.	
FEMA flood zones, county-level	Useful to eliminate unsuitable excavation sites due to flooding or saturated soils. Also useful to distinguish sites where it may be impossible to recover	

	or move carcasses.
County-level stream and water-body layers	Useful in states where there is a “minimum distance rule” or buffer established for burial or burning operations near still or moving water. Also useful for planning environmental impact of burning by pyre or burial.
CAFOs location maps	Useful to track the burial sites in the future.
Street-address type roads layer	Allows the GIS to make a “dot-on-the-map” for any street address. In rural areas this may be difficult to do, and should be prepared in advance.
County-level aerial photos	Useful for planning.

Burial at collection points such as CAFOS

Layer	Uses	Rating 0 - 5
FEMA flood zones, county-level	Useful to eliminate unsuitable excavation sites due to flooding or saturated soils. Also useful to distinguish sites where it may be impossible to recover or move carcasses. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
CAFOs location maps	With species, size, and contact info, this database becomes an aid in planning where to move carcasses for burial. Also useful to track the burial sites in the future.	
Military bases, especially National Guard and training grounds	May be used as burial sites. “Points-on-a-map” rather than lists may speed planning process. Armories may be used as equipment marshalling areas.	
County-level SSURGO map	Useful for excavation suitability and soil drainage ratings	
County-level water table maps	Useful to eliminate unsuitable excavation sites based on groundwater contamination possibility.	
County-level aquifer or aquifer-sensitivity maps	Useful to eliminate unsuitable excavation sites based on groundwater contamination possibility, including large amounts of disinfectant use.	
Street-address type roads layer	Allows the GIS to make a “dot-on-the-map” for any street address. In rural areas this may be difficult to do, and should be prepared in advance.	
County-level stream and water-body layers	Useful in states where there is a “minimum distance rule” or buffer established for burial or burning operations near still or moving water. Also useful for planning environmental impact of burning by pyre or burial.	

Burial at municipal or commercial landfill

Layer	Uses	Rating 0 - 5
Landfill locations	With contact info, this database is useful in planning transport.	

Disposal Option 6, 7 Chemical digestion, other

Basic planning layers for carcass movement

Layer	Uses	Rating 0 - 5
FEMA flood zones, county-level	Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts, during storm emergencies.	
Bridge layer	Layer which lists the height of the bridge over flood stage, to use in planning carcass movement. Useful with highway layers to map transportation problems in carcass movement, such as closed bridges and viaducts.	
Census designated places (2000 updated town boundaries)	These layers are outlines of the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, local jurisdictions.	
Census urbanized areas and urban clusters	These layers are outlines of urban sprawl outside the official boundaries of metropolitan areas. They are useful for planning transportation problems in carcass movement, such as closed bridges and viaducts, etc.	
Transportation buffer	Used with a CAFO database to alert the CAFO operators within a fixed distance of the highway systems that carcasses capable of airborne contamination have been or will be transported nearby. Typically constructed using some average wind direction and windspeed.	
Military bases, especially National Guard and training grounds	May be used as residue burial sites. “Points-on-a-map” rather than lists may speed planning process. Armories may be used as equipment marshalling areas.	
Street-address type roads layer	Allows the GIS to make a “dot-on-the-map” for any street address. In rural areas this may be difficult to do, and should be prepared in advance.	
Land application permits	Areas where “sludge” is licensed for application. (A digestion by-product may be considered “sludge” in some technologies.)	
Soil map	Useful for screening sites that will use large amounts of disinfectant on trucks, tractors, and digesters.	
Water table depth	Useful for screening sites that will use large amounts of disinfectant on trucks, tractors, and digesters. Groundwater contamination by disinfectant was an issue in England.	
POTW locations	Public water treatment plants. To be useful for disposal of digestion liquids, this list needs to be prescreened for tertiary treatment plants, plants with truck unloading facilities, and plants not statutorily forbidden from accepting off-site waste.	
Landfill locations	Dry residue product of some technologies could be landfilled if burial is not an option.	

Chemical digestion at collection points

Layer	Uses	Rating 0 - 5
Location of existing digestion sites	Makes decision easier if determined in advance no site is within reach.	
Location of possible processing sites	Transport of carcasses long distances into undiseased areas may preclude use of existing digestion locations in some cases.	
Location of current rendering	With some diseases render pickup points outside disease area may need	

pickups	to be closed to minimize spread. Use with road layer and CAFOs layer to map contamination warnings.
Transportation buffer	CAFO or animal owners can be alerted to movement of carcass to render pickups. Useful with airborne contamination possibility.
Trucking contractors	May need refrigerator trailer trucks to hold carcasses till digesters have capacity on site.
Schools, hospitals layers	With some technologies odor will be a problem.