THE PCOR PARTNERSHIP DECISION SUPPORT SYSTEM

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April 2005

EXECUTIVE SUMMARY

The Plains CO_2 Reduction (PCOR) Partnership has put into place a Web-based decision support system (DSS) to assist its research team in developing and assessing a wide range of sequestration opportunities for the PCOR Partnership region. The DSS is a central repository for the characterization information that is being collected through the project tasks. It allows the PCOR Partnership to browse, query, analyze, and download data regarding CO_2 sequestration in the PCOR Partnership region. Outputs from the DSS will be used in the PCOR Partnership model during the identification of CO_2 sequestration opportunities.

Most of the characterization information can be inspected through the DSS geographic information system (GIS) interface. This mapping interface contains tools for the interactive data analysis of the PCOR Partnership region, with both text- and map-based approaches. Data can be assessed using spatial and tabular analysis and exported for use in other software programs.

The DSS database contains the major CO_2 source locations and emission data for the PCOR Partnership region. Although much of the data were collected through various public Web sites, a significant portion was derived through calculations based on the operational parameters of the source. Geologic sink information includes the locations of oil and gas fields along with associated reservoir characteristics that are necessary to perform detailed field studies with respect to CO_2 sequestration, including porosity, permeability, reservoir thickness, surface area, original oil in place (OOIP), cumulative production data, and water and oil characteristics. This information was also collected through public Web sites and direct contacts with various public and private sector parties. Additional geologic sink characterization is provided for selected regional saline aquifer systems in the PCOR Partnership region. As new information is collected, the database is updated and becomes immediately available to the research team.

Other characterization information, such as regulations, deployment, and terrestrial information can be obtained through links from the DSS to CO_2-related Web sites, documents, and images that have been collected or created by the project team. The fundamental structure and architecture of the DSS can serve as a model for other regional assessments of CO_2 sequestration potential.

ACKNOWLEDGMENTS

The PCOR Partnership is a collaborative effort of public and private sector stakeholders working toward a better understanding of the technical and economic feasibility of capturing and storing (sequestering) anthropogenic carbon dioxide (CO_2) emissions from stationary sources in the central interior of North America. It is one of seven regional partnerships funded by the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory (NETL) Regional Carbon Sequestration Partnership (RCSP) Program. The Energy & Environmental Research Center (EERC) would like to thank the following partners who provided funding, data, guidance, and/or experience to support the PCOR Partnership:

- Alberta Department of Environment
- Alberta Energy and Utilities Board
- Alberta Energy Research Institute
- Amerada Hess Corporation
- Basin Electric Power Cooperative
- Bechtel Corporation
- Center for Energy and Economic Development (CEED)
- Chicago Climate Exchange
- Dakota Gasification Company
- Ducks Unlimited Canada
- Eagle Operating, Inc.
- Encore Acquisition Company
- Environment Canada
- Excelsior Energy Inc.
- Fischer Oil and Gas, Inc.
- Great Northern Power Development, LP
- Great River Energy
- Interstate Oil and Gas Compact Commission
- Kiewit Mining Group Inc.
- Lignite Energy Council
- Manitoba Hydro
- Minnesota Pollution Control Agency
- Minnesota Power
- Minnkota Power Cooperative, Inc.
- Montana–Dakota Utilities Co.
- Montana Department of Environmental Quality
- Montana Public Service Commission
- Murex Petroleum Corporation
- Nexant, Inc.
- North Dakota Department of Health
- North Dakota Geological Survey
- North Dakota Industrial Commission Lignite Research, Development and Marketing Program
- North Dakota Industrial Commission Oil and Gas Division
- North Dakota Natural Resources Trust
- North Dakota Petroleum Council
- North Dakota State University
- Otter Tail Power Company
- Petroleum Technology Research Centre
- Petroleum Technology Transfer Council
- Prairie Public Television
- Saskatchewan Industry and Resources
- SaskPower
- Tesoro Refinery (Mandan)
- University of Regina
- U.S. Department of Energy
- U.S. Geological Survey Northern Prairie Wildlife Research Center
- Western Governors' Association
- Xcel Energy

The EERC also acknowledges the following people who assisted in the review of this document:

Kim M. Dickman, EERC

BACKGROUND/INTRODUCTION

As one of seven Regional Carbon Sequestration Partnerships (RCSPs), the Plains CO_2 Reduction (PCOR) Partnership is working to identify cost-effective CO_2 sequestration systems for the PCOR Partnership region and, in future efforts, to facilitate and manage the demonstration and deployment of these technologies. In this phase of the project, the PCOR Partnership is characterizing the technical issues, enhancing the public's understanding of CO_2 sequestration, identifying the most promising opportunities for sequestration in the region, and detailing an action plan for the demonstration of regional CO_2 sequestration opportunities.

The goal of this phase of the PCOR Partnership is to characterize its region with respect to CO_2 sinks, sources, and infrastructure in order to develop action plans for CO_2 sequestration demonstration opportunities. The project is structured in research teams that gather and analyze information on specific segments of CO_2 sequestration, including sources and emission data, sink characteristics and estimated CO_2 capacity, current and evolving capture technologies, transportation and infrastructure options, and deployment concerns. This report focuses on the development of the decision support system (DSS), created to provide the research teams with a single point of access to a wide variety of research data for the evaluation of sequestration data and the development of potential scenarios.

Through a password-protected Web-based platform, the DSS contains the tools and capabilities designed to deliver functional and dynamic access to the data. The data are housed in a relational database and accessed through the map-based portion of the Web site. Web pages provide access to relatively static data, such as links to reports, CO_2-related Web sites, terrestrial maps, and snapshots of regional data. Figure 1 shows the home page of the DSS. Outputs from the DSS will be used in the PCOR Partnership model for the identification of CO_2 sequestration opportunities. The DSS system can serve as a model for the development of software tools for regional assessments of CO_2 sequestration opportunities.

ASSESSING GEOLOGICAL SEQUESTRATION DATA

Knowledge of the character and spatial relationships of sources, sinks, and regional infrastructure is basic to developing and assessing approaches to geological CO_2 sequestration. GIS technology enhances the users' understanding of regional opportunities by allowing them to visualize the spatially distributed nature of the data (Figure 2).

The Web-based GIS interface contains several analysis methods that allow the research teams to browse, query, analyze, and download data regarding CO_2 generation and sequestration in the PCOR Partnership region. Researchers can use the GIS to:

- Examine attributes of individual features or groups of features and their spatial relationships to other features.
- Query the underlying data to analyze the region and export selected data for manipulation in other software.
- Explore the nature of the data through thematic maps.

Appendix A contains a step-by-step guide on how to use the GIS interface.

Examining Features

The georeferenced data elements in the map interface are referred to as features.

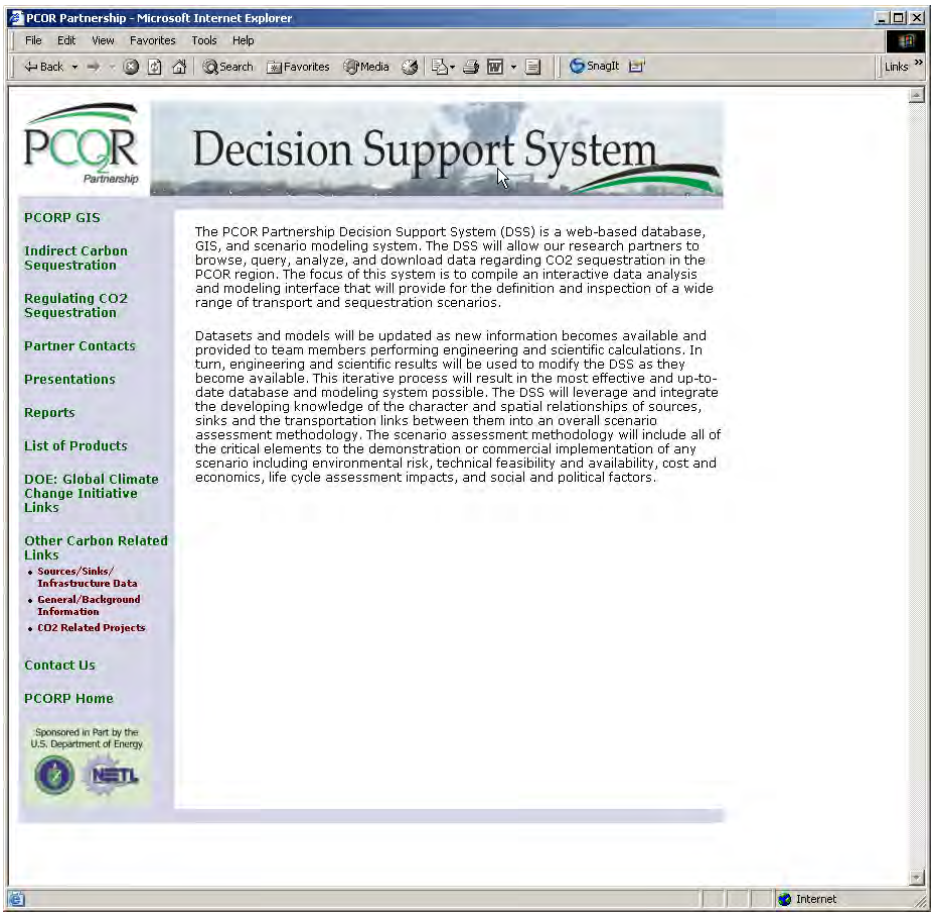

Figure 1. The home page of the DSS provides the interface to the PCOR Partnership research data.

Features sharing a common theme are grouped together in layers (see Table 1).

When the map is first displayed, several layers are initially visible, such as the towns, counties, and CO_2 sources. The visibility of these layers, and others, can be toggled on and off at the discretion of the user.

The availability of several of the layers is scale-dependent. For example, as the user zooms in to a smaller area of the map, more layers become enabled and some become disabled. At a more focused extent, the user can see more detailed features and their location relative to sources and potential sinks. By turning various layers on and off, the user can visually assess a variety of information about the surrounding area, such as wells, federal lands, towns, railroads, and roads.

Individual features are inspected by specifying an active layer and then selecting a single feature or drawing a rectangle around a group of features. Attribute data of the feature(s) will be displayed in the data grid area below the map. The attribute data include identifying information about the feature, such as the name, and key assessment data, such as production amounts. By clicking on an individual feature in the data grid, the user can view a report that displays the entire

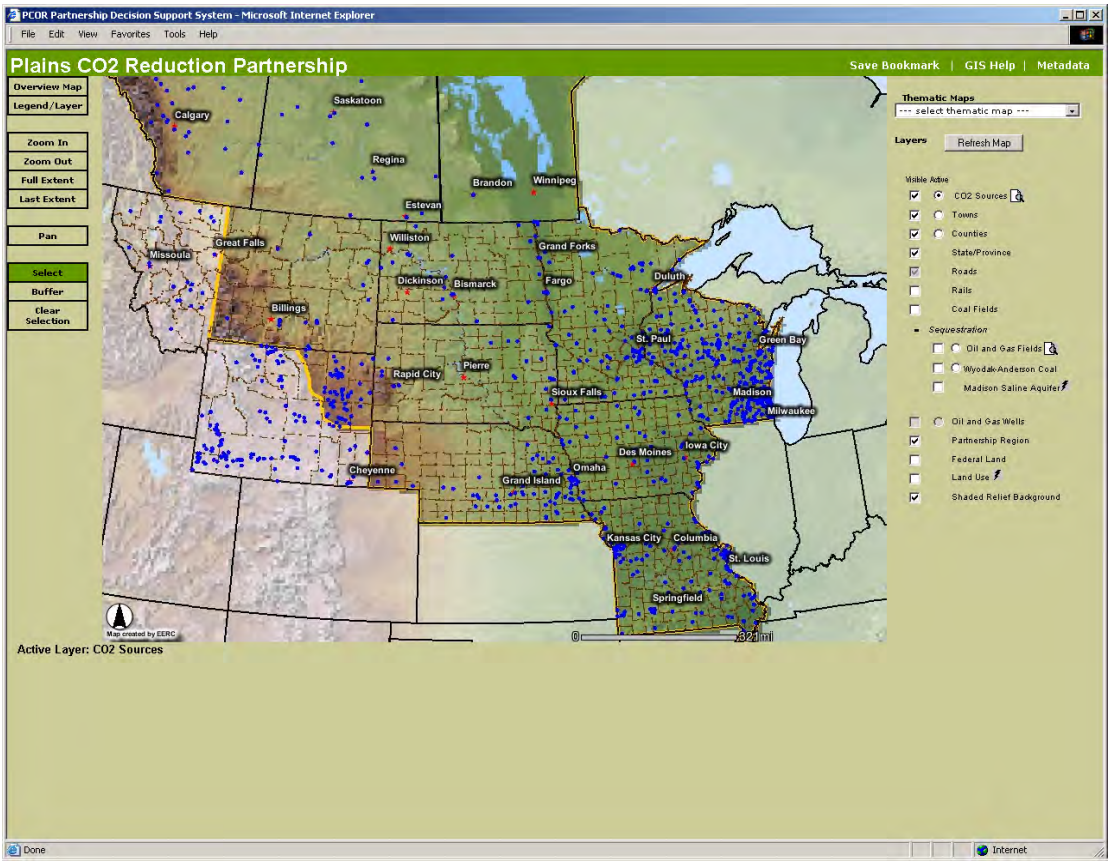

Figure 2. Initial view presented when entering the PCOR Partnership GIS site. The blue dots on the map show the distribution of CO_2 sources in the PCOR Partnership region.

Table 1. Definition of Map Layers

Layers	Description
CO_2 Sources	Point locations of the major stationary CO_2 sources in the region
Towns	Centers of population in the PCOR Partnership region
Counties	County boundaries for the United States
State/Province	State and provincial boundaries
Roads	Network of roads throughout the region
Rails	Network of railroad transportation throughout the region
Coal Fields	Regional coalfields for the U.S. portion of the region
Oil and Gas Fields	Formally defined areas of oil and/or gas production
Wyodak–Anderson Coal	Sequestration potential for the Wyodak–Anderson coal of northeastern Wyoming
Madison Saline Aquifer	Sequestration potential of the Madison saline aquifer system in the Williston Basin
Oil and Gas Wells	Point locations of oil and/or gas wells in the region
Partnership Region	The current boundary of the PCOR Partnership region
Federal Lands	Areas of federally managed lands for the U.S. portion of the PCOR Partnership region
Land Use	Global Land Cover dataset for the PCOR Partnership region

set of the associated attribute data for that feature (Figure 3).

Query and Export

In addition to directly selecting features on the map, the site allows the user to employ advanced selection methods. The attribute query option is a powerful tool for finding and examining features and data based on specific data attributes. This approach is available for sources and oil and gas fields. The search criteria form contains the data fields deemed most useful in determining potential sequestration strategies. For example, the query form for oil and gas fields includes options such as field name, field type, and production data (Figure 4). Once the search criteria have been established, any features with matching attributes are highlighted on the map and the results are displayed in the data grid.

An alternative feature selection process that also allows for sink/source proximity analysis can be employed through a spatial query. This approach uses the buffer tool to identify features that are located within a user-specified distance of the currently selected feature. Figure 5 is an example of using the buffer tool to identify oil fields that are located within 50 miles of a specific CO_2 source.

Once features have been identified and displayed in the data grid, functionality has been included to export the records in a comma-separated value (CSV) file format. The exported file includes the data elements displayed in the data grid as well as all of the associated data for each record. This data file can then be retrieved into a variety of programs, such as spreadsheets or databases, which typically display information in a columnar format.

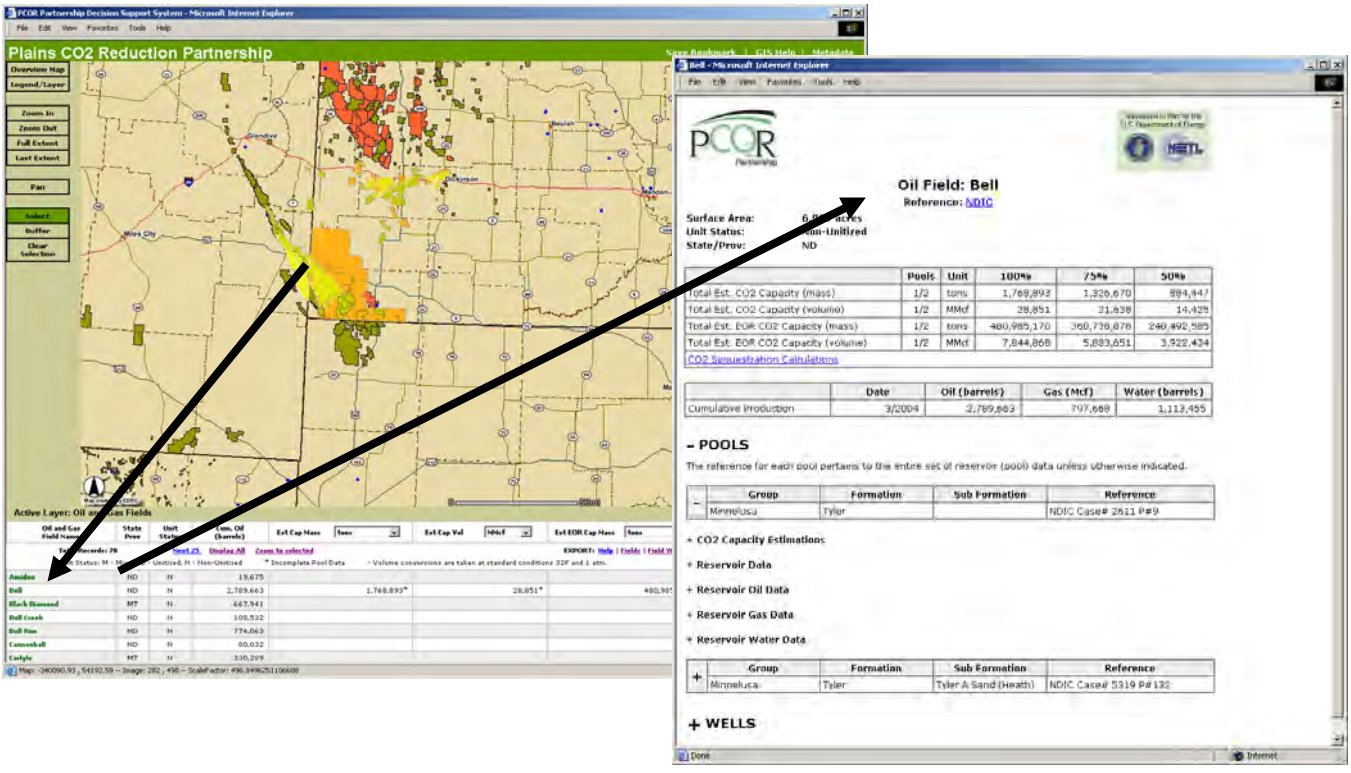

Figure 3. Several oil fields have been selected and are displayed in the data grid below the map. Detailed attribute data from one field are displayed in a report.

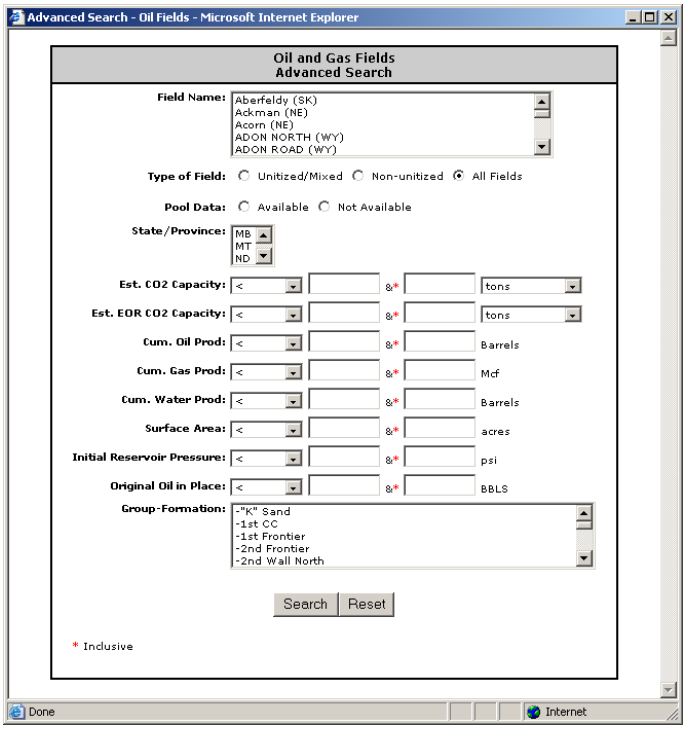

Figure 4. The advanced search option form for oil and gas fields.

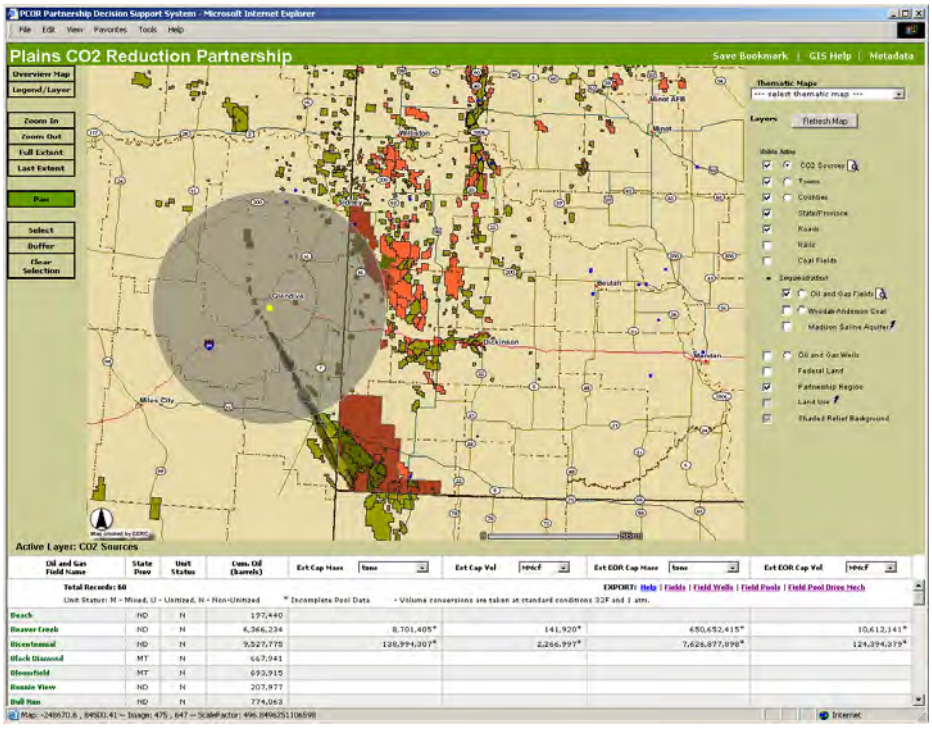

Figure 5. The buffer tool allows the user to view objects within a specified proximity of selected features. In this figure, oil fields within a 50-mile radius of a specific source are identified.

Thematic Maps

In general, thematic maps depict the spatial distribution of one or more specific data themes for an area of interest. Both qualitative and quantitative maps have been developed for selected themes in the PCOR Partnership region. Qualitative maps are designed to display data attributes to answer questions such as, "What is it?" while quantitative maps visually display answers to, "How much is there?" An example of a qualitative thematic map for CO_2 sources is the "CO_2 Sources by Type" map. When selected, this map depicts the CO_2 source types in various colors (Figure 6).

Quantitative maps include comparisons of CO_2 emissions from individual sources, CO_2 emissions aggregated by county, and oil and gas field production data. Figure 7 displays a thematic map of oil and gas field production data for a small area of the PCOR Partnership region.

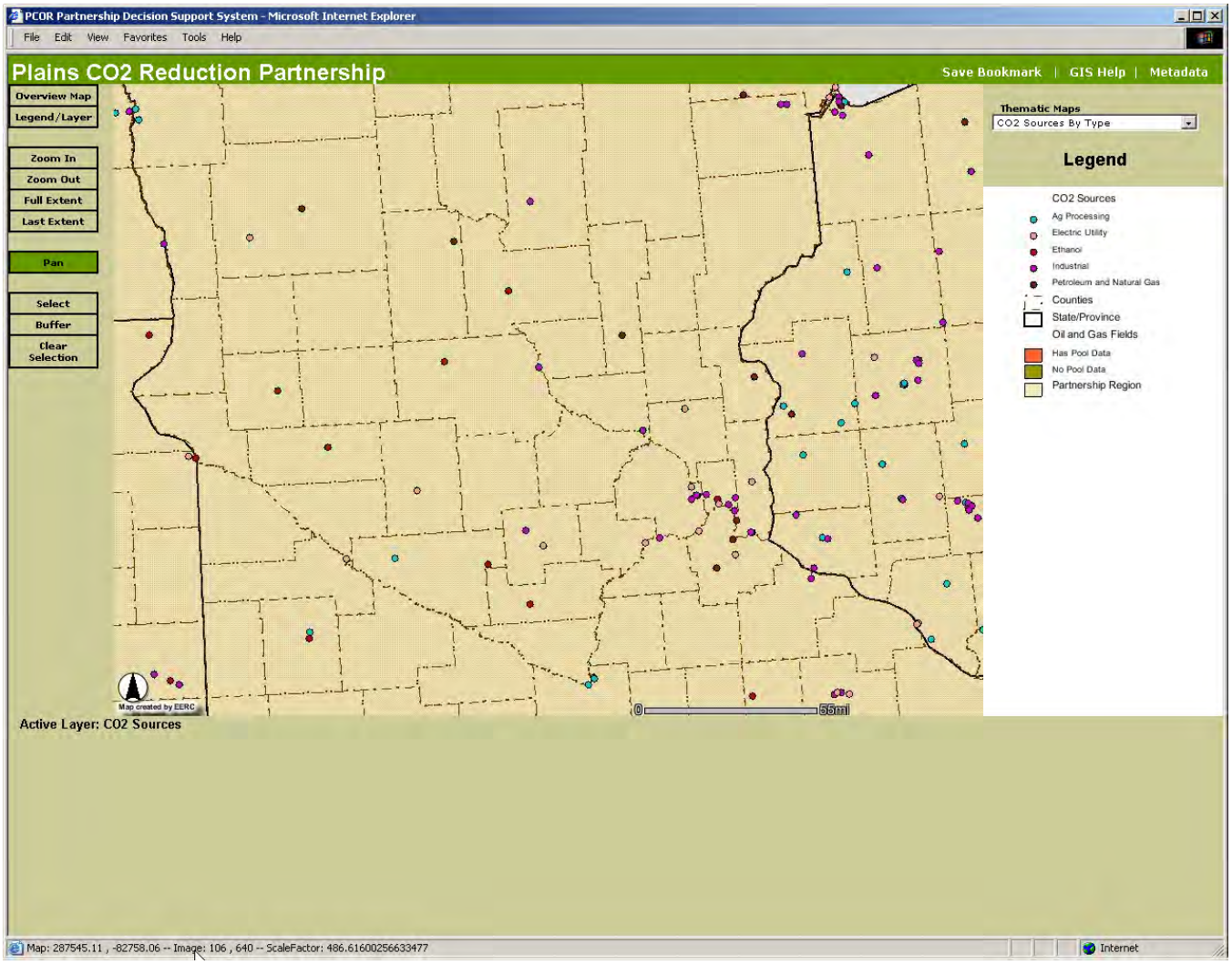

Figure 6. A thematic map displaying the various types of CO_2 sources, as represented by various colors.

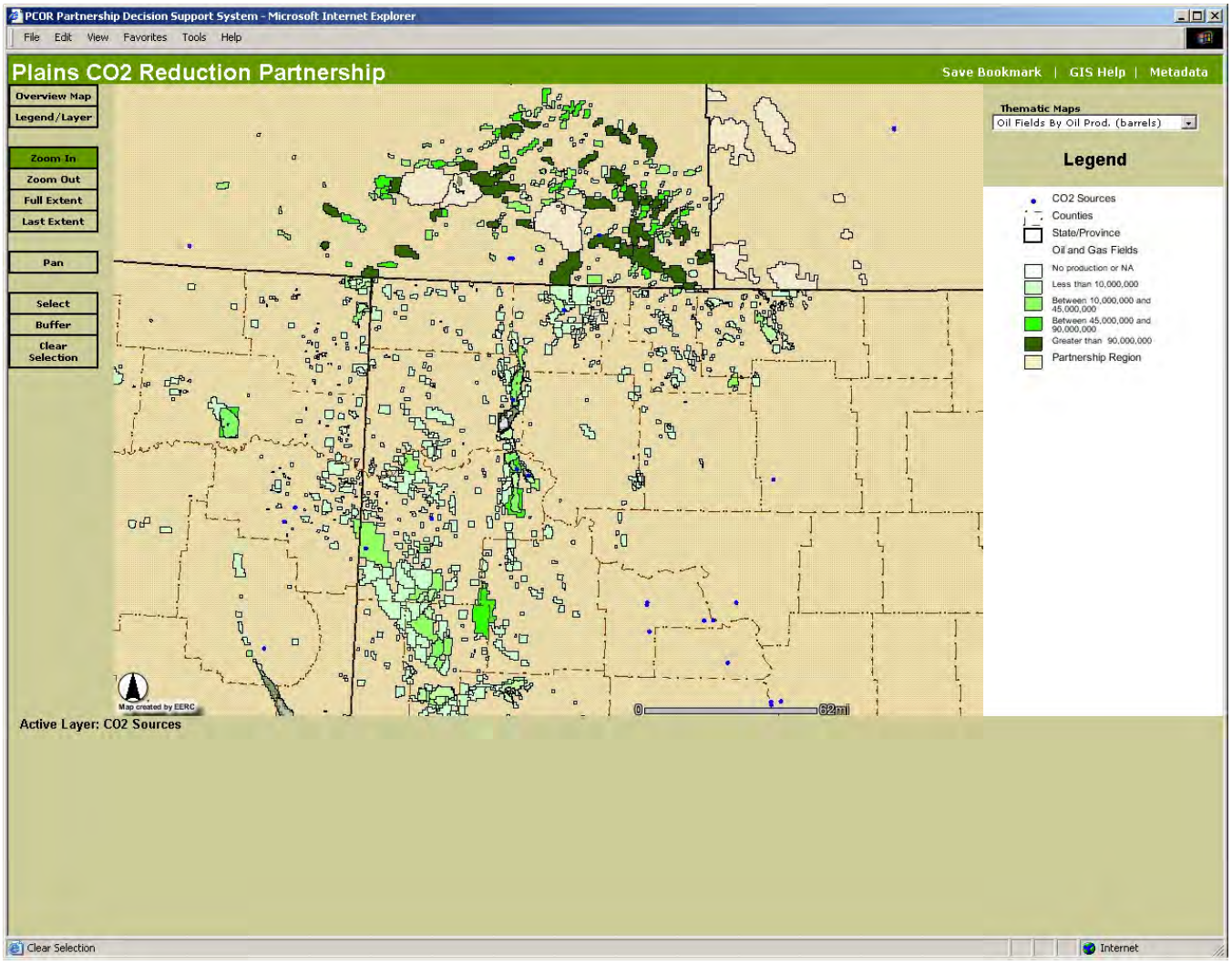

Figure 7. Oil and gas field production data displayed quantitatively in a thematic map.

ADDITIONAL FEATURES OF THE DSS

Frequent users of the GIS portion of the DSS often inspect the same focus area of the PCOR Partnership region each time they enter the site. To expedite the process of zooming into the same map extent, a bookmark feature is available that allows the user to store predefined map extents and layer configurations. This feature utilizes the bookmark or favorites functionality of Internet Explorer (Figure 8).

For those new to the GIS interface, an online help document is available that highlights the basic functionality of the site (Appendix A).

In addition to the mapping interface, the DSS contains traditional Web site features to help the researchers gain a comprehensive understanding of carbon sequestration. These features include an outline of the major federal, state, and provincial regulations regarding the transport and sequestration of CO_2 (Figure 9); descriptive links to other CO_2-related Web sites, including major CO_2

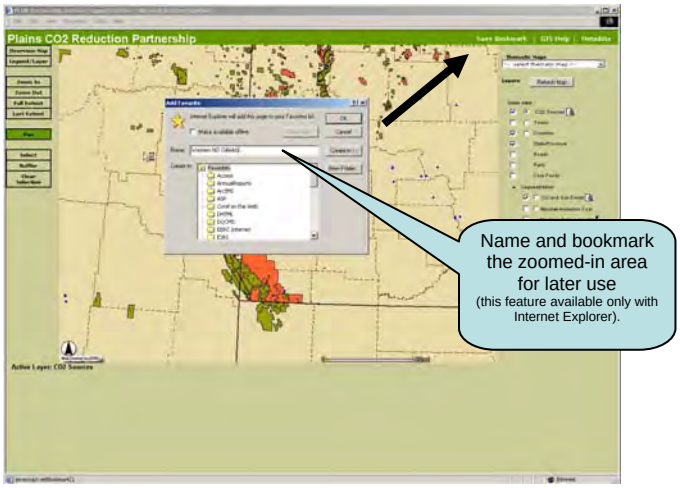

Figure 8. Bookmark the map for later use.

Figure 9. DSS page outlining CO_2 regulations in the PCOR Partnership region.

projects that are outside of the PCOR Partnership region; and links to reports, documents, and related products that have been created or collected by the project team.

The nature of the PCOR Partnership region with respect to terrestrial CO_2 sequestration can be explored through a set of Web pages dedicated to terrestrial information. The terrestrial component of the site is organized into sections representing the primary variables that promote carbon accumulation in soils, including land cover and land use, soil conditions, land resources, and climate. Within each section, users will find detailed information, maps, and links to associated Web sites or documents. Figure 10 displays the terrestrial Web site main page and an example of linking to a terrestrial-based map.

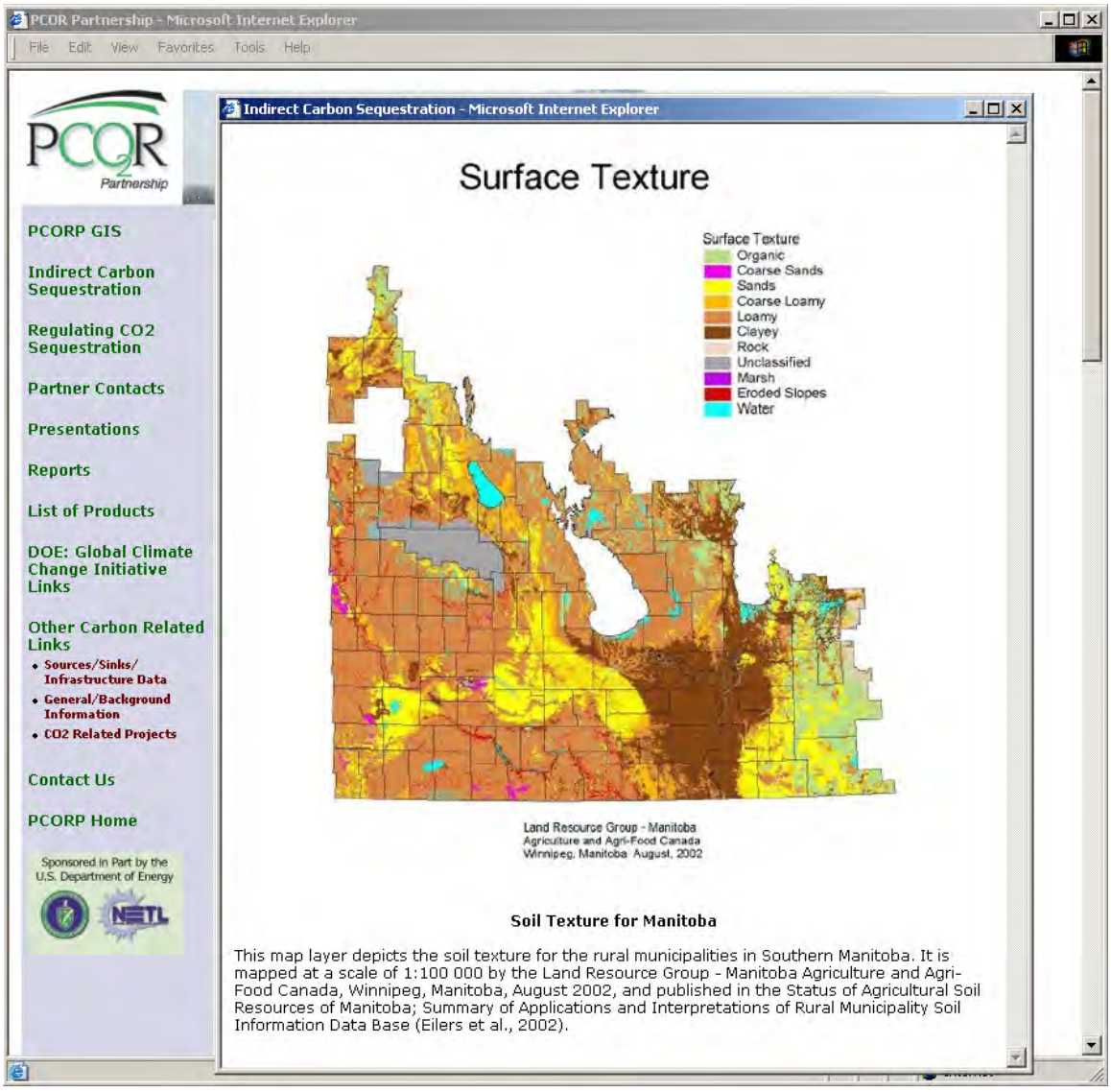

Figure 10. Soil condition maps are one example of the items available from the indirect carbon sequestration section of the DSS.

DATA ACQUISITION AND STORAGE

The Web-based GIS interface of the DSS contains several themes of georeferenced data that are considered crucial for the initial phase of the PCOR Partnership project. These data include detailed source and sink characterization information that has been collected or generated by the research team. The detailed attribute data associated with the features in these layers are managed in a relational database. The GIS server contains the majority of the base layers and associated characteristics, including political boundaries, cities, regional geology, road and rail transportation, shaded relief, and land use. Appendix B contains a description of the database elements. Appendix C contains the metadata document that describes the references and agencies used for acquiring data as well as quality assurance/quality control information.

Source Data

The majority of the source characterization data were downloaded from public data sources, such as U.S. Environmental Protection Agency (EPA) Web sites. The database currently contains information regarding all stationary CO_2 sources in the PCOR Partnership region. Stationary sources include heat and power generation (utility, industrial, institutional, and municipal) and industrial facilities representing the food, fuels, chemicals, minerals, metals, paper/wood, manufacturing, and waste-processing industries.

Largely, CO_2 emissions were estimated using fuel utilization data or unit production emission factors (e.g., tons CO_2/gallon ethanol). SO_x and NO_x emission data were included wherever available. Emission data are initially displayed in tons CO_2/year (mass) and MMcf CO_2/yr (volume); however, the GIS has a converter for users to select different units such as tons C/yr or Mcf CO_2/day.

Sink Data

The petroleum-related data (well and field locations along with associated management, production, and stratigraphic data) were provided by state agencies or gleaned from publications; however, the level, or detail, of available data was not always consistent from state to state. The database currently contains information on more than 100,000 wells with various attributes, including the American Petroleum Institute (API) number, operator name, well name, total depth, total vertical depth, well type, and well status. Since the terminology to describe the type of well is not consistent across the region, the wells were categorized more generally so that thematic maps of well types could be produced. When possible, wells are associated with specific oil fields and are displayed in the oil field report. Reservoir characteristic data were obtained by researching state agency case files for fields with a cumulative oil production greater than 800,000 barrels. These data pertain to reservoir characteristics that are necessary to perform detailed field studies with respect to CO_2 sequestration, including porosity, permeability, reservoir thickness, surface area, original oil in place (OOIP), cumulative production data, and water and oil characteristics.

Hardware and Software

The Web-based GIS portion of the DSS is designed using the Environmental Systems Research Institute (ESRI) ArcIMS, which provides a scalable framework for GIS Web publishing. Customized JavaScript and ASP programming languages were developed to integrate data managed in enterprise databases with function-focused applications that use geographic content. There is a GIS-dedicated Windows 2003 server running ArcIMS 9.0 with IIS 6.0. It has dual Pentium 3 processors at 1.4 GHz and 1.5 GB of RAM; the SQL server 2000 database runs on a dedicated Windows

2000 server with dual Pentium 4 Xeon processors at 3.06 GHz and 1 GB of RAM. Both servers contain SCSI mirrored hard drives for data redundancy. Data backups are performed daily, with a 2-month rotation stored in a fireproof safe.

RESULTS

The PCOR Partnership is accumulating a wealth of data in characterizing the partnership region with respect to CO_2 sequestration opportunities. These data are compiled, stored, and managed in the computer systems underlying the DSS. The DSS is used by the PCOR Partnership research team to develop knowledge of the character and spatial relationships of sources, sinks, and infrastructure. This knowledge will assist decision makers in the identification of major CO_2 sequestration opportunities in the region and development of action plans. To date, the DSS has been used to generate reports on the general reservoir characteristics of selected oil fields that may come under consideration for CO_2 flood enhanced oil recovery and to develop detailed information on potential sources that may provide CO_2 for such operations. The DSS has also been used to identify the location of areas that may present challenges with regard to deployment, such as Indian reservations, national wildlife refuges, national parks, national forests, or grasslands. The research team responsible for the development of geologic sequestration scenarios has used the DSS to download source information to a spreadsheet for use in a model that will identify potential source–sink matches.

For more information on this topic, contact:

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Visit the PCOR Partnership Web Site at www.undeerc.org/PCOR.

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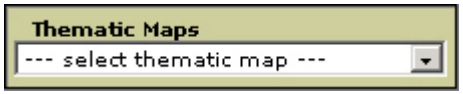
APPENDIX A

QUICK REFERENCE

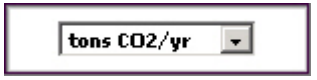
Navigating the Map

Action Button	Action Description
Overview Map	Display the location of the viewable map area relative to the entire PCOR Partnership region.
Legend/Layer	Change the view on the right hand side of the map between Layers (data choice view) to Legend (symbology used in the map).
Zoom In	Select and display a more focused viewing area.
Zoom Out	Select and display a less focused viewing area.
Full Extent	Refresh the map to the entire PCOR Partnership region.
Last Extent	Refresh the map to the prior viewing area.
Pan	Move the display in any direction without zooming.
Select	Display information on the active layer.
Buffer	View information about objects within a specified proximity of a selected feature.
Clear Selection	Clear the selected layers and refresh the map.

Choosing Data for the Map

Selection	Selection Description
	Display a set of data in predefined categories, such as "CO_2 Emissions by County."
	Refresh the map based on current data selections.
	The Visible layers are the layers that are displayed on the map. The Active layer is the layer in which information will be displayed when the user makes a selection from the map. Only one layer can be active at a time.
	Input search criteria for the associated layer based on layer attributes.
	Display the legend for the associated layer in a new window.

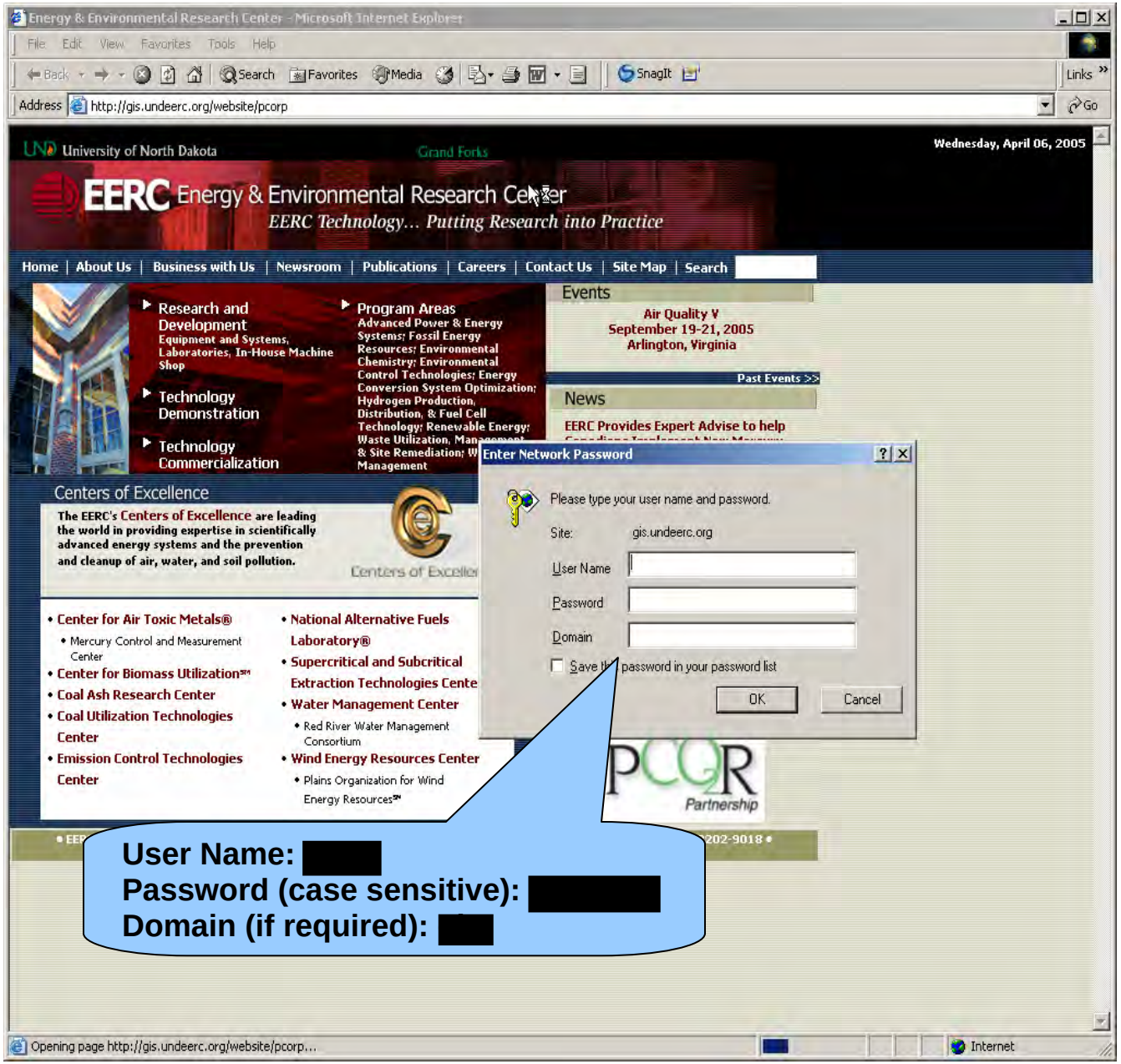
Working with the Data Grid

Selection	Action Description
	Focus the map on the selected records.
	Manage the number of records that are displayed in the data grid.
	View detailed information about a record in the data grid.
	Change the data that are displayed to the selected units.
	Export grid data to a comma separated value (CSV) file.

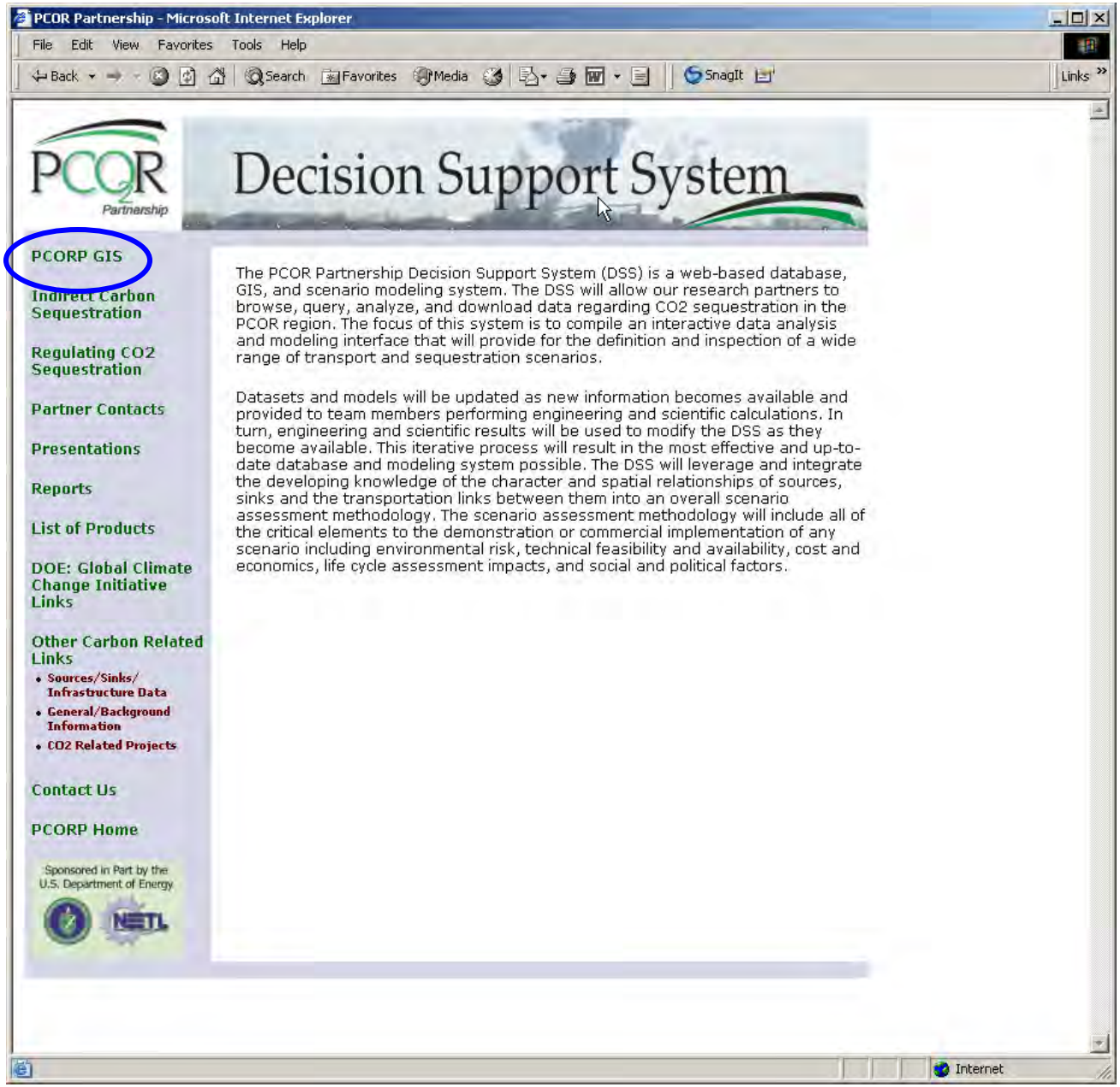
DSS Features

Selection	Action Description
Save Bookmark	Save the displayed map as a “favorite” in your browser (Internet Explorer browsers only).
GIS Help	View this Help document.
Metadata	View the DSS metadata.

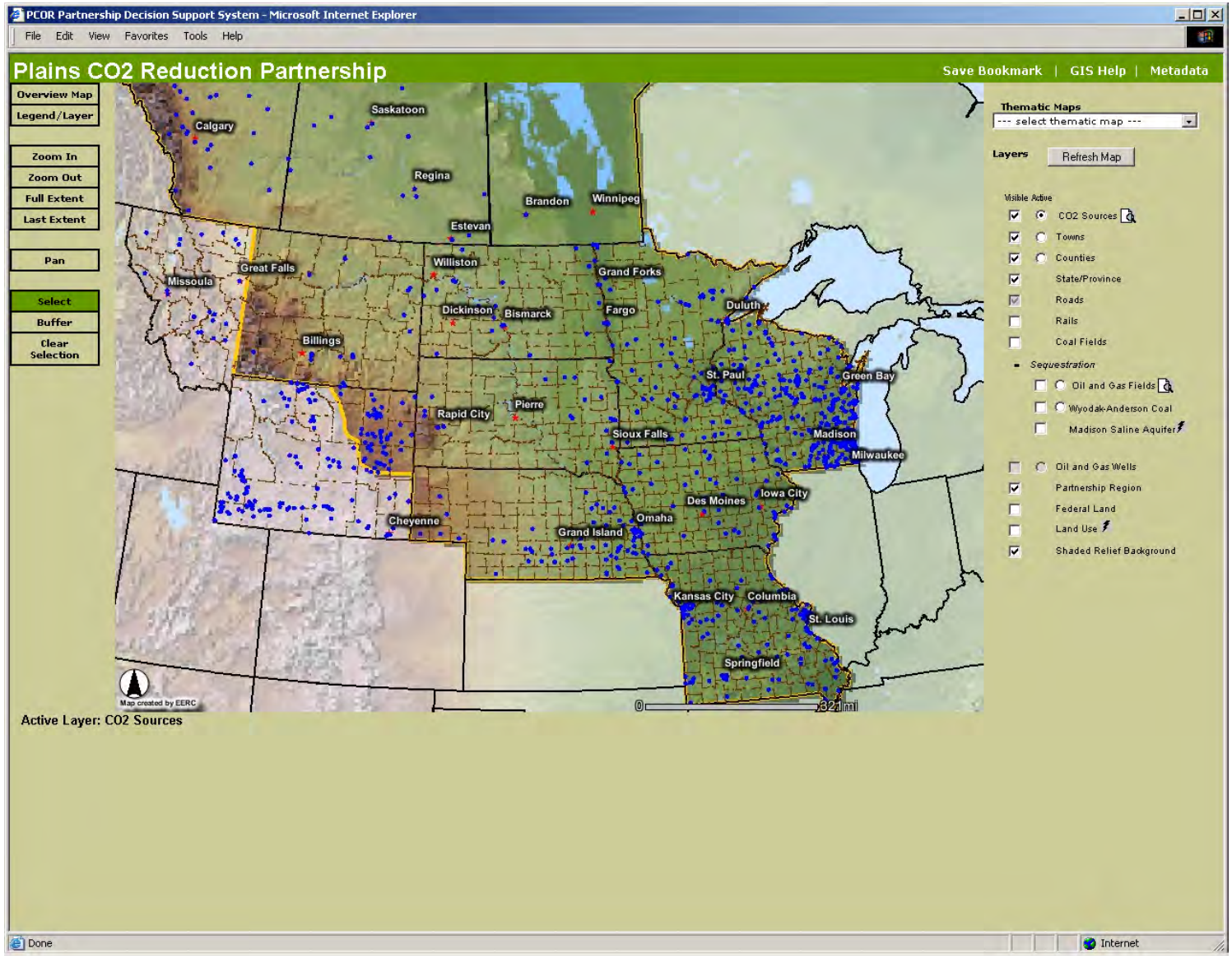
The PCOR Partnership GIS Web site address is http://gis.undeerc.org/website/PCORP You will be prompted to enter your User Name, Password, and Domain.



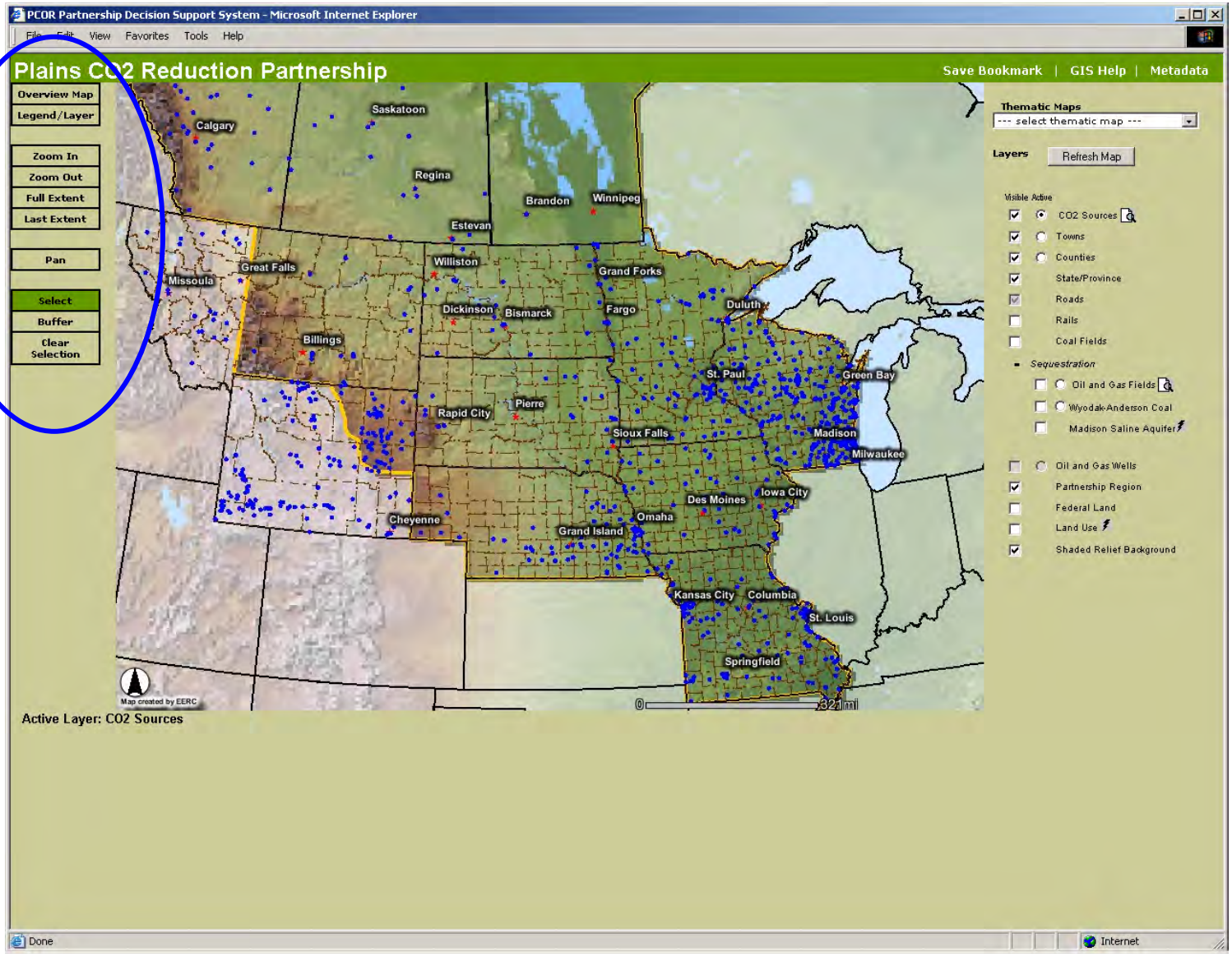
Click the PCORP GIS link to open the GIS Web site.



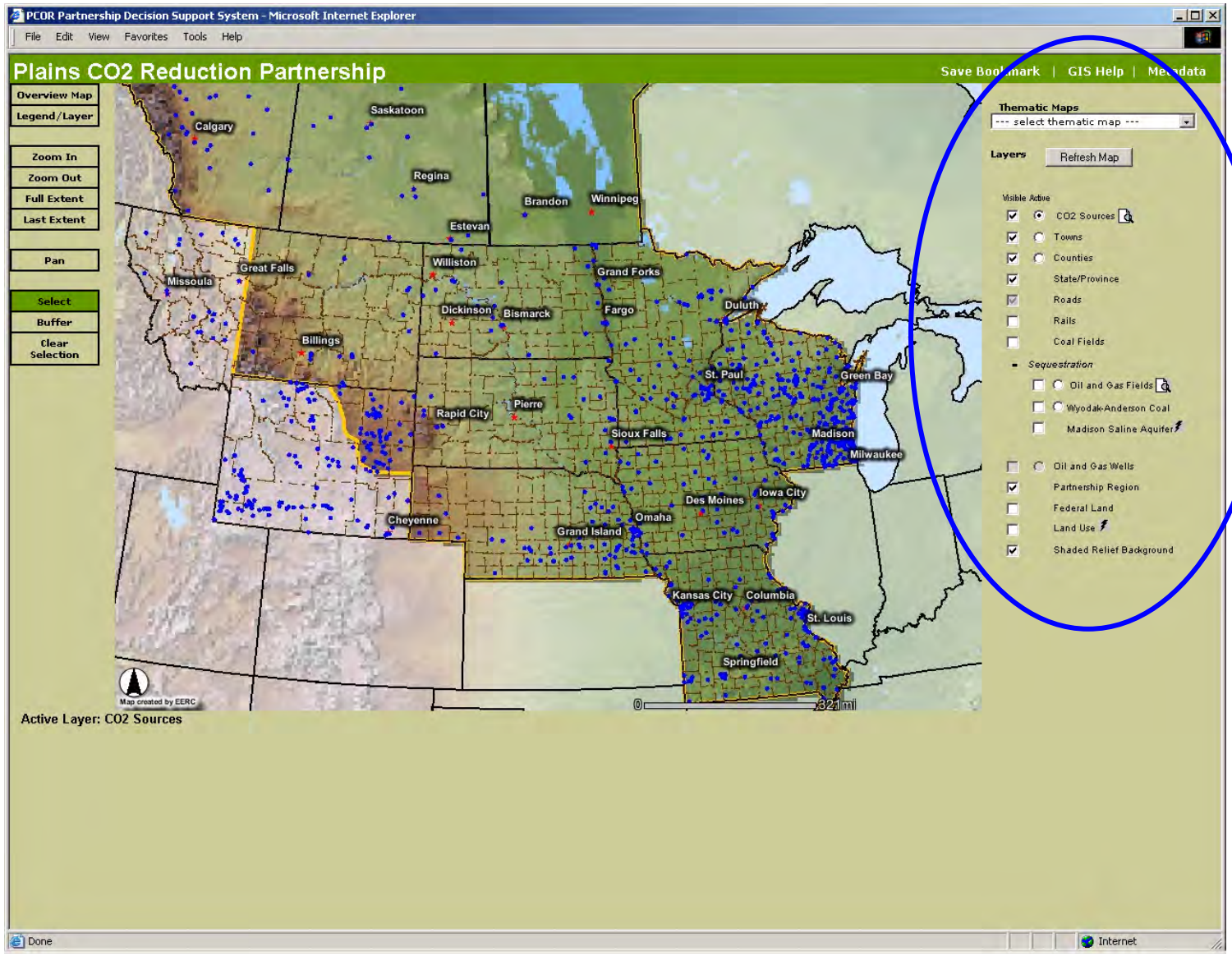
When the GIS site opens, the entire PCOR Partnership region is displayed in a new window.



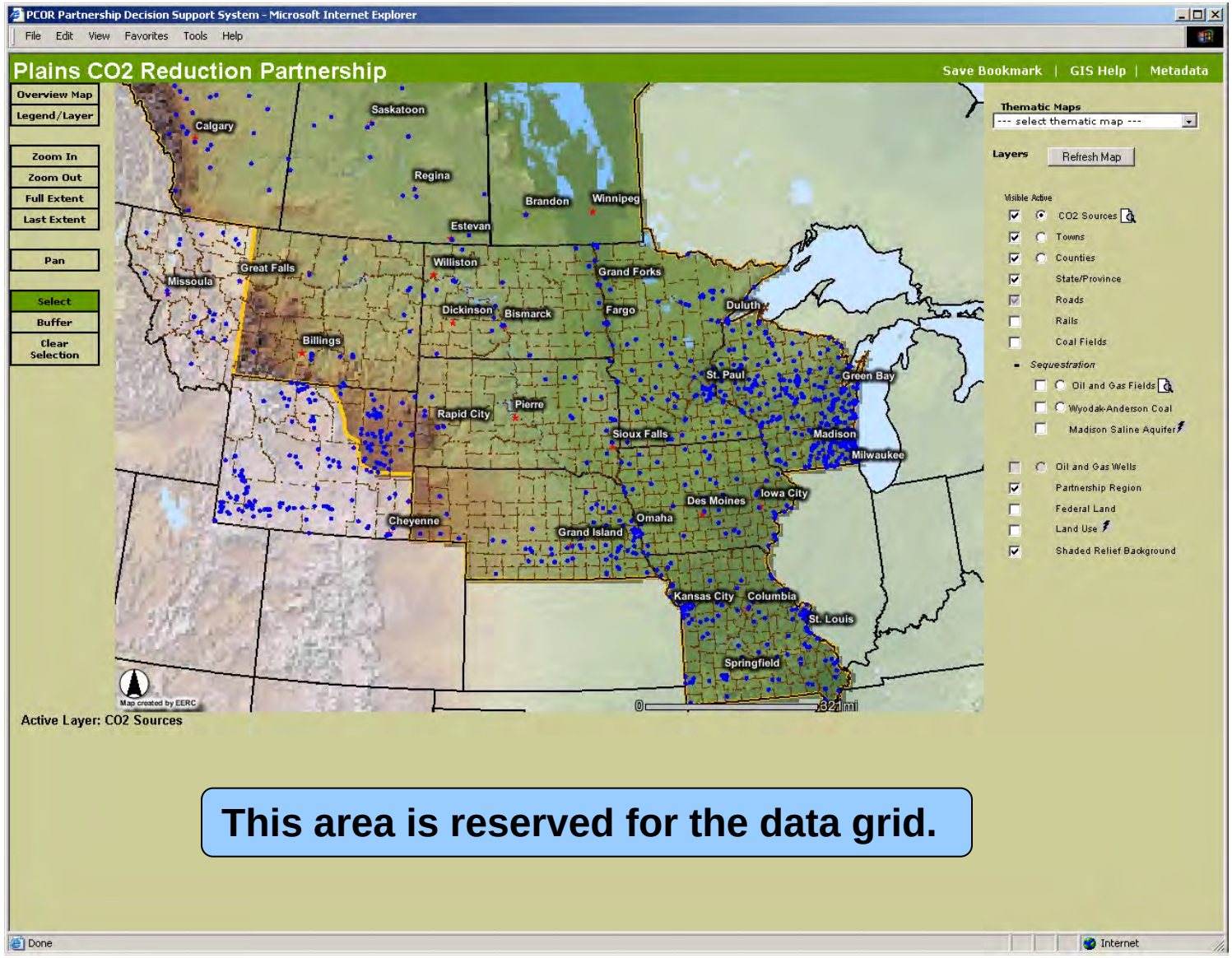
The left side of the map contains the ACTION menu items to interact with the map.



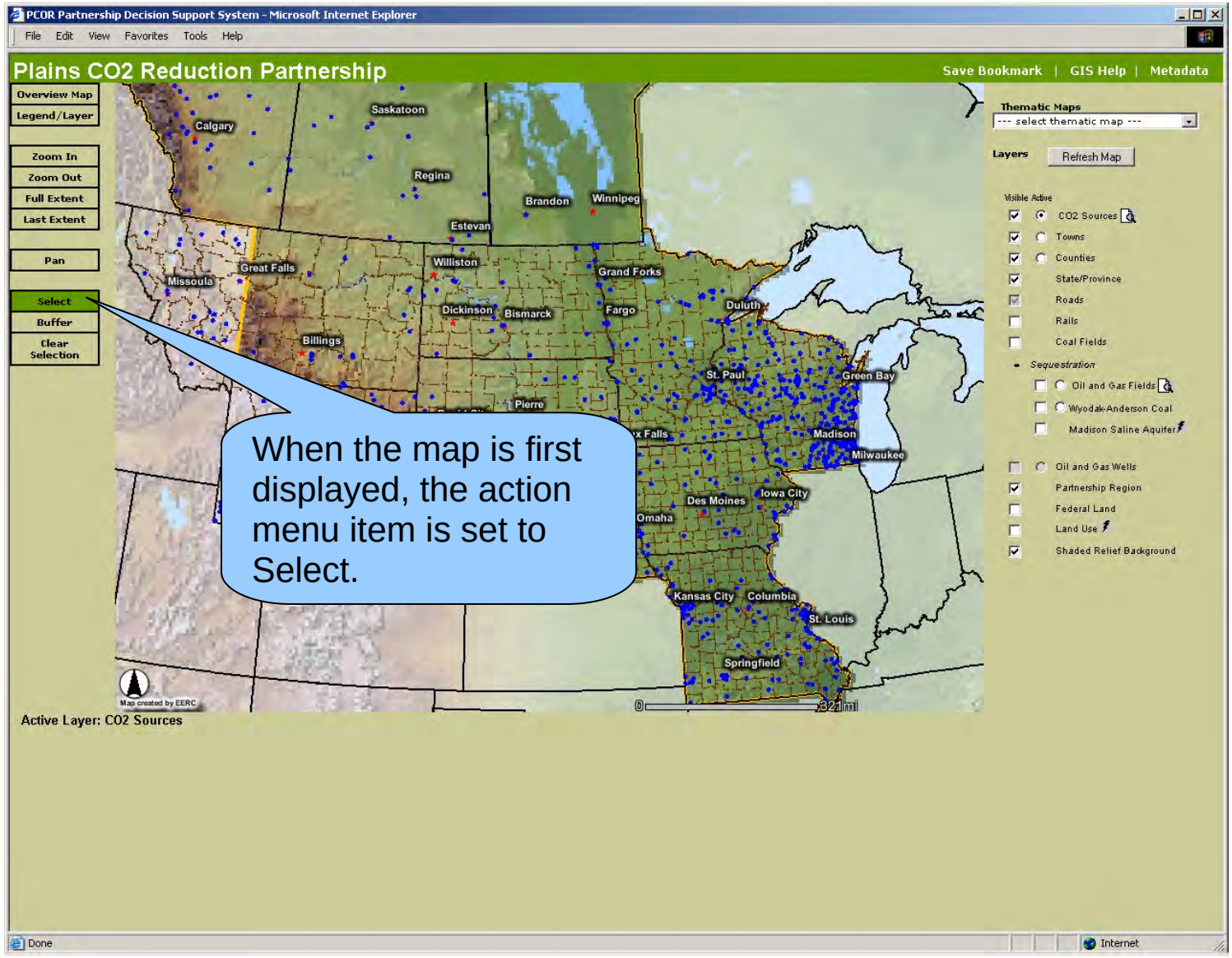
The right side of the map contains DATA CHOICE options to choose which data are displayed.



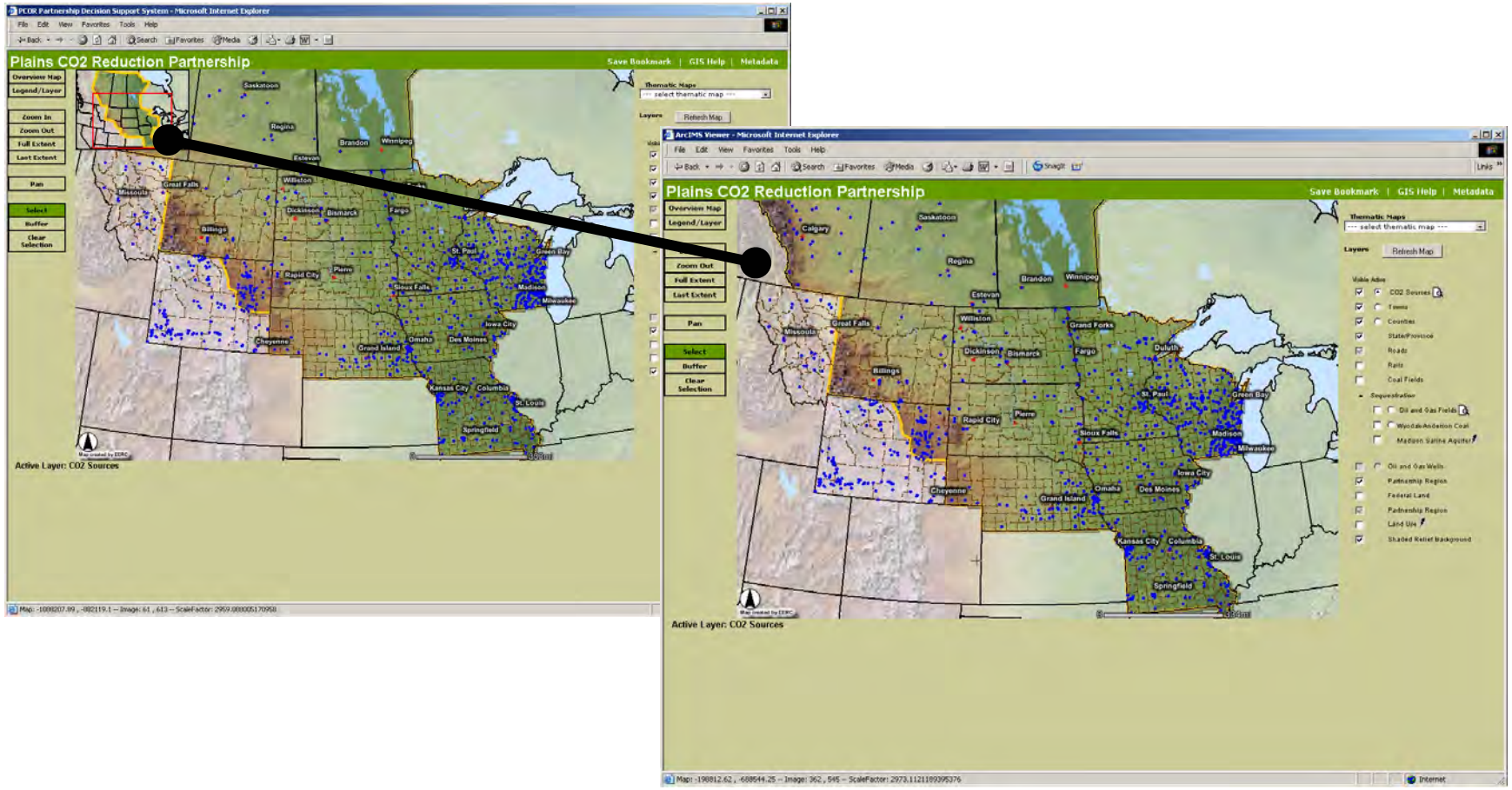
The area below the map is reserved for the DATA GRID – detailed information on selected items from the active layer.



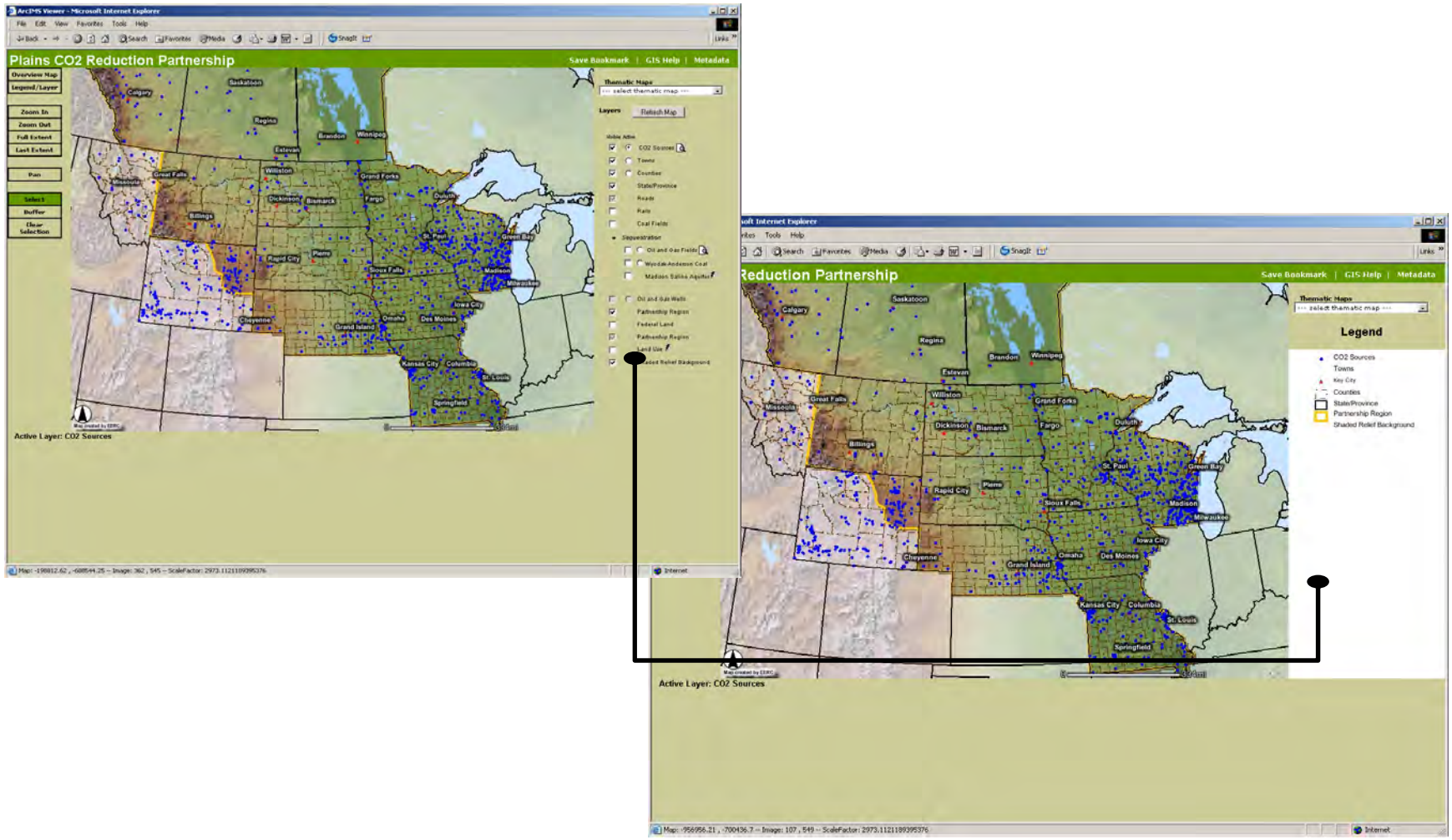
Action Menu Items: The highlighted action menu item is the action that will be performed the next time the user interacts with the map.



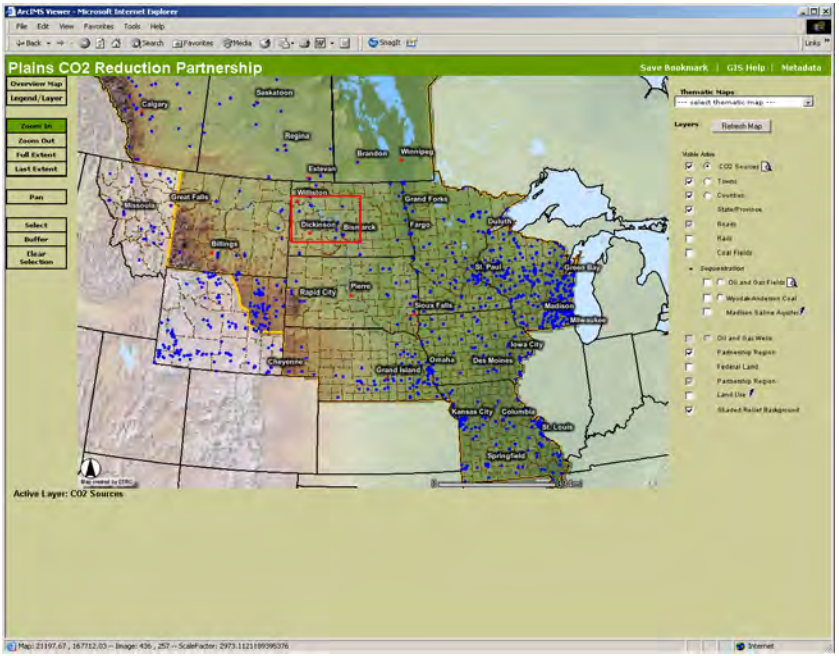
Overview Map Click to toggle the Overview Map on and off.

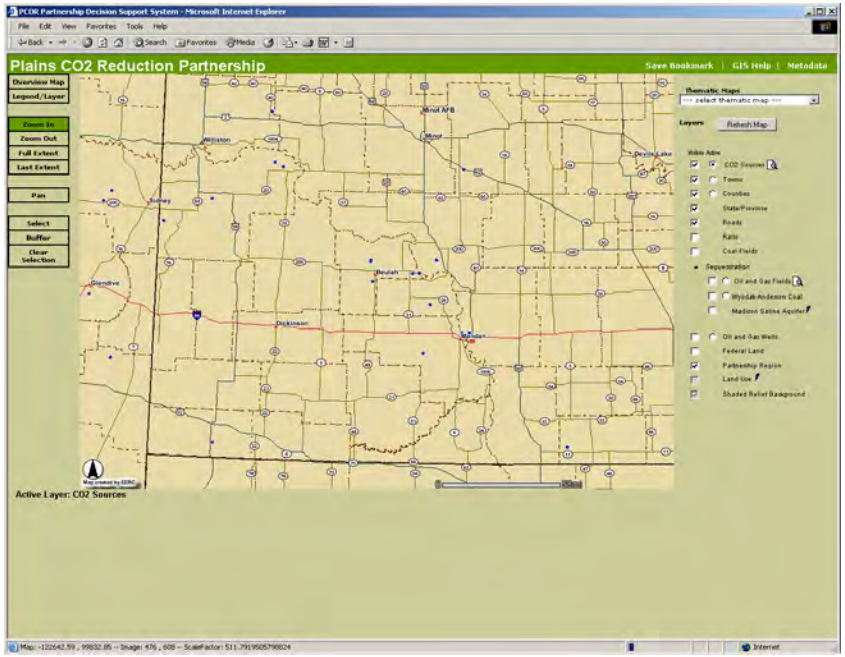


Legend/Layer Click to toggle between the legend and the layer view on the right side of the map.



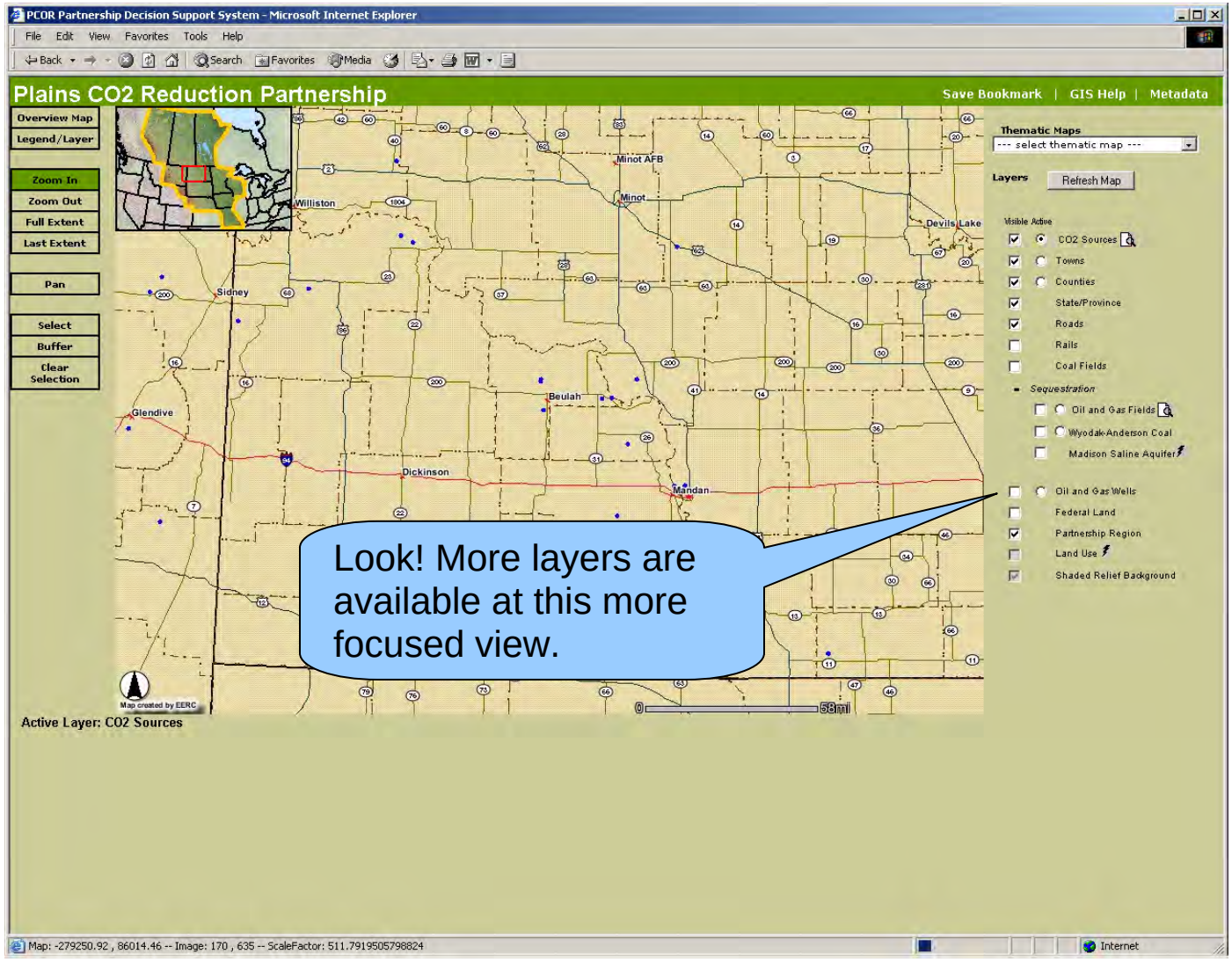
Zoom In Click to select a more focused viewing area.



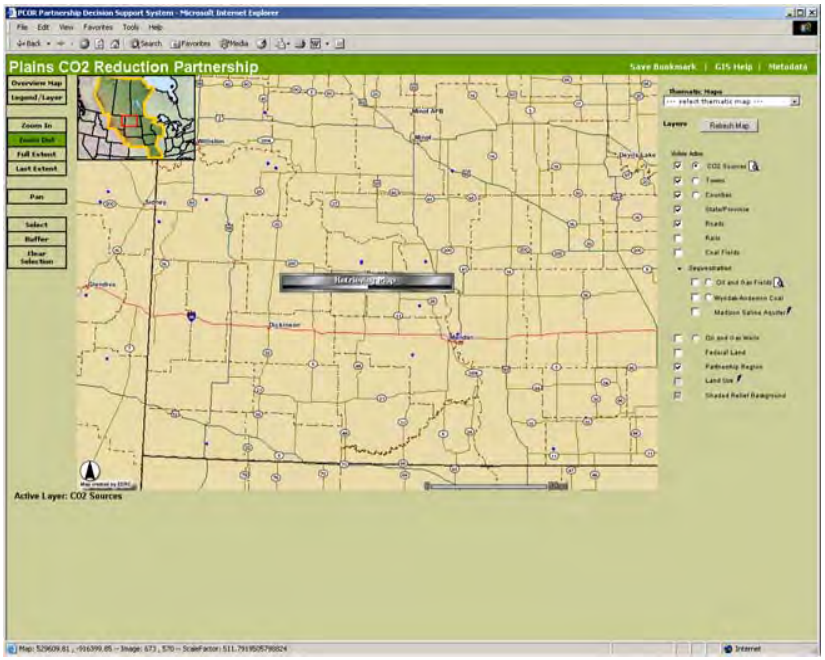


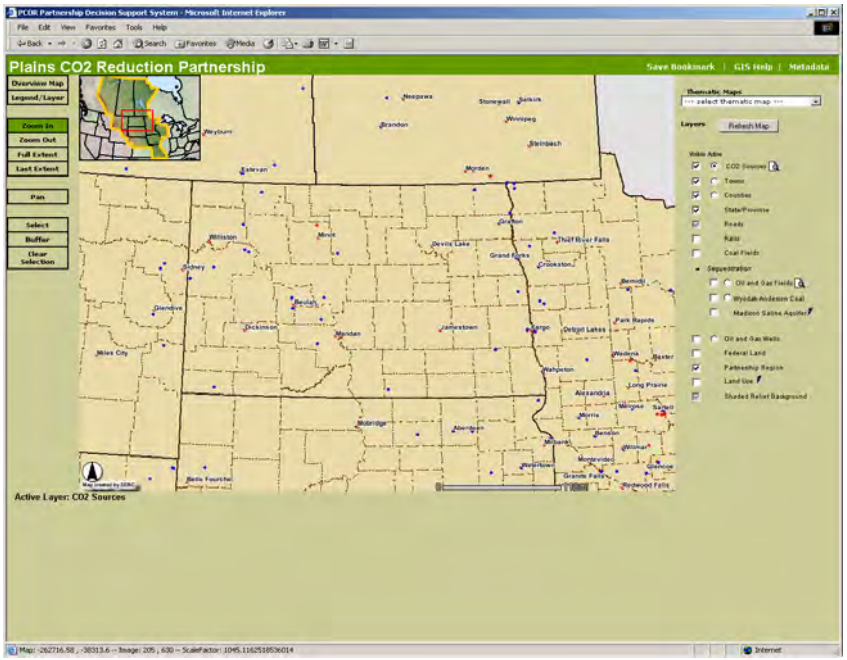
1. Click the Zoom In button. The mouse pointer will appear as a crosshair on the map.
2. Hold the left mouse button down and drag a rectangle around the area you wish to focus on.
3. Let go of the left mouse button. The map will zoom in to the selected area.

Tip: When you are zoomed in, click on the overview Map button to orient your focused view relative to the larger PCOR Partnership region.



Zoom Out Click to select a less focused viewing area.

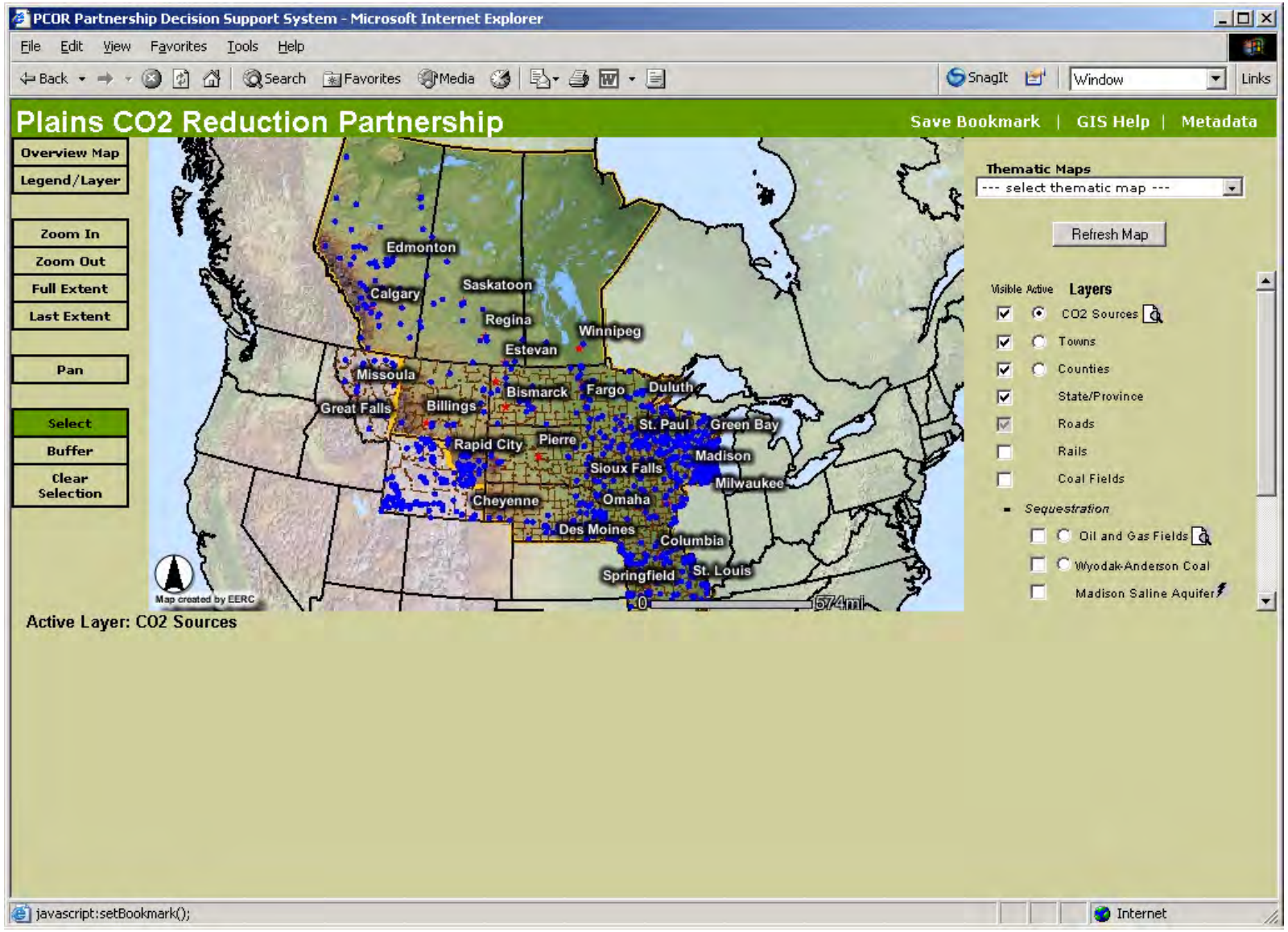




1. Click the Zoom Out button. The mouse pointer will appear as a crosshair on the map.
2. Hold the left mouse button down and drag a rectangle around the area you wish to zoom out from or click a single point on the map.
3. Let go of the left mouse button. The map will zoom out to the selected area.

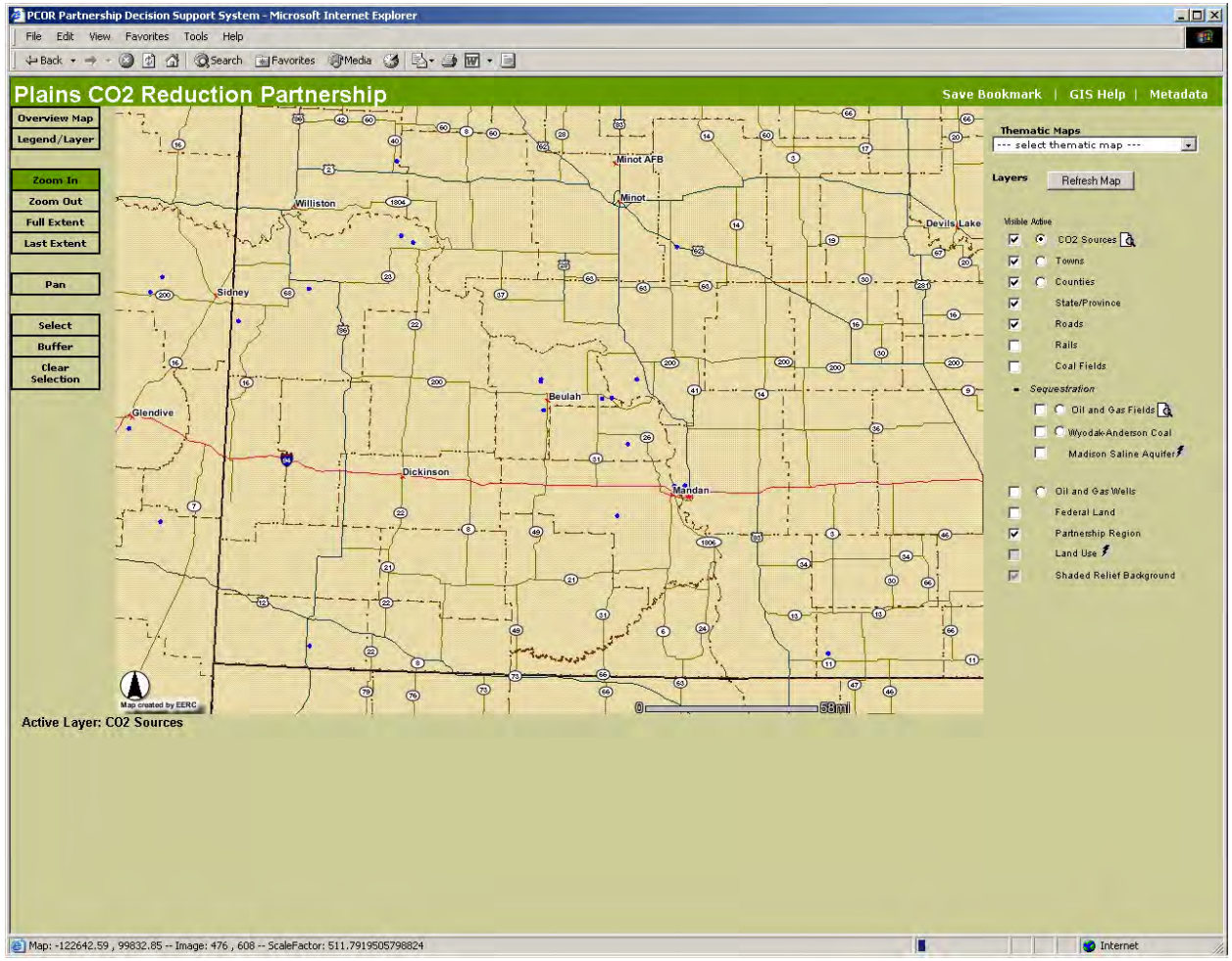
TIP: Wait until the “Refreshing Map” notification disappears before performing anymore actions on the map.

Full Extent Click to refresh the map to the entire partnership region.



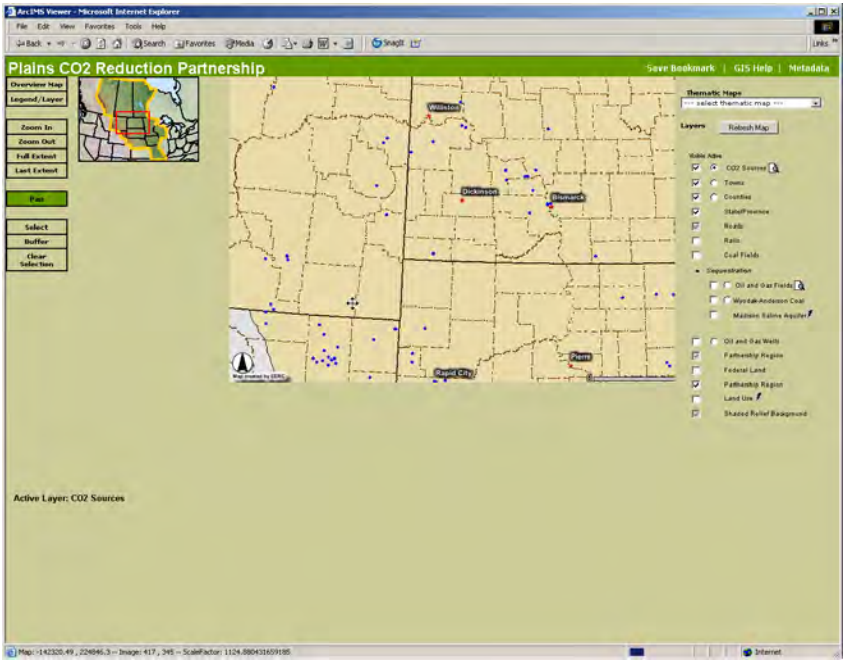
Last Extent

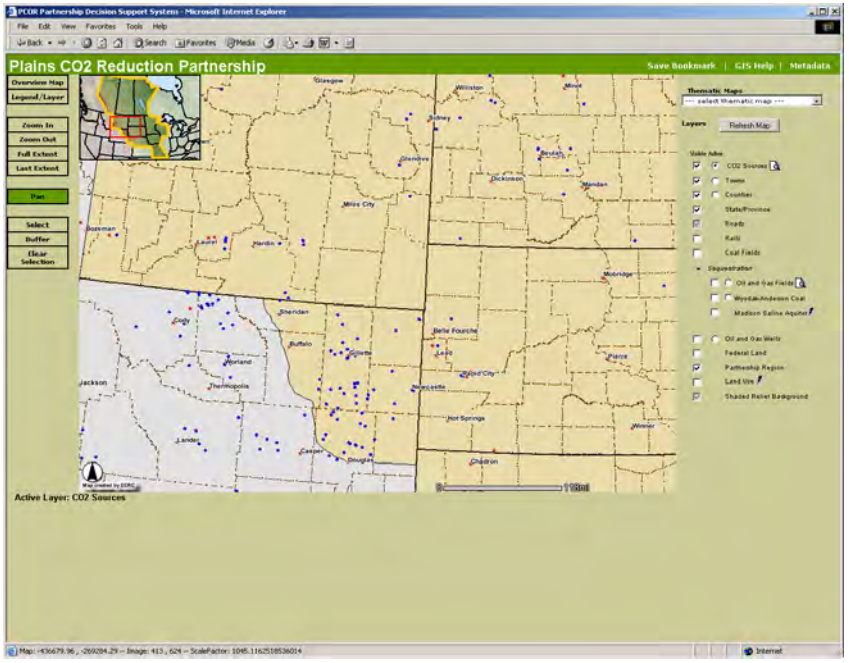
Click to refresh the map to the prior extent. This is useful when zooming in and out.



Pan Move the map in any direction.

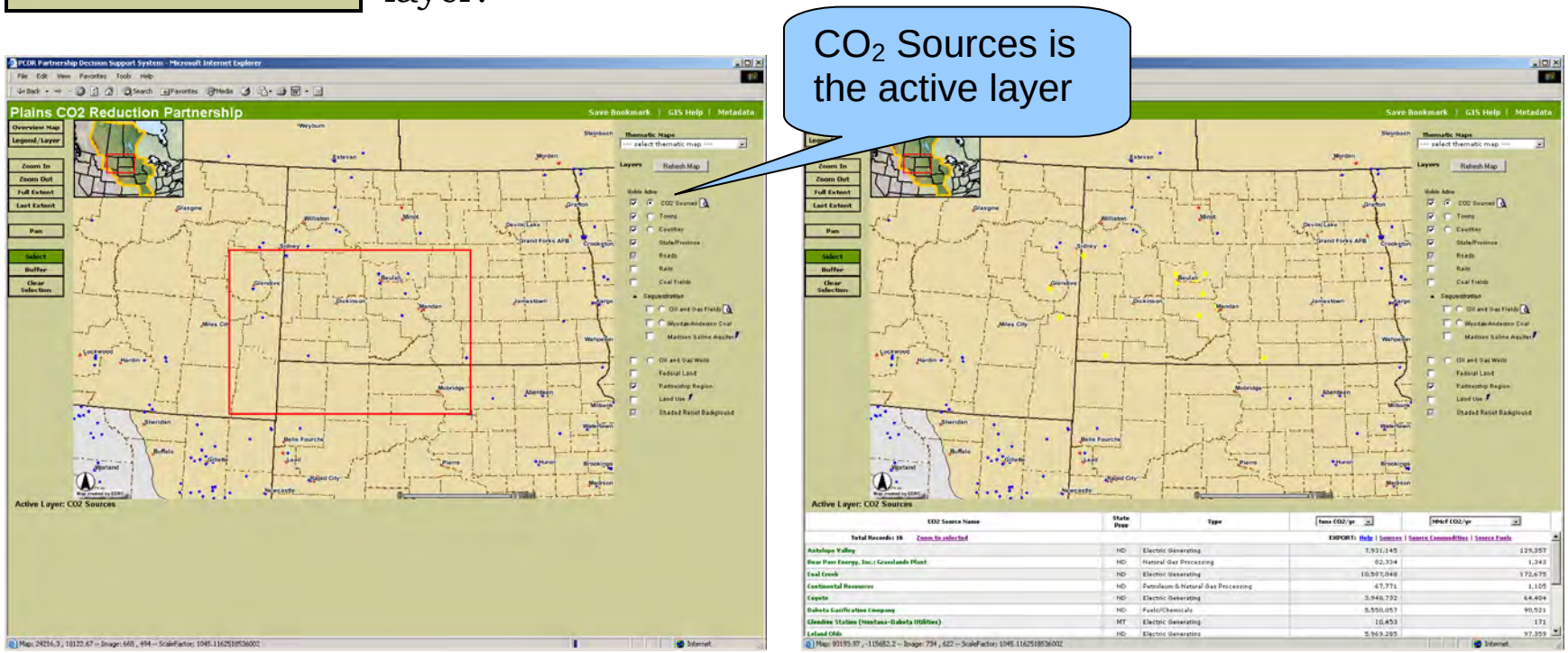
TIP: Do not use your Back button on your browser to retrieve a previous view – you may receive unexpected results!





1. Click the Pan button. The mouse pointer will appear as a crosshair on the map.
2. Hold the left mouse button down and click on the map. Drag the map in the opposite direction of the area you wish to view.
3. Let go of the left mouse button. The map will refresh to the new area.

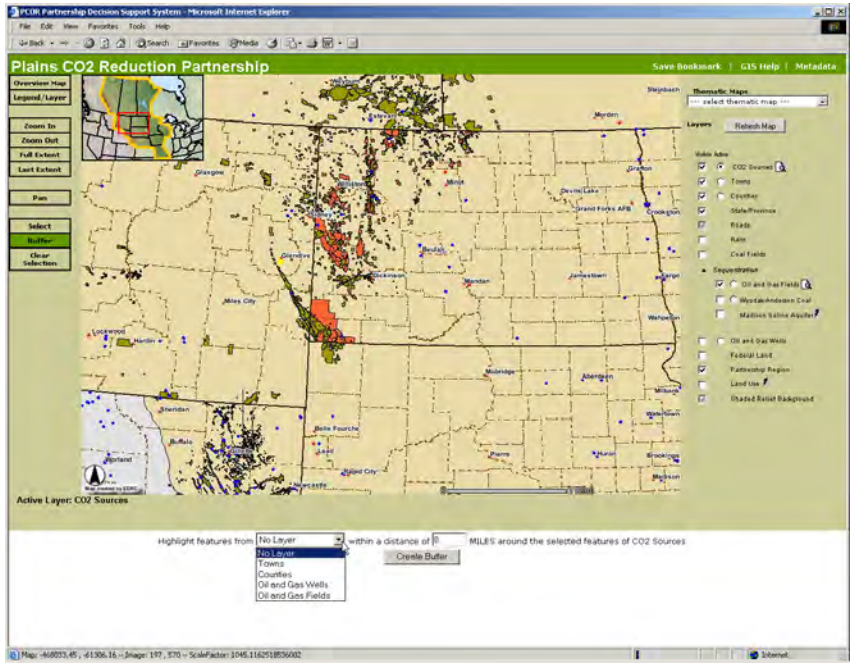
Select Click to display information in the data grid on the active layer.

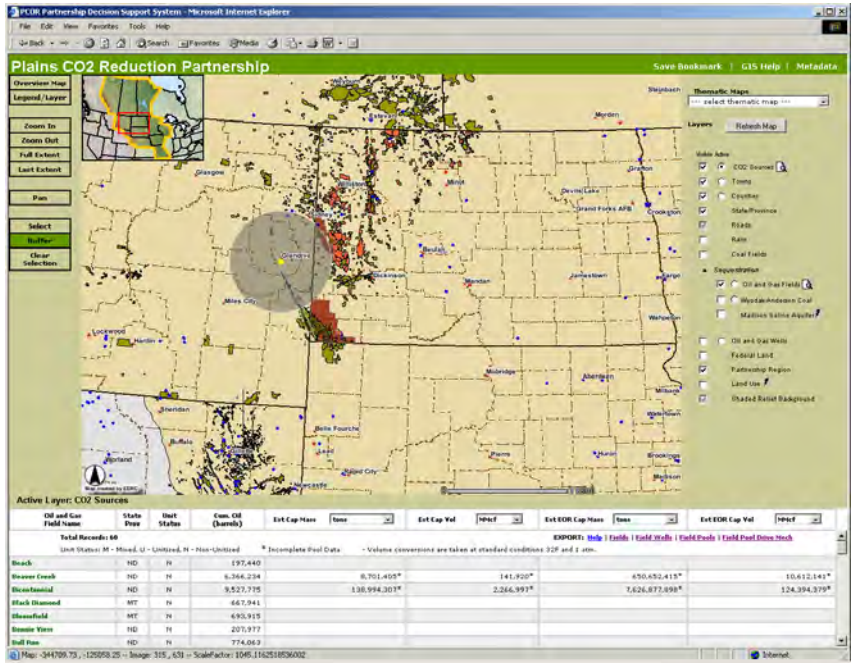


1. Click the Select button. The mouse pointer will appear as a crosshair on the map.
2. Hold down your left mouse button and drag a rectangle around the features you wish to select. The features must correspond with the active layer. Information on selecting layers begins on page 25.
3. Let go of the left mouse button. The map will refresh, and the selected features will be highlighted. A record for each selected feature will be displayed in the data grid below the map. Information on working with the data grid begins on page 30.

Buffer

Click to find objects within a specified proximity of selected features.

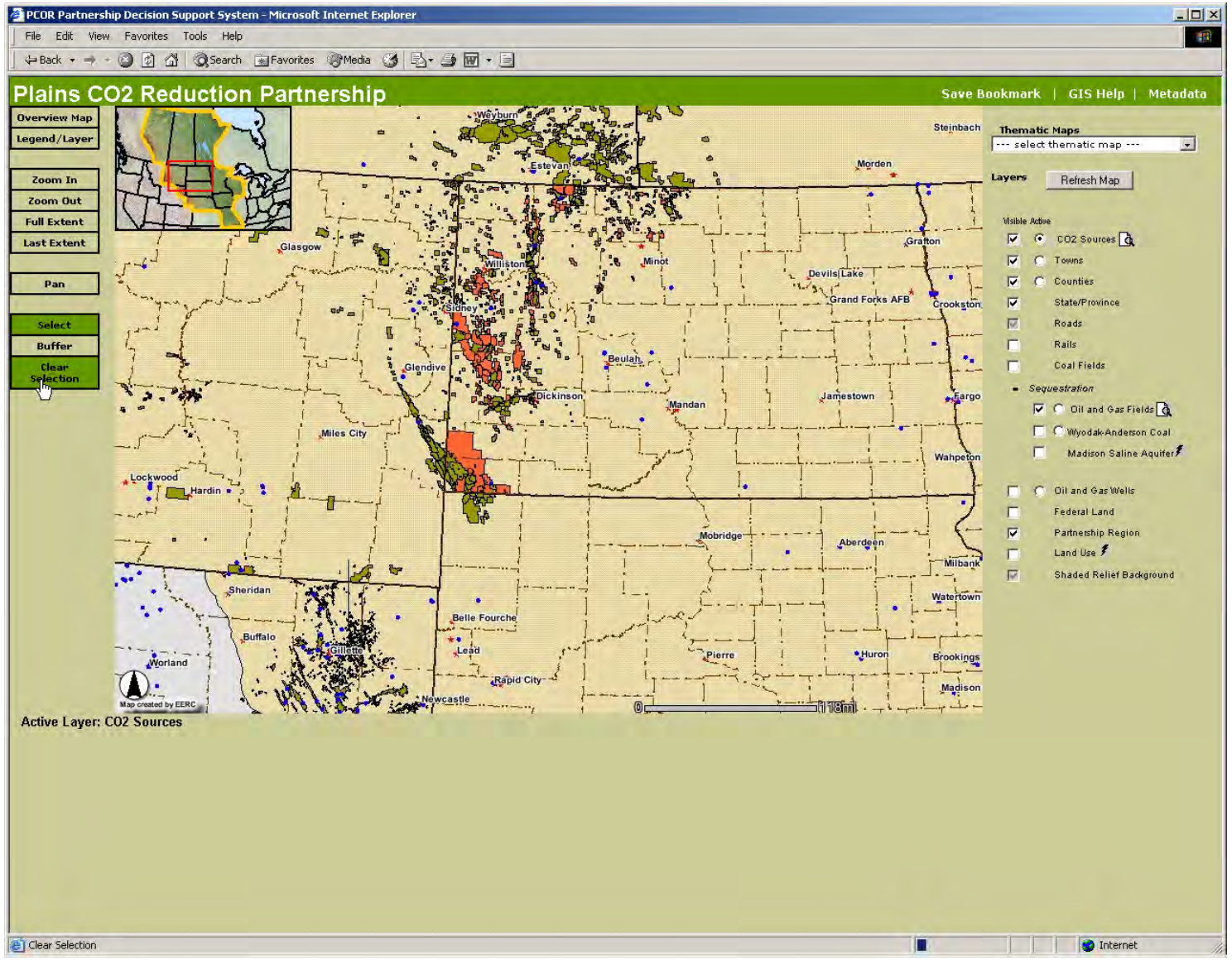


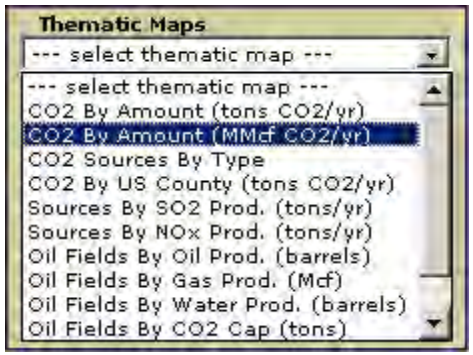


1. Click the Buffer button. The area below the map will display buffer options.
2. Complete the buffer options by selecting a feature and a distance.
3. Click the Create Buffer button in the options area.
4. The map will refresh. The buffered area will appear as a gray circular area. The features that intersect the buffer area will be highlighted on the map, and corresponding records will be displayed in the data grid.

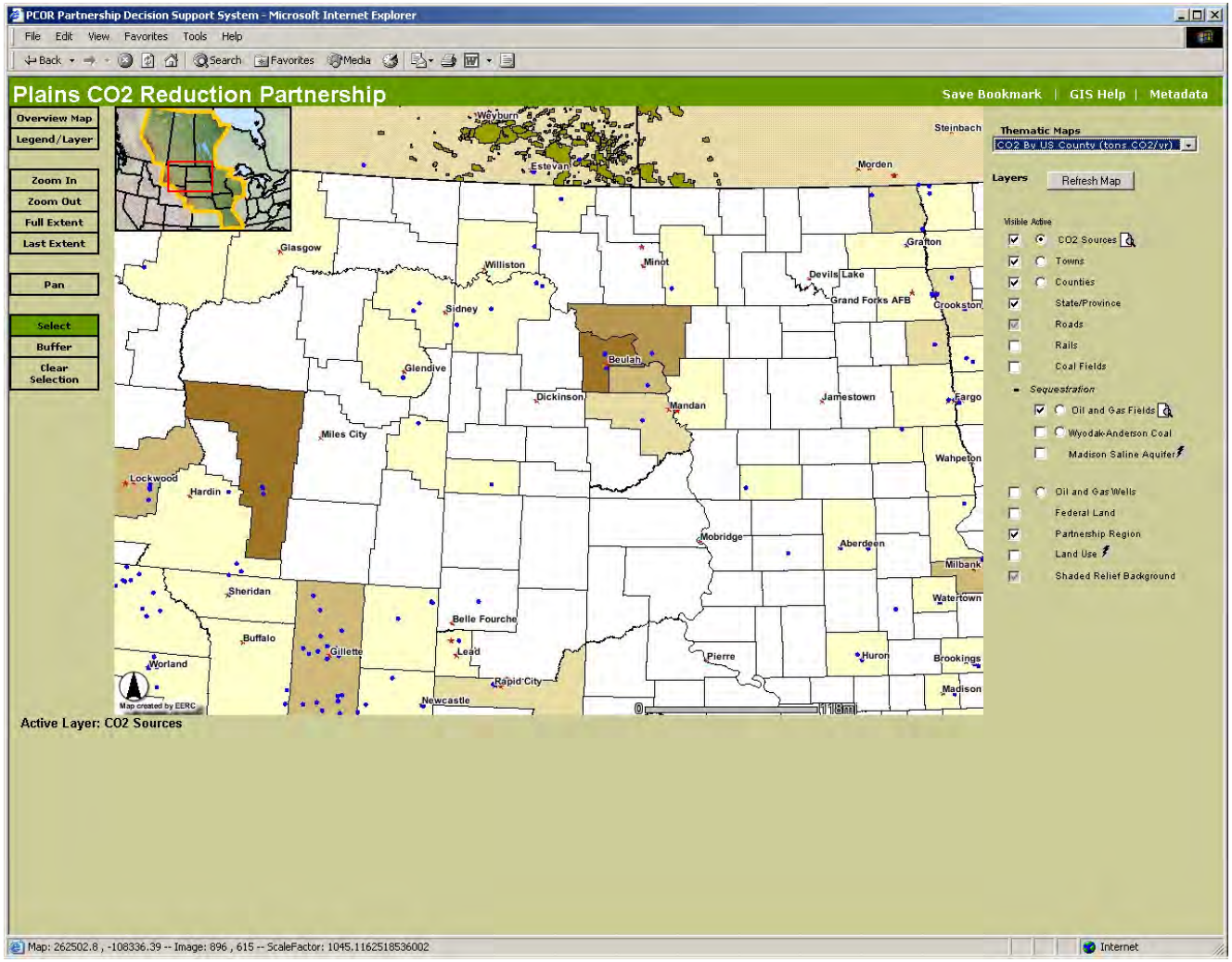
Clear Selection

Click to clear the selected (highlighted) features. The map will refresh, and the data grid will be empty.

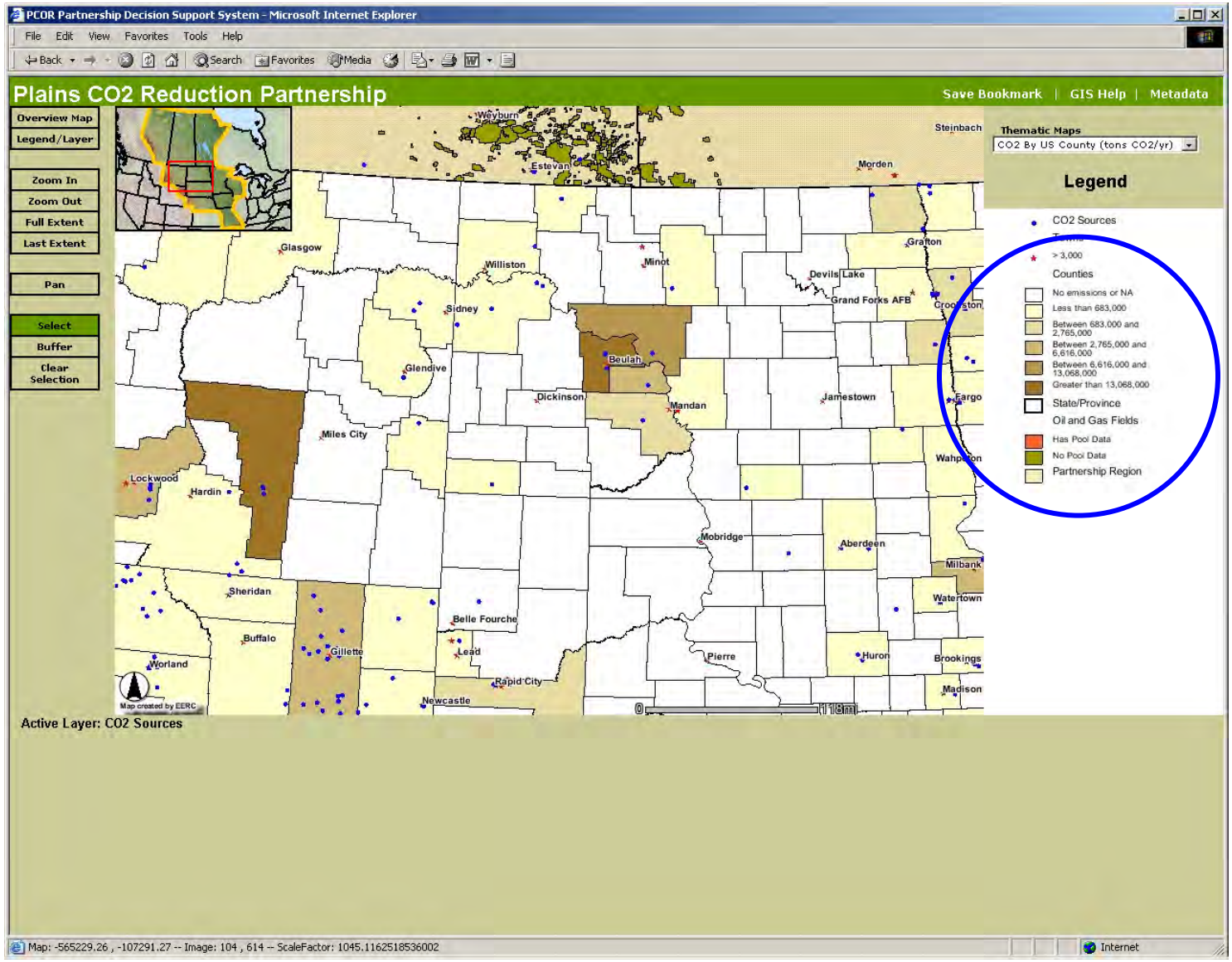




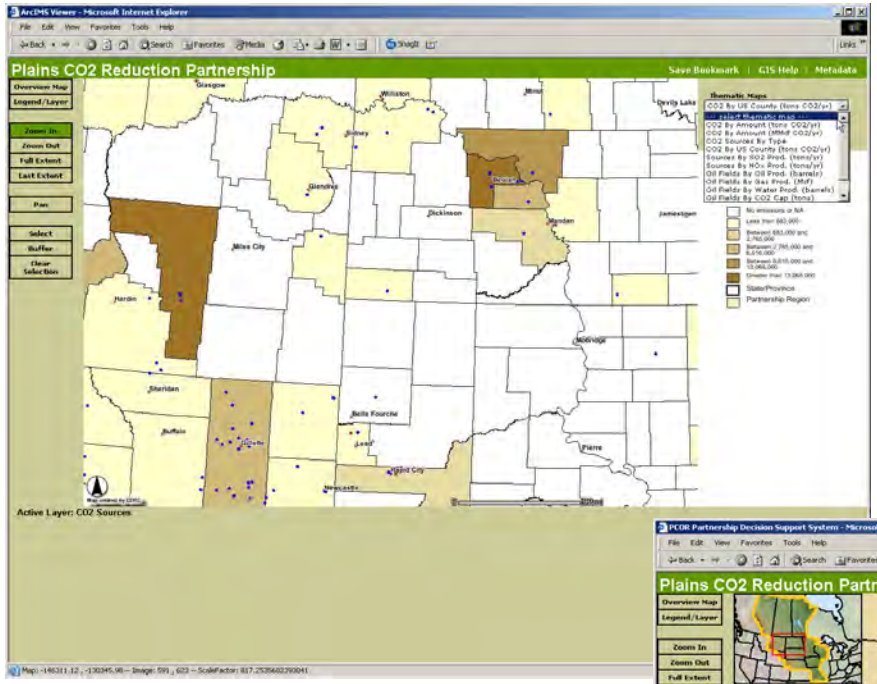
Select a thematic map to display data in a predefined categorical fashion.

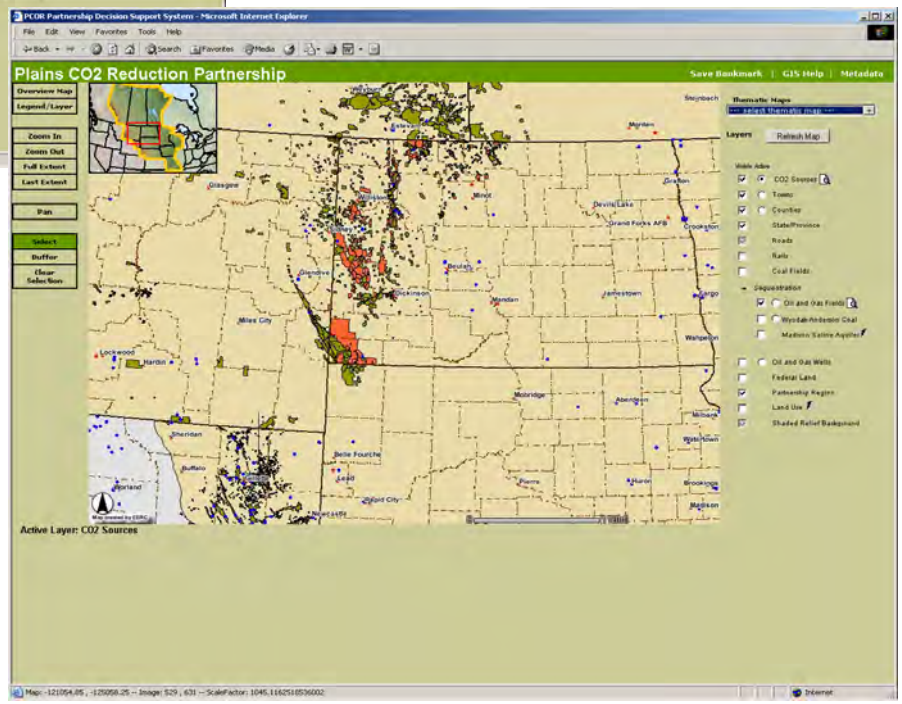


TIP: Use the Legend/Layer button to see the category descriptions.

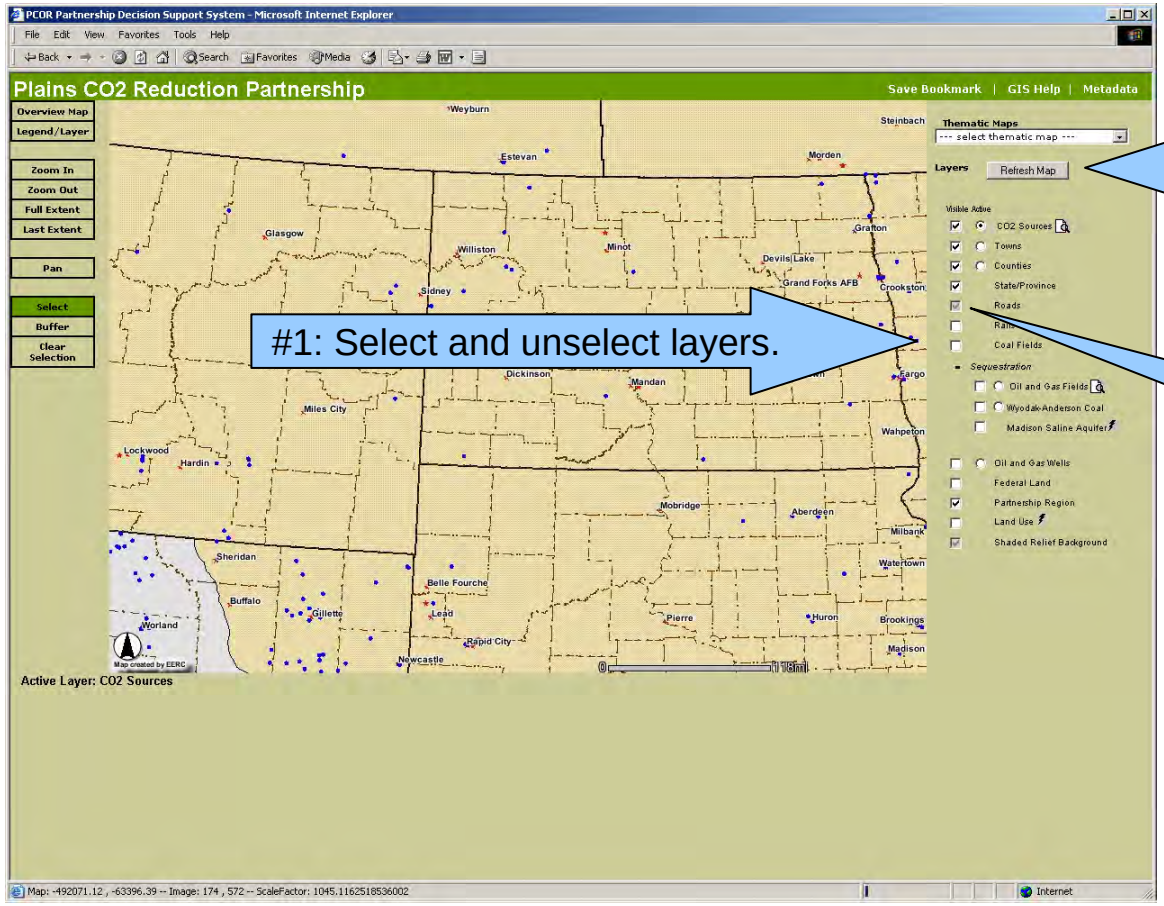


To clear the thematic map, choose --- select thematic map --- from the dropdown menu.

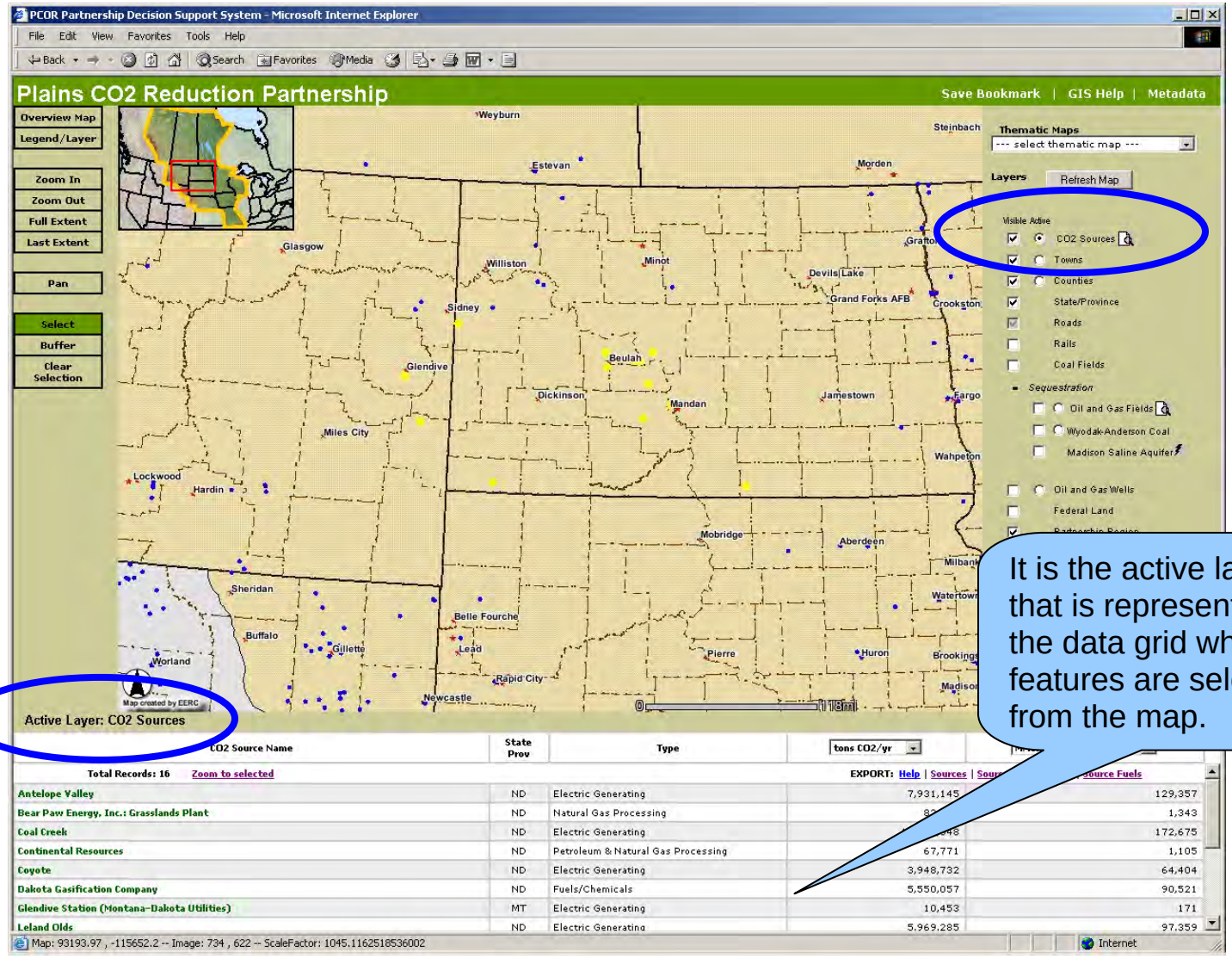




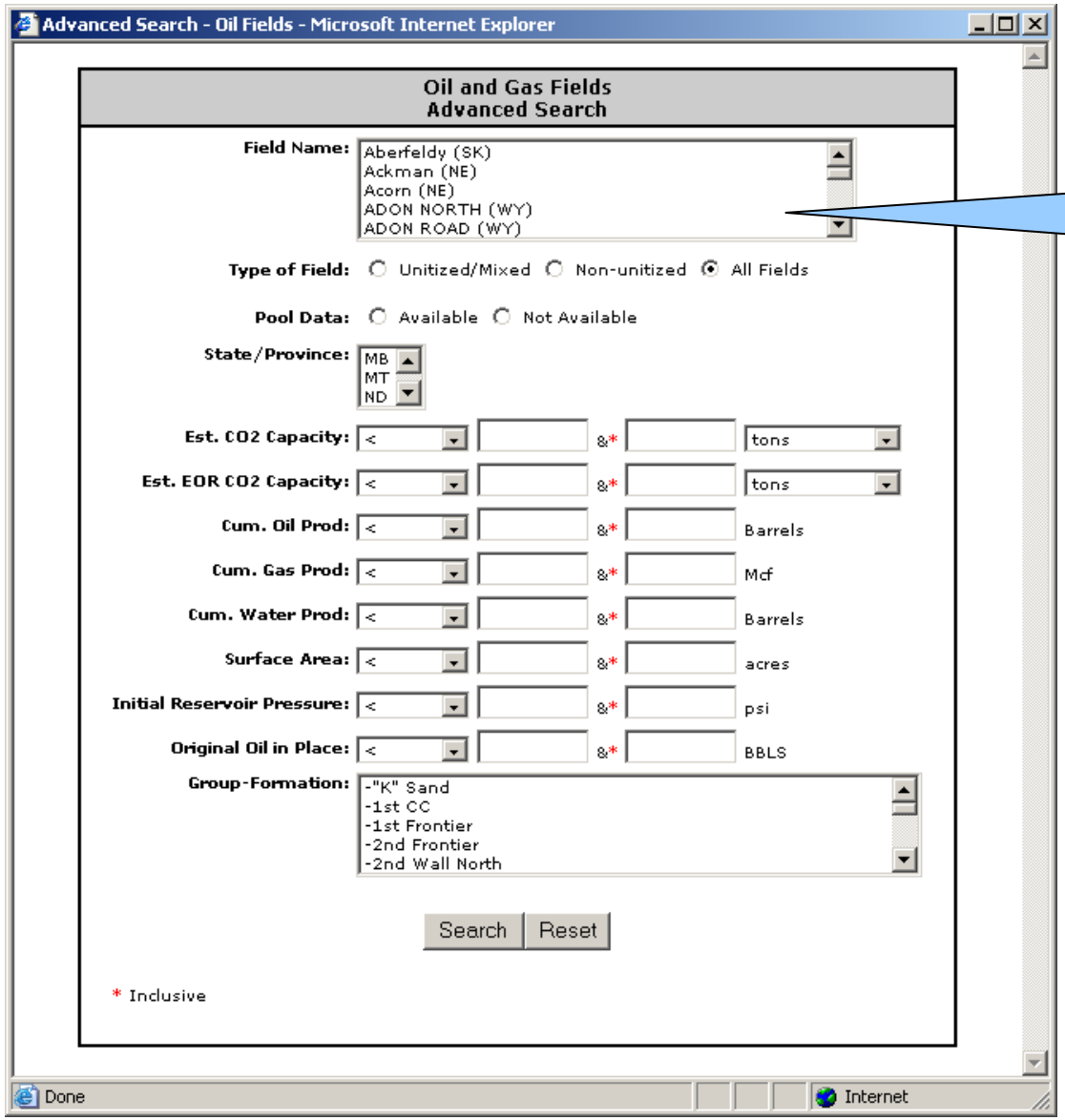
Layers can be visible or not visible by checking or unchecking the box next to the layer name. Click the Refresh Map button after making your selections to view the selected layers.



Only one layer can be active at a time. The active layer is represented by the selected button in the Active Layer column and is listed in the text directly below the map. *You do not need to click the Refresh Map button after changing the active layer.*

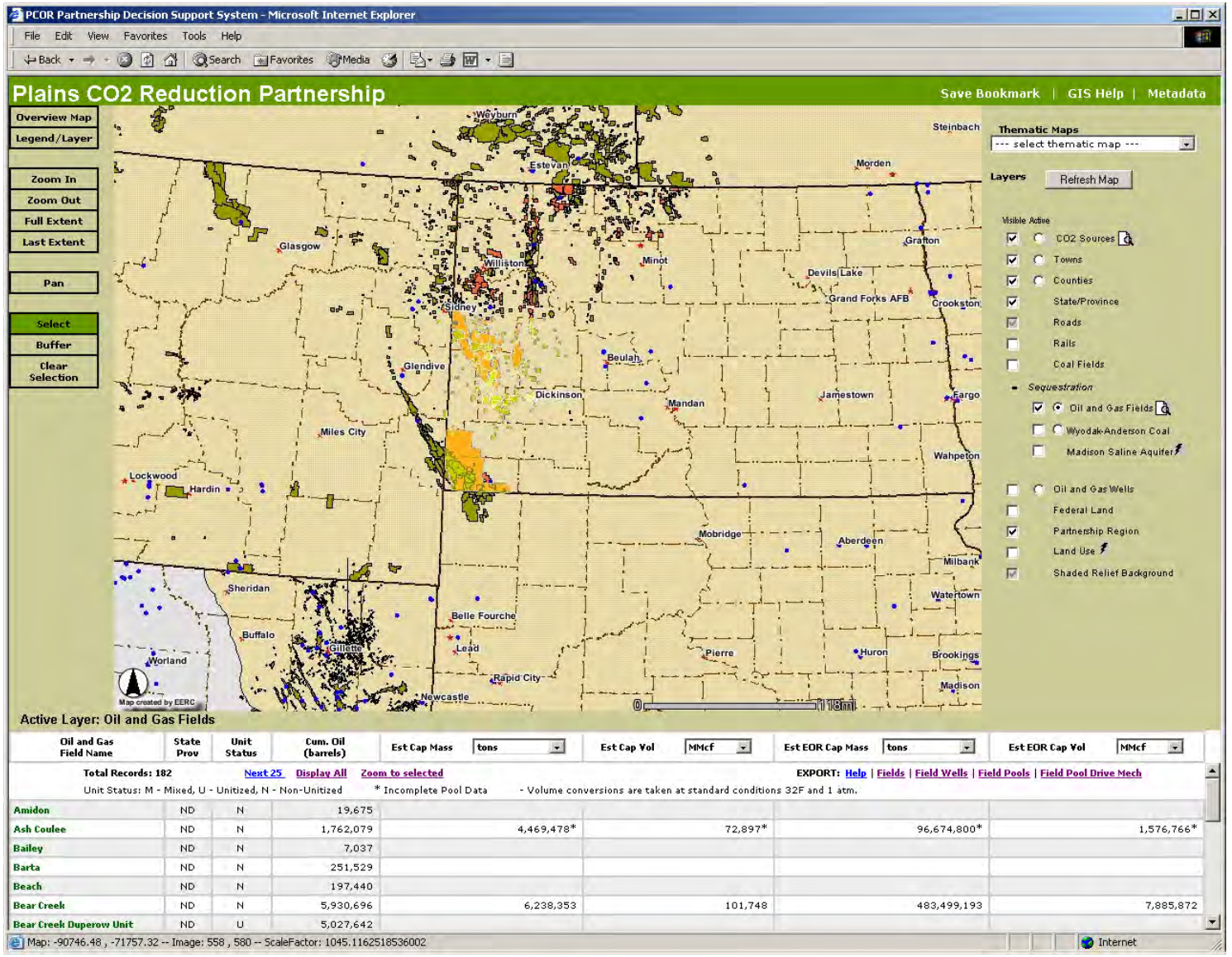


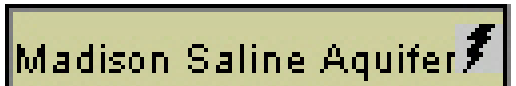
Click this icon to perform an advanced search for the layer. Enter your search criteria, then select the search button.



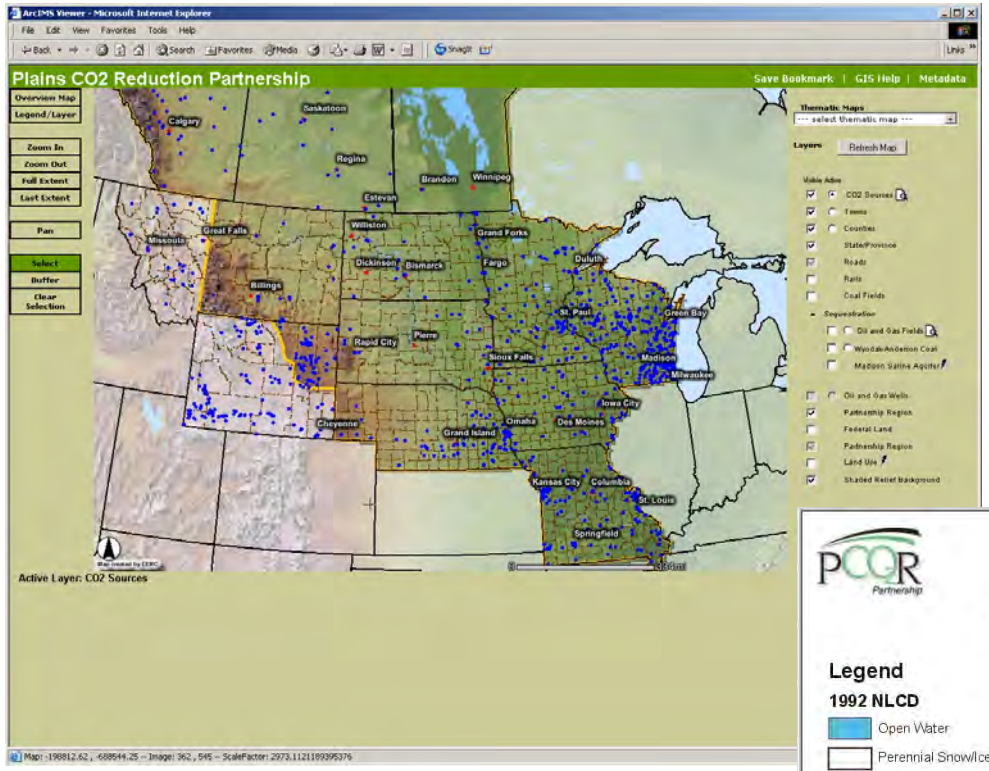
Multiple selections can be made by holding down the Ctrl key and clicking the item.

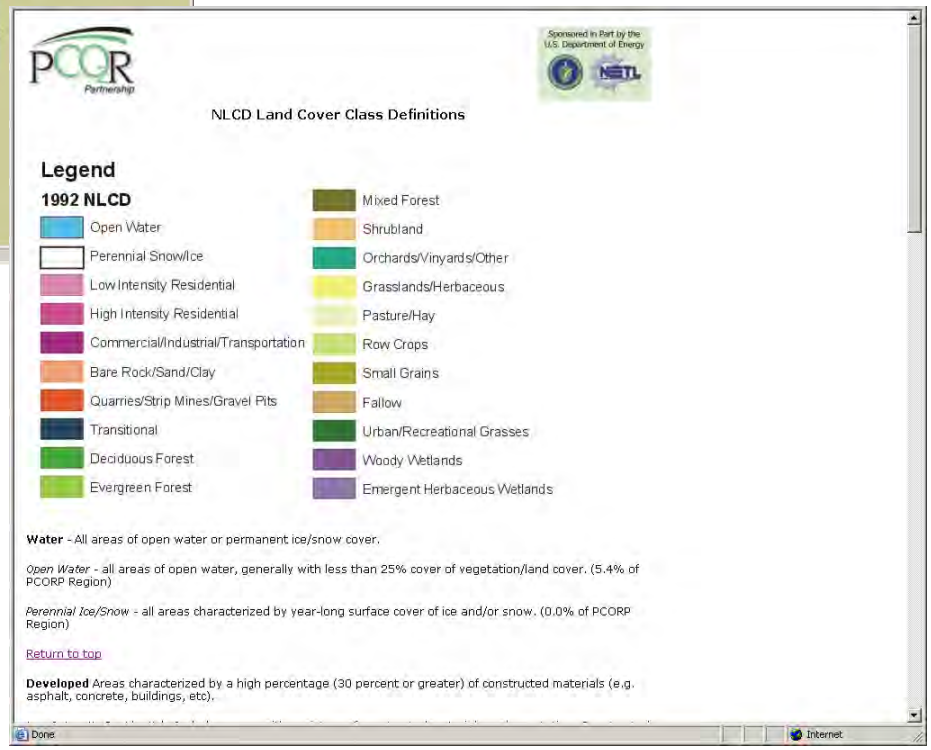
Search Results: The features matching your search criteria are highlighted on the map. Records corresponding to those features are displayed in the data grid.





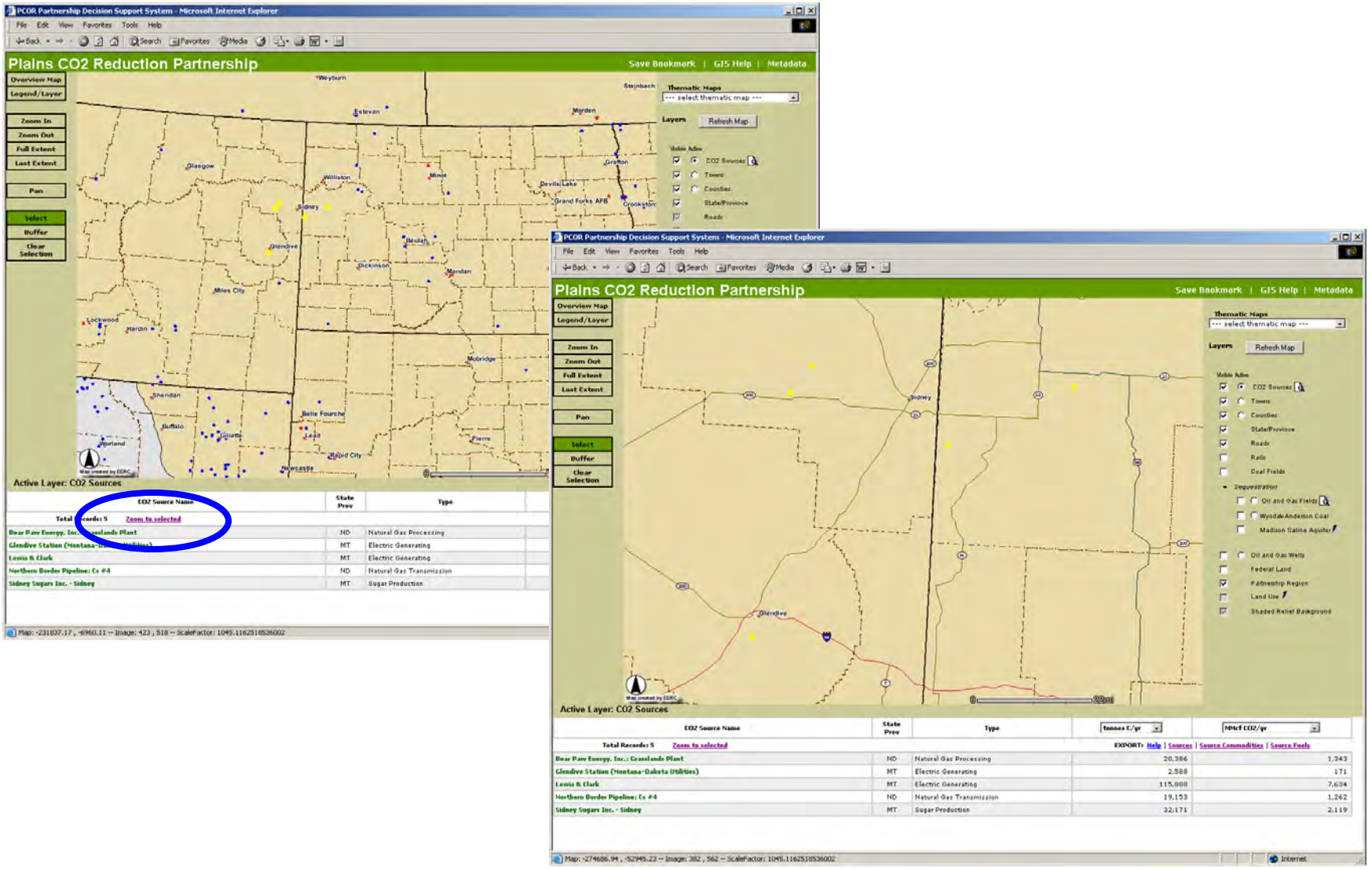
The legend for some layers is viewed by clicking on the icon next to the layer.





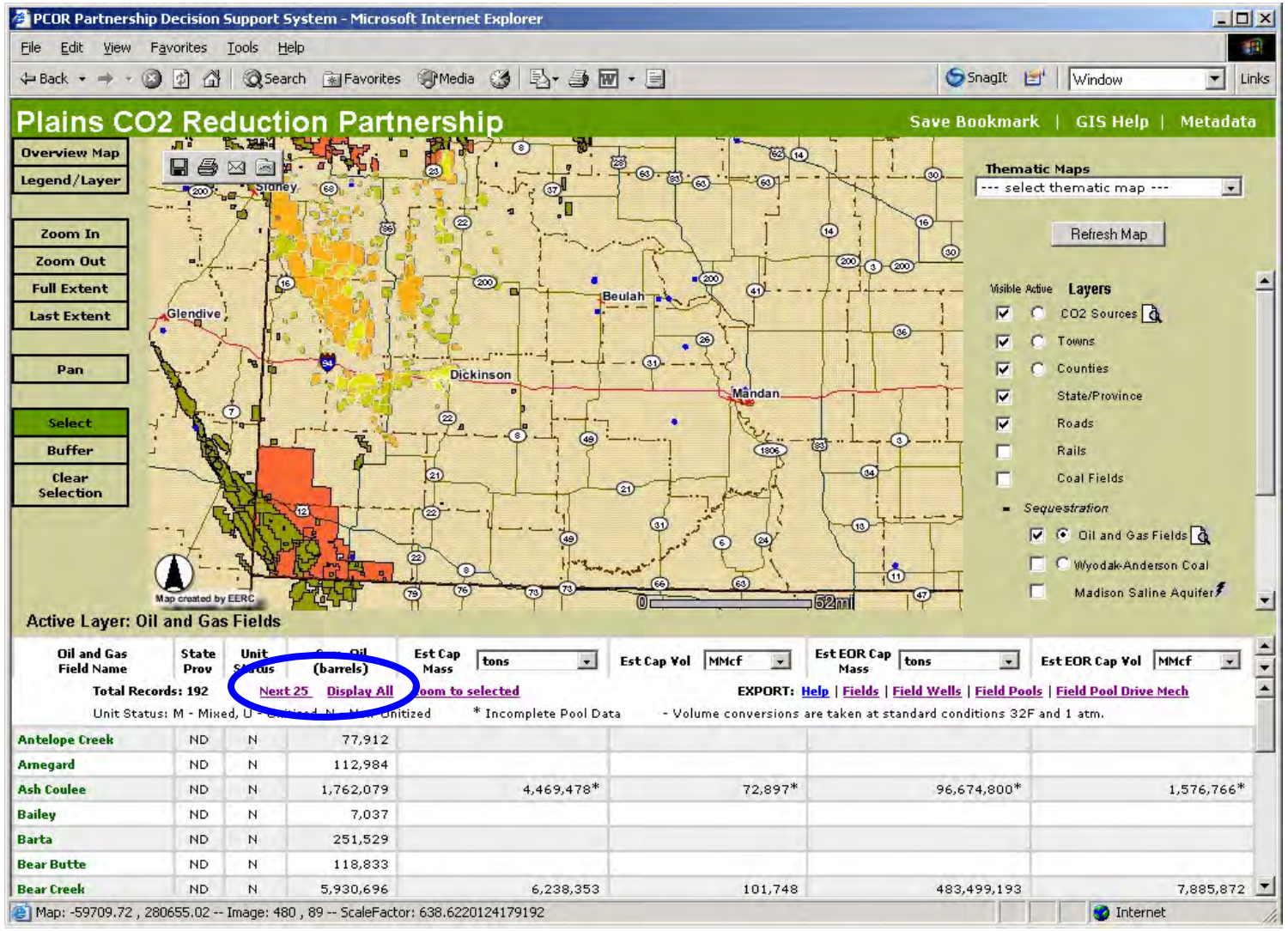
Zoom to selected

Click on Zoom to selected to change the extent of the map to include the selected features.



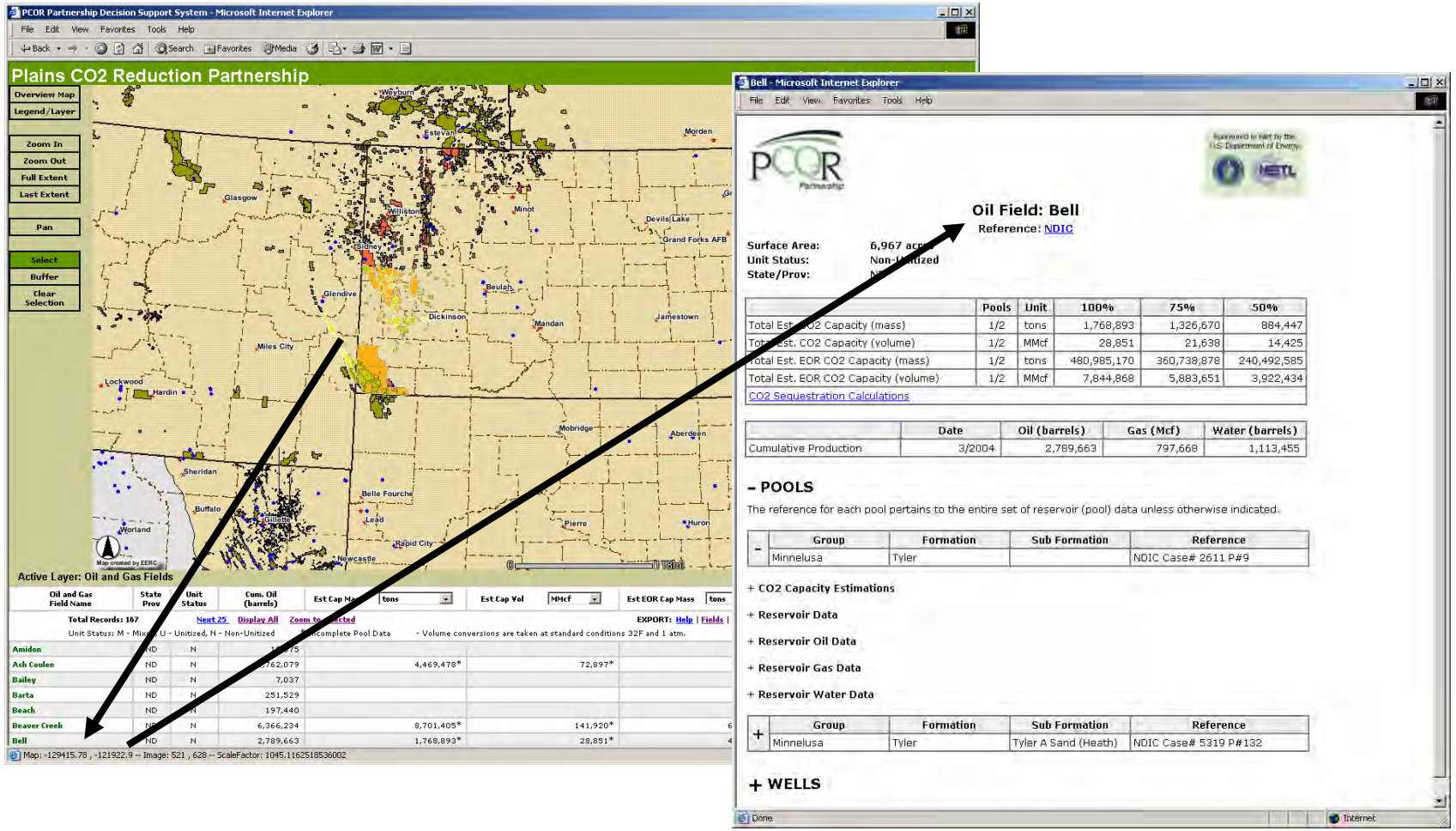
Next 25 Display All

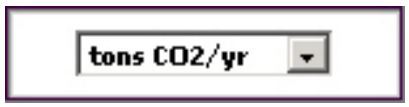
Click these options to manage the number of records that are displayed in the data grid at one time. The default is 25 records.



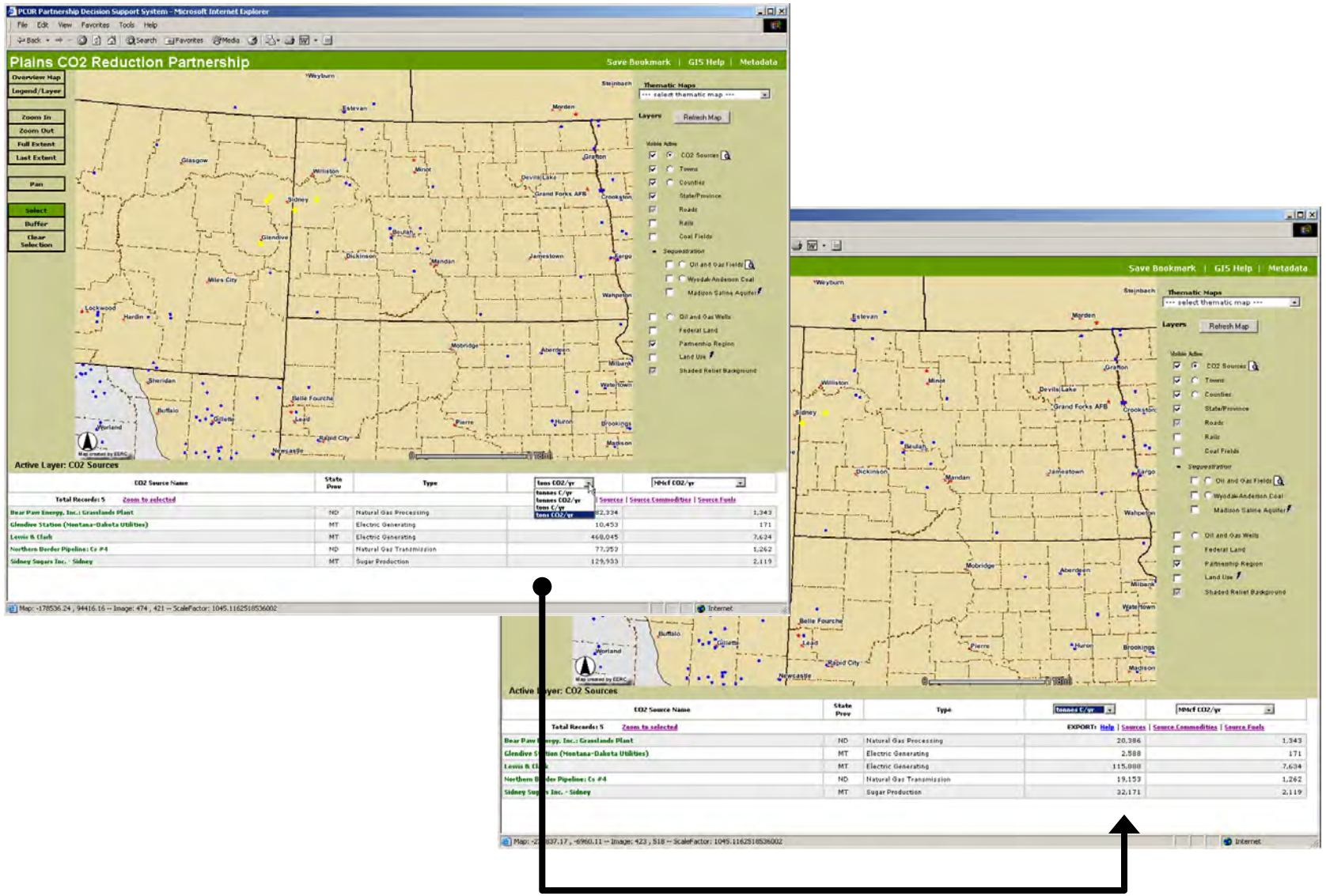
ADM Processing
Alameda

Data regarding selected features, highlighted on the map, appears in the grid below the map. Click on a record to view a report of detailed information about that record.



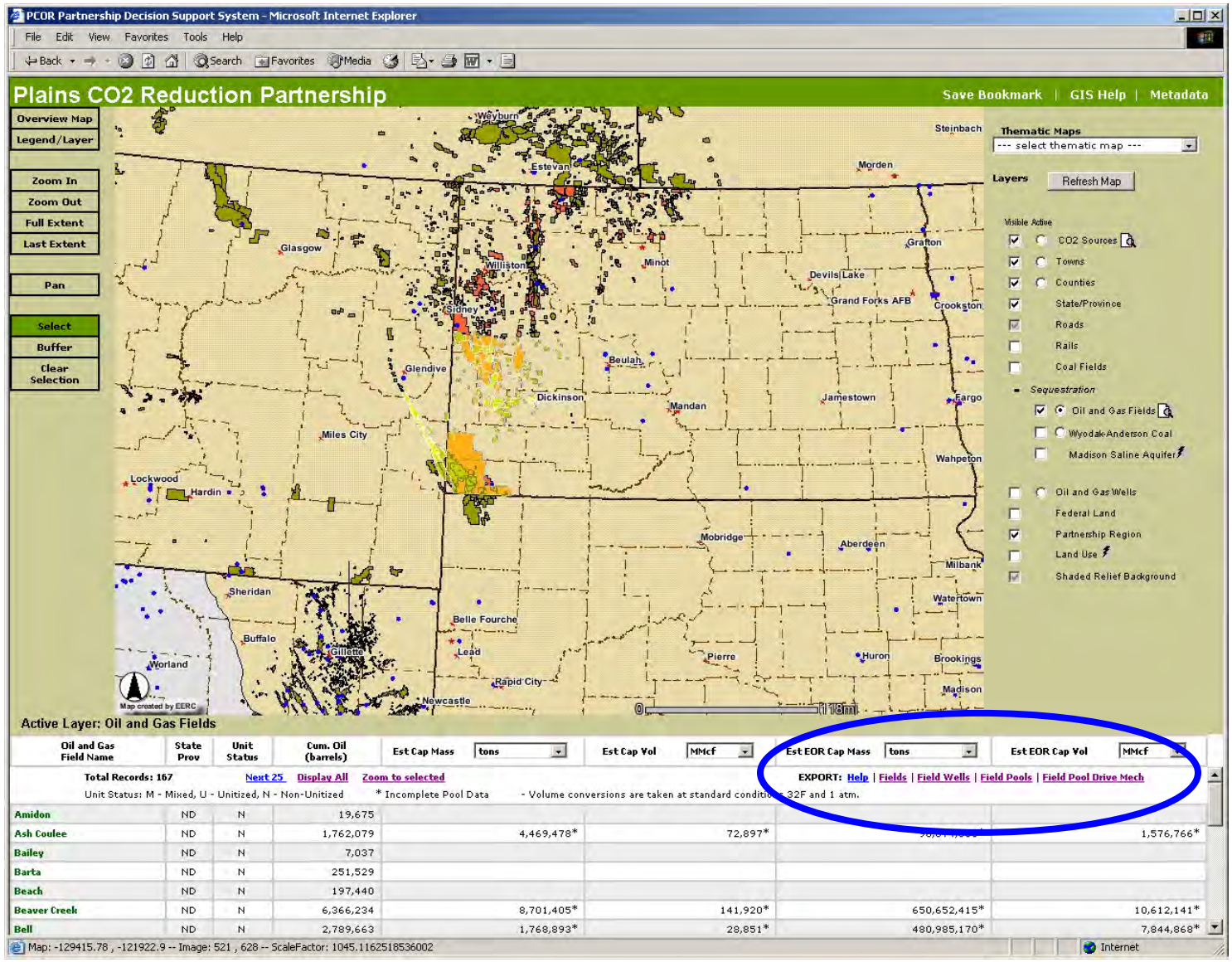


Some layers have a feature that allows you to change the data displayed in the grid to a different unit. This conversion is carried over into data that are exported or displayed in a report.



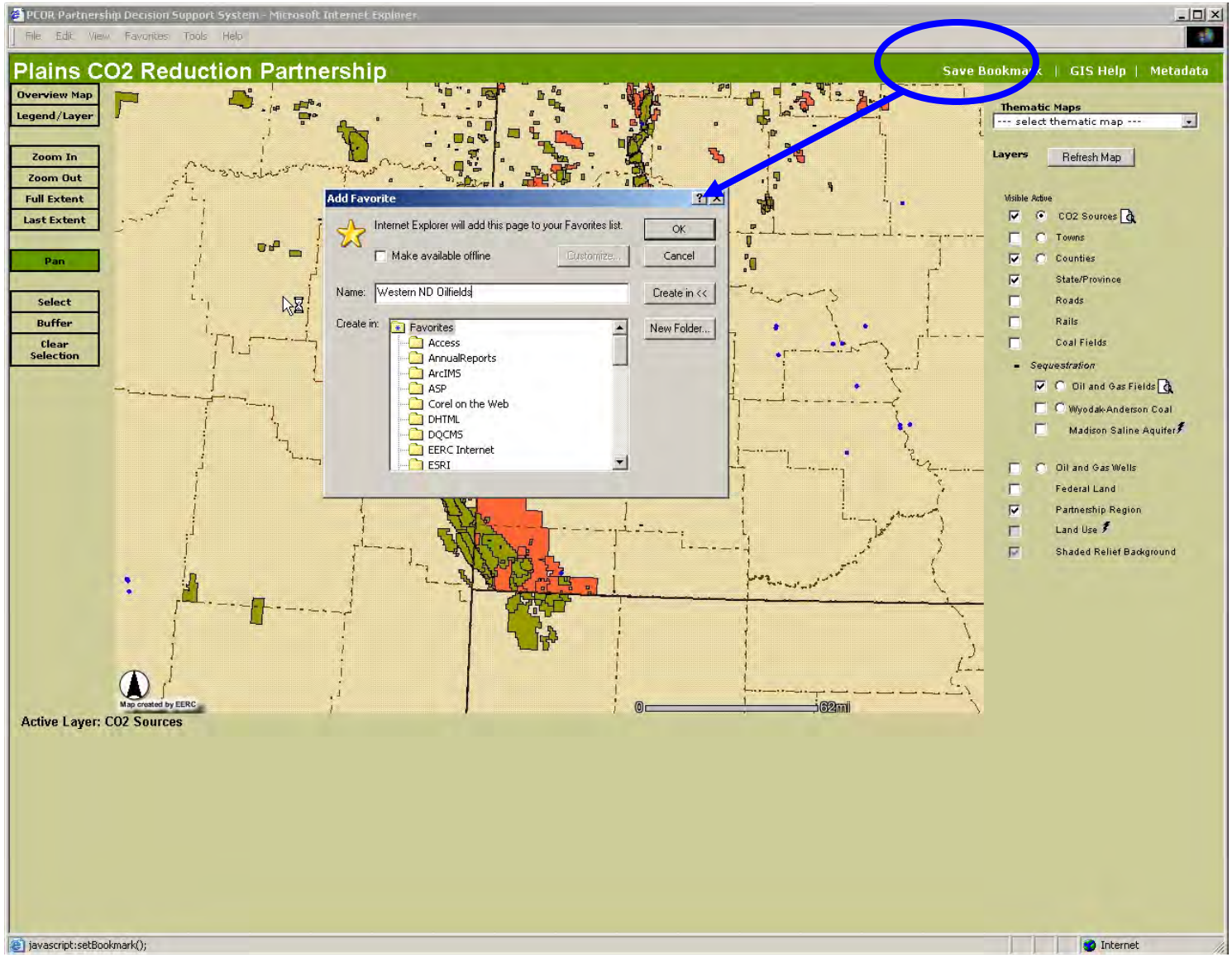
EXPORT: Help | Sources

Records in the data grid can be exported to a CSV file, which can be imported into spreadsheet software.

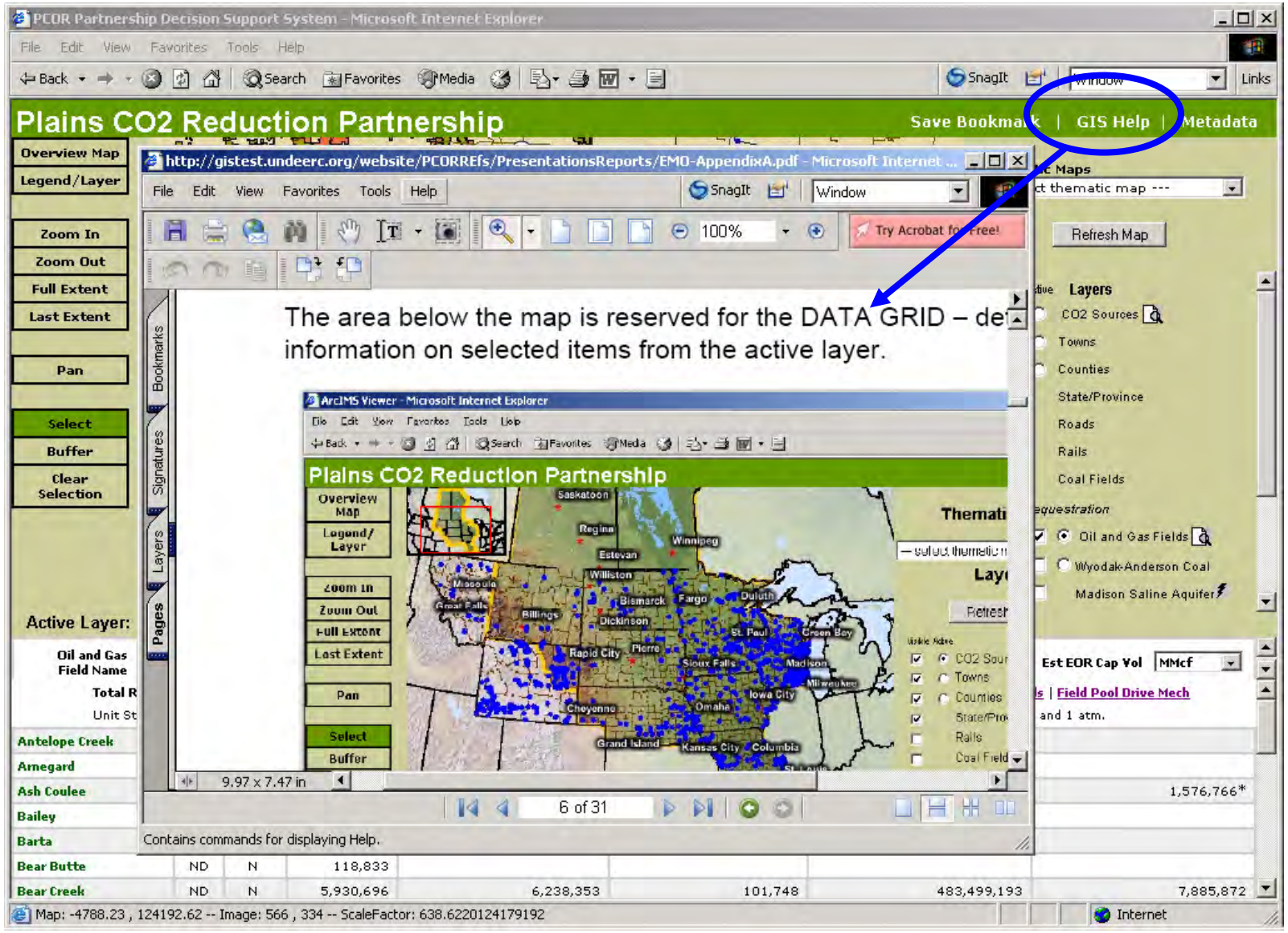


Save Bookmark

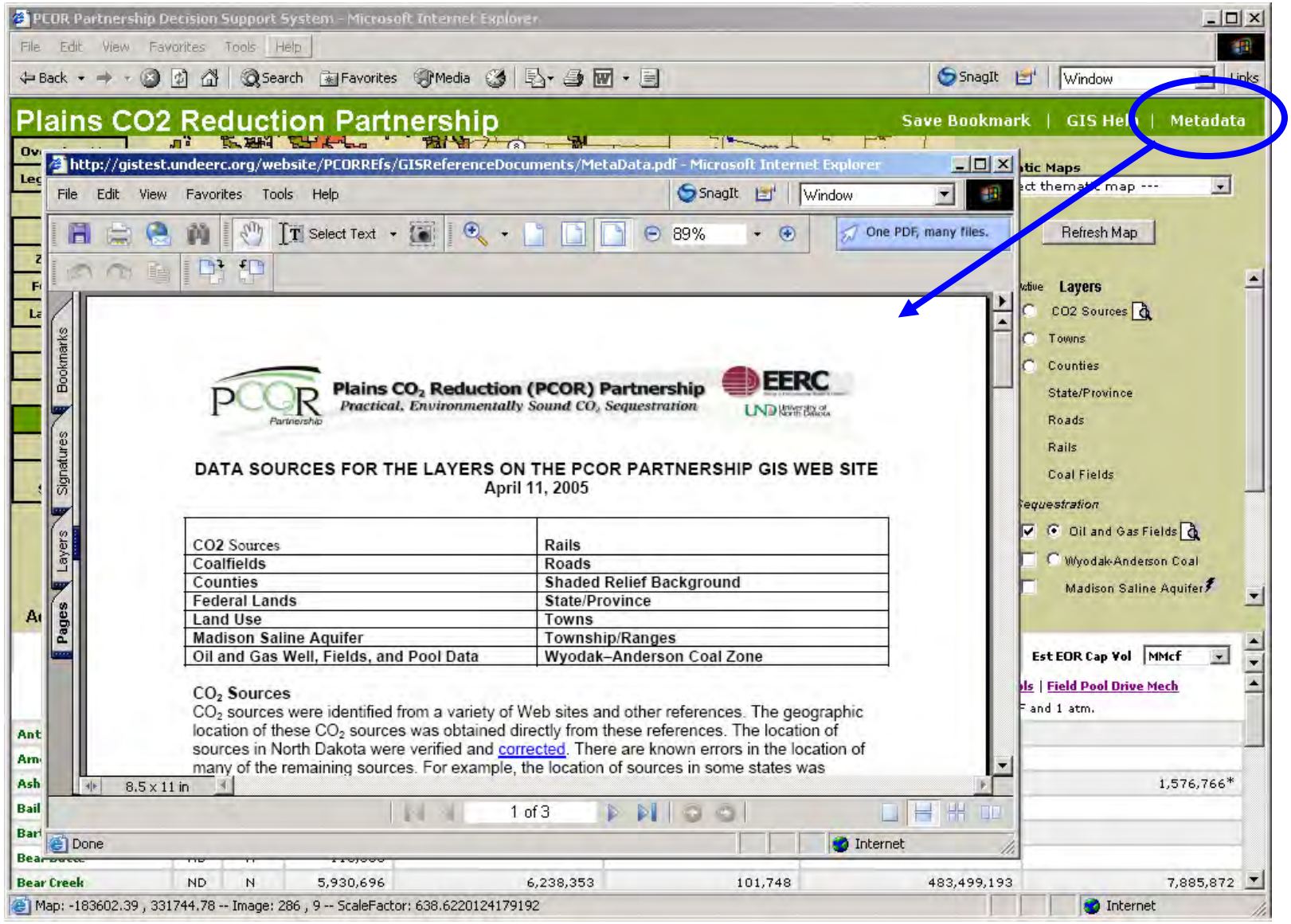
The map can be saved as a browser Favorite for retrieval at a later date (Internet Explorer only).



GIS Help Click on the GIS Help link to display this help document in a browser window.



Metadata Click on the Metadata link to open a document describing the data sources and other relevant map layer information.



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APPENDIX B

DATABASE ELEMENTS

DATABASE ELEMENTS

CO_2 Sources
Source name
State location
Latitude
Longitude
Source type (industry)
Fuel type
Fuel amount
Total combustion CO_2 produced (tons/yr)
Commodity type
Commodity amount produced
Total noncombustion CO_2 produced (tons/yr)
Total CO_2 produced (tons/yr)
Total SO_2 produced (tons/yr)
Total NO_x produced (tons/yr)

Oil and Gas Wells
API number
Operator name
Well name
Field name
Latitude
Longitude
State location
Well type
Well status
Spud date
Total depth
Vertical depth

Oil and Gas Fields
Field name
State location
Operator name
Surface area (acres)
Indicator of unitization (yes/no)
Cumulative production data for oil, gas and water
Point-in-time production data for oil, gas, and water

Oil and Gas Pools – Reservoir Data
Geologic group, formation, subformation, field
Lithology
Average depth to top of pay
Datum (ft, MSL)
Minimum and maximum depths (ft)
Average pay thickness (ft)
Average porosity (%)
Indicator of secondary porosity reported (yes/no)
Average permeability (md)
Minimum and maximum permeability (md)
Average reservoir temperature (°F)
Average initial water saturation (%)
Initial reservoir pressure
Average reservoir pressure
Current reservoir pressure
CO_2 density (lb/ft^3)
Current pressure date
Bubble point
Residual oil/gas (%)
Formation volume factor at reservoir pressure (rb/stb)
Oil formation volume factor at bubble point (rb/stb)
Original oil in place (BBLS)
Closure (ft)
Primary and other drive mechanisms
Initial gas-to-oil ratio (cf/bbl)
Gas-to-oil ratio (cf/bbl)

Oil and Gas Pools – Reservoir Oil Data
Geologic group, formation, subformation, field
Oil gravity (API)
Pour point (F)
Total sulfur weight (%)
Paraffin weight (%)
Viscosity
Salt content
Saturation pressure

Oil and Gas Pools – Reservoir Gas Data
Geologic group, formation, subformation, field
Gas specific gravity
H_2S content
CO_2 content
N_2 content (%)

Oil and Gas Pools – Reservoir Gas Data
Geologic group, formation, subformation, field
Water specific gravity
Total salinity (ppm)
Resistivity (ohm-meters) at reservoir temperature (°F)

Resistivity temperatures other than reservoir temperature (°F)
Resistivity (ohm-meters) @ 77°F
Formation volume factor (Pi)
Formation volume factor (Ps)

APPENDIX C

PCOR PARTNERSHIP GIS WEB SITE METADATA

PCOR PARTNERSHIP GIS WEB SITE METADATA

CO_2 Sources

CO_2 sources were identified from a variety of Web sites and other references. The geographic location of these CO_2 sources was obtained directly from these references. The location of sources in North Dakota was verified and corrected. There are known errors in the location of many of the remaining sources. For example, the location of sources in some states was reported as the center of the county in which the source resides. In other instances, the location of the facility was considered to be coincident with the location of the corresponding city.

Each source record has been referenced to a specific source. The following table lists all of the source references for the U.S. portion of the region, based on source type.

Source Type	Industry	Reference
Ag Processing	Agricultural processing, animal and animal by-product processing, sugar production	U.S. EPA Technology Transfer Network Ozone Implementation Web Site[1]
Electric Utility	Cogeneration	US EPA Clean Air Markets Web Site[2]
	Electric generating	US EPA Technology Transfer Network Ozone Implementation Web Site[1] US EPA Clean Air Markets Web Site[2]
	Municipal heat and power	US EPA Technology Transfer Network Ozone Implementation Web Site[1]
Ethanol	Ethanol manufacturing	Ethanol facilities[3]
Industrial	Ammonia production	Ammonia production facilities[4]
	Cement/clinker production	Cement clinker facilities[5]
	Iron ore (taconite pellet) processing	Iron ore facilities[6]
	Lime production	Lime production facilities[7]
	Asphalt production, chemical production, fertilizer production, foundries/ manufacturing, fuels/chemicals, industrial/institutional heat and power, manufacturing, metals processing, minerals processing, mining, miscellaneous, paper and wood products, waste processing	US EPA Technology Transfer Network Ozone Implementation Web Site[1]
Petroleum and Natural Gas	Natural gas liquids, natural gas processing, natural gas transmission, petroleum and natural gas processing, petroleum transmission	US EPA Technology Transfer Network Ozone Implementation Web Site[1]
	Petroleum refining	Refinery facilities[8]

[1] U.S. Environmental Protection Agency (EPA) Technology Transfer Network Ozone Implementation Web Site. www.epa.gov/ttn/naaqs/ozone/areas/state/stindex.htm (accessed May 2004)

[2] US EPA Clean Air Markets Web Site. http://cfpub.epa.gov/gdm/index.cfm (accessed May 2004)

[3] Ethanol Facilities (accessed May 2004)

1. Renewable Fuels Association Web site. www.ethanolrfa.org/eth_prod_fac.html.
2. Minnesota Pollution Control Agency. www.pca.state.mn.us/publications/aq1-20.pdf.
3. The Innovation Group Web site. www.the-innovation-group.com/ChemProfiles/Ethanol.htm.
4. North Dakota Department of Agriculture Web site. www.agdepartment.com/RES/Jocie%20Iszler.pdf.
5. Personal communication, Shannon C. Textor, Iowa Corn Growers Association, March 3, 2004.

[4] Ammonia Production Facilities (accessed May 2004)
US Geological Survey information on ammonia production/utilization industry in US
http://minerals.er.usgs.gov/minerals/pubs/commodity/nitrogen/nitromyb02.xls.

[5] Cement/Clinker Facilities (accessed May 2004)

1. U.S. EPA Technology Transfer Network Ozone Implementation Web Site – list of Portland cement plants. www.epa.gov/ttn/atw/pcem.
2. U.S. Geological Survey (USGS) Web site – data on Portland cement, masonry cement, and clinker (cement precursor) production. http://minerals.usgs.gov/minerals/pubs/commodity/cement/cememyb02.pdf.

[6] Iron Ore Facilities (accessed May 2004)

1. Duluth News Tribune Web site. www.duluthsuperior.com/mld/duluthtribune/7880078.htm, www.duluthsuperior.com/mld/duluthtribune/business/7129904.htm.
2. Mesabi Daily News Web site. www.virginiamn.com/placed/index.php?sect_rank=1&story_id=160725.

[7] Lime Production Facilities (accessed May 2004)

1. U.S. Geological Survey directory of U.S. lime plants. http://minerals.usgs.gov/minerals/pubs/commodity/lime/limedir03.pdf.
2. U.S. Geological Survey production data (no per plant data). http://minerals.usgs.gov/minerals/pubs/commodity/lime/limemyb02rev.pdf.
3. Graymont Western (Townsend, MT) Web site. www.graymont-ut.com/indiancreek.htm.
4. Mississippi Lime Co. (Ste. Genevieve) Web site. www.mississippilime.com/about/divisions_view.asp?divisionID=1.
5. Western Lime Co. (Eden and Green Bay, WI) Web site. www.westernlime.com/locations.html.
6. Wyoming Lime Producers (Frannie, WY) Web site. www.basinelectric.com/dcc/limeplan.htm.

[8] Refinery Facilities (accessed June 2004)

1. U.S. Department of Energy (DOE) Energy Information Administration Web site. www.eia.doe.gov/neic/rankings/refineries.htm, www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/current/pdf/table_36.pdf.

www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/current/pdf/table_47.pdf.

2. U.S. DOE Energy Efficiency and Renewable Energy Web Site. www.eere.energy.gov/industry/petroleum_refining/pdfs/profile.pdf.

Canadian Source facilities were obtained from the Alberta Energy and Utilities Board Web site, www.ags.gov.ab.ca/website/co2/viewer.htm (accessed September 2004).

The CO_2 emission amount is referenced for each individual CO_2 source record. Combustion and noncombustion amounts were either obtained from the source document or calculated based on fuel usage and the commodity produced. There are several sources where the CO_2 emission amount is blank, because the data were not available.

Coalfields
This data set was obtained from the USGS National Atlas Web site (http://energy.cr.usgs.gov/coal/nca/prbgis.htm), accessed November 2004. It shows the coalfields of Alaska and the conterminous United States. Most of the material for the conterminous United States was collected from James Trumbull's "Coal Fields of the United States, Conterminous United States" map (Sheet 1, 1960). The Gulf Coast region was updated using generalized, coal-bearing geology obtained from state geologic maps. The Alaska coalfields were collected from Farrell Barnes's "Coal Fields of the United States, Alaska" map (Sheet 2, 1961). These data are intended for geographic display and analysis at the national level and for large regional areas. The data should be displayed and analyzed at scales appropriate for 1:5,000,000-scale data.

Counties
This 1:100,000-scale polygon data set for the U.S. counties was obtained from the U.S. Department of Transportation Bureau of Transportation Statistics (www.bts.gov/gis/), accessed November 2004.

Federal Lands
This data set was obtained from the USGS National Atlas Web site (http://nationalatlas.gov/fedlandsm.html), accessed March 2005. This map layer portrays the federally and Indian-administered lands of the United States that have any area equal to or greater than 640 acres. The government agencies that administer these lands include the Bureau of Indian Affairs, Bureau of Reclamation, Bureau of Land Management, Department of Defense, Forest Service, Fish and Wildlife Service, National Park Service, and Tennessee Valley Authority. This map layer was produced by the USGS. It does not include linear (long, relatively narrow) features.

Land Use
The 1992 National Land Cover Data (NLCD) were derived from the early to mid-1990s Landsat Thematic Mapper satellite data (http://landcover.usgs.gov/natllandcover.asp) accessed March 2005. The NLCD is a 21-class land cover classification scheme applied consistently over the United States. The spatial resolution of the data is 30 meters and is mapped in the Albers Conic Equal Area projection, North American Datum (NAD) 83.

Madison Saline Aquifer
In order to calculate the sequestration potential for the Madison, a model was developed to produce a continuous grid surface representing the volume of CO_2 that could be sequestered per square kilometer. In general, the model is based on existing data relating to hydrological

studies of regional aquifer systems; oil, gas, and water well data; and existing GIS (geographic information system) map data.

Surfaces of continuous data were generated by digitizing specific analog maps of the Williston and Powder River Basins. The natural neighbor method of grid generation was applied to the digitized data. This method was used for both interpolation and extrapolation of results, as it generally works well with clustered scattered points. A list of the maps used is shown below:

- Porosity/thickness distribution (Downey, 1984)
- Total dissolved solids (Downey, 1984)
- Structure contour map (Peterson, 1984)

The depth to the top of the Madison Group (North Dakota definition), or equivalent, was obtained from log top databases for Montana, North Dakota, and South Dakota. Data for the northern portion of the Powder River Basin were derived from an analog map of the Madison Formation (Peterson, 1984). The combined data set was used to create a continuous surface depth map. From this, a new set of maps was generated for pressure and temperature of the Madison throughout the region. It should be noted that these maps are based on average temperature and pressure gradients of (15°F/1000 ft) + 60°F and 0.46 psi/ft, respectively, obtained from the Schlumberger oil field services glossary at www.glossary.oilfield.slb.com/.

The net result of the exercise was the creation of a continuous surface map at 1-kilometer resolution (based on the above discussion) that represents the total storage capacity of the Madison Aquifer system.

Oil and Gas Well, Fields, and Pool Data
Shape files, locations, and attribute data for oil and gas fields, wells, and pools were downloaded from state Web sites or provided directly through contacts with various state agencies. The CO_2 sequestration estimates were calculated at the pool level and summed up for individual fields.

Manitoba
The oil and gas data as depicted for the province of Manitoba were taken from a pdf document entitled “Designated Fields and Pools 2004” from the Manitoba Industry, Economic Development and Mines Petroleum Branch Web site (www.gov.mb.ca/itm/mrd/index.html), accessed October 2004.

Individual pool characteristics were provided in May 2004 by Kathryn Gompf, Petroleum Engineer, Manitoba Industry, Economic Development, and Mines Petroleum Branch.

Cumulative production is through December 31, 2002, and was accessed through the above reference.

Location data for oil and gas wells and the GIS layer for the Manitoba field boundaries were supplied by the Manitoba Department of Industry, Economic Development, and Mines (www.gov.mb.ca/itm/petroleum/gis/index.html), accessed November 2004.

Montana

The oil and gas data as depicted for the state of Montana were downloaded from the Montana Online Oil and Gas Information System Web site (http://bogc.dnrc.state.mt.us/jdpIntro.htm), accessed May 2004.

Cumulative production was taken from the above Web site and represents all production through May 31, 2004.

Nebraska

The oil and gas data as depicted for the state of Nebraska were downloaded from the Nebraska Oil and Gas Conservation Commission Web site (www.nogcc.ne.gov/), accessed August 2004.

Individual pool characteristics were gathered in person on August 11, 2004, at the office of the Nebraska Oil and Gas Conservation Commission, Sidney, Nebraska.

Cumulative production is through December 31, 2003, and was taken from the 2003 Nebraska Oil Activity Summary.

The oil fields that are depicted were created in a GIS by digitizing a polygon around groups of wells belonging to a particular oil field. Although there are many fields indicated in the oil/gas well file, only wells belonging to the top 25 producing fields (as indicated on the Nebraska Oil and Gas Conservation Commission Web site) were used to create the oil field layer.

North Dakota

The oil and gas fields and well data for the state of North Dakota were provided by the North Dakota Industrial Commission (www.oilgas.nd.gov/) in November 2004. For vertical wells, the total depth was also input into the total vertical depth field. Cumulative production that is reported reflects the total production of nonunitized fields through December 31, 2003.

Saskatchewan

The oil and gas data for the province of Saskatchewan were provided by Rick McClean of Saskatchewan Industry and Resources. The shape files representing the oil fields were modified to allow them to be represented in a manner consistent with the rest of the PCOR Partnership region. In addition, the well depth was converted from meters to feet to be consistent with the rest of the well files and input into the total depth column.

Cumulative production data were taken from the Saskatchewan 2002 Reservoir Annual. The production is through December 31, 2002.

South Dakota

The oil and gas data as depicted for the state of South Dakota were provided by the South Dakota Department of Environment and Natural Resources, Division of Environmental Services, Minerals & Mining Program (www.state.sd.us/denr/DES/Mining/Oil&Gas/O&Ghome.htm). The data was sent to the EERC by Gerald (Mack) McGillivray, Senior Geologist, in June 2004.

Cumulative production data were collected in September 2004 and represent all production through August 2004.

Wyoming

The oil and gas data as depicted for the state of Wyoming were downloaded from the Wyoming Oil and Gas Conservation Commission Web site (http://wogcc.state.wy.us/) in November 2004. Cumulative production is through October 29, 2004.

The downloaded data contained several thousand records with no latitude/longitude values and many instances where the well plotted outside of Wyoming. In both cases, the wells were removed from the data set. There were duplicate well records based on the API number for many of the remaining wells. In these instances, the well record with the most recent approved date was used. Some records contained a status code that did not have a related status code definition. In those instances, the code was removed and replaced with "No Data."

The downloaded data listed a value for Target Depth, which was input into the Total Vertical Depth column.

The oil field boundaries of the Powder River Basin region of Wyoming were obtained from the Wyoming Geographic Information Science Center (www.sdvc.uwyo.edu/clearinghouse/oilshale.html) in September 2004. The names associated with the fields in this data set were matched against production data obtained from the Wyoming Oil and Gas Conservation Commission (http://wogcc.state.wy.us/) in September 2004.

Rails

Data for the U.S. portion of the region were obtained from the USGS National Atlas Web site (http://nationalatlas.gov/railroadsm.html), accessed November 2004. This data set includes railroads in the conterminous United States and Alaska. It is intended for geographic display and analysis at the national level and for large regional areas. The railroads for the Canadian portion of the region were obtained from the Global GIS data set of North America published by the American Geological Institute.

Roads

Data for the U.S. portion of the region were obtained from the USGS National Atlas Web site (http://nationalatlas.gov/roadsm.html), accessed November 2004. The major roadways for the Canadian portion of the region were obtained from the Canadian roadway data set published by the Environmental Systems Research Institute (ESRI).

Shaded Relief Background

This map layer, showing the shaded relief throughout North America, was obtained from the USGS National Atlas Web site (http://nationalatlas.gov/shadedm.html), accessed November 2004. The image data included in this map layer are a portrayal of the terrain, intended for visual purposes only.

State/Province

This data set was formed by combining the 1:100,000-scale coverage of the state boundaries obtained from the U.S. Department of Transportation Bureau of Transportation Statistics (www.bts.gov/gis/), accessed November 2004, with a 1:100,000-scale coverage of Canadian provinces obtained from the GeoBase Web site (www.geobase.ca/), accessed November 2004.

Towns
The latitude and longitude for the cities and towns were obtained from the Geographic Names Information System (http://geonames.usgs.gov/gnishome.html), accessed May 2004. Data for the cities in the United States were obtained from the 2000 Census. Information regarding the cities in Canada was gleaned from various sources on the Internet.

Township/Ranges
Data for the U.S. portion of the region were obtained from the USGS National Atlas Web site (http://nationalatlas.gov/plssm.html), accessed November 2004. This map layer portrays the boundaries of the Public Land Survey System of the United States.

Wyodak–Anderson Coal Zone
The geologic sequestration data for the Wyodak–Anderson coal zone in northeastern Wyoming were derived from the PCOR Partnership topical report, "Geologic CO_2 Sequestration Potential of the Wyodak–Anderson Coal Zone in the Powder River Basin."