

THE AGRICULTURAL CHEMICAL EVALUATION AND MANAGEMENT SYSTEM

AGCHEM Project Team
Division of Agricultural Sciences and Natural Resources
Oklahoma State University

Mark Gregory, Agronomy
Tom Haan, Agricultural Engineering
Harry Mapp, Agricultural Economics
Ed Miller, Forestry
David Nofziger, Agronomy
Pat Norris, Agricultural Economics
Dan Storm, Agricultural Engineering

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University Center for Water Research
Oklahoma State University
Stillwater, Oklahoma

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An Example of the Practical Application of GIS Technology

In 1988 the O.S.U. Agricultural Experiment Station and the University Center for Water Research initiated joint support for a multi-discipline research project concerning water quality in agriculture. The resulting project was called the Agricultural Chemical Evaluation and Management System, or AGCHEMS, project. The basic objective of the project was to develop a system for evaluating the potential environmental and economic impact of management practices for chemicals utilized in agriculture.

The overall objectives of the AGCHEMS effort were to help define rational chemical regulation and management systems for agriculture and to assist agricultural producers in selecting agricultural production systems that are environmentally and economically sound. The ultimate goal of the project was to develop an analytic tool that will aid agencies and possibly legislators in arriving at rational (in an environmental and economic sense) controls on the use of agricultural chemicals. This same effort can also be utilized as a companion analytic tool that would help agricultural producers make production decisions in the face of possible regulations on the utilization of agricultural chemicals. These tools were developed such that they can be operational from work-stations in agency, county extension, and possibly private offices.

The approach used involved the coordinated, independent modeling schemes. The chemical transport model, CMLS (Chemical Movement in Layered Soils) (Nofziger and Hornsby, 1986), was utilized to evaluate the movement of agricultural chemicals through soils. The predicted chemical movement incorporates soil characteristics, chemical properties, weather, irrigation, and other management practices. A weather generator model (WGEN) (Richardson and Wright, 1984) was employed to produce long sequences of weather data, which drive the CMLS transport model. The weather generator produces multi-year weather sequences characteristic of any weather station in Oklahoma. Simulating chemical movement for many weather sequences at a given site enables the association of probability levels with predicted chemical movement and resultant changes in ground water quality. Finally, an economic optimization model (Norris and McCroskey, 1993) was used to help select appropriate practices and evaluate the costs to the producer of potential chemical regulations. These three models are operationally interfaced by utilization of Geographic Information System (GIS) technology.

GIS Technology

Briefly, a GIS is an information technology that can capture, store, analyze, and display, both spatial and non-spatial data. Within the GIS context, data can be captured, stored, and then analyzed and displayed as either points, lines, or areas (see Figure 1). Point type data are indicated on this map as red dots, which represent the location of towns within Caddo County, Oklahoma. Point data could also include sample locations, discharge points, and weather stations. Major roads and highways

are displayed in Figure 1 as irregular black lines and represent an example of line data. The state or federal highway number is also located at intervals along the indicated roads. Other common examples of line data could include railroads, pipelines, streams and rivers. Finally, watershed boundaries as defined by the Hydrologic Unit Map of the U.S. Geological Survey (USGS) are indicated in Figure 1 with green lines. When combined with one another, these green lines connect together to form areas or polygons. Polygons are spatial units within which the entire area inside a single polygon possesses the same value or feature characteristic, in this case, areas that belong to the same watershed or drainage basin. In addition to watershed boundaries, other common polygon or area data include political and legal delineations, land cover/use information, and soil mapping unit maps.

Regardless of the type of data (point, line, or area), the data within a GIS is generally organized in layers or themes (see Figure 2). Each layer, such as soil type, water well location, or transportation network, provides the location information for the value or category of all observations within that theme or data layer. The data layers are connected, or "tied together," because all layers are oriented or registered to the same coordinate grid system. Common coordinate grid systems include latitude and longitude, Universal Transverse Mercator, and State Plane coordinate systems.

GIS technology can also store information concerning the topology of the data or relationship between the elements or observations within a data layer. Topological information might indicate which streets intersect with each other and the location of those intersections so that routing or distance analyses are possible. Another example of topological information is a stream network and hydrologic flow pattern. Topology can identify the connection between individual stream segments and the directions of flow so that an integrated stream network can be produced and utilized for analysis.

One of the most important aspects of GIS technology is that any graphic or map layer can also be attached or linked to a database or databases. In turn, the databases can contain numerous attributes (spatial or non-spatial in nature) that may be associated with each layer value or category. These databases can also be linked to additional databases so that all databases can be queried with traditional database manipulation of both spatial and non-spatial attributes. Analyses can then be performed with the result directly linked to the spatial or graphic data for later analysis or display. This active link between spatial and non-spatial data was essentially unattainable prior to access to GIS technology.

Another major advantage of GIS technology and its concept of data layers is that data can be gathered from a variety of sources and data types and then integrated into a single analytic process. It does not matter to the technology if the data is obtained from existing maps and charts, remote sensing capabilities, original samples and field investigation, or even output from models that may utilize any of the mentioned data sources. What can be an advantage can also be a disadvantage unless proper training and understanding of the technology and data accompanies the analysis. For example, the flexibility to combine information from different sources can

result in erroneous analyses if proper consideration is not given to such factors as data integrity, accuracy, resolution, and scale.

In addition to the analysis of existing data layers, GIS technology also has the ability to combine or merge data layers together to produce "new" data layers. For example, given a data layer of soil mapping units and another layer containing land use information for the same area, a third data layer could be produced which indicates soil mapping units, but only for those areas where the land use data layer indicates irrigated or non-irrigated cropland. This process involves more than a simple graphic or visual overlay of different layers; it involves an analytic overlay and generation of a new, unique data layer. This type of data combination will be demonstrated with examples of AGCHEMS output later in this document.

Because of the characteristics of geographic information systems, GIS technology is now commonly utilized in a wide variety of disciplines and numerous multi-discipline areas of interest. As such, GIS technology was selected for utilization within the AGCHEMS project not only for its ability to capture, analyze, and display spatial and non-spatial data, but also to aid in the coordination of data management between the various models (input and output requirements) involved in the overall AGCHEMS concept.

AGCHEMS Project Requirements

At the center of the AGCHEMS concept is the CMLS transport model. The CMLS model requires information concerning soil type, land use, and weather for the geographic area over which the model is applied. Soil mapping unit information was captured and entered into the system by digitizing USDA Soil Conservation Service (SCS) Soil Surveys. Land use information was interpreted from color infrared aerial photography and similarly digitized into a GIS. Both of these two sets of data were input as separate data layers and are available for all of Oklahoma.

Figure 3 is a map of the soil mapping unit data layer for Caddo County, Oklahoma. In the interest of space, no mapping unit legend is provided with the map. Each of the 61 soil mapping units present within Caddo County are represented in Figure 3 with a different color. The associated database to which the soils data layer is linked was created based upon the SCS Form 5 soil data. Within the database, numerous soil attributes were recorded or estimated for each soil mapping unit. The soil attributes include soil texture, bulk density, percent organic carbon content, and water characteristics for each soil horizon. Therefore, when the soil data layer is accessed within a GIS, any or all of the attributes in the database can be "transparently" accessed and analyzed, mapped or passed onto

one of the models. The land cover/use data layer is maintained and accessed in a similar manner.

The CMLS model requires daily estimates of water entering the soil and leaving the soil by transpiration through plants and evaporation from the soil surface. These

estimates can be obtained from historical weather data at one of 311 weather stations across Oklahoma. In addition to utilization of the actual, historical data, the AGCHEMS project also processed the historical data to determine the stochastic parameters that characterize the weather at each site. These parameters along with the WGEN weather generator can be used to generate long weather sequences typical of any of these sites. The ability to generate many weather sequences for the site enables the AGCHEMS system to express results in a probabilistic sense.

The concept of a GIS as a data management tool and the interaction of the different models with one another is displayed in Figure 4. Because of the flexibility of the technology, data layer or attribute information within the GIS can be transferred as output from the GIS and accessed as input by one of the models. Similarly, model results can be transferred to the GIS and incorporated as a data layer or attribute within a database. In either situation, the GIS can be utilized to graphically display results and generate summary tables and statistics of model results.

Study Area Examples

The GIS framework also allows users to select a sub-set of a geographic area with which to work. Figure 5 again covers Caddo County, although in this case only the soil mapping unit information for a selected area is indicated. This selected area is the Lake Creek Watershed, which is a sub-basin of the Cobb Creek-Fast Runner Creek Watershed previously indicated on Figure 1. The Lake Creek Watershed covers an area of approximately 18,712 hectares (72 square miles) and is approximately 25 by 11 kilometers (16 by 7 miles) in size. The watershed boundary can be manually or automatically derived by analysis of contour or elevation data from a source such as USGS topographic maps. Automatic generation of watershed boundaries involves the utilization of digital elevation data to determine the angle and direction of slope across the area. With either the manual or automatic method, the derived boundary can be used to "cut out" the desired area for further use and analysis. The Lake Creek Watershed will be used to further illustrate the AGCHEMS.

CMLS Model

For the present AGCHEMS project, the concern is the analysis of potential movement of agricultural chemicals. Because the chemicals analyzed are only utilized in cropland situations, the main concern is the analysis of soils that are presently utilized as cropland. Soils utilized for cropland can be located, displayed, and passed onto the other models with a simple intersection of the soil mapping unit and land use data layers. Conversely, this process will eliminate from analysis those soils that are not presently utilized as cropland. Figure 6 is a map of land use for the Lake Creek Watershed. County section line roads are indicated on the map as the regular set black lines. The major stream system within the watershed is shown as irregular blue lines converging near the bottom of the watershed. Also, there is a distinction between irrigated and dry land cropland in the land use classification.

The results of the next step in this process are indicated in Figure 7. This new data layer was generated by the intersection of information from both the land use and the soil mapping unit data layers. As such, Figure 7 contains soil mapping unit information for those areas that were classified as cropland (dry land or irrigated) in the land use data layer. Thus, soils information is eliminated in this new data layer where non-cropland conditions exist within the land use data layer. This resultant data layer (Figure 7) will be the basis for all future examples of CMLS output concerning potential chemical movement.

The CMLS transport model estimates the vertical migration of the chemical in and beyond the agricultural root zone in a layer-by-layer manner. The model requires the depth of each soil layer, organic carbon content, soil bulk density, field capacity, and permanent wilting point, in addition to daily infiltration and evapotranspiration, chemical partition coefficient, and degradation half-life. Daily infiltration amounts are determined from daily rainfall and the SCS curve number method. Daily evapotranspiration is estimated with the Blaney-Criddle method. After performing a water budget, the CMLS model determines the amount of water moving past the chemical and moving it downward. The location of the chemical is updated daily. Output from the model includes an estimate of the amount and location (depth) of the chemical.

Model Output

Examples of CMLS model output are indicated in Figure 8. These maps indicate the travel time for the center of mass of the nematocide aldicarb to reach a depth of one meter. This analysis and the display of output only indicate results for areas within the Lake Creek Watershed where cropland presently exists. It should be noted that the analysis that generated both of these maps also assumes dry land (non-irrigated) conditions for all cropland within the watershed, regardless of the irrigation information within the land use data layer. The rate of chemical application utilized for these analyses was based upon the recommended rate for the Caddo County area.

The map of the left side of Figure 8 indicates that it takes at least five years for the center of mass of the chemical to reach a one meter depth for the entire watershed. The map on the right of the figure, however, indicates that in some portions of the watershed the center of mass of the applied aldicarb will reach the one meter depth in less than one year, while for almost all of the watershed the center of mass will reach one meter in less than five years. The difference between these two results is due to different weather patterns. In other words, the map on the left (noted as Rainfall Season A) resulted from a sequence of relatively dry years. However, the map on the right of Figure 8 (Rainfall Season B) indicates the results from a sequence of relatively wet years.

Thus, large differences in chemical leaching patterns can result from differences in weather patterns typical of this area. Since there is no way of knowing future weather, predictions of chemical movement should be viewed in a probabilistic sense.

Users of the system can then observe the probability of a particular chemical management system having a detrimental effect on ground water quality.

Irrigation Management Potential

Since chemicals tend to move with soil water, irrigation practices can have a dramatic effect on chemical movement. Such may be the case in the Lake Creek Watershed, where over 23 percent of the cultivated land is irrigated. Surveys of farmers in the area indicate that a common irrigation practice is to apply approximately 50 mm of water per week from mid-June until late September. To help determine the potential effect of irrigation, CMLS simulations were carried out using two levels of irrigation (50 mm/week and 25 mm/week) as well as dry land farming, or no irrigation. In addition to graphic or map output, a GIS can directly compute and output analysis results as summary statistics as shown in Table 1. This table summarizes the travel times for aldicarb movement to the one meter depth under these three water regimes. Clearly, irrigation at the 50 mm/week rate has a major impact upon the travel times.

Table 1. Percent of land area in which aldicarb leaches to 1 meter depth in specified travel time.

Travel Time years	Irrigation Amount		
	0 mm/wk	25 mm/wk	50 mm/wk
0.0 - 0.5	0	0	99
0.5 - 1.0	0	0	0
1 - 2	0	40	1
2 - 4	0	0	0
4 - 6	25	3	0
6 - 8	0	54	0
8 - 10	18	2	0
0 - 12	56	1	0
12 - 14	1	0	0

Environmental Significance

The amount of a chemical reaching the ground water and the toxicity of that chemical must be used to determine the environmental significance of a chemical application. The U.S. EPA health advisory level (HAL) is a measure of the toxicity of chemicals to human beings. The CMLS model was used to estimate the amount of the chemical reaching ground water. Under the assumption that the chemical reaching the ground water is uniformly mixed in the top meter of ground water, the concentration of the chemical can be estimated and then compared to the HAL. By repeating this process many times, the fraction or percentage of the simulations for

each soil producing concentrations in excess of the HAL can be determined. In that way, the CMLS analysis can estimate the probability of the chemical reaching the ground water in sufficient quantity to exceed the HAL.

Figures 9 and 10 show maps of the probabilities of exceeding the HAL for the irrigation systems described above. Irrigation at a rate of 50 mm/week results in a very high probability of exceeding the HAL for most of the cultivated land. Lower rates of irrigation and dry land agriculture result in low probabilities of leaching a sufficient amount of aldicarb to exceed the HAL in the ground water. Notice that all of the cultivated land within the watershed received these irrigation treatments. Therefore, these maps represent the potential effect of irrigation within the area if all of the cropland were irrigated.

Actual Irrigation Conditions

All of the previous maps of model results have considered all cropland within the watershed as being cultivated under dry land or irrigated (50 mm/week or 25 mm/week) conditions. In actual practice, however, only about 23 percent of the Lake Creek Watershed is irrigated. The map on the left side of Figure 11 indicates the generalized land use of the watershed. That is, only four land use classes are present on the map: dry land cropland, irrigated cropland, non-cropland and water (lakes). The map on the right of Figure 11 displays the results from the previous 50 mm/week analysis for those areas mapped as irrigated (in the map on the left) and the results from the previous dry land analysis for those areas mapped as non-irrigated cropland (also in the map on the left). These maps should represent a more accurate picture of the effect of irrigation on the movement of the nematocide aldicarb, given actual land use conditions within the study area.

Multiple Chemical Analysis

Frequently several chemicals exist to control the same pest. The AGCHEMS enables the user to evaluate alternate chemicals for their impact on ground water quality. Figure 12 indicates the probability of exceeding the HAL for two different chemicals (Aldicarb and Mocap) applied at their respective, standard rates and under the same environmental conditions. These simulations indicate that Mocap appears to have a significantly lower probability of leaching through the soil in an

amount to raise its concentration above the HAL. Information such as this may be quite valuable in the selection and utilization of agricultural chemicals.

AGCHEMS GIS Laboratory

All information processing for the AGCHEMS project and production of the above examples was performed within the AGCHEMS computing network. This network consists of a series of UNIX workstations and DOS personal computers connected through a local area network (LAN) within the Division of Agricultural Sciences and Natural Resources. The network is also connected through fiber optics

to the OSU University Computer Center (UCC) and through Internet to computer systems world-wide.

The processing capability of the AGCHEMS network is centered in a series of ten (10) SUN SPARC stations. Hard disk storage capacity within the network exceeds 10 gigabytes. The network also has a 5 gigabyte cartridge tape drive and a series of 1/2 inch cartridge tape drives; four CD ROM readers; and a multi-function, 940 megabyte CD ROM device that allows for either Read/Write or Write Once Read Many (WORM) capability. Through the fiber optic connection to UCC, the system also has access to the extensive mass storage capacity of the University mainframe computer system and 9-track magnetic tape drives with capabilities for 800, 1600, or 6250 bpi tape density.

The main AGCHEMS processing laboratory also includes extensive input and output capability. Basic digitizing is performed on several Altek or Houston Instruments graphic digitizers, ranging from 24" by 24" to 24" by 36" in size. In addition, an ANatech Eagle 3640 optical scanner is utilized to scan images and graphics up to 36 inches wide at a resolution of 800 dots per inch. With appropriate software for conversion of the scanned raster images, simple graphics such as soil maps and detailed graphics such as topographic contour lines can be efficiently converted to vector representation for utilization within a GIS.

In addition to normal text output with laser printers, graphic output is also available with a Tektronix Colorquick printer and a Hewlett Packard PaintJet XL300 printer. The Colorquick printer can print maps and graphics up to 11 inches wide and has 216 dots per inch resolution. This printer is utilized to produce report quality chloropleth or area maps as shown in this report. The PaintJet printer has a resolution of 300 dots per inch and can be utilized to produce report quality transparencies or slides. As an alternative, color graphics can also be produced by use of a 36 inch wide Calcomp 1043 8 pin color plotter. The Calcomp pin plotter is generally utilized for the generation of products that emphasize point or line features, while the Colorquick and PaintJet printers are best suited for production of maps dominated by colored polygons or areas.

GIS Software

The principle GIS software package utilized by the AGCHEMS project is GRASS (Geographical Resources Analysis Support System). GRASS is written and maintained by the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) and as such is available as public domain software. GRASS is an easy to use, raster-based GIS that allows for the incorporation and analysis of both raster and vector data. A major benefit of GRASS, in the context as a data manager and interface between models (such as the AGCHEMS project), is the ease of transfer of information between models, and into or out of GRASS. As a public domain package, the GRASS program source code is also available to a user. Such access allows for a better interface between developed models and the GIS package or for the development of models as simply GRASS application programs. GRASS also

contains extensive image processing capabilities, which can be utilized to analyze (and then incorporate into a GIS analysis) remotely sensed data such as Landsat, SPOT, and AVHRR satellite data.

In addition to GRASS, the AGCHEMS laboratory also employs a variety of other GIS or GIS-related software packages. These packages include Workstation ARC/INFO, pcARC/INFO, IDRISI, Atlas GIS, EarthONE, MicroStation PC, and AutoCad. These software packages are utilized to perform a variety of operations depending upon the particular project or application.

State-Wide Data Bases

The center of any analytic operation, however, is the data. In general, data represent the largest investment to obtain and to maintain compared to any other GIS analytic component. As shown in the above examples, soil mapping unit and land use data are often critical components to many analyses concerned with natural resources. In that regard, the AGCHEMS GIS laboratory maintains a digital database of both soil mapping units and land use for the entire State of Oklahoma. This data is maintained on a county basis and is stored in raster or cell form at a 200 meter by 200 meter (4 hectare) spatial resolution. Produced in cooperation with the USDA SCS, these databases represent the only state-wide databases of this kind within Oklahoma. Separately or in conjunction with other databases, these two databases possess tremendous potential for research and application activities, particularly in the area of natural resources.

With the realization that 4 hectare land use information may not satisfy all needs, the AGCHEMS laboratory also possesses the capability to process and interpret digital satellite data such as Landsat MSS or TM, SPOT, and AVHRR. The lab is presently conducting an analysis of Landsat Thematic Mapper digital data, SPOT imagery, and aerial photography to map Eastern Red Cedar distributions and densities within portions of Oklahoma and Iowa. In addition, the lab maintains an extensive supply of Landsat digital data tapes across Oklahoma. The laboratory also maintains complete stereoscopic coverage of Oklahoma with 1:58,000 scale

color infrared (CIR) aerial photography. Both the satellite and the aerial photography can be employed for a variety of analyses concerning land cover and land use and then serve as a basis or input for a variety of projects or applications.

While the AGCHEMS project has utilized weather information to estimate parameters for the weather generator employed in the project, the AGCHEMS laboratory can easily incorporate historical climatic or weather information as well as current weather information. Such information can be directly incorporated into a GIS analysis as an additional data layer, or in the case of weather stations, as sites or points of information within the GIS. With the advent of the Oklahoma MESONET (Mesoscale Network), GIS technology would seem a logical vehicle to manage the incoming data and to further incorporate the data into research efforts and models.

Another significant data layer maintained by the AGCHEMS is state-wide digital elevation coverage. This data can be utilized in a wide variety of applications, particularly in the area of surface runoff hydrology. Figure 13 is an example of a three dimensional representation of a digital elevation model (DEM) derived from elevation data. Given the elevations and their locations within a GIS, the DEM can compute slope angle (percent), slope aspect (direction), and slope length. These characteristics may be maintained as separate data layers or as attributes of the elevation data layer. In either case, the computed slope data may be incorporated into further analysis. These slope characteristics can also be utilized for procedures such as the automatic delineation of watershed boundaries, prediction of flow or runoff paths, and computation of numerous hydrologic parameters such as percent slope of watershed, watershed length and width, and the watershed drainage pattern. Other data, such as land use, can also be "visually draped" or laid over the elevation data to show the data set (such as land use) in three dimensions. Laboratory personnel recently entered into a project with USGS for the production of digital elevation models for Oklahoma by the optical scanning and analysis of 1:24000 scale USGS topographic quadrangles.

Other data sets of importance maintained by the AGCHEMS laboratory include a digital land grid for the State of Oklahoma. This data set is a set of State Plane coordinates that define the legal description (township, range, and section) for the Public Land Survey System (sections) within Oklahoma. These data were produced by digitizing coordinates on 1:24000 USGS quadrangles to completely define every section (or part of a section) of land in Oklahoma. While these coordinates are in a State Plane coordinate system, they can be easily transformed in other coordinate systems, such as latitude/longitude or Universal Transverse Mercator systems. The data can then be utilized for accurate location of land parcels or as a reference base for locating and mapping such features as sample points, test plots, and well locations. The importance of precise registration of data to a stable reference system such as this digital land grid cannot be over-estimated.

Similarly, the AGCHEMS lab also maintains a database of the U.S. Census Bureau TIGER (Topologically Integrated Geographic Encoded Reference) files. The TIGER files contain all graphic information generally available from USGS 1:24000 scale quadrangle maps, with the exception of elevation contour lines. In other words, this database contains the location of such features as all roads (interstates, U.S. and state highways, county roads, and city streets), railroads, pipelines, and numerous other linear features. In addition, the TIGER files also contain numerous legal boundaries, including boundaries for the states, counties, incorporated cities, voting districts, and other political boundaries, and all Census delineations such as tracts and blocks. Finally, the TIGER files also contain digital representations of a variety of physical features, including hydrologic information such as the drainage network (rivers and streams) and bodies of water. While not precise enough from a location point of view for such activities as engineering work or parcel or tax mapping, TIGER files represent extensive information for general location and mapping purposes. The 1990

U.S. Census of Population and Housing information can also be accessed, analyzed and mapped, utilizing the TIGER files to generate the base map.

Another state-wide data set maintained by the AGCHEMS laboratory is a digitized representation of published USGS maps of ground water sources. Specifically these digital data include the identified boundaries of confined aquifers, alluvial areas, and their recharge zones. This digital data set is becoming increasingly more valuable as analyses attempt to model the potential effect of surface activities on sub-surface water supplies.

In addition to the digital data mentioned above, the AGCHEMS laboratory maintains a variety of maps and satellite images. These products are maintained at a variety of different scales and are located primarily over Oklahoma. Plans also include the housing of a complete state-wide coverage of 1991 black and white aerial photography (1:20,000), originally flown for the Oklahoma Ad Valorem Task Force and the USDA Agricultural Stabilization and Conservation Service. The laboratory also maintains numerous other databases or data layers, generally over smaller areas, but generally in greater detail than the state-wide databases. That concept is one of the advantages of GIS technology. That is, a project or application can utilize data from existing state-wide databases, but also compliment these data with intensive, detailed information gathered specifically for that project or effort.

GIS Potential

There exists a vast potential for the application of GIS technology in such areas as agriculture, natural science, engineering, and natural and human resources. In addition to the AGCHEMS example, numerous other projects are already taking advantage of GIS technology within the Division of Agriculture and Natural Resources. These projects include modeling of surface hydrology, Eastern Red Cedar inventory, well-head protection, and endangered species projects, to name only a few. Common applications of GIS technology also include the area of range management and a variety of forestry applications. AGCHEMS personnel are also actively involved with the State of Oklahoma initiative to integrate and coordinate GIS technology within state agencies. This effort should ultimately aid in the development of the GIS coordination between all levels of government from the local level to the Federal agencies within Oklahoma.

GIS technology provides a tool with which to manage, analyze, and display data from a variety of sources and integrate the information into a single analytical framework. Potential applications and uses of GIS technology are limited only by the imagination of the users.

For further information concerning the AGCHEMS project please contact any of the following project members:

Mark Gregory, Agronomy
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Dan Storm, Agricultural Engineering

References

Nofziger, D. C. and A. G. Hornsby. 1986. A microcomputer-based management tool for the chemical movement in soil. *Applied Agricultural Research* 1:50-56.

Richardson, C. W. and D. A. Wright. 1984. WGEN: A model for generating daily weather variables. USDA, Agricultural Research Service, ARS-8, 83 pp.

Norris, P. E. and J. M. McCroskety. ca 1993. An expanded budget generator with environmental parameters for input management decisions. *Oklahoma Experiment Station Bulletin*. In review.

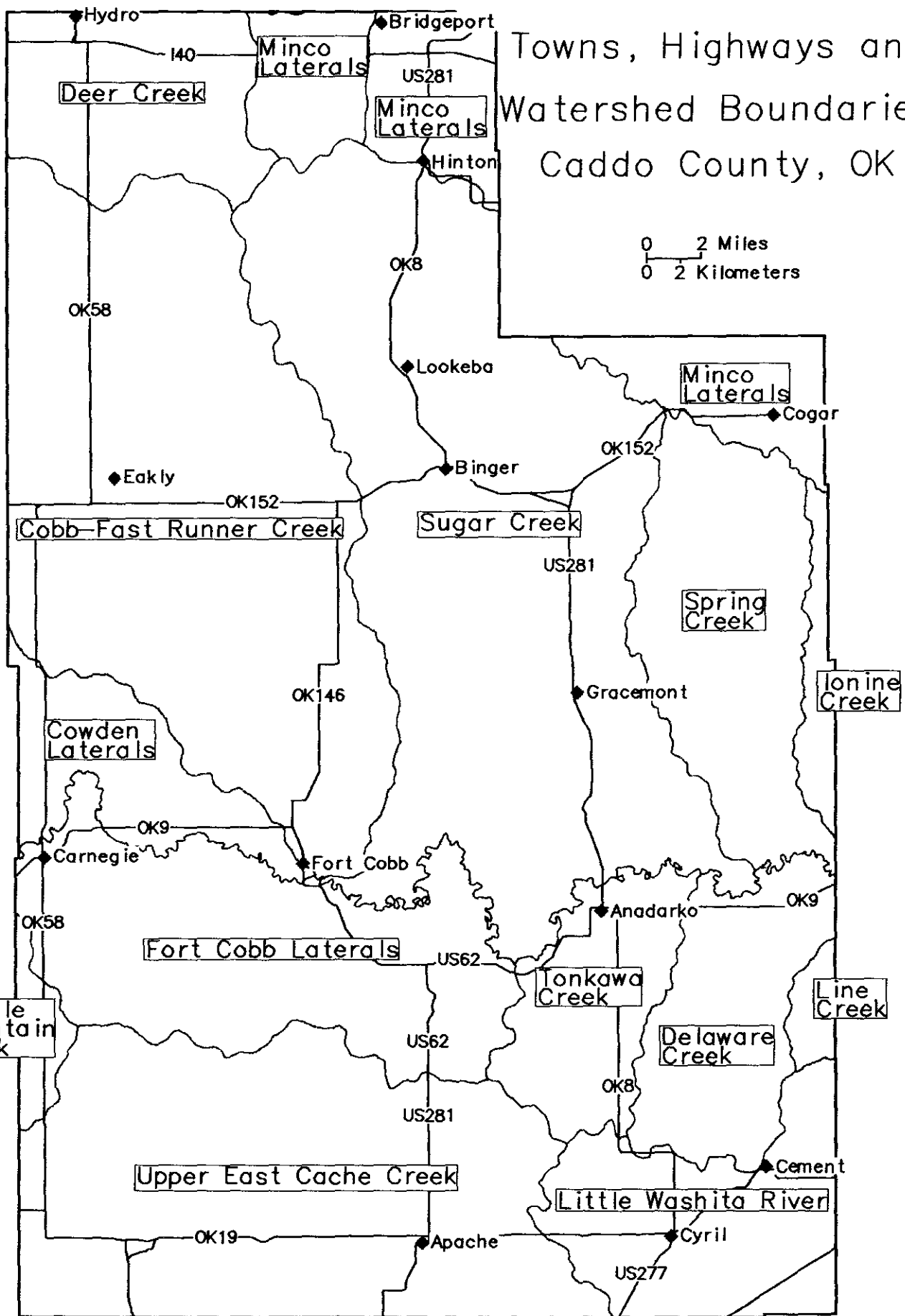


Figure 1

MAP DATABASE LAYERING CONCEPT

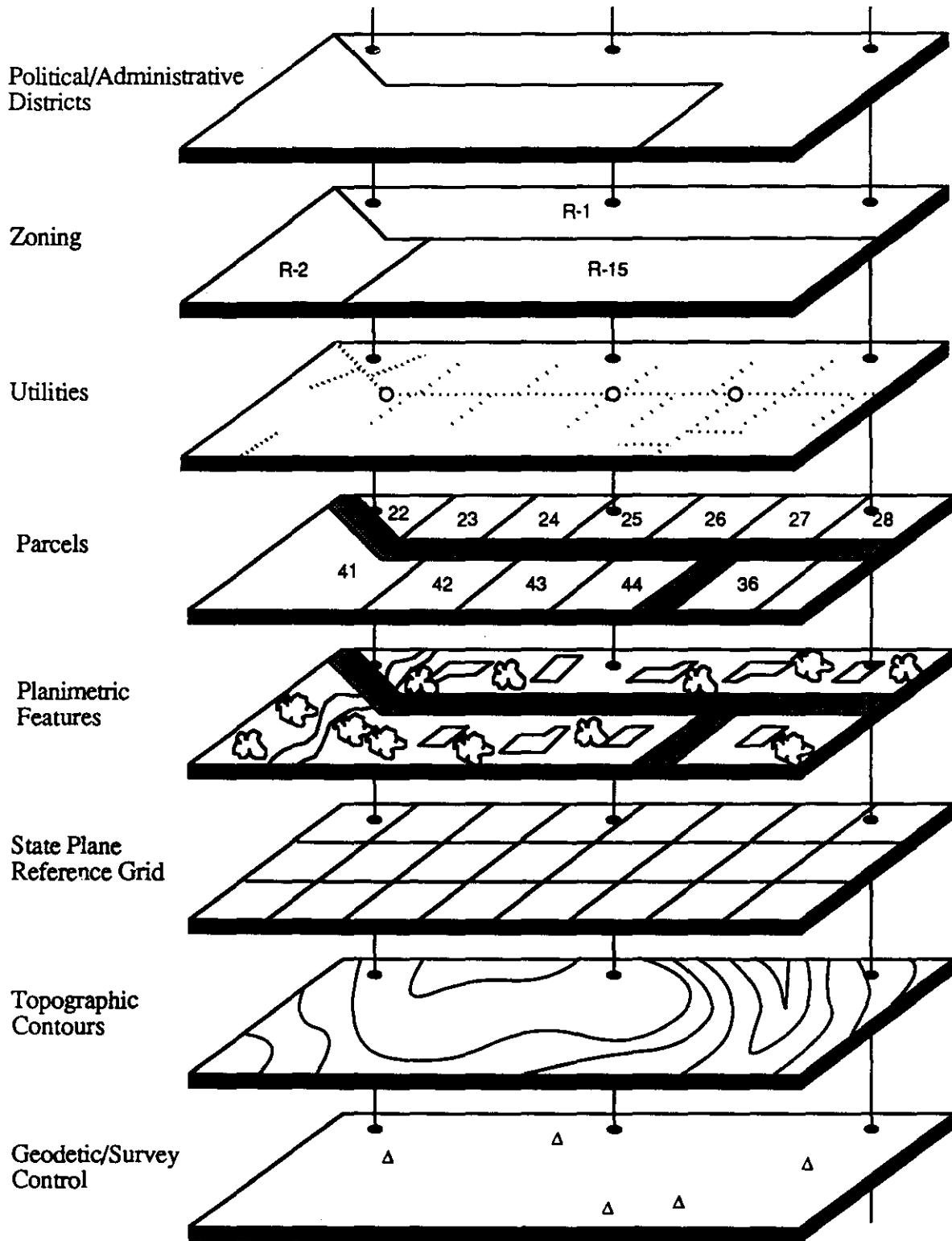


Figure 2

Soil Mapping Units Caddo County, OK

0 2 Miles
0 2 Kilometers

T12N
T11N
T10N
T9N
T8N
T7N
T6N
T5N

R13W R12W R11W R10W R9W



Figure 3

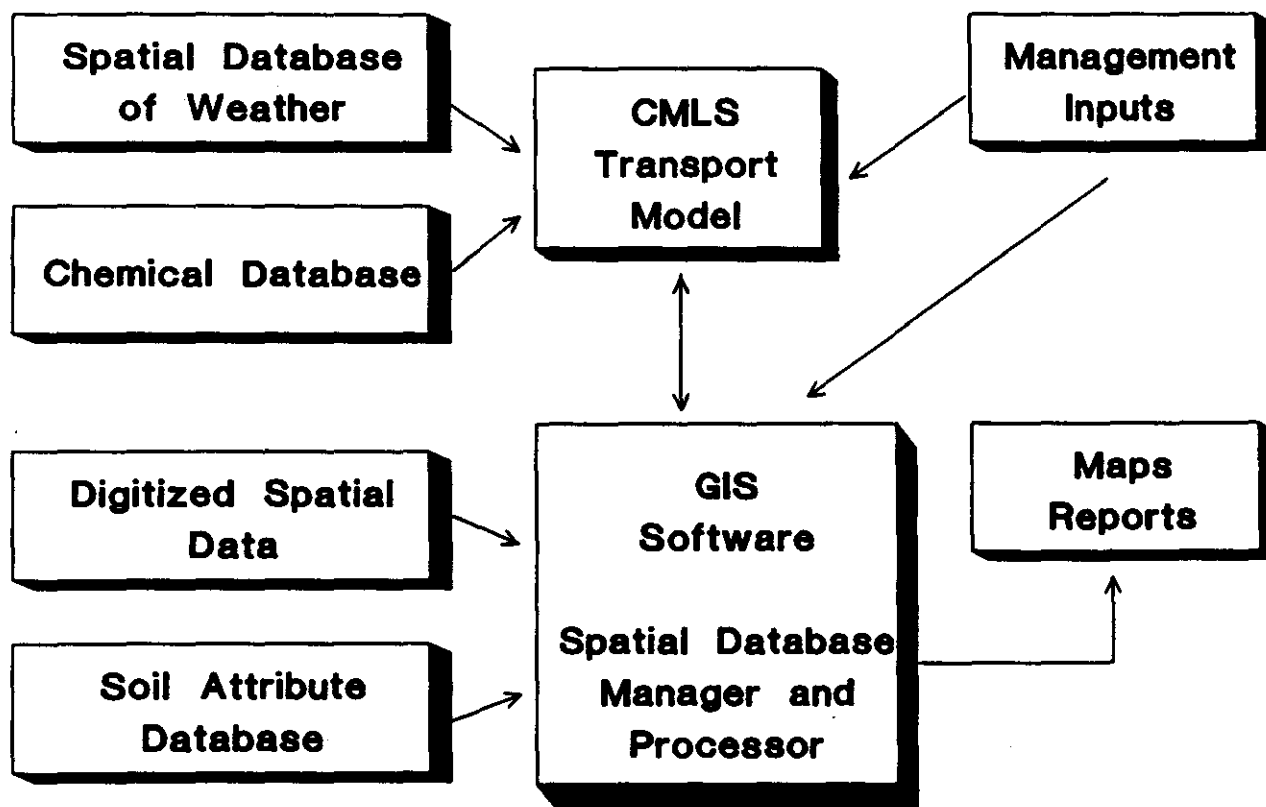


Figure 4

Soil Mapping Units
Lake Creek Watershed
Caddo County, OK

0 2 Miles
0 2 Kilometers

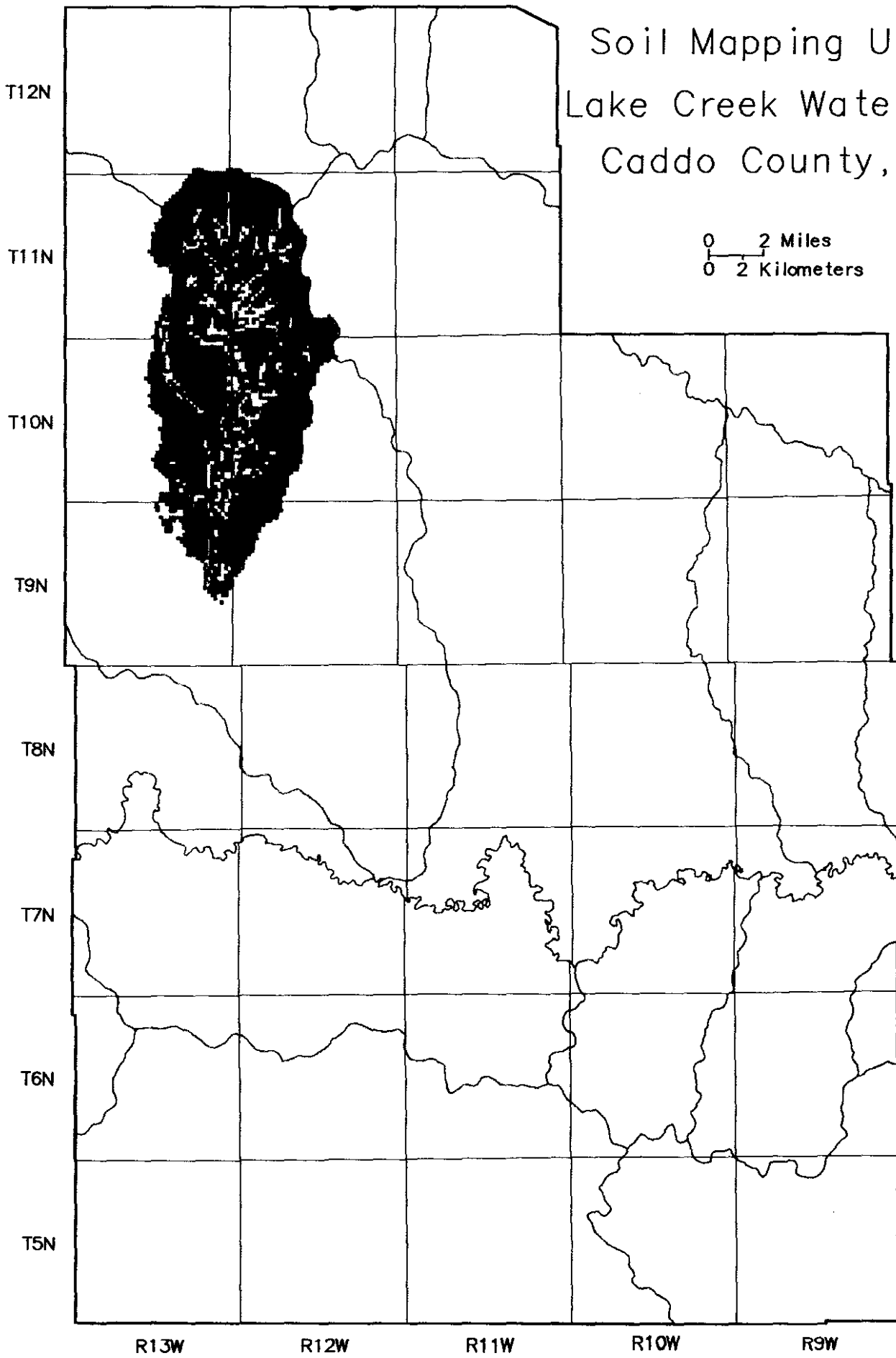


Figure 5

Generalized Landcover/use Lake Creek Watershed Caddo County, OK

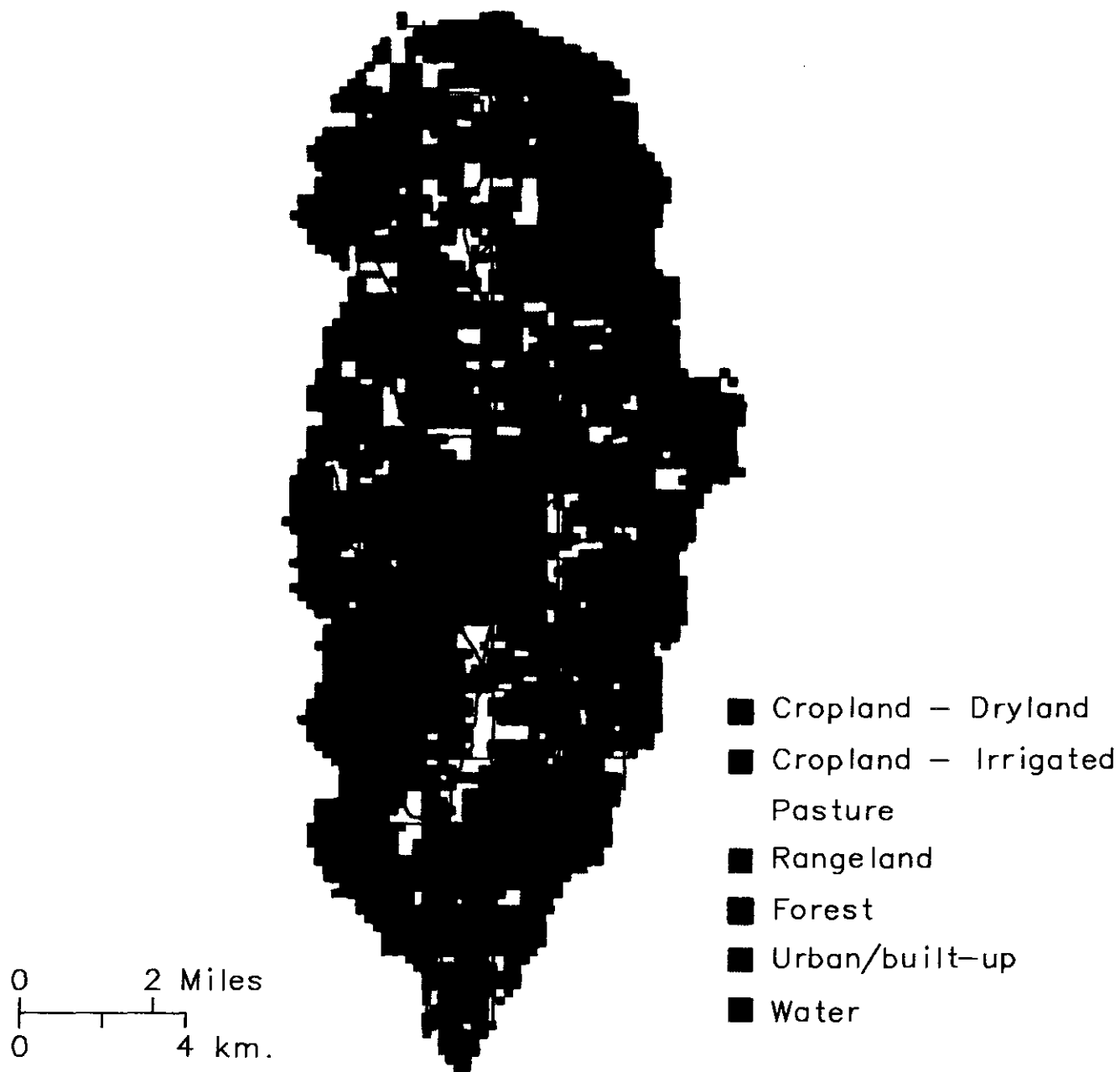


Figure 6

Soil Mapping Units on Cropland
Lake Creek Watershed
Caddo County, OK

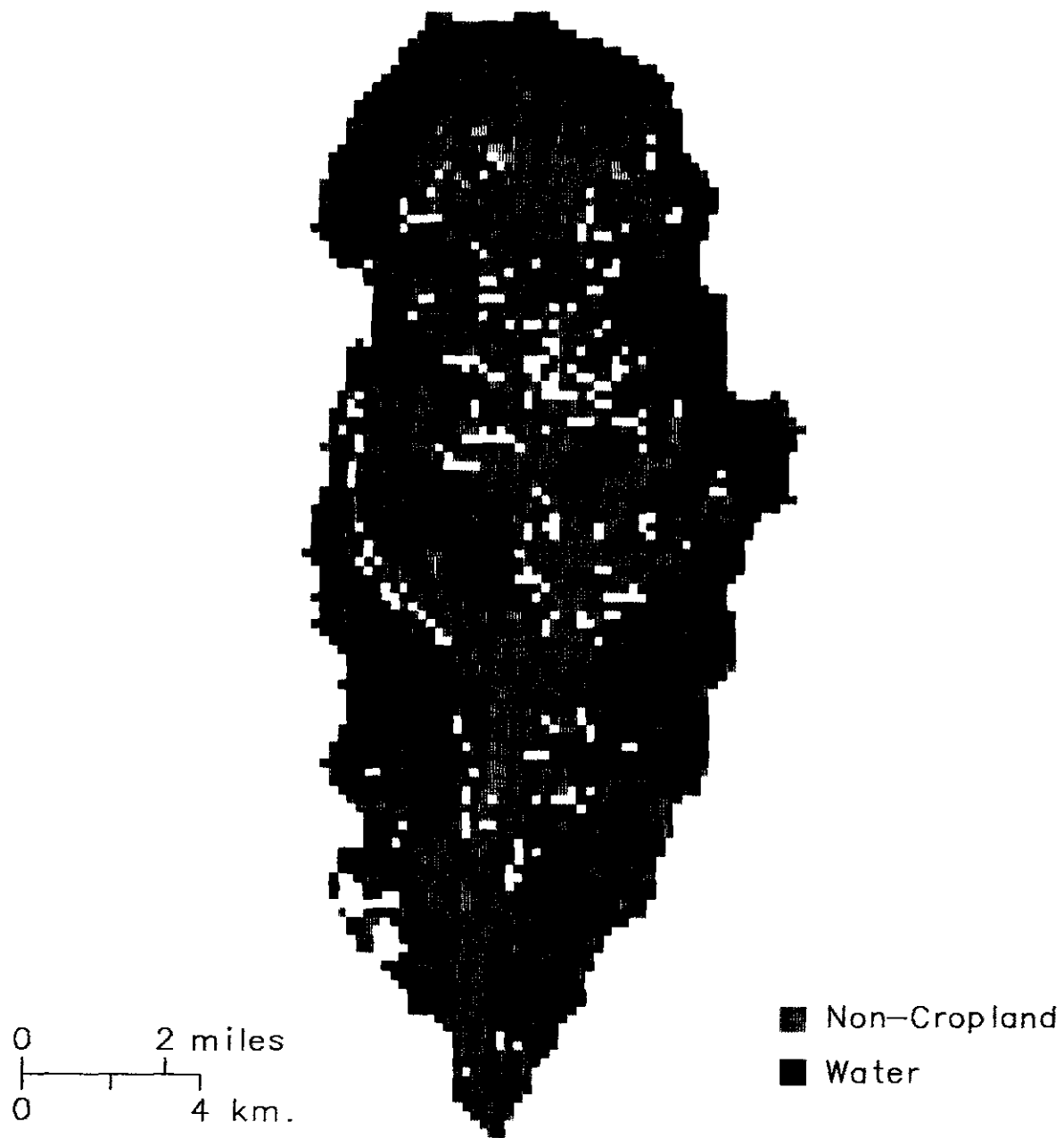


Figure 7

Travel Time Aldicarb Passing 1 Meter
Dryland Condition for Multiple Rainfall Seasons
Lake Creek Watershed, OK

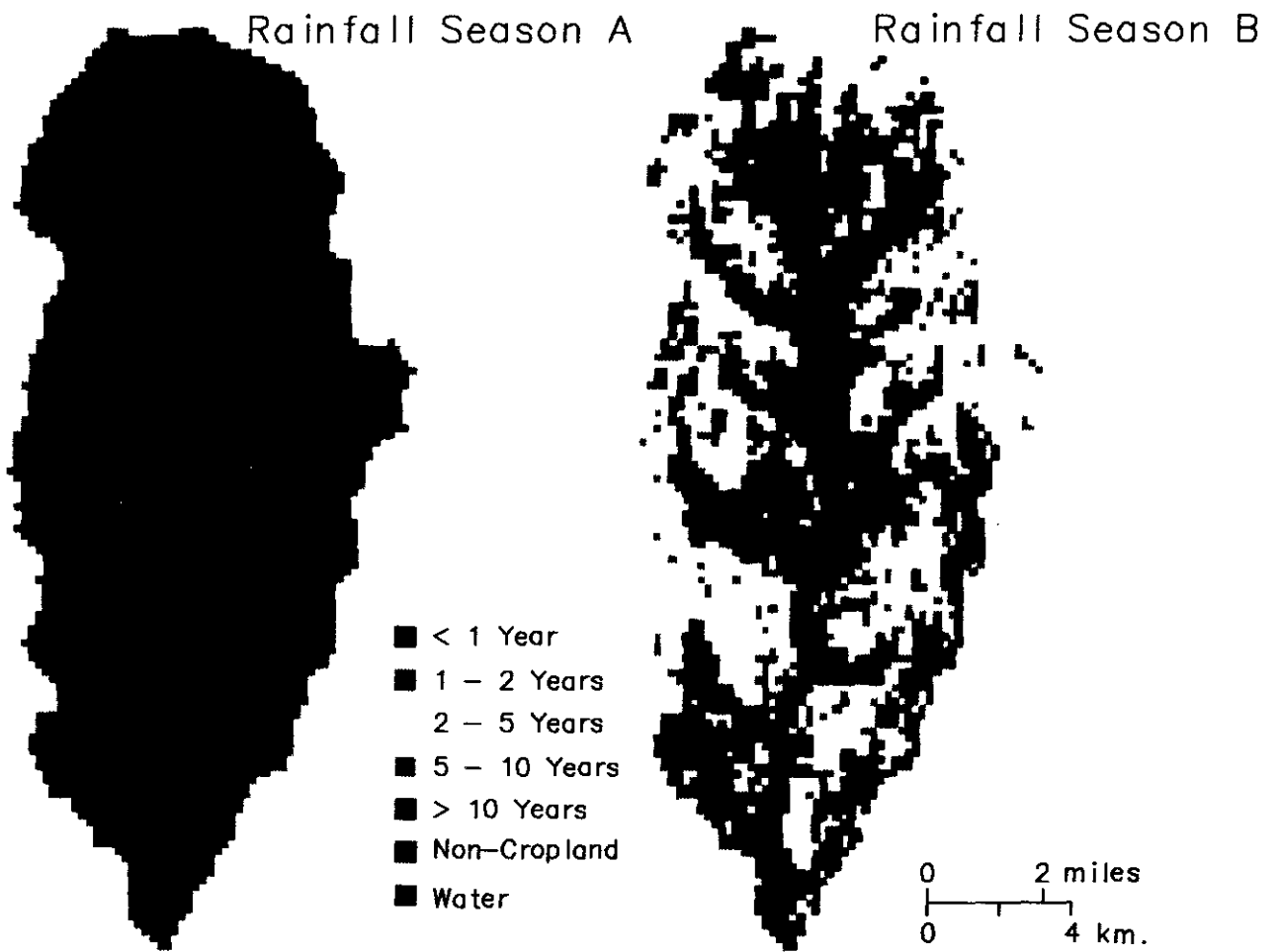


Figure 8

Probability of Exceeding Health Advisory Level
Lake Creek Watershed, OK
ALDICARB (with irrigation)

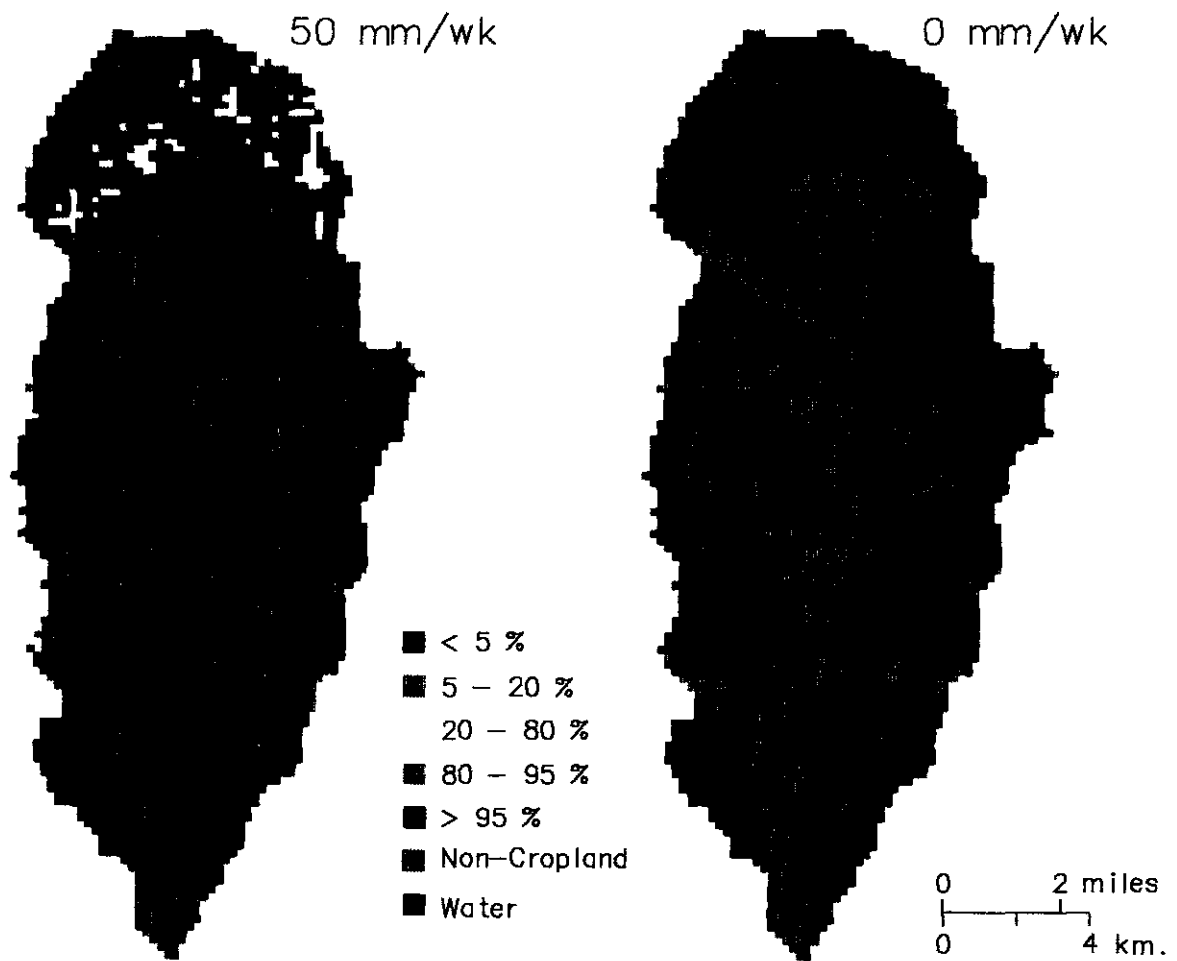


Figure 9

Probability of Exceeding Health Advisory Level
Lake Creek Watershed, OK
ALDICARB (with irrigation)

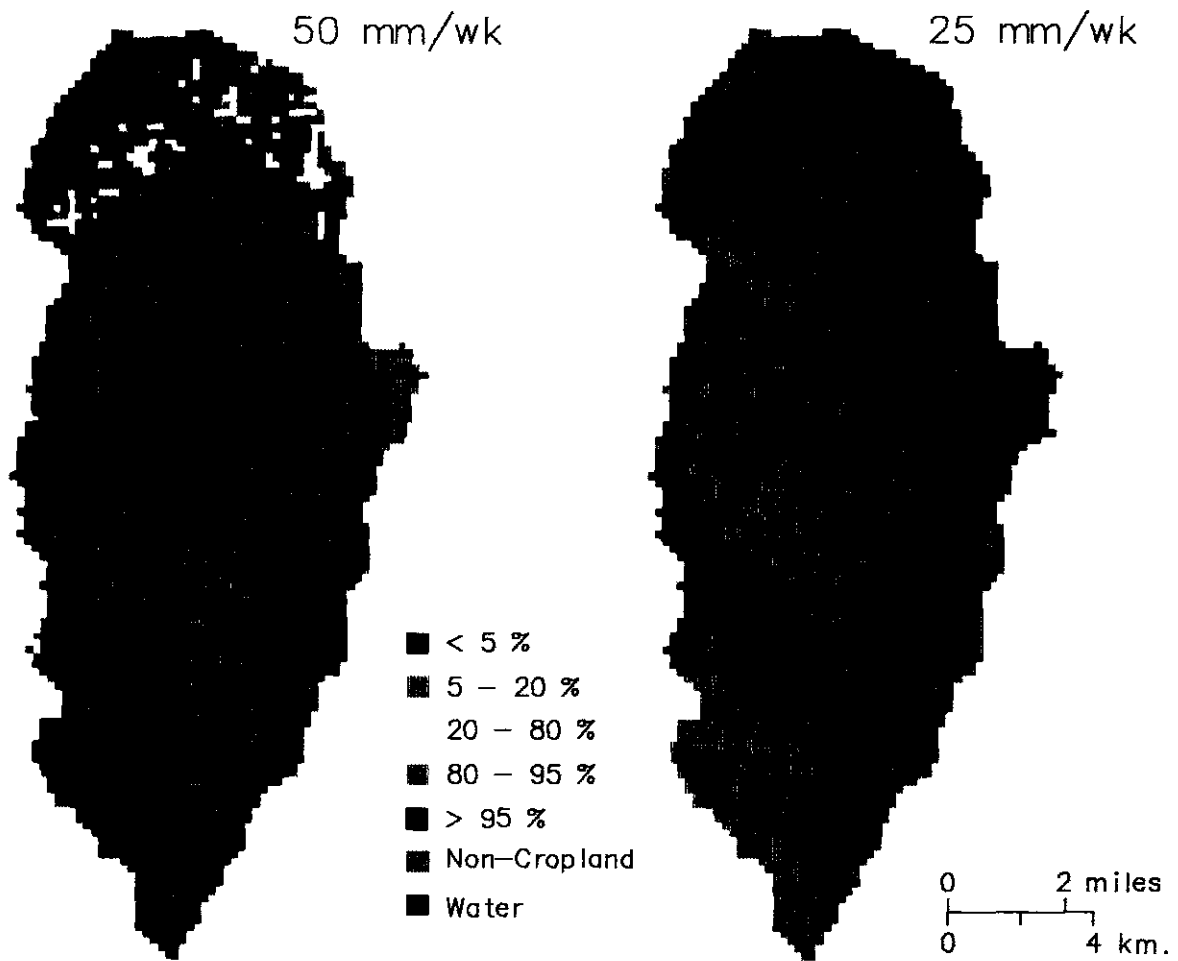


Figure 10

Actual Cropland Use (Dryland or Irrigated) and Probability of Exceeding HAL for Aldicarb Lake Creek Watershed, Caddo County, OK

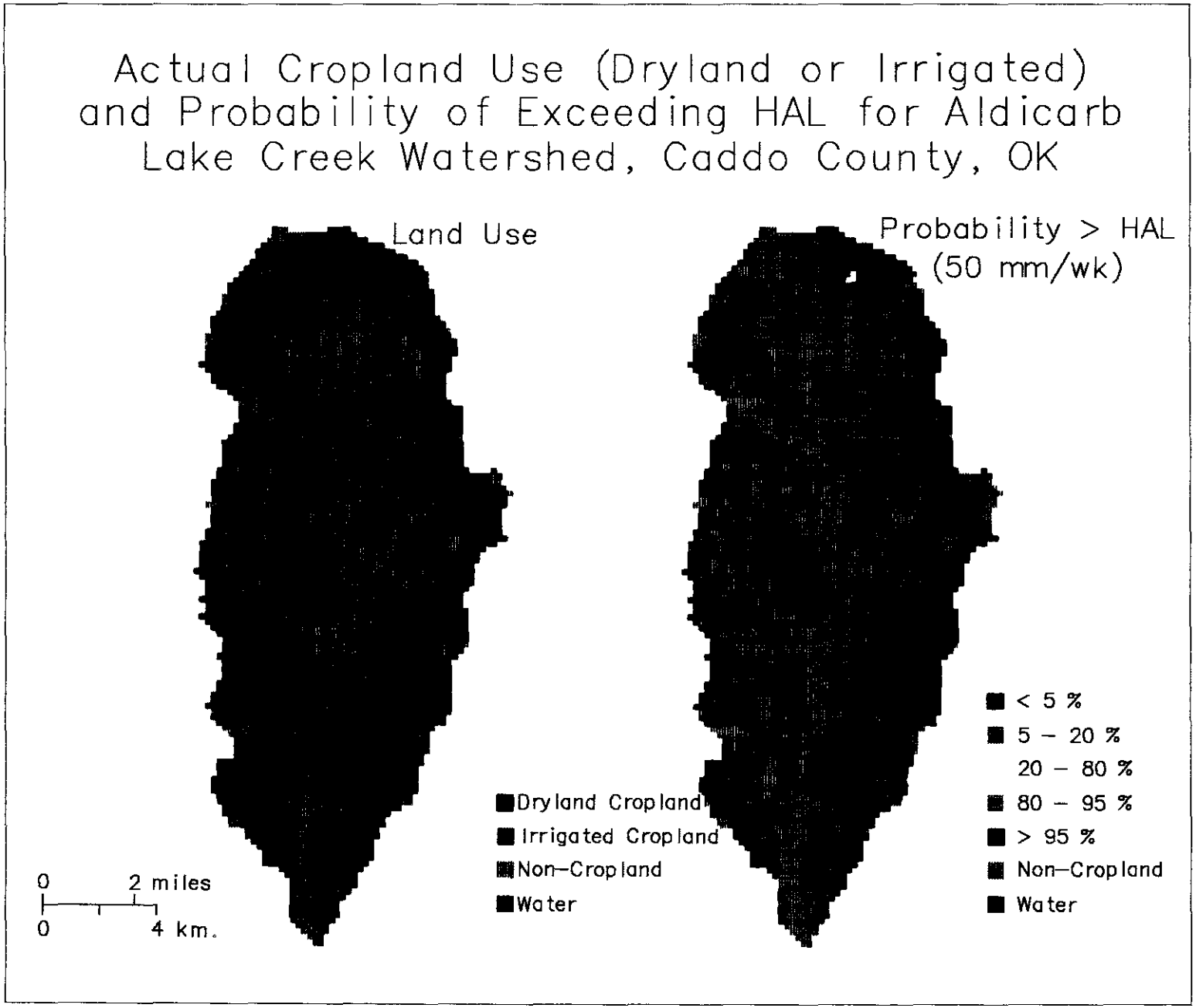


Figure 11

Probability of Exceeding Health Advisory Level
50 mm/week Irrigation
Lake Creek Watershed, OK

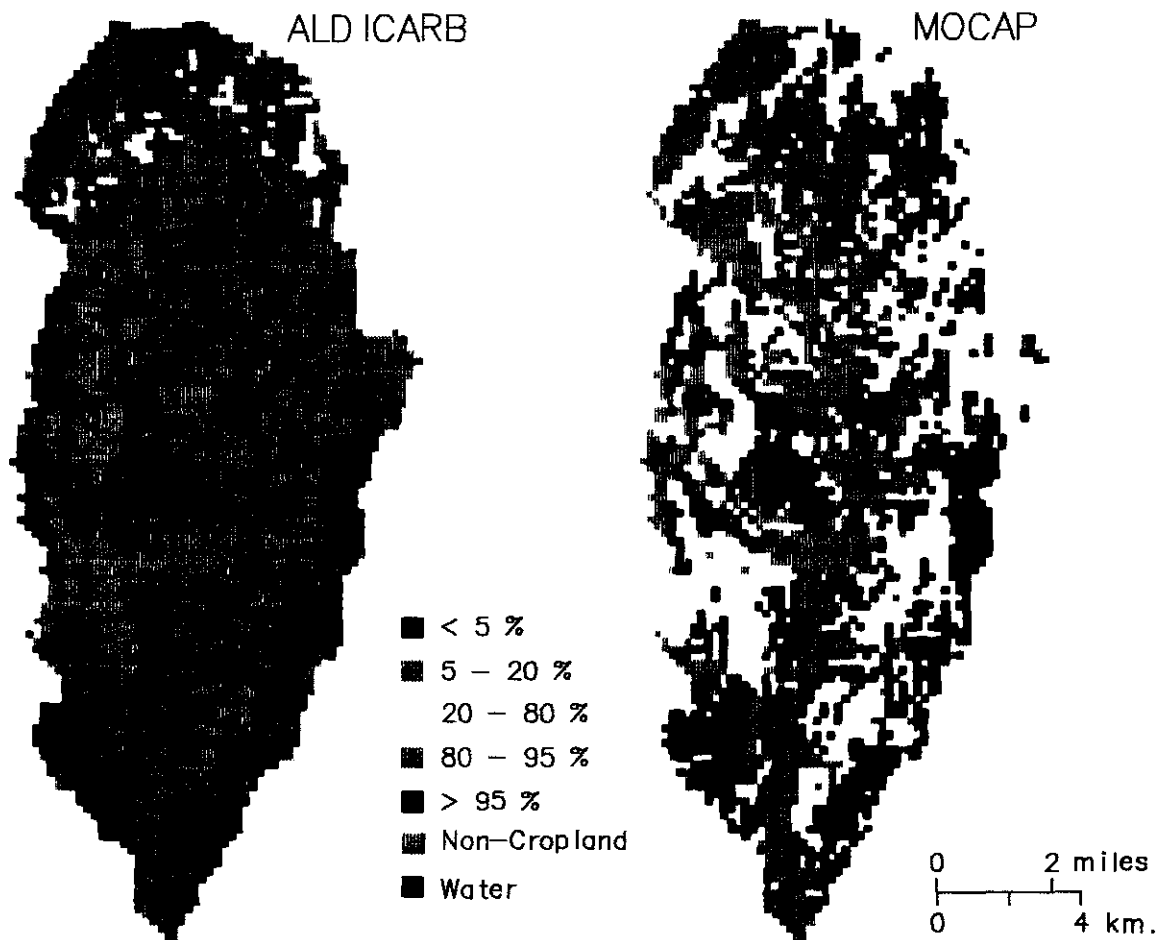


Figure 12

Digital Elevation Model

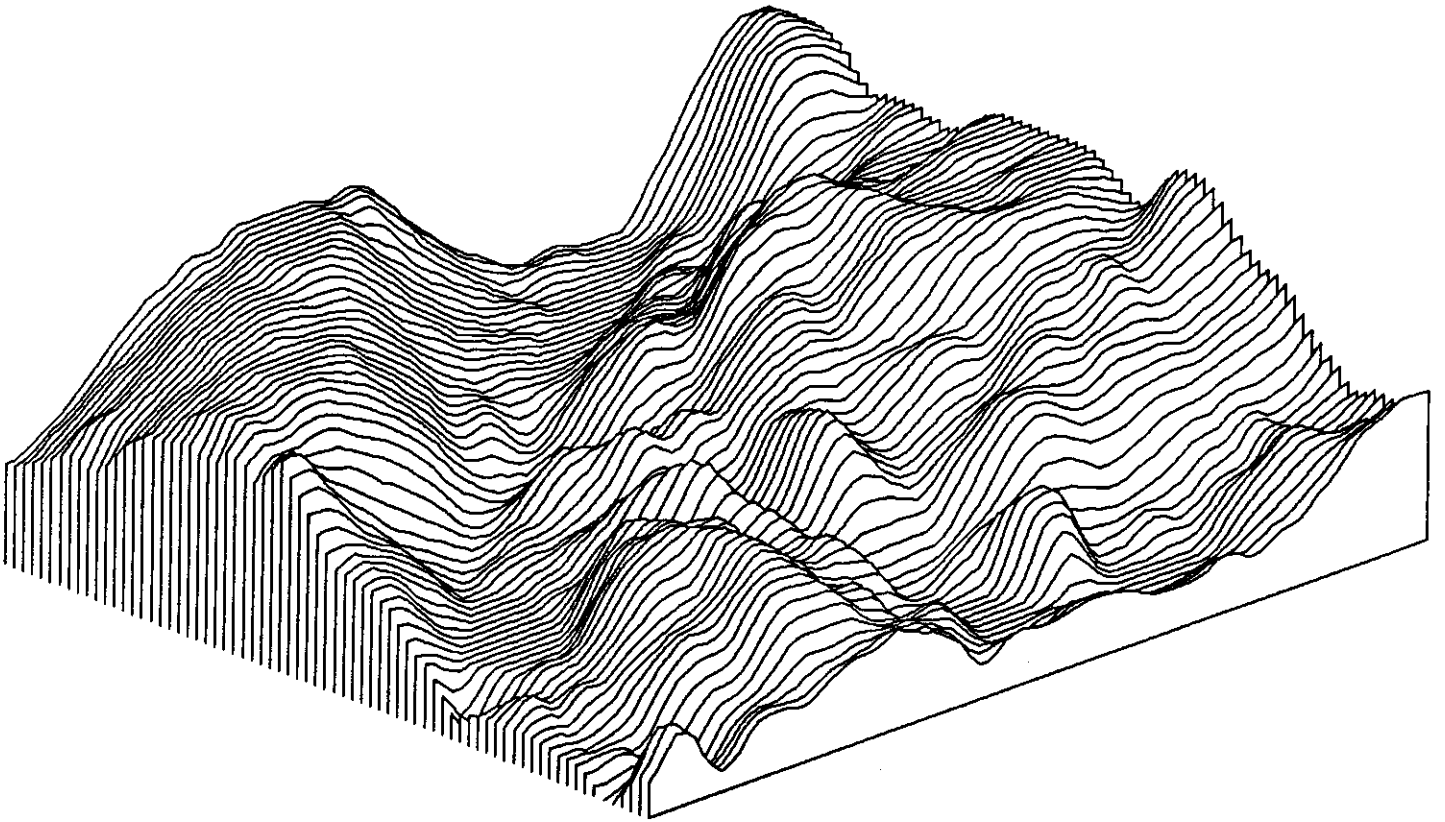


Figure 13