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Foreword

This report is a product of a cooperate project involving five different organizations. These are the geologic surveys in Illinois, Indiana, Kansas, Kentucky and Ohio. The people participating in the project are listed on the web at: http://www.midcarb.org/contacts.shtml.

Abstract

This annual report describes progress of the project entitled "Midcontinent Interactive Digital Carbon Atlas and Relational Database (MIDCARB)". This project, funded by the Department of Energy, is a cooperative project that assembles a consortium of five states (Indiana, Illinois, Kansas, Kentucky and Ohio) to construct an online distributed Relational Database Management System (RDBMS) and Geographic Information System (GIS) covering aspects of carbon dioxide geologic sequestration (http://www.midcarb.org). The system links the five states in the consortium into a coordinated regional database system consisting of datasets useful to industry, regulators and the public. The project is working to provide advanced distributed computing solutions to link database servers across the five states into a single system where data is maintained at the local level but is accessed through a single Web portal and can be queried, assembled, analyzed and displayed.

Each individual state has strengths in data gathering, data manipulation and data display, including GIS mapping, custom application development, web development, and database design. Sharing of expertise provides the critical mass of technical expertise to improve CO_2 databases and data access in all states. This project improves the flow of data across servers in the five states and increases the amount and quality of available digital data.

The MIDCARB project is developing improved online tools to provide real-time display and analyze CO_2 sequestration data. The system links together data from sources, sinks and transportation within a spatial database that can be queried online. Visualization of high quality and current data can assist decision makers by providing access to common sets of high quality data in a consistent manner.

Executive Summary

The Midcontinent Interactive Digital Carbon Atlas and Relational DataBase (MIDCARB) is a joint project between the Geological Survey's of Illinois, Indiana, Kansas, Kentucky, and Ohio, with funding from the Department of Energy National Energy Technology Laboratory. The purpose of MIDCARB is to enable the evaluation of carbon sequestration potential in these states. When completed, the digital spatial database will allow users to estimate the amount of carbon dioxide (CO_2) emitted by source supplies (such as power plants, refineries and other fossil fuel consuming industries) in relation to geologic reservoirs that can provide safe and secure sequestration over geologic periods of time. MIDCARB is organizing and enhancing the critical information about CO_2 sources, and develop the technology needed to access, query, model, analyze, display, and distribute natural-resource data related to carbon management.

The project has established reliable communication and data sharing among all the various servers of the MIDCARB Consortium. Data and information on CO_2 Sources and geologic sequestration sites is obtained from multiple and heterogeneous servers and databases in five different states. The MIDCARB Internet Map Server processes data on servers remote from the data and the results displayed on the user's desktop (http://www.midcarb.org). The process is relatively seamless and response time is good and getting better. Web-database connectivity uses state of the art tools to provide access to heterogeneous relational databases and software maintained independently on numerous servers in the five sites.

The project has developed tools to query, display and analyze CO_2 source, transportation and sink data. Data is obtained from the databases plotted and analyzed in real-time. Tools can relate source and potential sink through spatial query (e.g., find all the oil fields/wells with X distance of a source and provide the necessary information to evaluate the two), and can be modified to limit sources or sinks to various criteria (e.g., depth of sink).

PROJECT OBJECTIVES

Current federal energy policy assumes that hydrocarbons will continue to be the primary source of energy for the United States and the world well into the 21st century. However, there is concern about increasing atmospheric concentrations of carbon dioxide and its possible role in global climate change. For this reason, it may become necessary to manage anthropogenic CO_2. Sequestering CO_2 in geological reservoirs may be one way to safely sequester carbon over long periods of time, if the proper data and tools to analyze the geological feasibility as well as the associated costs can be developed.

The Midcontinent Interactive Digital Carbon Atlas and Relational DataBase (MIDCARB) is a joint project between the Geological Survey's of Illinois, Indiana, Kansas, Kentucky, and Ohio, with funding from the Department of Energy National Energy Technology Laboratory. The purpose of MIDCARB is to enable the evaluation of carbon sequestration potential in these states. When completed, the digital spatial database will allow users to estimate the amount of carbon dioxide (CO_2) emitted by source supplies (such as power plants, refineries and other fossil fuel consuming industries) in relation to geologic reservoirs that can provide safe and secure sequestration over geologic periods of time. MIDCARB is organizing and enhancing the critical information about CO_2 sources, and develop the technology needed to access, query, model, analyze, display, and distribute natural-resource data related to carbon management.

Large stationary sources of CO_2 emissions are identified, located, and characterized. Potential CO_2 sequestration targets, including producing and depleted oil

and gas fields, unconventional oil and gas reservoirs, uneconomic coal seams, and saline aquifers, will be characterized to determine quality, size, and geologic integrity. All information will be available online through user query. Information will be provided through a single interface that will access multiple servers in each state. The approach is one of the first demonstrations of large scale distributed natural resource databases and geoinformatics. Access to the up-to-date technical information can be used at the regional and national level as a tool to minimize the negative economic impact, and maximize the possible value of the CO_2 sequestration to hydrocarbon recovery from oil and gas fields, coal beds, and organic-rich shales.

PROJECT STATUS

After a several frustrating attempts communication has been established among all the various servers of the MIDCARB Consortium. Web-database connectivity uses both the ColdFusion application server, and ARC-Internet Map Server (IMS) using ARC Spatial Data Engine (SDE). These applications access relational databases and software on numerous servers in the five sites.

Accomplishments

The major project accomplishments are:

1) Established reliable communication and data sharing among all the various servers of the MIDCARB Consortium. It is not obvious to the user that data and information is obtained from multiple and heterogeneous servers and databases in

five different states. The MIDCARB Internet Map Server processes data on servers remote from the data and the results displayed on the user's desktop. The process is relatively seamless and response time is good and getting better. Web-database connectivity uses both the ColdFusion application server, and ARC-Internet Map Server (IMS) using ARC Spatial Data Engine (SDE). These applications access heterogeneous relational databases and software maintained independently on numerous servers in the five sites.

2) The project has developed tools to query, display and analysis CO_2 source, transportation and sink data. Data is obtained from the databases plotted and analyzed in real-time. Pages are not static; instead they provide dynamic access to the most current data maintained on independent servers operating with the MIDCARB Consortium.
3) The project has developed tools that can relate source and potential sink. This is normally a spatial query (e.g., find all the oil fields/wells within X distance of a source and provide the necessary information to evaluate the two), but they can be modified to limit sources or sinks to various criteria (e.g., depth of sink).
4) The project has developed the prototype tools to automate the process of individual states submitting the required information concerning new MIDCARB databases and coverages. This will permit consortium members to automate processes of loading data into the MIDCARB systems and lead to rapid growth in data and information available.
5) We have provided a strong prototype that has an extensive and very useable coverages and information on CO_2 sources (Table 1). Data is concentrated on

electric generation facilities but also includes other high concentration CO_2 sources (e.g., ethanol plants, refineries, fertilizer plants and cement plants).

6) We have provided a strong prototype that has an extensive and very useable data and information on CO_2 sinks. Data is concentrated on petroleum and coal, but will include information on aquifers. For example one can query and display information on all the oil fields in Indiana (e.g., area, thickness, depth), coal beds in Illinois (e.g., depth thickness), and all the operating oil and gas wells in Kansas. This information can be very detailed and include for the oil and gas well example, production, depth to reservoir intervals, electric logs, pressure transient tests. This information can be related to the CO_2 source (or potential source) through spatial query (how much CO_2 can be potentially sequestered within a given distance). It can also be used to query for new opportunities in terms of locating a new CO emission source.
7) Provided initial coverages and query of transportation options (i.e., oil and gas pipelines). Indiana as the first state provides an important link between source and sink. This will be expanded to the other consortium members.
8) We have provided technology transfer to the geologic community through talks and posters (see http://www.midcarb.org/events.shtml for a listing and examples). Some of these have won best presentation awards (e.g., AAPG Eastern Section Meeting on September 23-25, 2001 in Kalamazoo, Michigan won the Levorsen Memorial Best Paper Award (http://www.midcarb.org/Documents/AAPG-Sept-2001.shtml). Several upcoming presentations are scheduled.

Short-Term Goals

Immediate short-term goals that will be realized prior to the end of the next project year are to:

1) Add significant new coverages and databases that increase the richness of the MIDCARB site. Expand and provide the same coverage types in every state of the consortium. We have concentrated on getting one data type going in one state. However, we will clone the approach in the others (example pipelines in Indiana will be spread to the other states). This approach provides a synergy by allowing individual states to pioneer coverage and database types and spread the expertise to the other states.
2) Develop and add better query and analysis tools. The present tools represent a significant increase in capability, but are still relatively crude. The biggest need is to develop complex query capabilities that provide flexible and focused access to specific data types (e.g., all the coal beds at a specified depth and within a given distance of a CO_2 source that have a predetermined reservoir characteristics).
3) Expand the data sets to include more information on the properties of the reservoir and the fluids. Property data is very sparse compared to the number of wells, reservoirs and area of coal. We need to work on catalogs that can be used as analogs properties in order to compute at least rough viable values. For example: There are only a few values of methane content of subsurface coals and these are usually concentrated in a small spatial area. We need to let the user select from a viable range of values to be able to compute the methane content of

a individual coal bed covering a very large area. You can extend this uncertainty and paucity of data to the potential CO_2 to methane substitution ratios.

4) Provide improved display and analysis tools to summarize data over a specified area (e.g., total annual CO_2 emissions within a polygon and plot the emission data on a quarterly basis over the year). Provide flexibility to designate scales of plots. Provide improve download capabilities to move data and coverages to the client's machine for additional analysis.
5) Provide a method to maintain the communication and growth in the databases after the project has ended. We need to get over the hump and make this a system that will be maintained by the individual organizations. We also need to provide an incentive for other states to join and link to the MIDCARB system.

SUMMARY OF TECHNICAL PROGRESS

Overview

A major challenge of the MIDCARB project is to bring together within an efficient, easy to access, and readily maintained knowledge management system the millions of records pertaining to CO_2 sequestration that resides in the five states of the MIDCARB Consortium (Illinois, Indiana, Kansas, Kentucky and Indiana). The MIDCARB system provides global access across the organizations to manipulate pertinent geologic and engineering data related to the issues involved in identifying and evaluating opportunities for geologic CO_2 sequestration. Relational databases are developed in each state to characterize stationary sources of CO_2 and potential oil, gas, coal, and brine reservoirs for sequestration.

The MIDCARB Consortium uses a distributed approach with applications, such as Internet Map Server (IMS) and Plot Servlets, that access and aggregate data from Relational Database Management Systems (RDBMS) at each organization (Figure 1). The system provides pre-selected map themes, custom map themes, and flexible query capabilities. The IMS is a scalable and failure-resistant system that can issue spatial queries to a spatial database engine (SDE) sitting on top of the various RDBMS on each of the cooperating computers maintained by each MIDCARB organization. The system is built to be highly reliable and efficient with programming focused on interface technologies that will be of particular benefit to end-users in particular discipline areas, policy makers, and the interested public. Work is focusing on designing adequate metadata standards to assure data quality and consistency. Online users will see a single window to enter queries and receive results. However, the technical and spatial information on, both CO_2 sources and potential CO_2 sequestration sites, reside and are maintained at the local level (i.e., the individual states), and data is stored in relational tables of varying structure on systems that are unique to each participant.

The MIDCARB Internet Map Server (IMS) issues spatial data queries to spatial data engines (SDE) and relational database management systems (RDBMS) operating on servers in each of the five states of the consortium. The IMS approach is scalable and flexible. It does not require individual organizations to follow rigid standards for hardware, software, metadata or data formatting. Additional states and organizations could be added to the MIDCARB System with little additional effort. The data assembled using the MIDCARB browser comes from up to five different servers in five different organizations. The MIDCARB Internet Map Server, related analysis tools and

available data sets are rapidly evolving and growing. The system that is described in this report will be very different from week-to-week, but functionality, data richness and response time will constantly improve. The MIDCARB system is only the first step in the first distributed system of natural resource data focused on CO_2 sources and potential geologic sequestration sites.

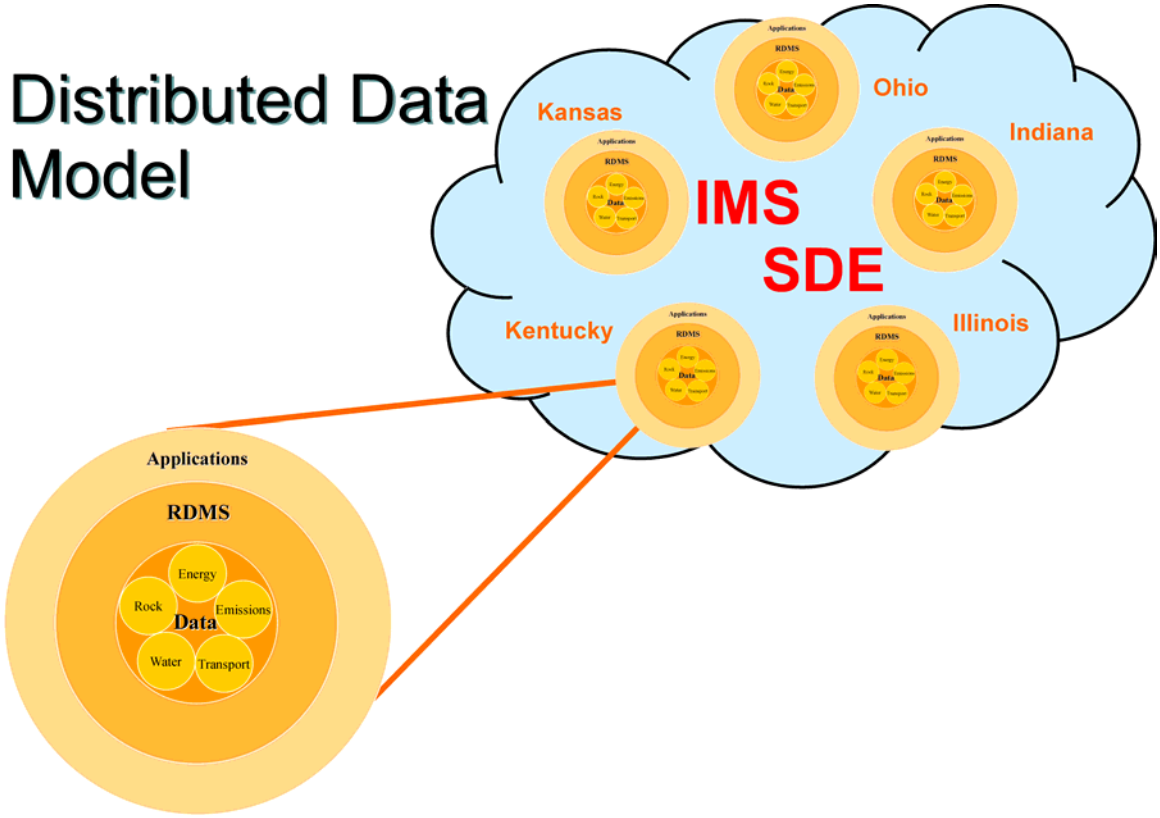


Figure 1 – Conceptual diagram of the MIDCARB data model. Data covering aspects of the sources and geologic sinks related to CO_2 sequestration are on located servers in each state of the MIDCARB Consortium (Illinois, Indiana, Kansas, Kentucky and Ohio). Data are stored in data tables with various structures within a relational database management system (RDBMS). Mapped data structures at each site are linked to the MIDCARB Internet Map Server (IMS) using spatial data engines (SDE's) operating at MIDCARB site.

Server Connectivity – Internet Map Server

An interactive map server using a geographic information system (GIS) approach has been created to test and demonstrate the connectivity of spatial and temporal databases among the five states cooperating on the MIDCARB project (Illinois, Indiana, Kansas, Kentucky, and Ohio). Interactive map layers are loaded in real time from databases distributed on independent servers in the separate states (Figure 2). The two-letter state abbreviation prefix included in the layer name indicates which state's database is being loaded (for example, "IL - Power Plants" is loaded from the Oracle server at the Illinois State Geological Survey). Map layers not having a state prefix, such as "USA - Rivers," are loaded from the SQL Server database at the Indiana Geological Survey.

The interactive map is used to distribute information about major sources of carbon dioxide and potential geologic sequestration targets in the five-state mid-continent region. Web-to-Database connectivity tools are provided to access relational databases on each individual server. Data from many millions of objects can be queried, manipulated and displayed in real time (see next section). As long as the basic table structure is maintained, data can be modified and updated on the individual servers independent and without informing the other organizations. This independence while providing a useful product, maximizes the value of the data-maintained by the MIDCARB Participants on individual servers. It also minimizes the overhead costs imposed by strict standards imposed by a top-down rigid data-system structure, maximizes the flexibility of the system to demonstrate new information technologies and incorporate different servers in different organizations. Many of the data tables and map layers included in the MIDCARB Internet Map Server are in a preliminary state of

completion. As a result, the content of layers and format of the page will change as additional data and analysis tools are developed.

The MIDCARB site uses ArcIMS to connect to SDE servers at the different sites. The IMS interface supports industry-standard GIS formats including ArcView GIS shapefiles, ArcInfo coverages, Spatial Database Engine (SDE) layers, DWG, DXF, DGN, and a variety of graphic images. IMS also does something that no other Web-based mapping solution can: it enables true distribution of GIS applications through the Internet. Data can be maintained in formats developed at the local level. Data does not need to be converted to a proprietary format, so the MIDCARB approach can immediately Web-enable GIS and CO_2 data from other states and organizations. A cookbook approach to demonstrate the current capabilities of the MIDCARB Internet Map Server is provided in Appendix A. A overview of the MIDCARB Internet Map Server tools is provide in Appendix B.

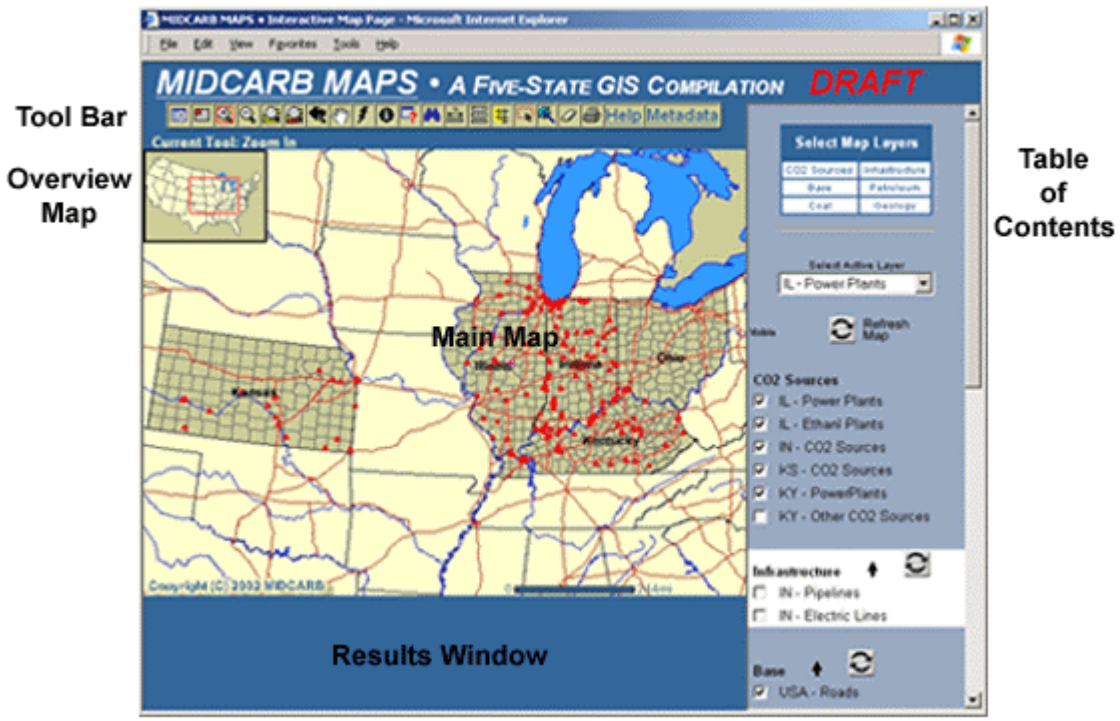


Figure 2 – View of the MIDCARB Internet Map Server showing the different frames.

Web-to-Database Connectivity - ColdFusion

Web-to-database connectivity for the MIDCARB web site is built using the ColdFusion application server. The approach allows computation and display of data retrieved from numerous data tables in relational databases scattered across the five states. Through the Internet Map Server one can query an individual object. Objects include emission sources but prototypes have been developed for other objects with time sequence data (e.g., oil and gas wells, and water wells). As an example, a sample page displays sources of emissions data from electric power generation facilities (Figure 3). Data includes all emissions data as reported to the EPA and state organizations. Information is also available from other industrial CO_2 emission sources (e.g., cement and ethanol plants).

The active layer is selected in the frame on the right side of the screen (i.e., IL – Power Plants). Clicking on the Hyperlink Tool then on the map object initiates the Query to the local database (Illinois) and to the ColdFusion client located on the Kansas server.

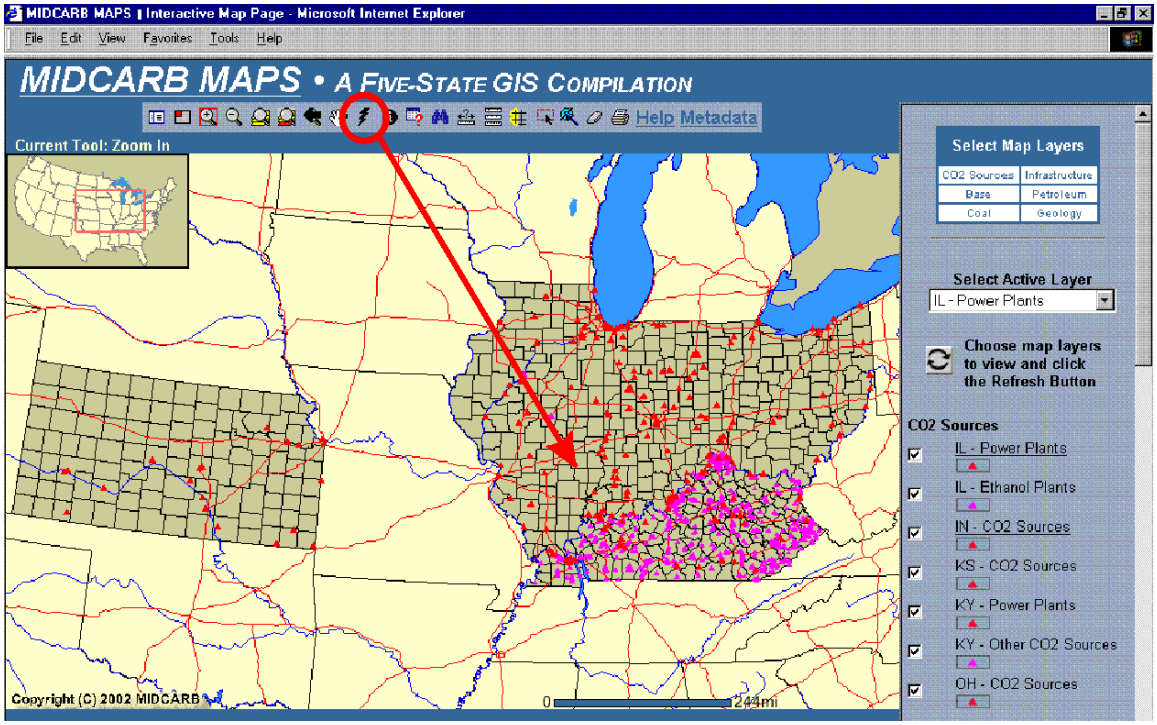


Figure 3 – Internet Map Server Page with a circle around the *Hyperlink Tool* ("Thunderbolt"). Using the *Hyperlink Tool* on an object in a select state sends a query to the relational database located in that state. Web pages are created on demand using HyperText Markup Language (HTML), a markup language that tells the web browser how to format and organize the text and figures that make up the page. ColdFusion uses HTML extensions to that replace the static text on a web page with the result of the database query. The result is displayed in Figure 4.

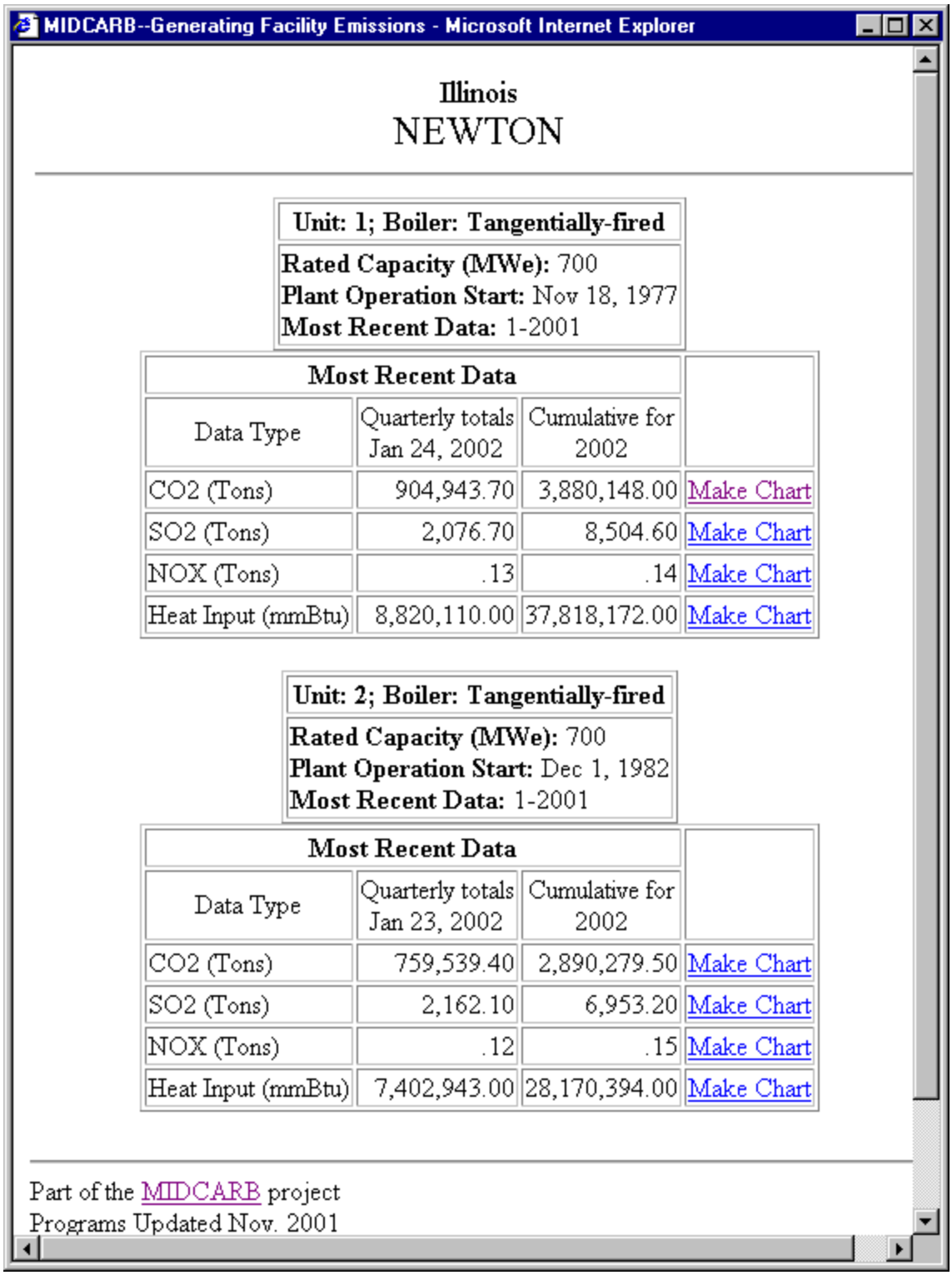


Figure 4 – Summary data for emissions at selected source returned by the ColdFusion client after query. Data is the most current available and retrieved from remote server in Illinois or any of the five MIDCARB States. Clicking on the *Make Chart* tag results in the client generating a plot of all emissions data through time (Figure 5).

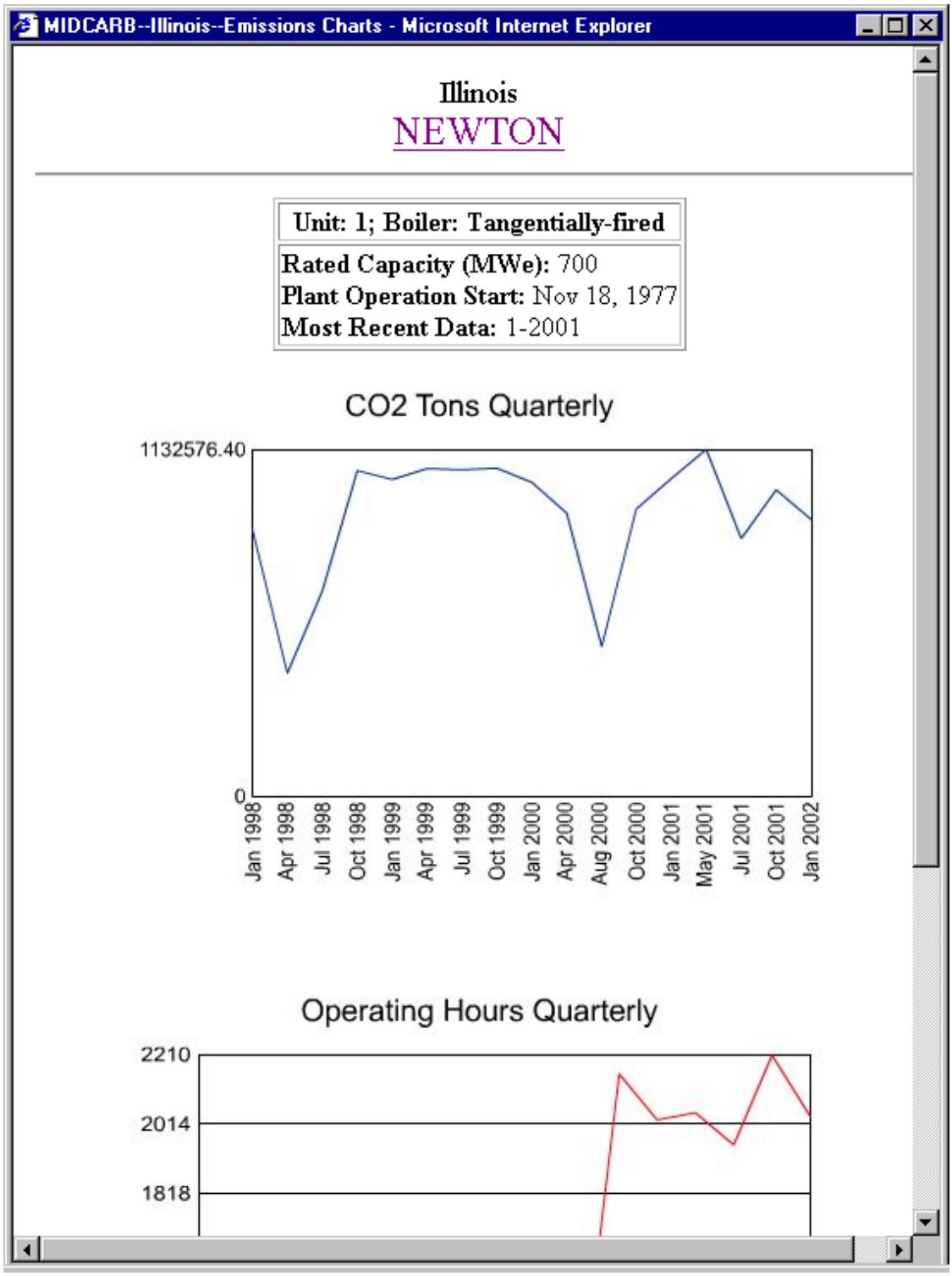


Figure 5 – Plot of CO_2 emissions for selected source and components. Plot is generated on demand using ColdFusion applets from data stored in remote databases. To return to summary page click emission source tag (Newton). Data is current through January 2002.

A benefit of ColdFusion over other database connectivity tools is its ease of connecting to multiple databases at remote locations. While proprietary solutions are available from each database vendor, ColdFusion connects to all commercial relational database management systems using the same standards.

A web page created using ColdFusion is made of three parts. The first is the database connectivity, set up on the Web-ColdFusion server. The server must be told where to find the database of interest and how to log in to that server. In the examples below the data source has been called "illinois." This will access the database maintained at the Illinois Geological Survey (Figure 4). The query is independent of changes in the database content.

The second part is to add a query to a web page. An example query from the MIDCARB site would have the form of:

```
<cfquery name="g_facil_q"
     datasource="illinois"
     dbtype="ODBC">
select PLANT_NAME,CALENDAR_QUARTER,CALENDAR_YEAR,
     EPA_FACILITY_ID
from EPA_FACILITES
where FACILITY_ID=#f_idSent#
</cfquery>
```

One benefit of ColdFusion is the transparent use of HTML and Special Query Language (SQL) database queries. Very little modification is required to move from a static web

page to a ColdFusion page. The <cfquery> tag describes where the data resides and what the query will be called. That is followed by standard SQL. The term "#f_idSent#" is sent in from a web page. This selection can be made from a list of text links, a query form, or a clickable map. In the example from MIDCARB this query is through a clickable map (Figure 2). Clicking on a location send a query to the remote server to recover appropriate information (Figure 4).

The third part uses a <cfoutput> tag to run the query and display the data. The query output can be placed inside standard HTML formatting, though the ColdFusion system contains many custom tags to assist in formatting. In this example, the output will be placed in a table cell:

```
<cfoutput query="g_facil_q">
<table>
<tr><th>Power Plant Name:</th></tr>
<tr><td># g_facil_q.PLANT_NAME#</td></tr>
</table>
</cfoutput>
```

Because of the <cfquery> tag, the value "# g_facil_q.PLANT_NAME#" is replaced by the value from the query defined earlier on the web page.

ColdFusion also includes tags to create loops or if-then-else structures so that a set of queries can be repeated for different input values. There are also tags for making charts, creating forms, and many other utility functions (Figure 5). These charts are generated on demand.

Summary of Available Coverages and Databases

The MIDCARB site is bringing together high quality coverages and databases of CO_2 sources, potential geologic sequestration sites and transport options into a single system that permits query, display and analysis. The past year has concentrated on developing prototypes that cover one or more states. A list of currently available coverages is provided (Table 2). After a coverage and database is tested for a part of the MIDCARB consortium it will be extended to all the states. The coverages and databases described are in production mode and available online. Additional coverages are being added.

A database and coverage of CO_2 sources has been developed that relies on both US Department of Energy EIA and Environmental Protection Administration data for industrial sources. The coverage contains the latest quarterly emissions data and source characteristics (e.g., location, plant size, etc.). The data can be queried and displayed in real time using a combination of the MIDCARB Internet Server and applets (figures 3 – 5).

The work on locating and identifying geologic reservoirs has concentrated on available oil reservoirs, gas reservoirs, coal beds, and saline aquifers geographically and in depth. This is a very large task but progress has been made in development of a data structure and methodology for mapping petroleum reservoirs. The best example is in Indiana. Currently data is available on the area and outline of petroleum reservoirs in Indiana (See Appendix A for example). The mapping is being extended to incorporate initial production and pay zone data extracted from the Indiana petroleum database. Mapping is automated using a custom-built extension for ArcMap that calculates a set of

statistics for each reservoir outline based on values from the wells within the outline. In Kansas, access is being developed to provide access to over 300,000 oil and gas wells. The approach is similar to the CO_2 source database. The user can query, and plot production and other data from individual wells. Another approach to oil and gas reservoirs provided by Ohio is almost ready to be placed online, and is discussed in the next section.

Coverages of selected coal horizons in the Illinois basin and Ohio are available online and can be queried and displayed (Table2 and see Appendix A for example). Data includes thickness, depth and preliminary information on methane content. Note: The methane content in addition to overburden thickness can be used to estimate potential quantities of CO_2 that can be sequestered. Work is now underway to obtain additional CH_4 / CO_2 values for important coals in the consortium states.

Work is nearly complete on several saline aquifer coverages in the consortium. These include the Hunton Aquifer (Muscatatuck and Maquoketa Groups) and the Mt. Simon.

For example we have completed entry of stratigraphic pick data for all Indiana saline wells that penetrate the Silurian. Data were used to extrapolate grid surfaces, which delineate the top and bottom of the Hunton Aquifer (Muscatatuck and Maquoketa Groups). The structure of GIS files and databases are being finalized to manage saline aquifer data for MIDCARB. Saline aquifer point data include thickness of porous units, aquifer salinity, and aquifer porosity. The preliminary mapping and calculation of the estimated total pore volume available within the porous zones of the Hunton Aquifer in southwestern Indiana has been completed. The results of the analysis were presented at

North-Central/Southeastern GSA in Lexington, KY (See Solano-Acosta, Wilfrido and Nathan K. Eaton). A version of this analysis covering the complete Hunton Aquifer is in progress, and will include more detailed estimations of CO_2 sequestration capacity. This approach is being expanded to additional zones of interest.

As the structure of the MIDCARB system has become more robust, stable and efficient it is expected that the number of coverages and databases available for the MIDCARB consortium states will increase substantially over the next year.

Examples of Future Near-Term MIDCARB Products

As part of the MIDCARB project, we intend to calculate the coalbed methane resources and CO_2 sequestration potential of all the significant coalbeds in the consortium area. We are collecting data on methane adsorption and coalbed characteristics. CO_2 can be sequestered in coalbeds in a number of ways (e.g., solubility, hydrodynamic, and adsorption trapping). CO_2 can also be geologically sequestered either as a gas or in a supercritical state. As an example, a GIS evaluation of coals underway in Ohio will be integrated into the MIDCARB Project. Structure contour maps of the Mississippian-Pennsylvanian boundary, net coal thickness maps, and overburden maps of the Pennsylvanian-Permian sedimentary section are being generated. Note: A number of these maps are available on the MIDCARB Internet Map Server. These maps when combined with desorption data (methane content per ton) can be used to calculate an estimate of the suitability and potential of individual coal beds to sequester CO_2 (Figure 6a-d). Using these types of coverages and data within the MIDCARB Internet Map

Server will allow query and display capability and spatial analysis in relation to CO_2 sources.

Tools and approaches are being developed as part of the MIDCARB project to calculate the amount of CO_2 sequestration in oil and gas fields (Figure 7). The results will be used as a template for the other consortium states and integrated with the MIDCARB Internet Map Server. In this example, the Clinton sandstone oil and gas pools GIS layer are displayed, along with the attributes associated with the oil and gas pools (Figure 7). Each pool in the GIS layer is represented by a color filled polygon, and each of the polygons is tied to a record in the attribute table. Each pool has different attributes associated with it, such as Average Thickness, Average Porosity, and Original Oil In Place. The attributes associated with each polygon are used to estimate the quantity of CO_2 that can be sequestered in individual oil and gas pools. The calculations used to make the estimates are also attributes associated with each polygon in the GIS. Highlighted in yellow, the Canton Consolidated oil & gas field is estimated to able to sequester over 51 billion tons of CO_2.

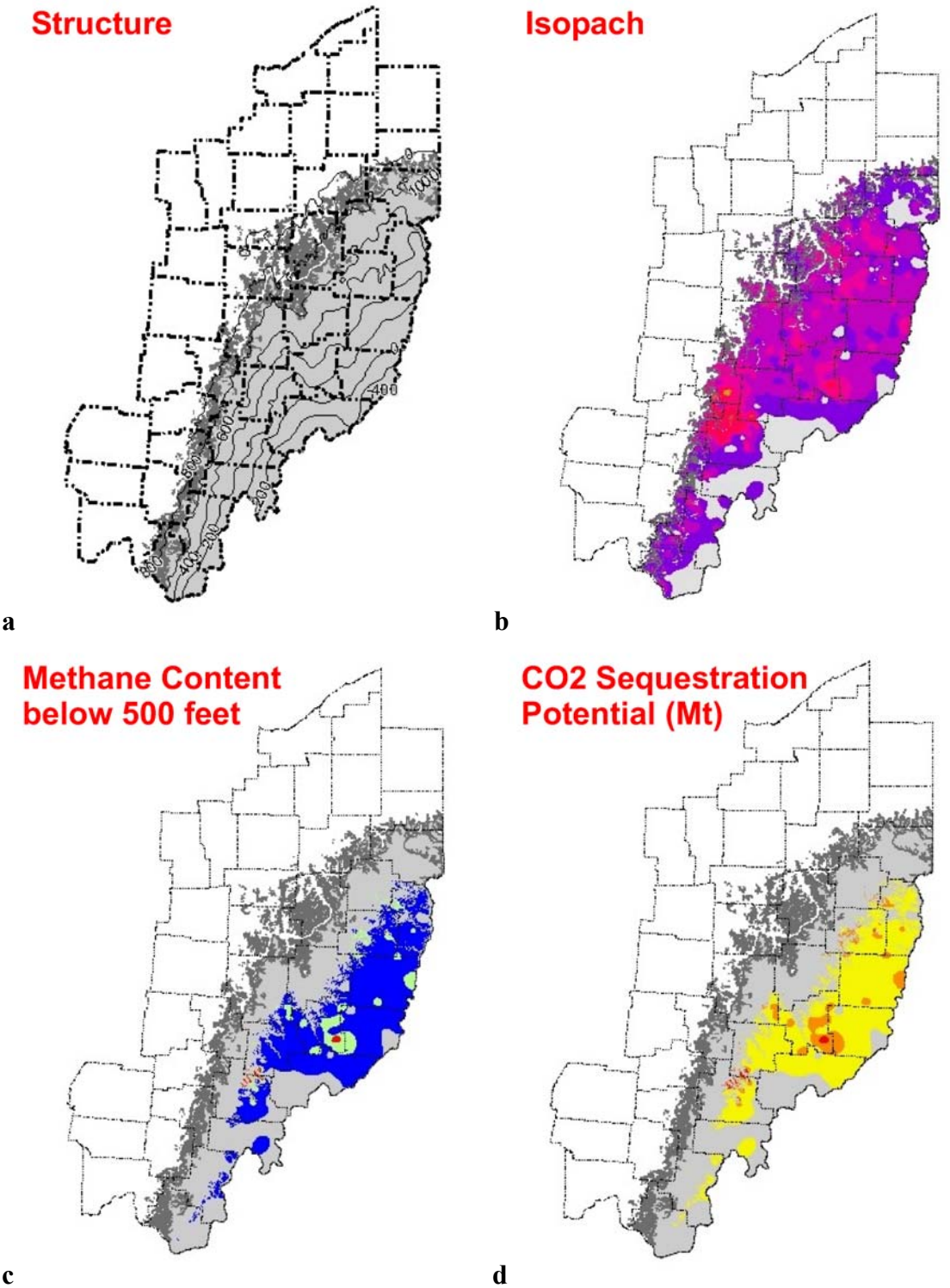


Figure 6(a-d) – Example of maps of Middle Kittanning Coalbed in eastern Ohio. The map coverages are available on the MIDCARB Internet Map Server. The goal will be to bring the data behind the maps including coal quality and reservoir characteristics within the MIDCARB system. Structure map (a), isopach map (b), computed methane content below 500 feet of depth (c), computed CO_2 sequestration potential (5d).

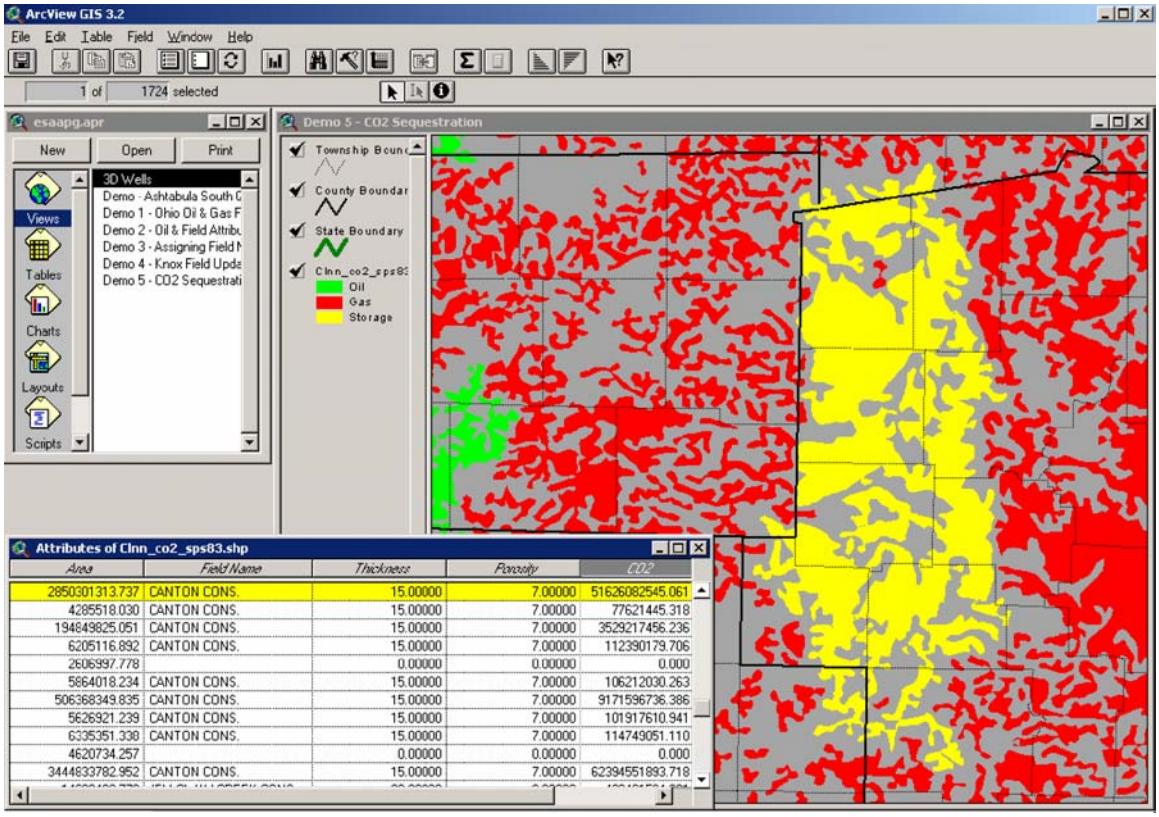


Figure 7 – A GIS layer created for Clinton sandstone oil and gas pools. The layer contains attributes associated with the oil and gas pools. Each pool has many different attributes associated with it, such as Average Thickness, Average Porosity, and Original Oil In Place. Using the attributes associated with each polygon, the quantity of CO_2 that can be sequestered in individual oil and gas pools can be estimated. The calculations used to make the estimates are attributes associated with each polygon in the GIS. Highlighted in yellow, the Canton Consolidated oil & gas field is estimated to have the capacity to sequester over 51 billion tons of CO_2.

DISTRIBUTED COMPUTING ENVIRONMENTS

The five states involved in the MIDCARB Project have a heterogeneous computer environment (Table 1). However, each institution has installed three products to implement MIDCARB in a distributed computing environment:

- RDBMS - Relational DataBase Management System - Provides network access to tabular data. RDBMS can be from various suppliers.
- SDE - Spatial Data Engine - Provides network access to spatial data
- IMS - Internet Map Server - Provides web access to dynamically generated maps.

The current hardware and software computing environment of each state is continuously evolving, but changes can be handled as long as the three elements listed above are maintained. The computing environment in each state is discussed.

Indiana

The Indiana Geological Survey hosts its own Web site (http://adamite.igs.indiana.edu/index.htm) using Microsoft IIS on an NT 4 server. Indiana uses ColdFusion to access databases from the Web site and ESRI's MapObjects Internet Map Server for accessing map data. Indiana hosts more than 1000 Web pages and offers GPS basestation files and various PDF documents for download. Indiana is upgrading the Web server to Windows 2000 Server, IIS 5, ColdFusion 5 (when it becomes available), and ArcIMS 3.

Internally, the IGS is runninga Microsoft SQL 2000 server and is developing a centralized geologic database. ISGS has ArcView, ArcInfo, 3D-Analyst, Spatial Analyst,

and custom extensions installed on one network server from which staff access applications and extensions. Indiana has installed ESRI's SDE and implemented it using SQL 2000 later this year. Indiana is upgrading the network-wiring infrastructure from 10MB Ethernet to 100MB Ethernet on the desktop and eventually Gigabyte at the server level.

Illinois

The Illinois web site (http://www.isgs.uiuc.edu) runs on a dual processor Sun Solaris machine using Apache, with 2 connections to the network; one for inside the building and a second one dedicated to web serving. The Illinois web site serves thousands of static pages (maps, papers, etc) over the web. Much of our effort goes into serving data to staff only from our Oracle database on our Intranet.

Illinois uses Oracle's Web Application Server (3.0.1) and Oracle's PL/SQL language to generate html pages from our Oracle database in real time and deliver formatted pages to the user. Illinois also uses Developer 2000 to create Oracle input and retrieval forms for staff. We also provide custom maps, printouts and digital data extracts from our database to the public for a fee.

Illinois is currently running Oracle 7.3.3 on a dual processor SPARC machine (Solaris 2.5), and will upgrade to 8i in the not too distant future. Illinois supports in-house ODBC access to the database, and ESRI's Spatial Data Engine software to provide remote access to ESRI users around the world. As an official node for the FGDC National Spatial Data Infrastructure, Illinois maintains the local Natural Resources Geospatial Data Clearinghouse, and are used to delivering data over the web.

ESRI products for GIS work such as the latest version of ArcIMS on a Sun Ultra 10 running Solaris 7. We currently serve 6 maps to the Internet using ESRI's first Internet map product, ArcView IMS. These maps see about 40 users per month. We have recently started a project to provide Digital Orthophoto Quarter Quads via the Internet. These quarter quads are being compressed using Mr. Sid to optimize delivery to the user. Currently there are 1007 quarter quads online covering various parts of the State. We hope to have the entire state available within a year from now.

While Illinois has a large amount of well data in our Oracle database, there is always more data to be gathered, organized and entered. The Geologic Records section is the main contributor to the database. The data is mainly entered into the database on a project-by-project basis due to funding limitation.

Kansas

The Kansas web site (http://www.kgs.ukans.edu/index.html) runs on a Sun Solaris machine using Apache. The goal is to put everything done in Kansas on the web. While Kansas serves thousands of static pages (maps, papers, etc), much new effort goes into serving data from our Oracle database on the web. Kansas uses Oracle 8.1.7 with the bundled Oracle Application Server and Oracle's PL/SQL language to generate html pages from our Oracle database in real-time and deliver formatted pages to the user. We also support and encourage extracts from our database. We have some people doing Cold Fusion work, and have started a multi-year Java project to improve data access (See http://www.kgs.ukans.edu/Gemini/index.html for details.

Kansas runs Oracle 8.1.7.2 on a quad processor SPARC machine (Solaris 2.8). Kansas supports Oracle DBLINK connections and ODBC access to the database. We have ESRI's Spatial Data Engine software installed, and can provide remote access to ESRI users around the world. Kansas offers direct access to data vendors and other interested parties either over the web or via direct connections to the database.

Kansas uses ESRI products for GIS work and are actively working to move all of our spatial data to Oracle using SDE. We have the latest version of ArcIMS installed on both Unix and NT and are working to get Kansas coverages on the web. Kansas has a very large oil & gas database in Oracle, and devotes considerable resources to adding new tables and improving the tables already loaded into Oracle.

Kentucky

The University of Kentucky hosts the website of the Kentucky Geological Survey (http://www.uky.edu/kgs). The University server is using Apache, but plans are being made to purchase a new server and it is not known what hardware and software will be used. KyGS files on the web server total approximately 210 MBytes with about 900 pages (not counting graphics).

The KyGS maintains its own ftp server for distributing GIS coverage's, pdf files, and other data (more than 1 Giga Bytes of data). The KyGS does not have a database server, however, the University is going to setup a data server (probably using Cold Fusion) that we will be able to use in 2001. The Survey is investigating several options for map serving, including either setting up our own server (using ArcIMS), using a state government server, or working with the U.S.G.S. server. KyGS is also researching

several options for e-commerce including using commercial e-commerce services or using a state government server.

Internally, the KyGS uses Microsoft SQL Server 7 running on MS Windows NT 4.0 server. Users access the database through any application utilizing ODBC (MS ACCESS, ESRI ARCView, MS EXCEL, etc). Most users have either Windows 9x PCs or Windows NT workstations served by a DELL Windows NT 4.0 Server. We are developing the spatial datasets utilizing ESRI's SDE spatial database engine and are evaluating SmallWorld in a cooperative arrangement with the USGS.

The KyGS tabular database has over 400,000 unique locations and millions of related records. The spatial database is currently being built and will contain all of the 707 digital geologic maps in addition to many types of other coverages being generated on a daily basis.

For GIS, KyGS relies on the University of Kentucky's license agreement with ESRI. Most of our users have ARCView with both Spatial Analyst and 3-D Analyst extensions. Those with the NT Workstations also have ARC/Info. We have several licenses for BlueMarble Geographic's software packages: Geographic Transformer (for georeferencing images) and Geographic Translator (for converting from one geographic projection to another). KyGS also uses Lizardtech's MrSID image compression software.

Ohio

Ohio http://www.ohiodnr.com/geosurvey/ runs SQLServer 7.0 on a dual processor MAXVISION machine (Window NT Server 4.0), and is considering an upgrade to SQL Server 2000 and Window 2000. Ohio is installing ESRI's Spatial Data Engine software.

Ohio is to using ESRI products for GIS work and is actively working to move all of spatial data to Arcinfo and then SQL Server.

Some of Ohio data is project specific data that resides in Access Databases. The main Ohio Oil and Gas database is RBDMS (used in conjunction with the Division of Minerals Resource Management) running on SQL Server. Ohio serves large amounts of data via our FTP site that is being web-enable in the future. For example we have county basemap files, well location database files, and production data files.

TECHNOLOGY TRANSFER

The development of the MIDCARB atlas is in itself a technology transfer activity, and will be ongoing from project initiation. In addition the members of the consortium have been very active in presenting results. The following technology transfer activities have occurred:

1) Lawrence H. Wickstrom of the Ohio Geological Survey made a presentation on MIDCARB at the NETL Conference on Carbon Sequestration in Washington, DC on May 14. Representatives from the geological surveys in Illinois, Indiana, Kansas and Ohio were in attendance. The Mid-continent Interactive Digital Carbon Atlas and Relational Database (MIDCARB)

2) James A. Drahovzal and Lawrence H. Wickstrom of the MIDCARB Consortium were co-conveners of a theme session held at the NC/SE-GSA conference held

April 3-5, 2002, in Lexington, KY. Geologic Sequestration of CO2 Theme Session: Introduction (PPT)

a. John B. Hickman, James A. Drahovzal, Lawrence H. Wickstrom, Timothy R. Carr, John A. Rupp, Beverly Seyler & Scott W. White, Midcontinent Interactive Digital Carbon Atlas and Relational Database, presented to NC/SE-GSA conference, April 2002, Lexington, KY. Midcontinent Interactive Digital Carbon Atlas and Relational Database (PPT)

b. McDonald, James, Riley, Ronald A., Wickstrom, Lawrence H., and Wells, Joseph G., Application of an Oil and Gas Fields Geographic Information System for CO_2 Sequestration in Ohio, presented to NC/SE-GSA conference, April 2002, Lexington, KY. Application Of An Oil And Gas Fields Geographic Information System For CO2 Sequestration In Ohio (PPT)

c. Seyler, Beverly, Christopher P. Korose, Steve Gustison, David G. Morse, John P. Grube, Bryan G. Huff, Randy Lipking, Phillip Johanek, Daniel O. Nelson, and Alison B. Lecouris, "Potential for Geologic Sequestration of CO_2 in Illinois," presented to NC/SE-GSA conference, April 2002, Lexington, KY. Potential for Geologic Sequestration of CO2 in Illinois (PPT)

d. Solano-Acosta, Wilfrido and Nathan K. Eaton, Characterization of a Deep Saline Aquifer for CO_2 Sequestration in Indiana: An Integrated Geology/GIS Approach, oral presentation at NC/SE-GSA conference,

April 2002, Lexington, KY. Characterization of a Deep Saline Aquifer for CO2 Sequestration in Indiana: An Integrated Geology / GIS Approach (PPT)

e. Vinciguerra, Mark, and E. R. Slucher, GIS Analysis of Potential Coal Bed Methane and CO_2 Sequestration in the Middle Kittanning (No. 6) Coal Bed in Ohio, presented to NC/SE-GSA conference, April 2002, Lexington, KY. Also presented at the Second Ohio Carbon Dioxide Reduction, Sequestration and Capture Forum, April 26, 2002, Lancaster, Ohio. GIS Analysis of Potential Coal Bed Methane and CO2 Sequestration in the Middle Kittanning (No. 6) Coal Bed in Ohio (PPT)

3) Carr, T. R., J. A. Drahovzal, J.A. Rupp, B. Seyler, L. H. Wickstrom and MIDCARB team, Midcontinent Interactive Digital Carbon Atlas and Relational Database (MIDCARB), Poster Presented at AAPG conference, March 2002, Houston, TX, KGS Open-file Report 2002-7.

4) James A. Drahovzal and other presented the Midcontinent Interactive Digital Carbon Atlas and Relational Database (MIDCARB) at the Eastern Section of the American Association of Geologists September 23-25, 2001 in Kalamazoo, Michigan. Winner of the 2001 Eastern Section American Association of Petroleum Geologists Levorsen Memorial Best Paper Award

5) Dubois, Martin K., Alan P. Byrnes, and W. Lynn Watney, Field Development and Renewed Reservoir Characterization for CO2 Flooding of the Hall-Gurney Field,

Central Kansas, at the AAPG Annual Meeting, June 3-6, 2001 Denver, Colorado, Winner of the Jules Braunstein Memorial Award for the best AAPG poster

6) Lawrence H. Wickstrom of the Ohio Geological Survey organized the **First Ohio Carbon Dioxide Reduction, Sequestration & Capture Forum** sponsored by the Ohio Coal Development Office and Ohio Geological Survey March 23, 2001 in Delaware, Ohio

7) Timothy R. Carr presented the **Midcontinent Interactive Digital Carbon Atlas and Relational dataBase (MIDCARB)** at the Geological Society of America Annual Meeting, November 2000, Reno, Nevada.

Table 1 - Summary of the diverse distributed computing environments that have been linked across the MIDCARB network.

State	RDBMS	SDE	ArcIMS
Illinois	Oracle 7.3.3 Upgrading to 8.1.7	8.0.2	3.0
Host:	volcano.isgs.uiuc.edu	midcarb.isgs.uiuc.edu	
Operating System:	Solaris 2.5 Upgrading to Solaris 8		
Port:	1521	5151	
Protocol:	TCP		
Instance:	isgs	midcarb	
Indiana	SQL Server 2000	8.1	3.1
Host:	129.79.145.6	129.79.145.6	
Operating System:	Windows NT 4.0		
Port:	1433	5151	
Protocol:	TCP		
Instance:	Midcarb_Sources	midcarb_gis	
Kansas	Oracle 8.1.7.2.0	8.0.2	3.1
Host:	abyss.kgs.ku.edu	abyss.kgs.ku.edu	
Operating System:	Solaris 2.8		
Port:	1521	5150	
Protocol:	TCP		
Instance:	ABYSS	ABYSS	
Kentucky	SQL Server 7.0.961	8.0.2	
Host:	128.163.49.110	128.163.49.110	
Operating System:	Windows NT 4.0		
Port:	1433	5151	
Protocol:	TCP		
Instance:		sequester	
Ohio	SQL Server 2000	8.1	
Host:	198.234.182.204	198.234.182.204	
Operating System:	Windows NT 4.0		
Port:	1433	5151	
Protocol:	TCP		
Instance:	OH_MIDCARB	sde_gis or OH_MIDCARB	

Table 2 - Summary of coverages available through the MIDCARB Internet Map Server. A number of coverages can be downloaded to the client. Coverages are constantly changing and the latest inventory is available online at

CO_2 Sources			
IL - Sources	IL SDE	EPA_FAC_IL	(10 KB)
IL - Ethanol Plants	IL SDE	IL_ETHANOL_PLANTS	not available
IN - Sources	IN SDE	IN_CO2_SOURCES	(7 KB)
KS - Sources	KS SDE	KS_CO2_SOURCES	not available
KY - Sources	KY SDE	KY_POWER_PLANTS	not available
KY - Sources	KY SDE	KY_OTHER_CO2_SOURCES	not available
Infrastructure			
IN - Pipelines	IN SDE	IN_PIPELINES	not available
IN - Electric Lines	IN SDE	IN_ELECTRIC_LINES	(214 KB)
Base Layers			
General Reference Layers			
Roads	IN SDE	USA_ROADS	not available
Rivers	IN SDE	USA_RIVERS	not available
Lakes	IN SDE	USA_LAKES	not available
Cities	IN SDE	USA_CITIES	not available
States	IN SDE	USA_STATES	not available
Counties	IN SDE	MIDCARB_COUNTIES	not available
Public Land Surveys			
IL - Townships	IL SDE	IL_TOWNSHIPS	not available
IL - Sections	IL SDE	IL_SECTIONS	not available
IN - Sections	IN SDE	IN_SECTIONS	not available
Petroleum			
Petroleum Fields			
IN - Field Outlines	IN SDE	IN_PETROLEUM_FIELDS	(11 MB)
Petroleum Wells			
IN - Wells	IN SDE	IN_PETROLEUM_WELLS	not available
KY - Wells	KY SDE	KY_PETROLEUM_WELLS	not available
Coal			
Coal Mines			
Danville Mines	KY SDE	IL_BASIN_DANVILLE_MINES	not available
Herrin Mines	KY SDE	IL_BASIN_HERRIN_MINES	not available

Springfield Mines	KY SDE	IL_BASIN_SPRINGFIELD_MINES	not available
Coal Structure Data			
IL - Danville Depth	IL SDE	IL_DANVILLE_DEPTH	not available
IL - Herrin Depth	IL SDE	IL_HERRIN_DEPTH	not available
Springfield Depth	KY SDE	IL_BASIN_SPRINGFIELD_DEPTH	not available
Springfield Elevation	KY SDE	IL_BASIN_SPRINGFIELD_ELEVATION	not available
Coal Thickness Data			
Danville Thickness	KY SDE	IL_BASIN_DANVILLE_THICK	not available
Herrin Thickness	KY SDE	IL_BASIN_HERRIN_THICK	not available
Springfield Thickness	KY SDE	IL_BASIN_SPRINFIELD_THICK	not available
Geology			
Bedrock Geology			
Bedrock Geology	IN SDE	MIDCARB_BEDROCK	not available

APPENDIX A - MIDCARB INTERNET MAP SERVER

A Guided Tour

NOTE: Software Requirements - The interactive map requires Microsoft Internet Explorer 5 or higher, with frames enabled. The current interactive map will not function correctly using a Netscape browser. The application is best viewed at a screen resolution of 1024 by 768 pixels or higher.

The non-technical discussion and images provided are intended as an introduction to, and overview of, the capabilities and the functions of the MIDCARB Internet Map Server. Based on the user's actions, the MIDCARB Internet Map Server (IMS) issues spatial data queries to spatial data engines (SDE) and relational database management systems (RDBMS) operating on servers in each of the five states of the consortium. The IMS approach is scalable and flexible. It does not require individual organizations to follow rigid standards for hardware, software, metadata or formatting. Additional states and organizations could be added to the MIDCARB System with little additional effort. The MIDCARB Internet map browser provides access to map themes and data. One can use the tools at the top of the browser to zoom, pan, obtain help, identify objects, display data, etc. The tools are described in detail in Appendix B. Map layers can be turned on or off. Individual objects can be identified and queried. Data retrieved with the server can be displayed, analyzed using spatial tools and Boolean queries, graphed and downloaded to the client's computer.

The data being assembled using the MIDCARB browser comes from up to five different servers in five different organizations. The MIDCARB Internet Map Server,

related analysis tools and available data sets are rapidly evolving and growing. The system that is described in this report will be very different from week-to-week, but functionality, data richness and response time should constantly improve. The MIDCARB system is only the first step in the first distributed system of natural resource data focused on CO2 sources and potential geologic sequestration sites. Follow the steps described in the following figures to investigate some of the functionality included in the MIDCARB Internet Map Server. Additional assistance can be found by accessing the HELP link on the MIDCARB Internet Map Server browser.

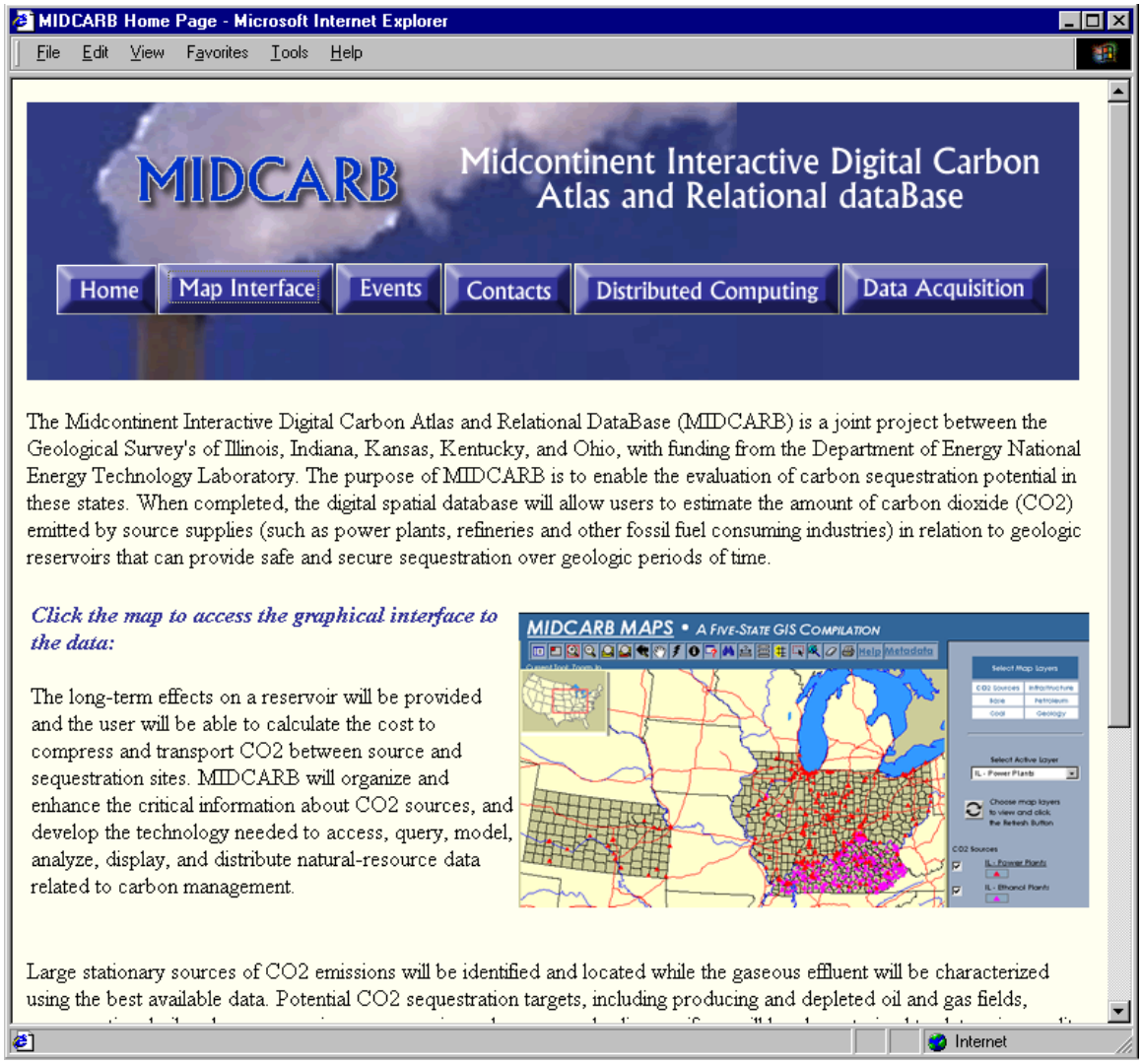


Figure A.1 – The MIDCARB Homepage (http://www.midcarb.org) provides links to project information and to the ***Map Interface***. A click on the Map Interface Button provides information and access to the latest version of the MIDCARB Internet Map Server (Figure A.2).

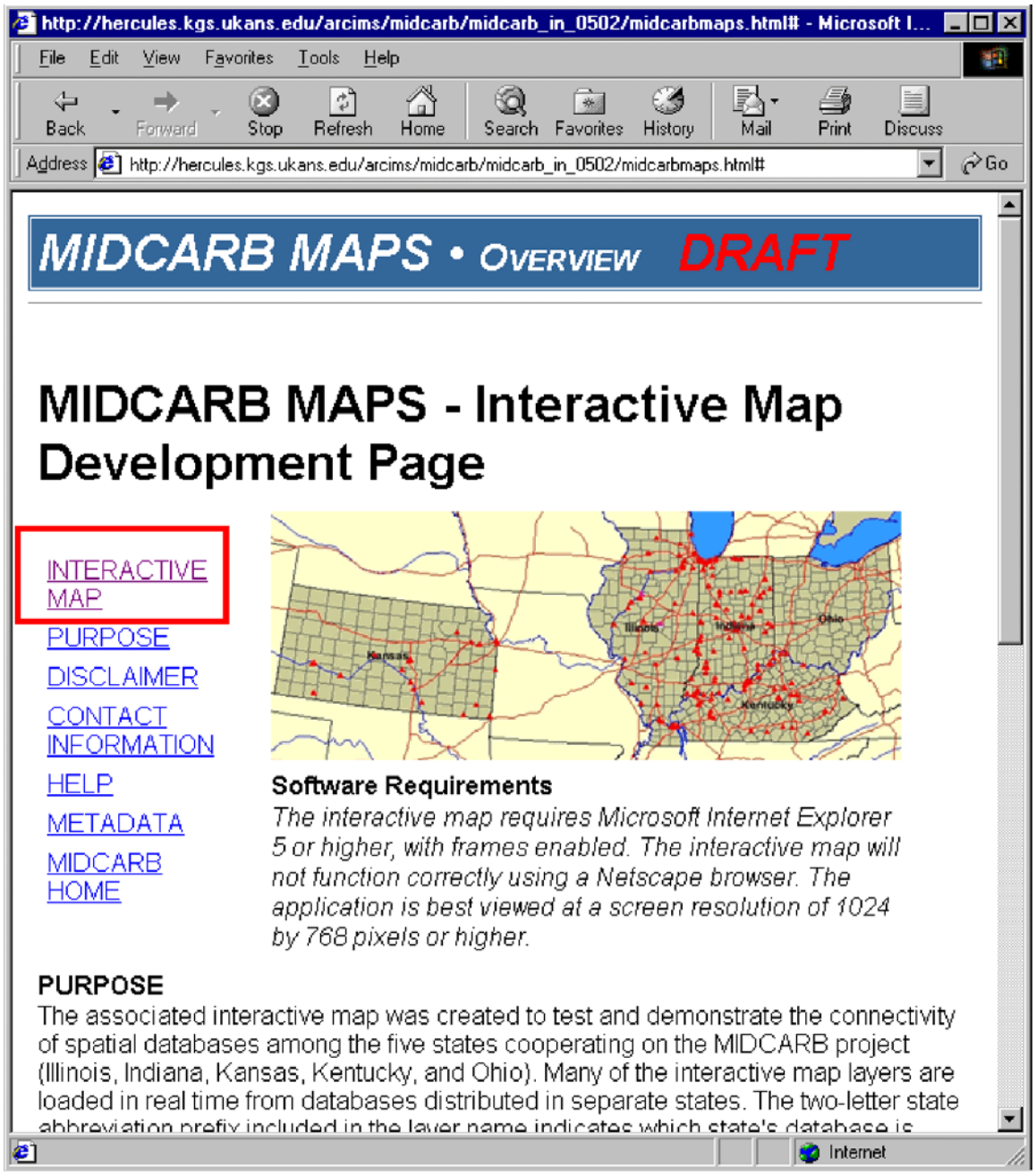


Figure A.2 – Clicking on the INTERACTIVE MAP link will bring up the MIDCARB Internet Map Server (IMS). The MIDCARB Internet map server was created to demonstrate the connectivity of spatial databases among the five states cooperating in the MIDCARB - project (Illinois, Indiana, Kansas, Kentucky and Ohio). Many of the interactive map layers are loaded in real-time from databases distributed in separate states.

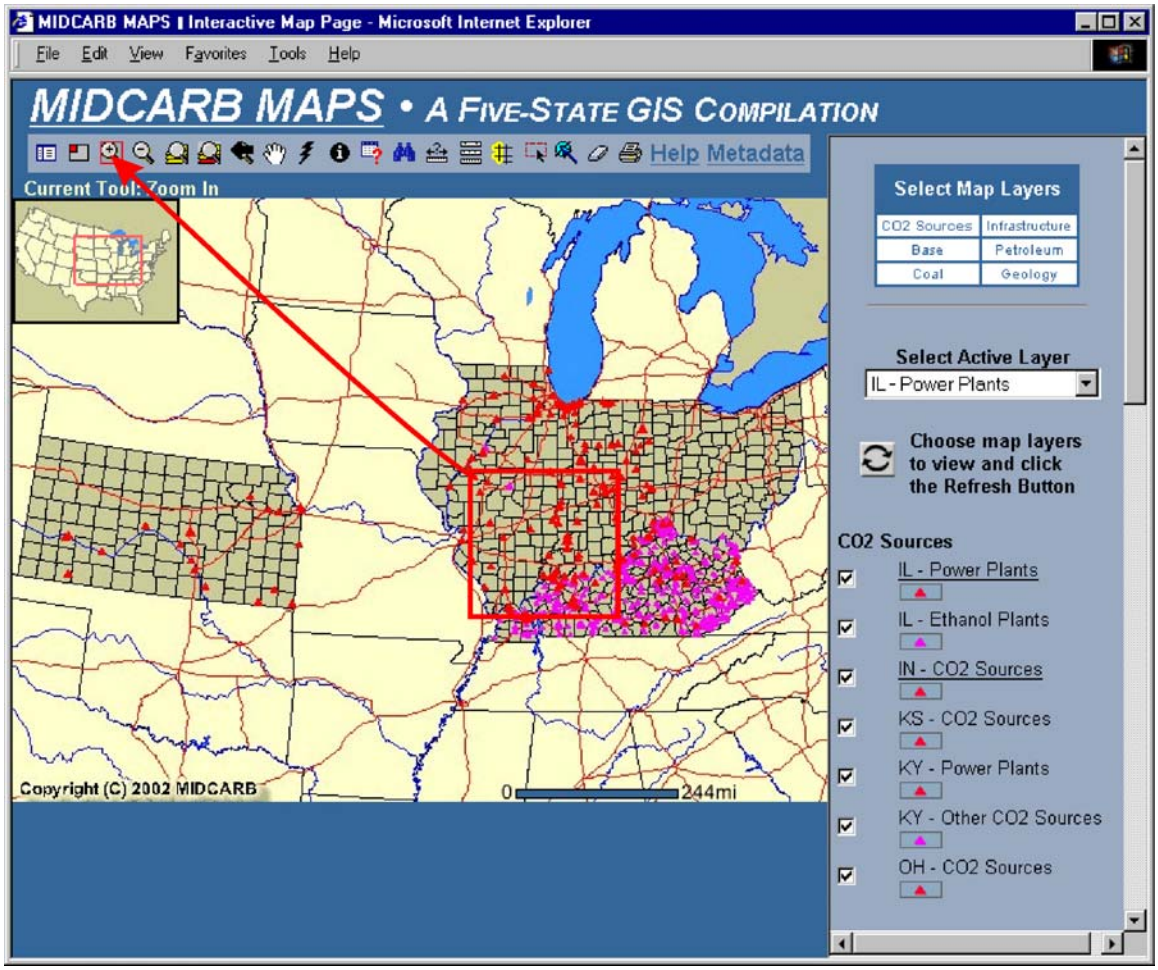


Figure A.3 – The MIDCARB browser is divided into three areas (i.e., map image frame, tool bar frame and frame to select map layers). The first map image shows the area of the five states participating in the MIDCARB project along with CO_2 sources in each state. The tool bar contains the basic tools for interacting with the map lay. The active tool is highlighted and shown at the top of the map image. Drawing a box with the *Zoom In* tool ( ) is shown at end if the arrow. The *Zoom In* tool changes the scale of the image to the area of the box drawn on the map image (Figure A.4). Information on all tools is provided by the Help link.

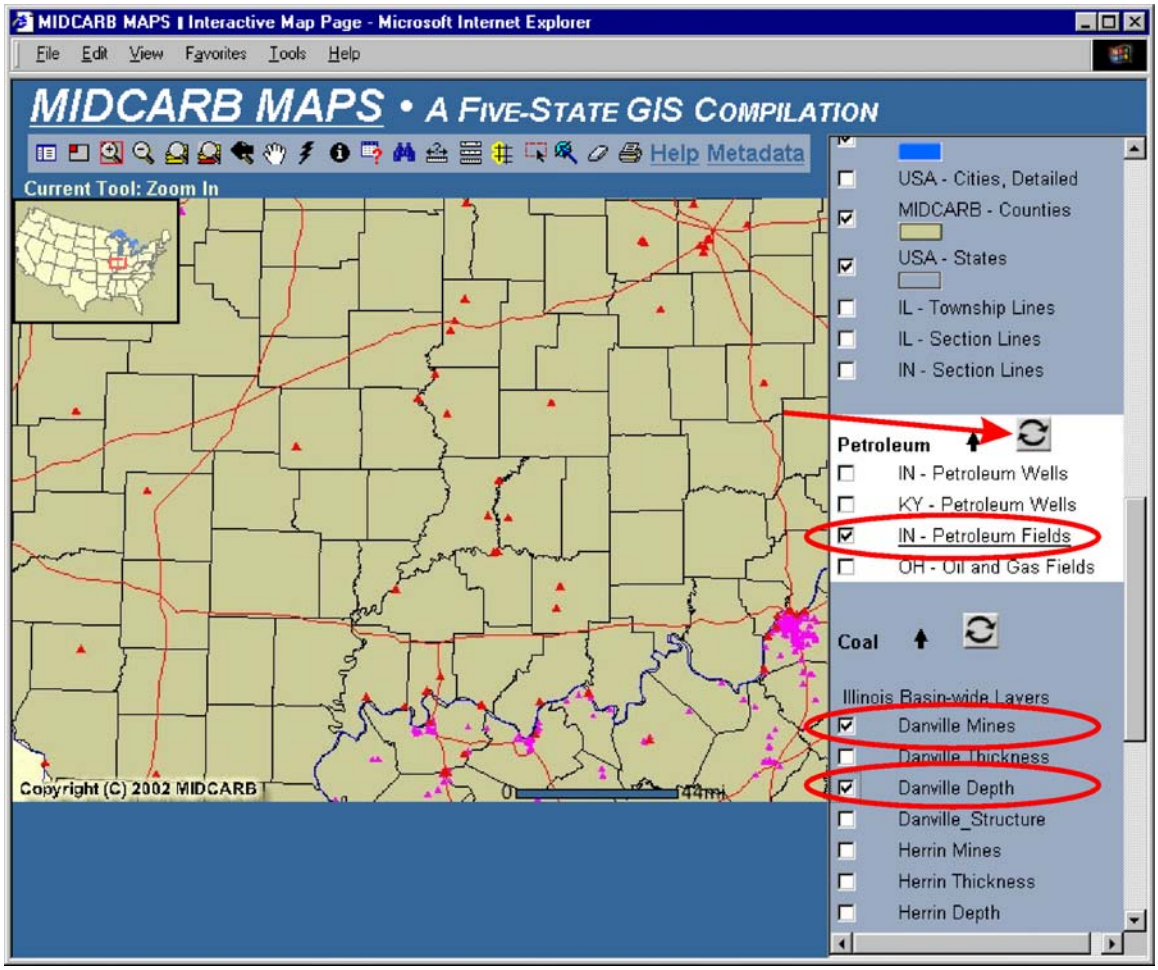


Figure A.4 – A zoomed image located in southeast Illinois, southwest Indiana and northern Kentucky. Additional map layers are added by checking the box next to the selected layer and then clicking the update button (at end of arrow). In this example Indiana oil and gas pipelines and fields and the depth of the Danville Coal and locations of mines in the Danville are added to the CO_2 source layers (Figure A.5).

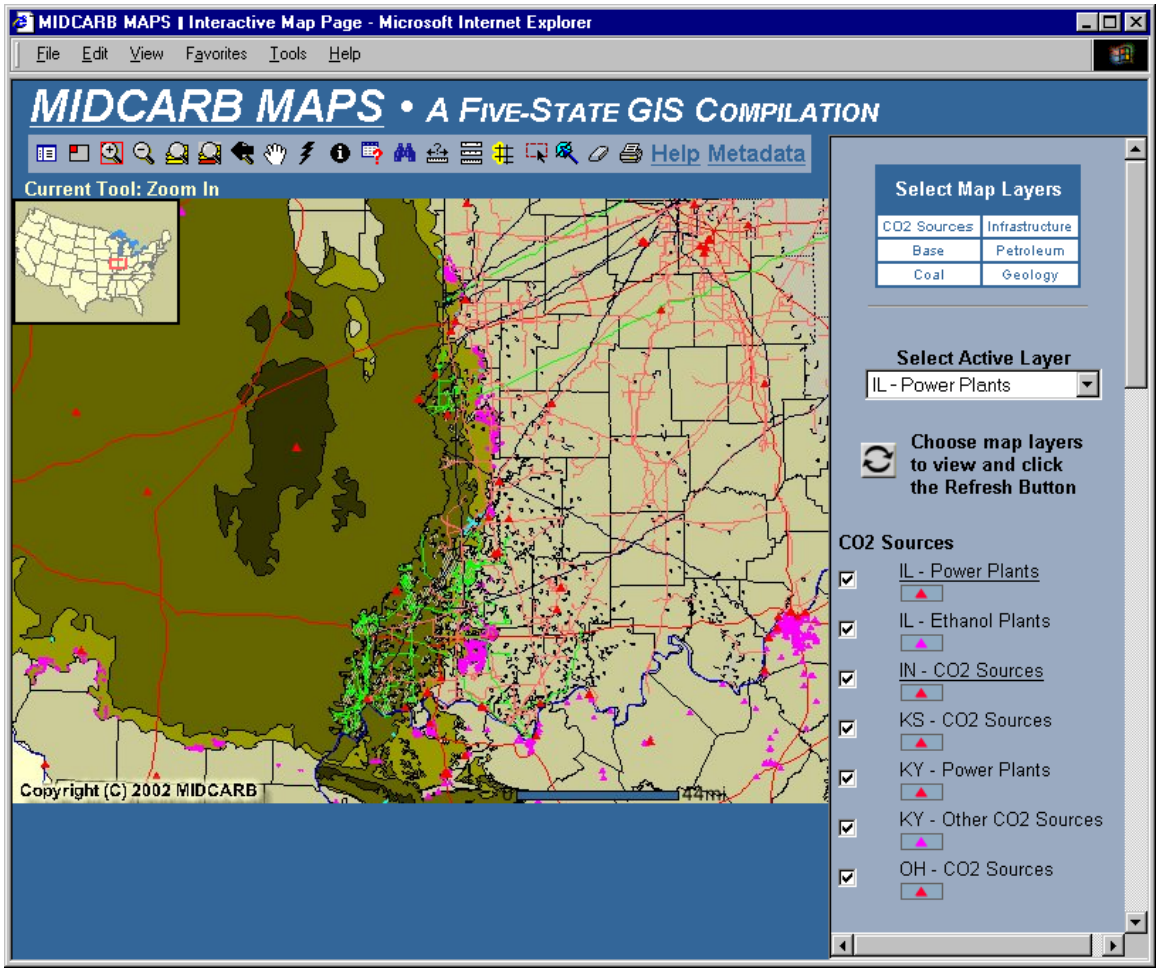


Figure A.5 –The resulting map image showing Danville Coal depth, the location of mines in the Danville Coal, Indiana oil and gas pipelines and the outlines of Indiana oil fields.

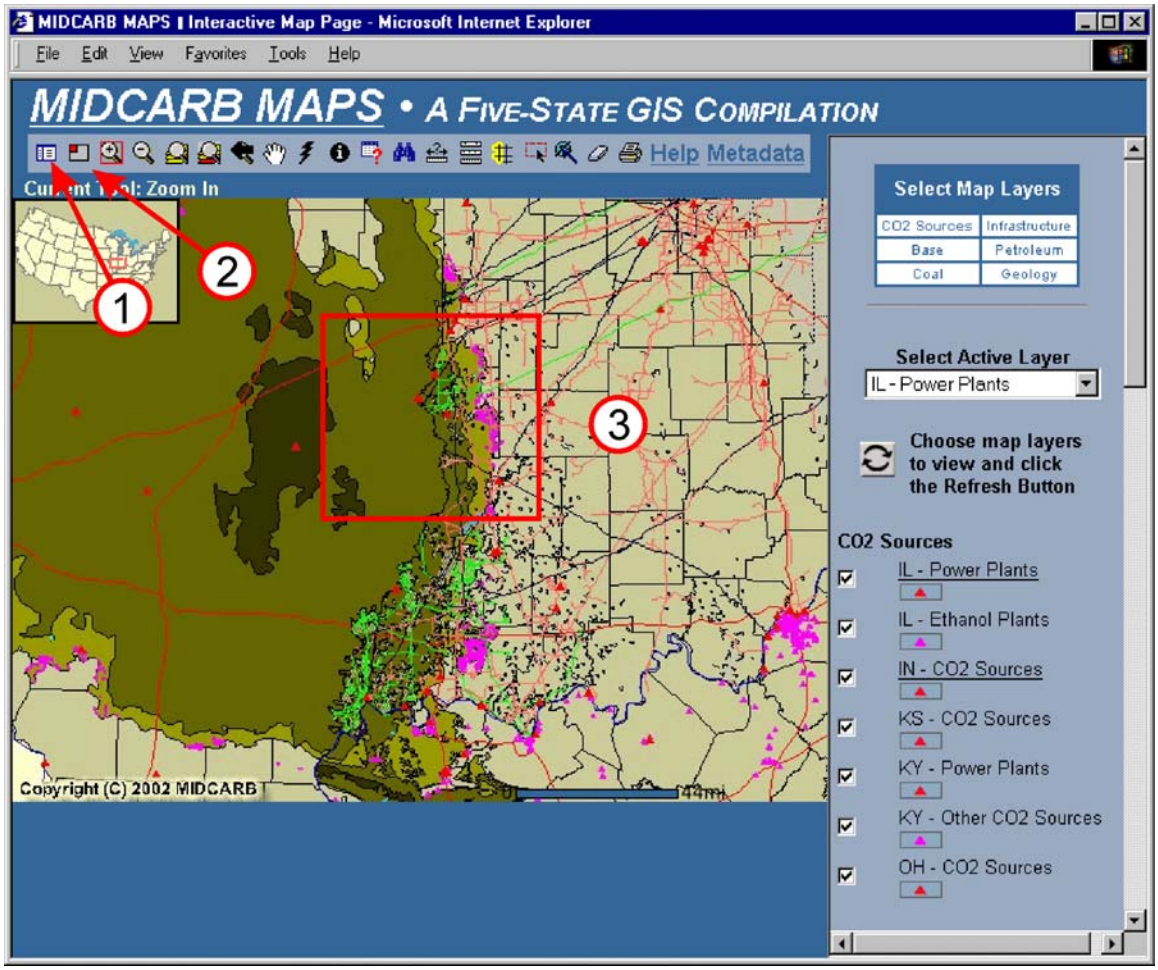


Figure A.6 – Using the *Legend* tool ( )to switch between the Select Map Layer frame and the Map Legend frame can further modify the map image (Arrow 1). The small overview locator map can be turned off using the tool ( ) in the upper left corner (Arrow 2). The *Zoom In* tool ( ) can then be used to zoom into the area along the boundary between Indiana and Illinois (Arrow 3). The resulting map image is shown in Figure A.7. There are other tools that can be used to change the scale and move the map image. These tools include:

Zoom Out Tool
Zoom Out to Full Extent of Map
Zoom (in or out) to the extent of the active theme
Zoom to the previous map extent
To move the map by pan

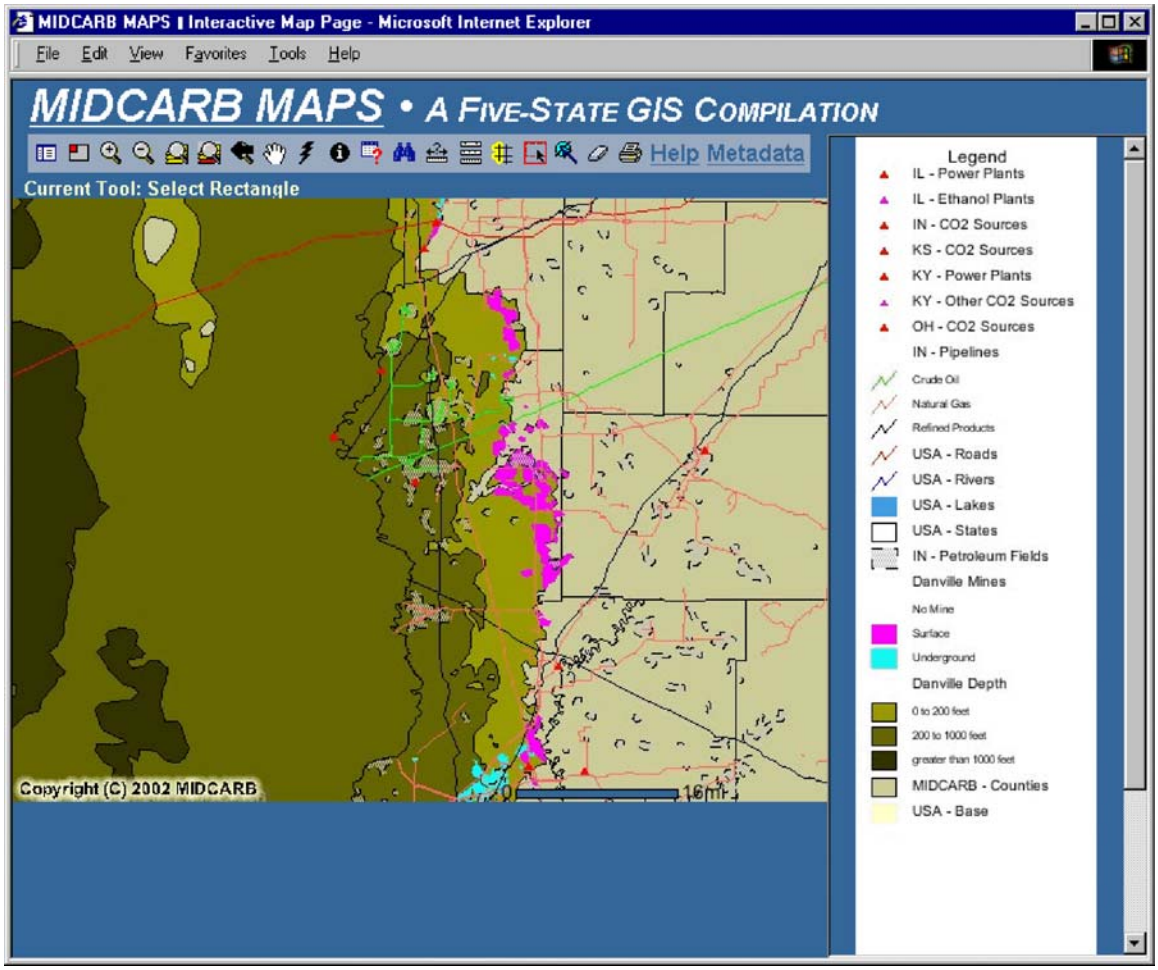


Figure A.7 – Resulting map image showing Danville Coal depth, the location of mines in the Danville Coal, Indiana oil and gas pipelines and the outlines of Indiana oil fields. Using the *Legend Tool* ( ) a Legend frame has replaced the Select Map Layer frame. Clicking on far-left button of Tool Bar will toggle back to the Select Map Layer frame.

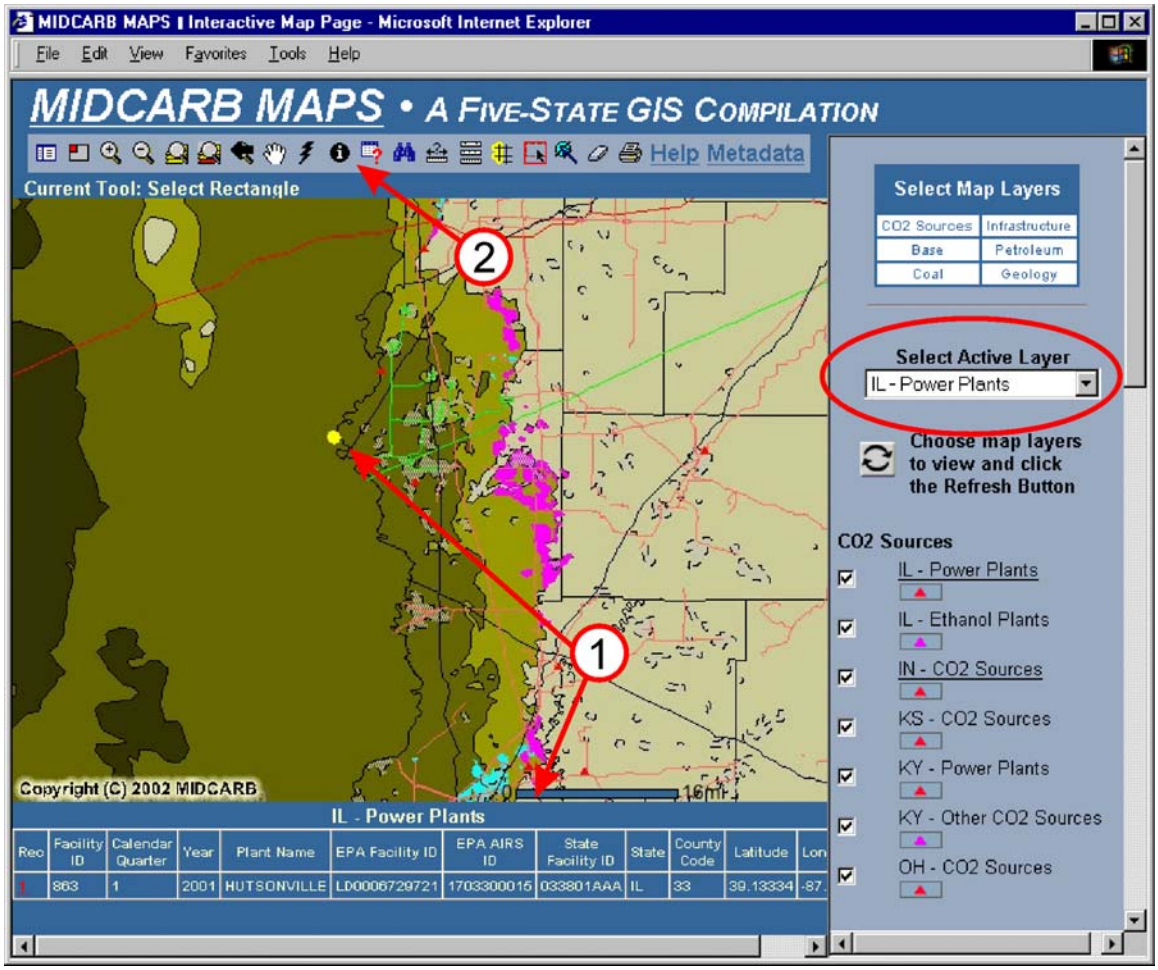


Figure A.8 – Using the *Select Rectangle* tool ( ) to select features from the active map layer (highlight by red box and listed at top of map image). In this example the active map layer is Illinois Power Plants (Red Circle) and only one plant was selected. Information of the plant is retrieved from a database on a server at the Illinois Geological Survey and displayed in the information frame at bottom of map image frame (Arrow 1). Clicking arrow at left of Select Active Layer pull-down box allows user to switch active layer that can be queried. Using the *Information* tool ( ) allows the user to view more information about the feature of the active map layer (Arrow 2). For example, selecting Indiana Oil fields as the active layer and using the *Information Tool* the user can click on a field and retrieve information from a database on a server at the Indiana Geological Survey and display it the information frame at bottom of map image frame.

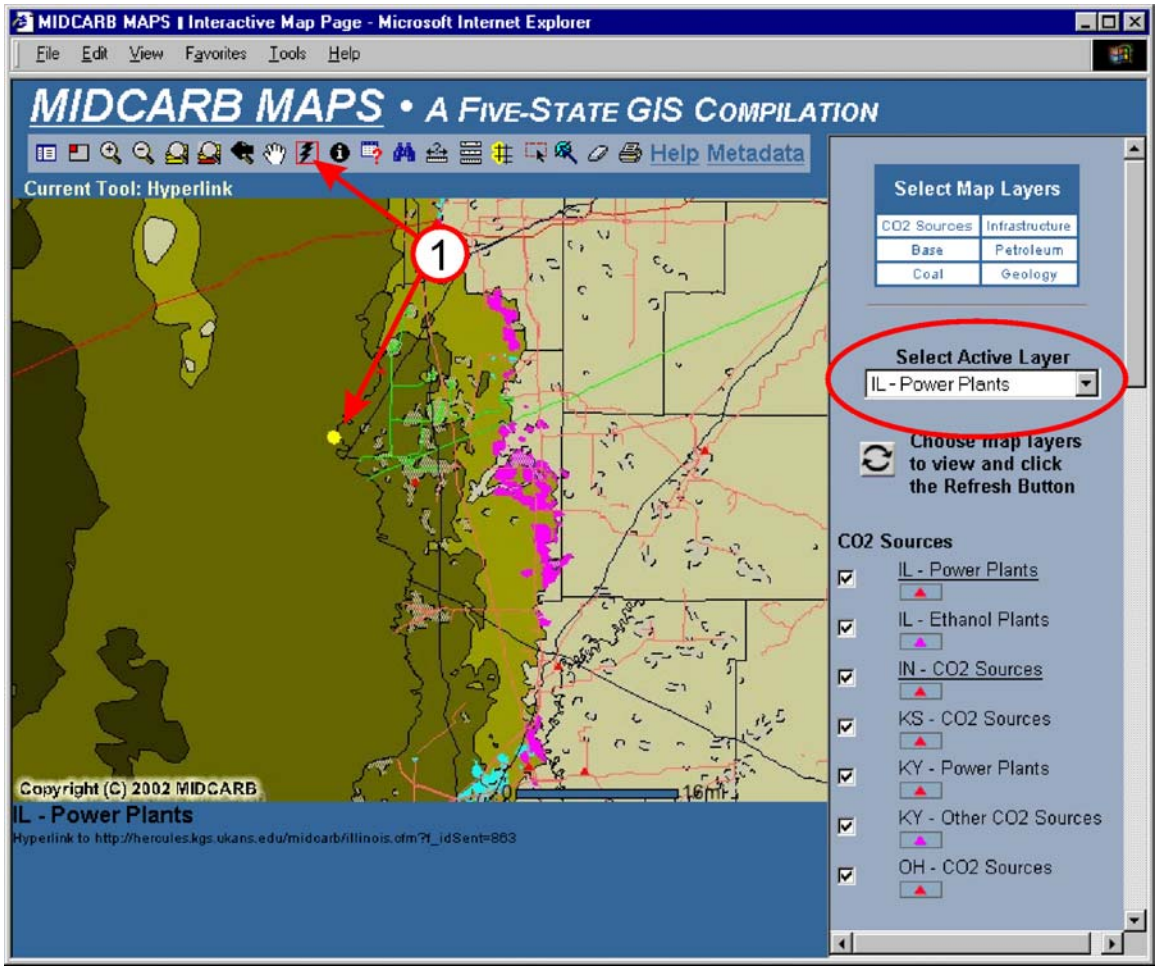


Figure A.9 – The *Hyperlink* tool ( ) can be used to select features from the active map layer in order to access and display detailed data about that feature (Arrow 1). In this example the active map layer is Illinois Power Plants (Red Circle). After the *Hyperlink* tool ( ) is active an Illinois Power plant is selected. Information of the plant is retrieved from a database on a server at the Illinois Geological Survey and displayed in a new browser window (Figure A.10).

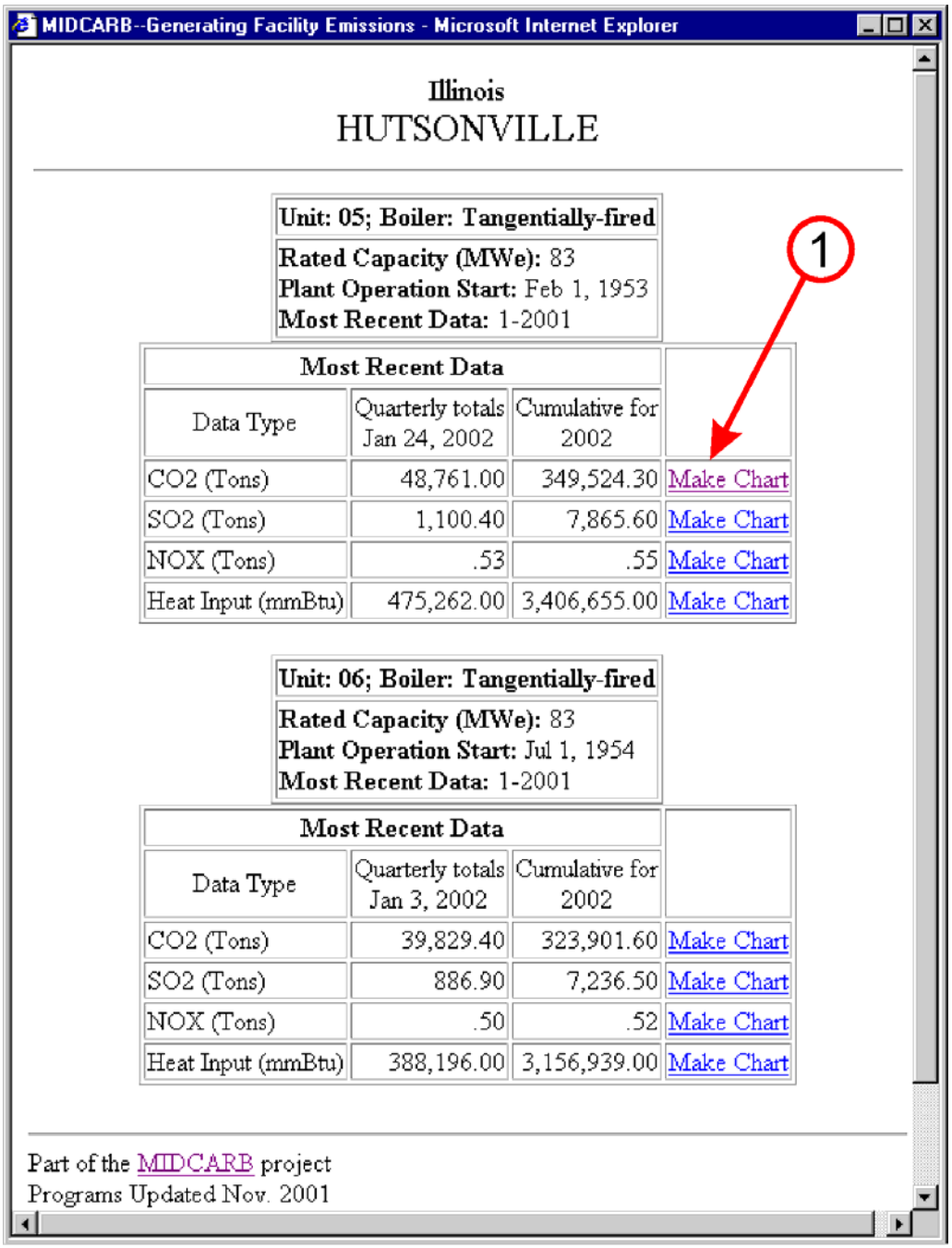


Figure A.10 – In the example shown the *Hyperlink* tool ( ) retrieves information on the selected feature from a database on a server at the Illinois Geological Survey and displays the data in a new browser window constructed on the demand using the most current data available. The program that constructs the paged is on the server at the Kansas Geological Survey. In this example, emission data is retrieved for an electric power plant in Illinois. Clicking on the *Make Chart* link (Arrow 1) charts the data (Figure A.11).

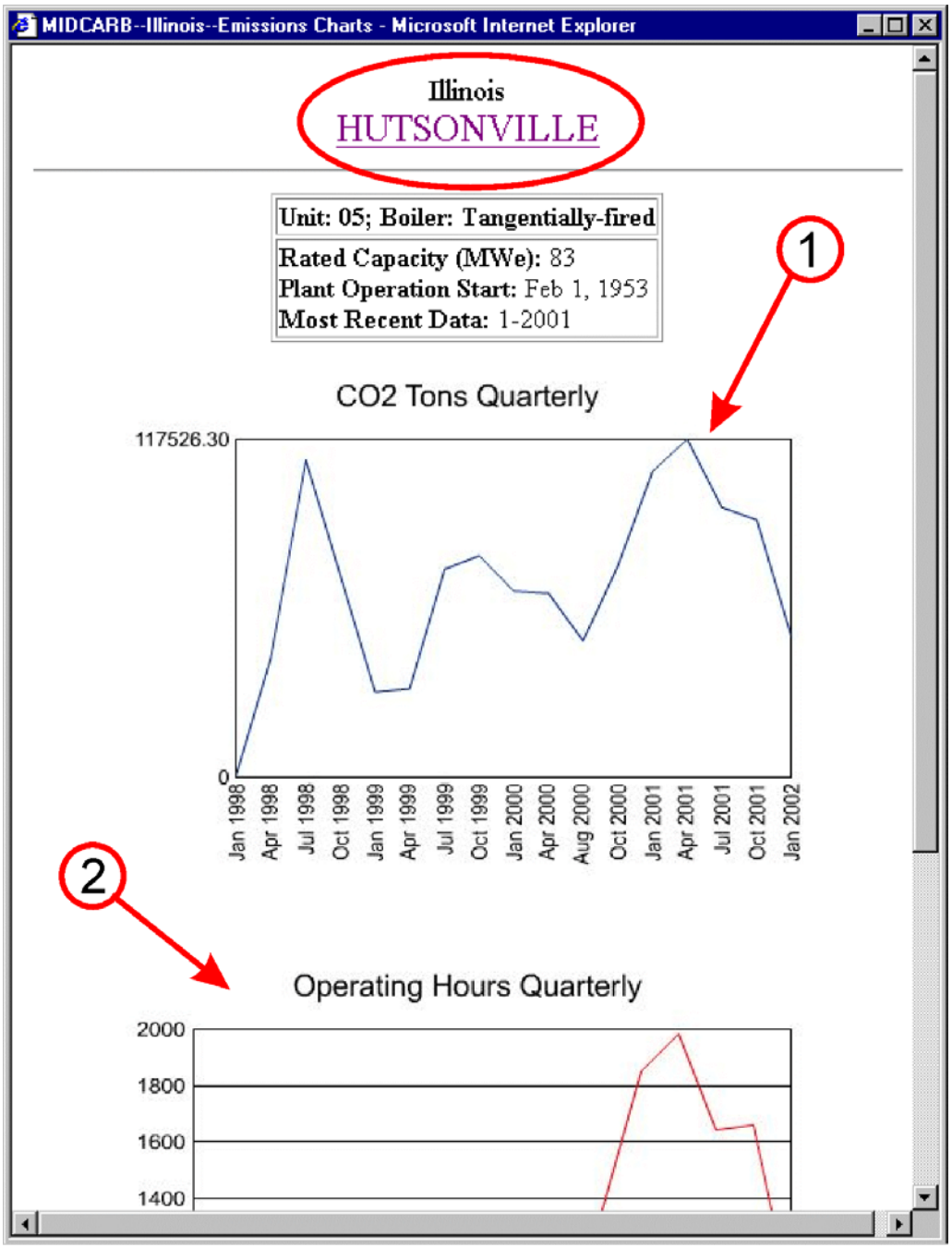


Figure A.11 – A chart constructed on demand using information on the selected feature from a database on a server at the Illinois Geological Survey. The program that constructs the chart is on the server at the Kansas Geological Survey. In this example, CO_2 emission data (Arrow 1) and operating hours (Arrow 2) are plotted for an electric power plant in Illinois. Clicking on the *Plant Name* link returns to user to the previous page (Figure A.10).

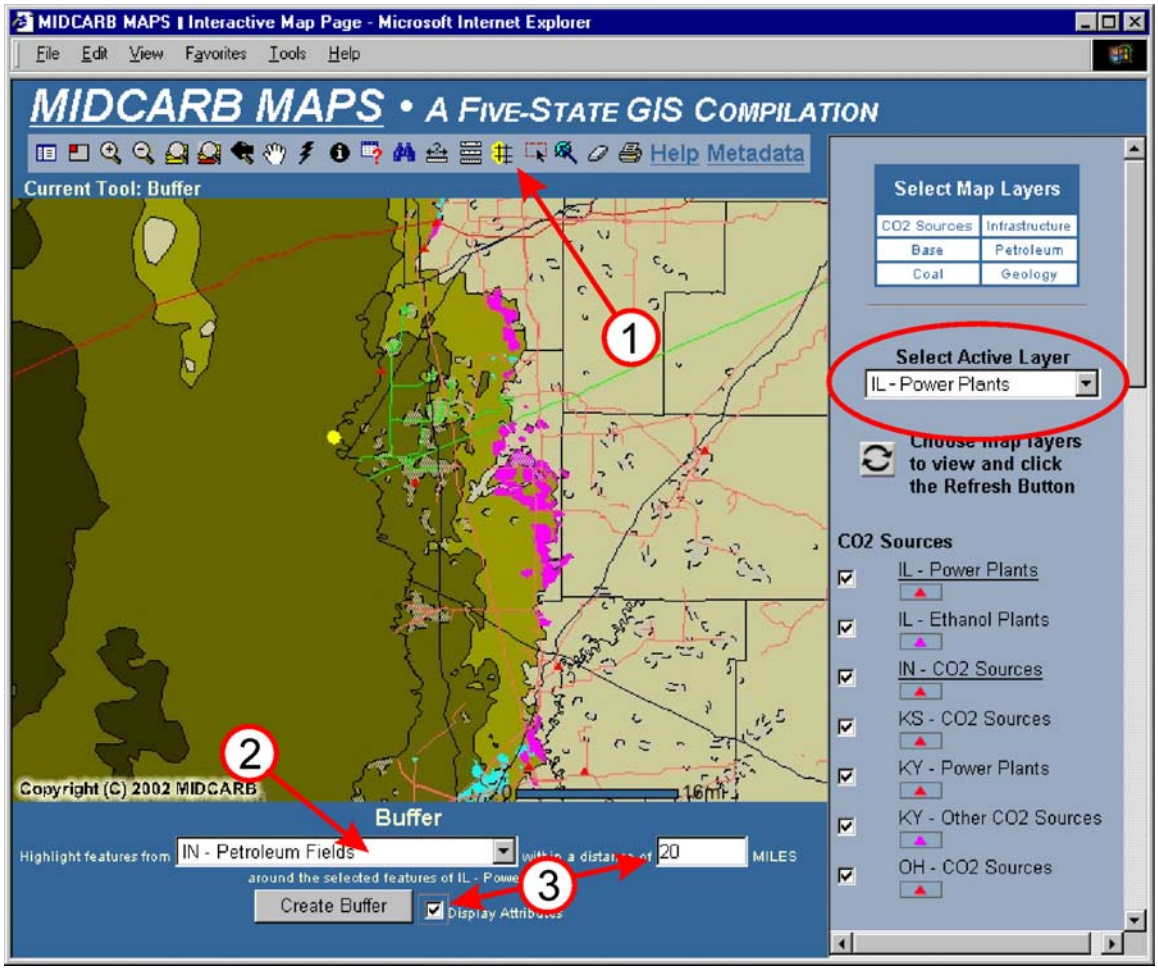


Figure A.12 – After using the *Select Rectangle* tool ( ) to select features from the active map layer (Figure A.8), the *Create Buffer* tool ( ) can be used to highlight map features and retrieve information on selected features (Arrow 1). In the information frame at the bottom of the map image the features to be related to the active layer features (red ellipse) are selected (Arrow 2) and a buffer zone created (Arrow 3). In this example, Indiana Petroleum fields within a 20-mile radius of the selected Illinois Power Plant will be highlighted. Information is retrieved by querying both the Illinois and Indiana geological surveys and plotted on demand using software located at the Kansas Geological Survey. Any combination of features can be used as targets with a buffer. The results are shown in Figure A.13.

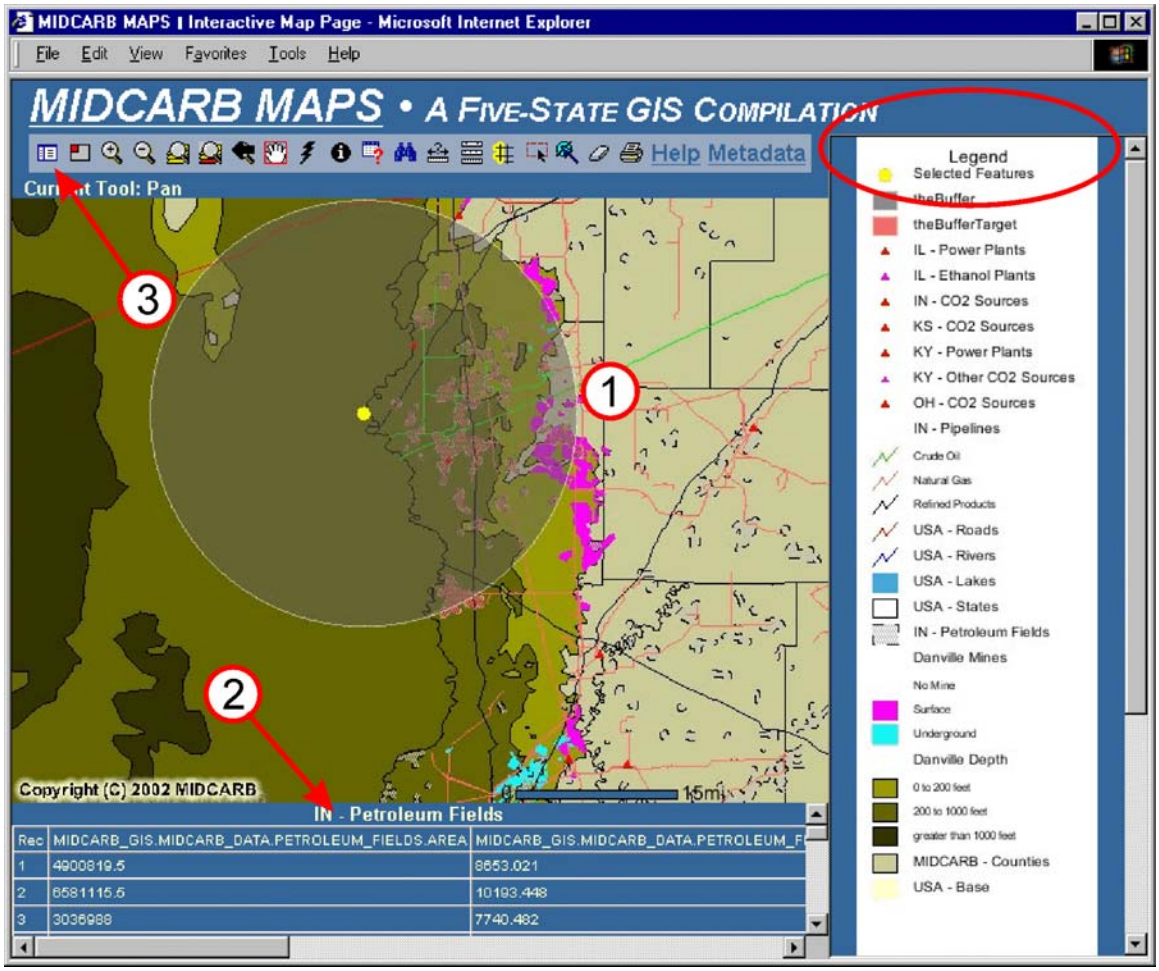


Figure A.13 – Results returned by the MIDCARB Internet Map Server after creating buffer. The buffer and targets features within the buffer are highlighted (Arrow 1), and information on all target features are listed in the information frame at the bottom of the map image (Arrow 2). In this example, information, on Indiana petroleum fields within a 20-mile radius of the selected Illinois Power Plant, is listed (e.g., field area, reservoir depth, and production). Programs are being developed to use the information to compute estimates of the volume and rates of CO2 that could be sequestered in the features (for example petroleum reservoirs). The *Legend* tool ( ) is used to switch between the select map layer window and show the map legend (Arrow 3).

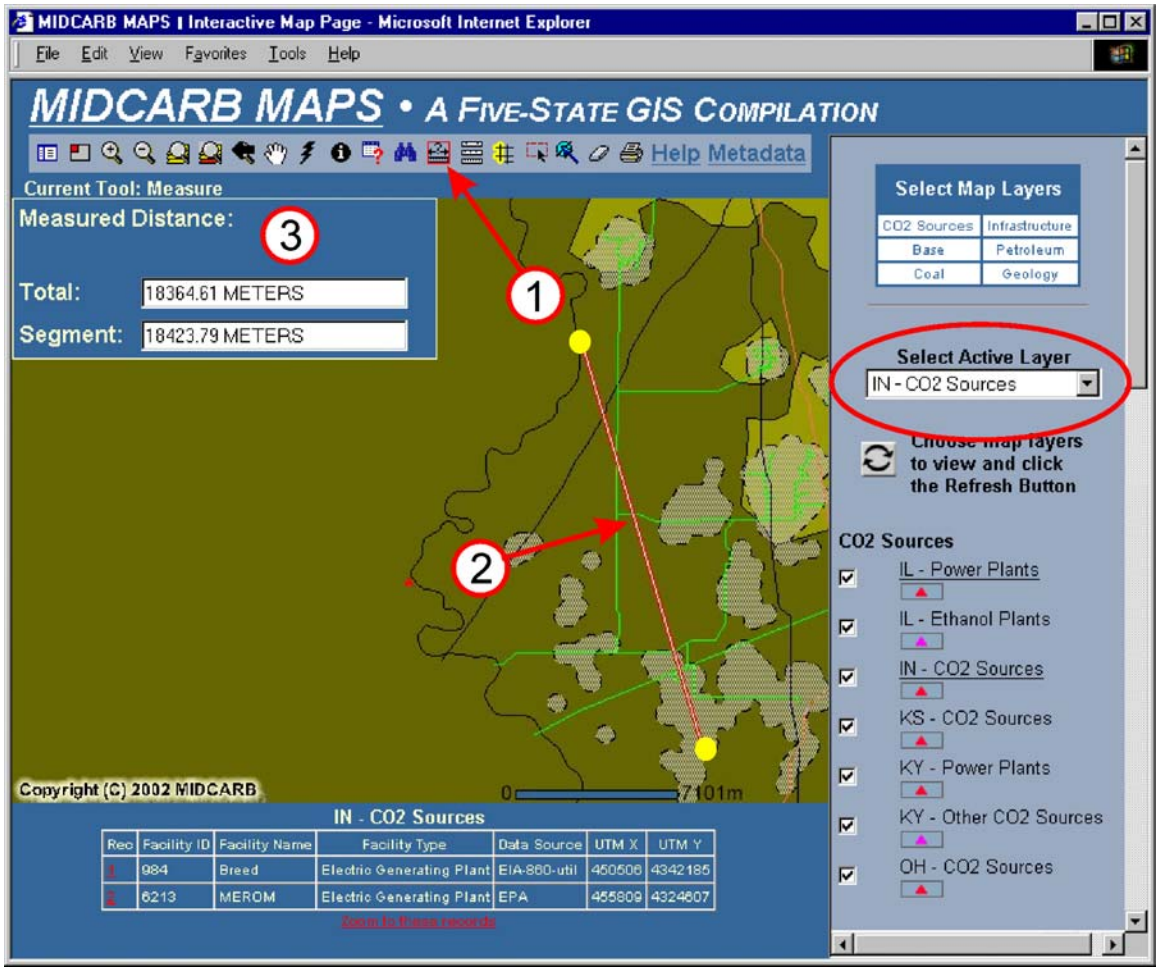


Figure A.14 – Results returned by the MIDCARB Internet Map Server after using the *Select Feature* tool ( ) to select information on the active layer (red ellipse). In this example two Indiana CO_2 sources are selected and information is displayed in the information frame. The *Measure* tool ( ) is selected (Arrow 1) and a line segment is drawn between the two Indiana CO_2 sources (Arrow 2). The measured distance is displayed in a separate window (Window 3). **Note:** If you wish to measure multiple line segments, you must wait for the new line segment to draw each time you click, or you will get an error. The displayed map units can be changed from miles to feet, meters, or kilometers ( ). The *Eraser* tool ( ) can be used to clear selected features, and the *Printer* tool ( ) can be used to create a custom-titled printable map page.

APPENDIX B - MIDCARB INTERNET MAP SERVER

Tools

The following is a brief graphical catalog of the frames and tools of the MIDCARB Internet Map Server. Appendix A provides a step-by-step overview of the server, while the body of the report provides technical discussion.

MIDCARB Internet Map Server is constructed of a number frames (or windows) arranged within a single page (Figure B.1).

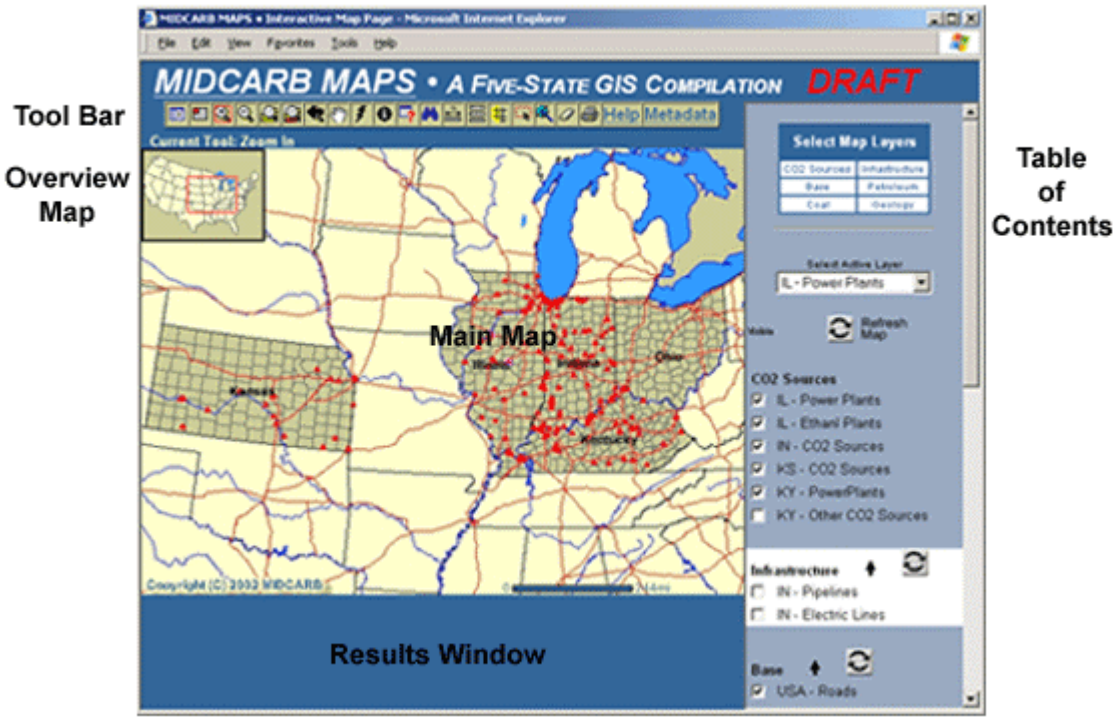
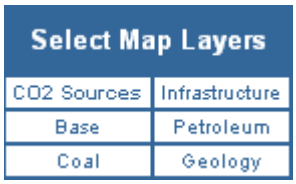


Figure B.1 –The different frames that make up the MIDCARB Internet Map Server.

Table of Contents Frame

The Table of Contents lists map layers that can be displayed. The Table of Contents has been separated into categories. Use the links to scroll to the listing of layers in that category.



☑ To display a layer in the map, click the box beside the layer and then click the *Refresh Map* button.



Click the drop-down list and select a layer to activate. Many IMS functions, such as find, query, and select function based on the active layer. For example, in order to view attributes from the IN - CO_2 Sources layer, you must first click the radio button next to that layer in the Table of Contents to make the layer active.



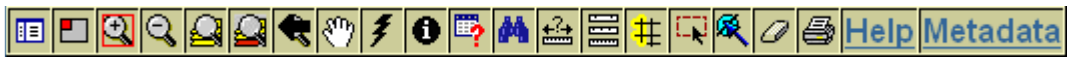
After checking layers in the Table of Contents click the *Refresh Map* button, located at each category heading, to redraw the map and view your changes.



Click the arrow to jump back to the top of the Table of Contents.

Tool Bar Frame

The tool bar is located at the top of the map image window and contains the following tools and links to



Click to toggle between Legend and Table of Contents.

Click to toggle Overview Map on and off.

Click and drag a box on the map to zoom in.

Click on the map to zoom out.

 Click to zoom out to the full extent of the map.

 Click to zoom (in or out) to the extent of the active theme.

 Click to zoom to the previous extent.

 Click and drag to pan the map.

 Click on a feature of an active CO_2 Sources layer to view detailed emissions data for a facility.

 Click on a feature of the active map layer to view more information about the feature.

 Click to interactively search the database containing information about features on the map. After your query has been processed, a list of the results is displayed at the bottom of the map. Click ClearSel under Queries to clear selection and do another query.

 Click to search the attribute table of the active map layer for a specific value.

 Click on the map and move cursor to display line segment and total line length values. **Note:** If you wish to measure multiple line segments, you must wait for the new line segment to draw each time you click, or you will get an error. Clear measure information using the *Clear Selected Features* button.

 Click to change displayed map units from miles to feet, meters, or kilometers.

 Click to add buffer features of the active map layer. To use this tool, first select one or more features from the active map layer using one of the selection tools provided: *Select by Rectangle* or *Select by Line/Polygon*.

 Click and drag a box on the map to select features from the active map layer.

 Click and draw line or polygon on the map (by clicking to create vertices) to select a set of records.

Click to clear selected features.

 Click to create a custom-titled printable map page.

Overview Map Frame



The Overview Map displays an overview of the mapped area, highlighting the extent of the main map with a red box. Note that once you are zoomed in to a small area the red box may appear to be a red dot.

Clicking on the Overview Map will also pan your main map to the center of the clicked point.

The Overview Map can be turned on and off using the *Toggle Overview Map* button on the toolbar.

Results Window Frame

The Results Window displays query results and menus associated with several of the tools from the toolbar.

The Results Window also showing menu associated with the *Set Units* button from the toolbar.

