Methods and Standards Development for Three-dimensional Geologic Mapping of the Antioch Quadrangle, Lake County, Illinois

A Pilot Study

Central Great Lakes Geologic Mapping Coalition

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Executive Summary

This Pilot Study for the Central Great Lakes Geologic Mapping Coalition (CGLGMC) focused on the Antioch Quadrangle, Lake County, Illinois. The quadrangle covers an area of complex glacial geology representing several advances and retreats by major ice lobes during the last 25,000 years. Within the thick succession of sediment are major deposits of sand and gravel that contain the groundwater resources so vital to the continued growth of the region. The rapid growth in population is affecting the delivery of services such as sewer and water, and the expansion of transportation networks. It is also bringing into focus the conflict in land use between suburban development, aggregate resource extraction, groundwater availability, and preservation and conservation of open space.

The geologists working on the Pilot Study have developed a series of map and digital products, several protocols for database development and maintenance, and field procedures to acquire and integrate drilling and geophysical data to more efficiently deliver our information to the interested public. The series of deliverables represent only the first phase of the project. A series of meetings with various county and municipal agencies and other public and private groups will be used to communicate our results and learn how we can better inform and train the public on the use of our information to assist in their decision making. Using information derived from these discussions and our on-going research and product development we will develop a series of additional, derivative products that address specific issues of concern. Additionally, we will use the information to better design maps and databases for ongoing CGLGMC quadrangle mapping in northeastern Illinois. During this pilot phase of the study we have produced the following:

Finished Products/Deliverables:

- 3-Dimensional (3-D) Model of Surficial Geology
- Surficial Geology map
- Bedrock Topography map
- Drift Thickness map
- 1939 Historical Aerial Photography map
- 1998-1999 Digital Orthophoto Image map
- Well Location (Data point) map
- Borehole Verification Protocol
- Data Entry/Working Database Protocol

- Contract report with Appendix

Each of the above products has an accompanying text on its map sheet explaining how the map/model was made, the data used to produce it, and the utility of the map. The contract report document includes short, separate sections on each deliverable explaining in greater detail how each map should be used and its importance in the overall project objective.

Specific Project Highlights:

- We have produced the first 1:24,000-scale, 3-D model depicting the geologic sediments from land surface to bedrock (approximately 250 to 300 feet in thickness) in the northeastern part of Illinois. The model was developed using location-verified archival data coupled with new project drilling by Illinois State Geological Survey (ISGS) geologists, whose boreholes provided high quality geologic data for interpretation with the model. In addition, our borehole geophysics team acquired natural gamma logs for each of these new boreholes. We correlated our detailed descriptions of the core sediments with the gamma log traces (signatures) to better understand their relationship. This allowed us to interpret subsurface sediment sequences using gamma logs from boreholes for which we did not have detailed sediment samples. This increased the number of high quality boreholes available for the modeling and mapping.
- The model layers are presented such that the aquifer(s) underlying this rapidly-expanding area northwest of Chicago can be clearly seen with a perspective view not previously available.
- Because each model layer, as well as the other map products, is presented within a GIS, these digital coverages can be combined with other geo-referenced information to create a variety of derivative maps such as resource extraction potential, groundwater contamination susceptibility, population density, planned growth, etc.
- We have developed a working relationship with a number of water well drillers to accompany them to new well construction sites to conduct downhole gamma logging. These opportunities provide us with a greater number of locations and a better opportunity to integrate this technique into our mapping.
- We have begun to integrate surface seismic transects (terrestrial and waterborne) into our mapping to better understand the subsurface stratigraphy. Equipment and procedural protocols are being developed and tested.
- We initiated a program of installing observation wells at each drill site. This network will be monitored for water levels in addition to being sampled for water chemistry. The water level data will be incorporated into our aquifer studies. We have spoken with public health departments about their assuming responsibility for periodically monitoring these wells in the near future.
- We developed protocols for verifying the location of boreholes used in our mapping and modeling. This was a very important step for maintaining the spatial resolution of our maps and our confidence in mapping accuracy.
- We developed and continue to refine data entry procedures, including the establishment of a dictionary of terminology for describing sediment samples and

cores in the field and laboratory. Formats for entering the new data into a working (dynamic) database as well as the archival database have been developed.

Interactions with the Public:

- We have developed three Memoranda of Understanding (MOU) for this project. One is with the County of Lake GIS and Mapping Division to supply digital records of transportation networks, tax parcels, and selected aerial photography; another with the County of McHenry for access to their in-house digital tax parcel records; and, a third, with a large, engineering consulting company (STS Consultants, Ltd.) to use their proprietary project records to investigate how these types of records can be integrated into our mapping programs.
- We already have met informally with personnel from numerous municipal water departments and county agencies (e.g., public health, forest preserve) to discuss our plans to meet with them and present our results. We will seek their feedback on how we can best present our data and interpretations to assist their decision-making.
- We are also planning a series of open meetings to present our information to the general public.
- We are communicating with a number of citizen action groups, keeping them informed of our progress and discussing with them our geologic interpretations of issues of concern to them.

Utility and Impact of our Information:

- Our 3-D model of the sedimentary succession is the showcase item of the Pilot Study because it offers, for the first time, the opportunity to both visualize and analyze the various types of sediment and stratigraphic units at a large scale. We can now present our information in an easily understood manner to the public agencies that are dealing with issues such as suburban growth, transportation network development, groundwater utilization, aquifer geometry and potential, surface water management, potential groundwater contamination, open-space and land use change, and aggregate resource identification and extraction. We will customize our maps and data visualization for various agencies and municipalities to help them better understand the implications of our mapping program.

FY04 and FY05 Schedule:

- We have begun work on the Fox Lake Quadrangle for the next phase of the Coalition project. The Fox Lake Quadrangle which is adjacent to the western boundary of the now-completed Antioch Quadrangle, covers an area of complex geology that includes large sand and gravel deposits and collapsed topography with intermixed ice contact deposits.
- We will continue our program of installing monitoring wells and gamma logging new private water wells. Both of these programs directly assist our mapping and modeling.
- We will increase our use and integration of surface seismic and borehole geophysics to map subsurface stratigraphy. By closely coordinating the geophysical and drilling locations we will be able to provide information that is complementary to both and will provide us with greater confidence in our models.

- We will continue to pursue additional funding through the USGS STATEMAP program to map the surficial geology of neighboring quadrangles. By scheduling drilling and fieldwork for STATEMAP and Coalition work and developing concurrently the necessary databases we can be more efficient and are able to maintain a high level of quality control. By implementing our new protocols we expect to produce deliverables similar to the Antioch Quadrangle, but in only about half the time, assuming current funding levels. We expect to deliver preliminary 3-D stratigraphic models and other map products for the Fox Lake Quadrangle by late calendar year 2004. We will also be revising a 3-D model for the Wauconda quad to the south of the Fox Lake quad and beginning another project on the Grayslake and Libertyville Quadrangles. By the end of calendar year 2005, a composite 3-D stratigraphic model for the Antioch, Fox Lake, Wauconda, and Grayslake quads should be available. This will provide us with a major tool for aquifer research and for addressing regional groundwater issues.
- We will complete the 3-D hydrostratigraphic model for the Antioch Quadrangle and we will extend our work to the neighboring Fox Lake, Wauconda, Grayslake, and Libertyville Quadrangles as our mapping progresses to those areas. This 3-D hydrostratigraphic model will be much more detailed than previous models for the area. Current models are generally small-scale, regional models developed using less data that have only limited applications in decision-making by county and municipal level agencies.
- Our hydrostratigraphic modeling will provide information on groundwater availability, aquifer conditions, potentiometric surfaces, and potential for groundwater contamination. The digital database supporting the 3-D stratigraphic and hydrostratigraphic models will be available for incorporation with other GIS-based data used for decision-making by county and municipal personnel.
- We will develop, in close cooperation with Lake County agencies (e.g., lakes, rivers, and wetlands; public health; planning), a series of custom maps, e.g., groundwater recharge areas, to be used in planning and evaluating land development options. These maps will provide guidance for assessing areas for their potential to affect groundwater resources. These products will be made available to municipalities through county agencies.
- We will continue meeting with various groups and agencies in the project area to discuss the application of our results and to assist in providing information needed for decision making. We will increase our outreach activities to include public meetings and presentations.

Project Overview

Project Objectives

The Antioch 7.5-minute Quadrangle, located in northwestern Lake County, IL, was the focus for the Coalition Pilot Study for Illinois (Fig. 1). Four state geological surveys (Illinois State Geological Survey, Indiana Geological Survey, Michigan Geological Survey Division, Ohio Division of Geological Survey) and the U.S. Geological Survey comprise the Central Great Lakes Geologic Mapping Coalition (Coalition). The Coalition was formed to conduct the necessary studies to depict in three dimensions (3-D) the complex glacial geology of this four-state region. The three-year project was initially funded in FY00 with work commencing in April, 2000 and finishing in September, 2003. The three-dimensional (3-D) geologic mapping of glacial deposits was designed to be a pilot project to (1) establish standard formats and methodologies for subsequent geologic mapping of 600, 7.5-minute quadrangles in priority areas in the four Coalition states, (2) provide initial maps and databases that would help decision makers address land-use and conservation issues, and (3) answer key scientific questions. Antioch was selected by Lake County officials as their highest priority quadrangle to map because rapid urban encroachment from Chicago was putting pressure on groundwater resources, aggregate resources, wetlands, transportation networks, land use compatibility, and municipal infrastructures. The complex glacial geology of the quadrangle also provided an opportunity to apply new digital mapping techniques to help interpret the three-dimensional geology and to develop new products to assist decision-makers.

Protocols and methodologies are needed to produce a uniform and compatible set of maps for the four states. The 3-D geologic maps to be developed under the Coalition's plan will give decision makers needed information to address critical growth and natural resources development and conservation issues. The most significant scientific issues to be addressed by this mapping are the origin, nature, distribution, and resource potential of the thick glacial deposits. The initial package of deliverables includes a 3-D model of the surficial geology (land surface to bedrock) and maps of the surficial geology, bedrock topography, drift thickness, well locations, 1939 historical aerial photography, and a 1998/1999 digital orthophoto image. In addition, protocols for verifying data points and for database development, data entry, and sediment sample description are provided.

Project Strategy

Because no widely accepted standards exist for geologic mapping and production of maps and databases in glaciated areas with thick drift cover, a principal objective for mapping the Antioch 7.5-minute Quadrangle was to draw on the human and material resources of all five Coalition surveys in a joint field-based mapping investigation to develop standards. It was considered desirable that all collaborating scientists use consistent terminology and methods for field mapping and for designing map and database products. Only then, could collaborators jointly address and overcome the scientific problems in order to produce more reliable maps and help meet the pressing societal needs for 3-D geologic information in the central Great Lakes states.

The Antioch Quadrangle, located on the northwestern fringe of the expanding greater Chicago metropolitan area in Lake County, Illinois, was designated in 1992 as a high priority for geologic mapping by the Illinois Geologic Mapping Advisory Committee. In 1998, the quadrangle was selected by Lake County planning and health officials as their #1 priority quadrangle to map because of ongoing and expected urban expansion with coincident pressures on locating and protecting groundwater resources and preserving declining wetlands. Therefore, an important objective of the mapping was to provide decision makers with critical earth-resource information to address growth issues that most effectively would help them to balance and direct development and conservation. Before societal issues can be addressed with appropriate derivative map products, 3-D geologic mapping of the glacial deposits must be conducted to answer specific scientific questions.

Scientific Objectives

The basic scientific goals of the mapping are to:

- Delineate, characterize, and classify the sediment units for the Antioch Quadrangle
- Interpret the glacial environments and glacial sequences represented by the sediment units
- Regionally correlate the sediment units and events to better understand the glacial history/chronology of the area
- Understand what the deposits of the Antioch Quadrangle reveal about ice sheet dynamics of the Lake Michigan Lobe in northeastern Illinois during the last glaciation

Geologists from all five geological surveys collaborated to the extent possible in describing outcrops and cores from exploratory drilling, and in utilizing high-resolution geophysics to map the surficial glacial deposits from land surface to the bedrock surface. New drilling and geophysical techniques and equipment were developed to optimize sample recovery and provide the "best" possible depiction of the complex glacial stratigraphy that exists beneath the surface of the quadrangle. Exploratory work supplemented subsurface data derived from thousands of logs from water wells and engineering borings. Locations of these borings were verified and the quality of the data was analyzed. In addition, laboratory protocols were established and laboratory analyses commenced to characterize the physical and geochemical attributes of samples. Oral communication and periodic field conferences were used to provide updates on work completed and to discuss preliminary results and field techniques with all members of the Coalition project team.

Data were stored in a common database that was designed to be user-friendly, not only for survey scientists, but also for non-geologists. Specialized geographic information system and spatial modeling software, such as ArcGIS, MapINFO, Vertical Mapper, EarthVision, and RockWorks were available to aid in the interpretation of the borehole and field data, to provide a computer-aided ability to visualize geologic units in three dimensions, and to produce basic and derivative geologic maps. Relational database and spreadsheet-based programs were also used to develop and maintain working databases. Recent upgrades for ArcGIS and RockWorks 99 and 2002 were employed to complete this project. Future upgrades in software and hardware may result in changes in our mapping and database management protocols.

Potential impacts and major products

By addressing specific scientific issues we sought to improve the accuracy of the conceptual 3-D model of the quadrangle and develop a working model (a scientific hypothesis) that could be tested and improved with data from other areas of future study. Scientific outcomes of mapping the Antioch Quadrangle included:

- Determining the origin of the uppermost heterogeneous diamicton unit and associated sediments
- Determining the geometry, sedimentary environments, and glacial events associated with a thick subsurface sand unit and interlayered lacustrine deposits
- Developing a regional-scale understanding of the sediment sequences and glacial history represented in the Antioch Quadrangle

Upon completion of mapping the 3-D glacial geology, derivative or interpretive maps will be developed that help address land-management and public-policy issues. The maps produced for the project show the following:

- the distribution and thickness of surface and subsurface sand and gravel aquifers and major aquitards,
- data on the location and quality of aggregate resources
- areas of geologic hazards (unstable soils, compressible foundation materials, flood-prone areas, areas of poor drainage, etc.)
- groundwater and surface water interactions as the affect the habitats of wetlands

- areas most and least susceptible to potential groundwater contamination from point and non-point sources

In addition, for the Coalition to achieve its goals, we must develop documented techniques that have proven successful for mapping the complexities of the glacial geology and we must develop a geologic information delivery system to transfer our geologic products into the hands of users. The geologic mapping program of the Antioch Quadrangle is designed specifically to set the groundwork for future Coalition mapping of about 600 quadrangles (about 150 quadrangles/state) over a 15-year period with adequate funding. Field mapping techniques, consistency of terminology, development of mapping formats, and outreach activities will all be “field-tested” in the Antioch pilot mapping area.

Overview of Glacial History

The Antioch Quadrangle is located in the hummocky morainal upland of the Valparaiso Moraine east of the Chain O’ Lakes/Fox River Lowland. Thick drift (250-300 feet thick) representing multiple events of the Wisconsin Episode (last) glaciation (Fig. 1) are intermixed with lacustrine sediments. A heterogeneous unit of gray, clayey diamicton (Wadsworth Formation) containing many discontinuous lenses of sand, gravel, silt, and clay occurs at land surface at the eastern edge of the map. It thickens to 100 to 150 feet westward toward the Chain O’ Lakes/Fox River Lowland. This clayey diamicton overlies a dense, gravelly, gray diamicton (Haeger Member, Lemont Formation), which is underlain by up to 100 feet of sand and gravel (Beverly Tongue, Henry Formation). Beneath these units lies a reddish gray diamicton (Tiskilwa Formation) and, in places, a sandy, gravelly diamicton and gravel unit (older drift) over bedrock. Regionally, organic-rich deposits in and beneath the reddish-gray diamicton have yielded ages of 25,000-26,000 radiocarbon years before present, indicating that the entire sequence was deposited during Wisconsin Episode glaciation. A peaty deposit encountered about midway down in one Coalition-STATEMAP borehole (WAUC-02-12) in the southwestern corner of the Wauconda Quadrangle (which is southwest of the Antioch Quadrangle; see Figure 2) yielded a radiocarbon age of 30,950 years BP (ISGS 5315). A second reddish diamicton underlying this peat had not previously been encountered in boreholes drilled by the Coalition team.

The topography and glacial sediment record changes dramatically westward toward the Chain O' Lakes/Fox River Lowland (Fox Lake Quad), an area dominated by ice-collapse topography, where lakes and marshes are abundant. The geology is complex due to the ice-marginal position and the intermixing of sediments from ice-collapse and melting and the subsequent reworking by fluvial activity. Farther westward, toward the edge of the Fox Lake Quadrangle, an extensive outwash plain was developed by meltwater flowing southward. Here, thick deposits of sand and gravel dominate the stratigraphy and constitute a valuable sand and gravel aggregate resource for commercial and residential development in northwestern Lake County and eastern McHenry County. These sand and gravel deposits also comprise major regional aquifers. Therefore, a potential land-use conflict exists. Excavating the materials for construction can delay significantly the future use of the area for commercial and residential use, whereas developing the site in lieu of excavating eliminates any future use for construction materials. While a sand and gravel pit is active, residential and commercial development may proceed in the surrounding areas and, eventually, limit the expansion of the pit. The pit may be reclaimed and developed for residential, commercial, and recreational land use. The Fox Lake Quadrangle is the next area of focus for our Coalition 3-D mapping (Fig.2).

Project Results

The preceding Project Overview section discussed the objectives, strategies, and deliverables as presented originally by Berg, et al. (1999). That plan envisioned a three-year Pilot-Study phase followed by a fourteen-year Mapping Phase. This ambitious timeframe was developed based on the timely delivery of our information to the appropriate county and municipal agencies. Their needs are current and the sooner the necessary geologic and aquifer data are available to them the better. The timely delivery of these products is contingent upon adequate funding, which is needed not only to complete the drilling, mapping, and other Pilot Study work, but is also needed to hire and train additional staff (geologists and technicians) to conduct the work on the large number of quadrangles on the priority lists of all four Coalition states.

Methodolog

A major objective of this project was to develop a methodology appropriate for the description of glacial deposits in the states of the Coalition. Even though Survey geologists in each of these states and the USGS employ similar techniques, equipment, and descriptive nomenclature, considerable differences still exist in the detail of recorded observations and in database development and data storage systems.

Coalition geologists at the ISGS worked closely during the past three years to identify attributes and methods we believe are needed to accurately and thoroughly describe field exposures and continuous core samples. In addition, we have developed equipment, field techniques, and applications to integrate various borehole and surface seismic geophysical records into our mapping procedure.

Sampling and Describing Core

Team-scale reviews of important cores increased our collective knowledge of each sediment type and stratigraphic and/or mapping unit and have promoted a more consistent and thorough description of sediment samples. These reviews provided the basis for developing working templates for describing geologic sediments and for entering those data into the working and archival databases. These core review discussions also provided the venue for refining and standardizing the amount of detail and interpretation a geologist should generate for each core. Our core description protocol includes a <u>preliminary summary of the field drilling log</u> and a <u>detailed laboratory description</u> to be completed at a later date.

Preliminary summary of the field drilling log. This log consists of the notes recorded by the geologist logging (describing) and boxing the core at the drill site. These notes are disseminated quickly to other project geologists, often by phone, who may be either working in the office on modeling or planning to arrive at the drill site to conduct borehole geophysics, install observation wells for aquifer studies, or conduct surface seismic transects. A written summary of this borehole log is generally sent to the research team within a few days of completing the borehole. In addition, a unique identifier (API number) is assigned to each borehole when it is entered into the archival relational (Oracle) database. This number links all of the data pertaining to this borehole.

Detailed laboratory description. This description of the entire core is completed within a few months of when the core was extracted (depending on the status of the on-going drilling season). The core boxes are opened and the aluminum foil wrapping the cores is removed, or the plastic sample bag containing the wet, "runny" sample (usually saturated sand) is opened, to allow the sample to air dry. The core is then split and described following a template of variables such as texture, color, unit thickness, etc. If the wet sand samples that are stored in plastic bags are from intervals from which complete or near-complete recovery is obtained, the core can be cut into sequential sections and stored in individually labeled bags. If the recovery is not complete, the stratigraphic integrity of the sample has probably already been disturbed and the sample is then washed or scraped from the sample tube into the plastic bag. These samples will be described in general and notes will be made regarding the quality of the sample. These descriptions are entered into our working database using a Microsoft Excel-based format (Figure 3), but other methods of data entry (e.g., Microsoft Access) may also be used. The protocol for core description and data entry is dynamic, with changes occurring due to our collective experience from testing new software and procedures. The template is comprehensive, but the geologist needs only to enter data appropriate to a specific sample. This detailed description includes an interpretation of the lithostratigraphic unit and the mapping unit and supercedes the preliminary summary because it is the more comprehensive core description. Any revisions of earlier interpretations for the core are recorded in the description and incorporated in the 3-D model and other maps.

Appended to this detailed core description is an annotated version of the natural gamma log.

By carefully annotating the gamma log while describing the core, we can correlate the two records and better understand their relationships and patterns in different types of geologic materials and depositional environments. A goal of this project is to develop a library of gamma log signatures that can be referenced when sediment samples are not available for a new water well or other borehole that is being logged.

Work at the drill site. This includes installing a 2-inch diameter PVC pipe for use with borehole geophysics equipment. We obtain a natural gamma log for each borehole. This log from land surface to the bottom of the borehole (most often 5 feet into bedrock), is annotated when the core is described in the laboratory. The primary borehole at each site is the stratigraphic borehole; its purpose is to provide a continuous core from land surface to bedrock. If aquifer material is encountered during the drilling of the stratigraphic borehole, we drill, a short distance away, an additional borehole to a specified depth in the aquifer, and install a monitoring well.

Obtaining a natural gamma log. Our current procedure is to contact the ISGS logging team just prior to the borehole being completed. Ideally, their arrival at the drill site will coincide with the borehole's completion. They are usually in the same general area accompanying well drillers and logging new water wells. There are times, however, when they are at the Survey, about 4 hours away, and it is in these situations when the down time of the drilling team can increase. The ISGS is purchasing a portable logging unit for exclusive use with the drill rig so, in the future, the logging team will not be required to leave their current work site or drive to our site specifically to log our borehole. This will decrease the down time experienced by the drilling team while they await the arrival of the logging truck. It will also eliminate the need to coordinate the schedules of the drilling and logging teams, allowing each to schedule their fieldwork more efficiently. The additional equipment and consequent change in logging procedure will decrease the time needed to complete the stratigraphic and monitoring well boreholes. It will also increase the number of new water wells the geophysical team can log. These changes will increase the number of boreholes available for developing a more refined 3-D model as well as the bedrock topography, drift thickness, and surficial geology maps.

Installing a Monitoring Well. At each drill site where aquifer material is encountered, a 4-inch diameter borehole is advanced into that material to install a monitoring well. It is faster and easier to drill a new 4-inch diameter borehole to a specific depth to set a monitoring well than it is to enlarge the 3-inch diameter stratigraphic borehole to create the space needed to install the well. The 2-inch diameter PVC pipe and the sand and grout needed to pack and seal the well require a larger borehole than that created with the 3-inch corer. The stratigraphic borehole is drilled using a 3-inch diameter continuous sampler with a wireline retriever whereas the monitoring well borehole is simply bored to a specific depth without collecting samples. It is also easier to maintain a straight borehole by drilling a new hole rather than enlarging a smaller hole and it is easier to install the well screen at the proper depth in a borehole of a specific depth. Five monitoring wells were installed during the 2003 drilling season. Water levels are being monitored and we will begin sampling for water chemistry in the near future. Eventually, we plan to transfer the monitoring duties to another agency such as the Lake County Department of Public Health.

Drilling the Borehole. Our drilling procedures have been modified and streamlined such that we now can drill a 250 to 300 ft-deep stratigraphic borehole, acquire a continuous 3-inch diameter core of sediment using a wireline sampler, and install PVC pipe for geophysical logging in about two drilling days. A borehole in which a monitoring well is installed requires about 1 to 2 days, depending on its depth and the difficulty of drilling. A work week is generally scheduled for each borehole. Due to the large distance between the Survey (Champaign County) and the Coalition study area (Lake County), we schedule our CME 75 drill rig and its two support vehicles and trailers to work consecutive weeks in our project area, moving around to pre-determined sites. This decreases travel time and only one mobilization from the Survey is required. The drill rig and support vehicles remain at the drill site. The drilling team shuttles weekly between the project area and the Survey to return the boxed core to the Survey Core Description Laboratory and to bring back additional drilling supplies and new core boxes to the drill site the following week.

A smaller drill rig, an AMS PowerProbe 9600, is used to acquire 1.5-inch diameter core from locations that are too restrictive for the larger drill rig and its support vehicles to operate. We use the PowerProbe to drill in areas that are too wet or too soft to support the bigger rig such as areas peripheral to wetlands and in depressions, in wooded areas with minimal access, and other restricted access locations. This direct-push drill rig can quickly acquire core to shallow depths (e.g., 50 ft) and is tooled to drill and sample boreholes up to 100 feet in depth. It has been very useful in mapping the thickness and extent of peat deposits and lake sediments in shallow depressions and for field verifying the surficial geology mapping units. During one very successful cold and rainy drilling day, we acquired 205 ft of core from 10 shallow boreholes in a soft farm field surrounding a wetland. We used these cores to define the areal extent of peat and peat-rich sediments in this depression and to determine the thickness of the two uppermost stratigraphic units.

We also used the USGS Hovercraft to drill four shallow boreholes in three lakes on the Antioch Quadrangle. Although our initial efforts were somewhat limited by environmental restrictions and a lack of access points, we did acquire some useful information concerning the thickness of recently-deposited sediments in these lakes. In addition, the Coalition project is now focusing on the adjacent Fox Lake Quadrangle in which a large portion of the map is occupied by lakes associated with major ice-collapse features. We will be running a number of seismic lines across these lakes to help determine their origin and it will be helpful to have boreholes along these lines to provide some sediment samples to help verify and constrain the geophysical information. For this, we will seek the services of the hovercraft again as part of the Coalition partnership.

Core Analysis, Storage, and Archiving

We use a continuous sampler to acquire core from all boreholes drilled by the ISGS for the Coalition project. These samples are described and correlated for use in the 3-D modeling and mapping. Selected cores may be sampled for various particle size and chemical analyses and photographed to illustrate both unique and representative characteristics of a specific geologic material or lithostratigraphic unit. All data are entered into the database and are linked by the borehole API number.

Sediment samples acquired during previous mapping or research projects in our study area were reviewed at the ISGS Geological Samples Library (GSL). Cores from two stratigraphic boreholes and sample sets (taken at 5-ft intervals) from 16 water wells were reviewed and interpreted by project geologists for use in the 3-D modeling (see deliverable sheet-3-D Model: Surficial Geology). Additional cores and sample sets are available for boreholes in the surrounding quadrangles and will be reviewed and incorporated into our on-going modeling and mapping in Lake County.

Database Development and Management

Most mapping projects will generate a large volume of data, especially those initiated since the conversion from predominantly hand-drawn, paper-based methods to computer-assisted, mapping programs with their numerous attendant files and tables. This conversion, however, has not necessarily decreased the amount of hand-written, field-based data gathered by project geologists. What has increased is the diversity of data gathered and the number of different formats into which those data are initially stored and, possibly, later imported. Instead of using only the standard USGS topographic map, we now use, additionally, either the digital raster graphic (DRG) or the digital line graphics (DLGs) for that map to create bases for field mapping. The digital orthophoto quarter quadrangle (DOQQ) offers both the planimetric and georeferenced qualities of the topographic map and the visual components of an aerial photograph. At a scale of 1:12,000, and capable of being projected to 1:6,000, the information on the DOQQ is more recent and more detailed than that depicted on the standard 1:24,000 topographic map and is, therefore, less likely to be outdated in our rapidly-changing mapping area (see Base Materials section below for more discussion of this problem and our response). By adding coverages such as well locations, mapping units, soils, etc. from the GIS, the field geologist, mapper, or modeler can create a customized product for use in the field or office.

Data entry includes both the addition of new well records into the archival database and the modification of current records by project geologists. During this Pilot Study, we drilled thirty-one (31) boreholes ranging from 5 to 284 ft in depth in the Antioch Quadrangle using ISGS drill rigs. The detailed core descriptions and accompanying natural gamma logs are part of the project database. We interpreted and used them to produce the various project maps and the 3-D model. The data entry methods and forms developed for this project are discussed in detail in Stiff (2002), which is included in the Appendix to this report and comprises our database protocol.

Even though this Pilot Study focused on the Antioch Quadrangle, a larger, more regional view is needed to better understand the distribution of the numerous lithostratigraphic units. Important glacial geomorphic features and related depositional environments occur outside the quadrangle boundaries and a larger geographic perspective is needed to interpret the units. To that end, we entered into the archival database all new borehole records (water wells, engineering borings, etc.) for Lake County, prioritizing first the Antioch and then the adjacent quadrangles, including a part of Wisconsin (Table 1, new water, engineering, and sample sets/cores). All new borehole records received at the ISGS are automatically entered into the archival database, and the paper proof copies are sent to the project geologists to review for possible immediate use in the project. In addition, for this project, all the paper records of water wells, engineering, and test boreholes were matched to the digital record to ensure they were in the digital database. When absent, they were reviewed and then entered (Table 1, old water, engineering, sample set/cores).

Data Retrieval and Verification of Data Point Location

Prior to the development of the master digital database at the Survey, the existing records of water wells and other boreholes were archived only as paper records in the GRU where they are organized in books by county, township-range-section coordinates, and alphabetized within each section. Geologists seeking the records for a particular area had to examine these files and either photocopy or manually transcribe pertinent information on maps for use in the field. In many rural areas, the number of available borehole records within the study area may total only 100 to 200. From that list, a few records would probably be discarded due to insufficient information on the location or the geologic materials encountered during the drilling of the borehole. The locations of the boreholes with the best records would then be verified in the field by visiting the location (e.g., farm house) and visually observing the location of the well or by talking with the landowner or well driller. The most accurate position of the well location would then be entered into a field book or marked on a topographic map or aerial photograph if it was possible to determine that position.

Water wells can seldom be located correctly using only the driller's log because the driller is required to record the location using township-range coordinates and can only be accurate to the quarter-quarter-quarter section, which is a 10-acre parcel of land. Many are located to a larger size plot, such as a quarter-section (160 acres) or even whole section (640 acres). When plotting these inaccurate locations from the digital database, the well is positioned in the center of the smallest coordinate, e.g., the center of the 10-acre parcel of land. The well, however, is generally close to the farm house, which often is near a road that runs along the section, or quarter-section, etc., boundaries. This repositioning alone may locate the well several hundred feet from its actual position. This problem is magnified when a large number of boreholes occur in the project area. Verifying the locations of the boreholes with the highest quality data becomes a very time-consuming task.

Incorrectly locating a well in hilly topography could cause a very significant problem because the land surface elevation at the wellhead (i.e., the borehole) is used to calculate the respective top and bottom elevation of each subsurface geologic unit encountered in that borehole. The top and bottom elevations of each unit are used by the computer model to correlate (match and connect) them with units in adjacent boreholes. Incorrect elevations would cause errors in the correlations and the accuracy of the 3-D model would decline.

During this Pilot Study we have developed and maintained the digital database for well records in Lake County such that any backlog of new records to be entered has been eliminated. This database of 20,000+ records is continually updated. The database also is upgraded when we work in adjacent quadrangles. The upgrading follows the protocol we developed for the Antioch Quadrangle wherein the paper and digital records are matched and reviewed to ensure that all records are in the digital database. We use digital overlays of tax parcel records and well locations on DOQQs or high-resolution air photos for on-screen verification and repositioning. In this way, we have reduced the amount of data handled while maintaining a larger, more diverse database.

In suburban areas where residential development is rapid and widespread, it is very difficult to stay current with transportation and subdivision changes. Because most of the new wells are located in these areas and many well addresses are listed as subdivision lot numbers rather than street addresses, we have developed our protocol to search tax records using these variables. This is a very efficient way to handle the hundreds of new well records that occur in these small geographic areas. Another reason to keep the transportation and subdivision databases current is related to the accuracy of plotting the locations of the data points (i.e., wells). We carefully verify the location of each well and reposition them as needed. When they are plotted on a recent map base, it is possible to relate the well location with streets and other boundaries. This is useful because street patterns provide a quick spatial reference and are a standard feature layer in the GIS used by decision-makers.

Sources of Map Bases

We use a variety of base materials for plotting interim and final map products and for on-screen verification, relocation, and selection of boreholes for use in modeling and mapping. The most commonly used base materials for plotting are the DOQQ, DRG, and DLG files and we have begun using USGS 1:24,000 Raster Feature Separate (RFS) files to make base maps. Maintaining the currency of each of these base material types is a problem in areas with rapidly growing population and widespread changes in land use. We initiated a Memorandum of Understanding (MOU) with the GIS and Mapping Division of the County of Lake Department of Information and Technology, to provide periodic updates for digital tax parcels, transportation networks, municipal boundaries, county forest preserves, hypsometry (elevations), recent and historical aerial photography, high resolution aerial photography, digital elevation models (DEMs), and other products and feature layers that would be useful to our mapping project. A similar MOU is in effect with McHenry County for accessing their digital tax base for verifying well locations. Both of these ongoing associations have proven very useful in increasing our efficiency and accuracy in well verification.

We use the 10- and 30-m DEMs for calculating surface elevations. The USGS-NIMA High-Resolution Orthoimagery (6-inch resolution) and other aerial photography (2-foot resolution) combined with LIDAR hypsometry (2-foot contour interval) are very useful when only small areas are displayed on-screen for detailed work such as repositioning wells. The 1939 historical aerial photography is rectified and georeferenced and is used both as a base for plotting and, more importantly, as a reference point for comparing land cover and land use changes. We also overlay the modern soil, parent material, and surficial geology maps to locate small areas we wish to investigate in more detail in the field. The aerial photography is more recent than the DOQQs for the study area and it provides a more complete record of the rapid development of subdivisions where most of the new wells are being drilled. The resolution of the aerial photography, however, is very high and the file is too large to display as large geographic areas either for plotting or for on-screen work.

Overview of Deliverables

The six maps and the 3-D model developed for this Pilot Study include both 1) traditional basic map products that the ISGS currently produces for each quadrangle (surficial geology, bedrock topography, drift thickness, data point location), or may produce for selected quadrangles (1939 historical aerial photography, digital orthophoto image), and 2) new products (3-D model and digital database) that will be developed for each new quadrangle.

Even though the 3-D model and database are the showcase deliverables for this project, the basic products will continue to be produced because they are byproducts and/or interim products created during the project workflow. The 3-D model and the bedrock topography and drift thickness maps share many common data points, but provide different views of the geology. Because the preliminary maps of bedrock topography, drift thickness, and surficial geology can be produced relatively early in the project, they provide guidance for scheduling and locating new sites for our drilling and, thereby, assist in the development of the 3-D model. Preparing the database for the 3-D model is very laborious and requires considerable time for interpretation and correlation.

The protocols and general methodologies developed during the Pilot Study will allow us to produce the traditional deliverables in about one-half the time (18 months) for future quadrangles assuming current funding levels. The period of development for the 3-D model should also decrease for similar reasons because as we complete the individual 3-D models for adjacent quadrangles, each new model will provide feedback on the position and characteristics of subsurface geologic units and depositional environments. The individual 3-D model for each quadrangle will be merged into the regional framework model (the aggregated quadrangle models) which, ultimately, will include the entire county. We also plan to train additional geologists in modeling and mapping so that we can move more quickly into adjacent quadrangles and complete our mapping in less time.

The 3-D model, database, and other deliverables are considered to be end products only for this initial model-development phase of the project. An additional goal of the Coalition project is to work with local governmental agencies to produce derivative maps and products that deal with aquifer delineation, recharge areas, and potential for contamination, and how these data can be incorporated into the regional planning and development decisions the county and municipalities are considering. The Lake County Regional Framework Plan (2001 draft: 4-16) is being written such that when maps of priority recharge areas, aquifer withdrawal rates, and other information become available from the Coalition or other agencies, the county and municipalities can revise their comprehensive plans, zoning maps, and land development regulations as needed. The 3-D model will present graphically a perspective of the geologic materials and hydrostratigraphic units previously unavailable and at a scale useful to decision-makers. Additional graphics will be developed and a number of presentations scheduled to communicate our results to various clients.

3-D Model: Surficial Geology

Our 3-D model (Hansel, 2005) provides a more detailed and accurate visualization of the entire succession of glacial geology of the Antioch Quadrangle than previously available. It should be used in conjunction with our surficial geology, bedrock topography, drift thickness, and data point maps. Slight differences occur in the methodologies, number of data points, and mapping algorithms we used to produce the 3-D model and the surficial geology, bedrock topography, and drift thickness maps. This resulted in minor differences in the calculation (interpretation) of the thickness and position of a map unit, at any given point. For example, the delineation of the units on the surficial geology map and those depicted at land surface on the 3-D model don't perfectly match because a different number of boreholes and data sources was used to interpret the geologic materials occurring at land surface. The 3-D mapping software established a slightly different set of rules for data entry, which resulted in a more generalized interpretation of surface and near-land surface sediments. We are researching a methodology to merge the surface geology map with the 3-D model. A similar difference occurs when comparing the top of bedrock topography as depicted by the 3-D model with that depicted by the bedrock topography map. Differences in data density and mapping software algorithms affect the calculations. These slight differences are, actually, an advantage because the different visualizations can be compared and used for quality control and for locating inconsistencies.

The model depicts the distribution and geometry of several sand and gravel units (yellow layers in the model). Our research, combined with preliminary anecdotal information from water well drillers and supervisors of water works in various municipalities, indicates that low-yielding areas exist even within the most widespread aquifer-bearing unit (Beverly Tongue-Henry Formation). We are planning follow-up interviews with personnel from various public works agencies to better understand the variability in water yield and water quality. Graphically displaying high and/or low yielding areas on our model may provide additional information on the local aquifers. Another derivative product will be an isopach map of each of the sand and gravel units which, when combined with our data set of verified well locations, will help us better understand the relationships between well density, depth, and location. Additional relationships that can be visualized include those between open space, proposed subdivision locations, high quality aquifer recharge areas, potential for aquifer contamination, wetland maintenance and reconstruction areas, projected population and growth areas, and zoning. The perspective and scale of the 3-D model is unique and new for this area and will provide administrators many opportunities to combine additional data to study different scenarios.

The boreholes used in the 3-D model were selected individually based on their location and quality of data, which includes both geological and locational information (Hansel, 2005). However, to obtain a broad perspective on the utilization and location of the different aquifers on the Antioch Quadrangle, we imported into a spreadsheet all water wells that had sufficient geological and locational information. This data set included both verified and unverified wells. We identified the geological material in which each well was screened and then classified it into one of our mapping units. We also recorded the depth at which the well was screened. These wells were then grouped and displayed by section on the Antioch Quadrangle using histograms and pie charts to illustrate the proportion of the wells in each section that were screened in the different geological materials (see Hansel, 2005, Figs. 3 and 4). Additional analyses of these data will focus on the location/depth patterns, which may reveal the presence of small, irregular, and discontinuous lenses or areas where the aquifer characteristics change.

A similar analysis will be conducted for each quadrangle in the mapping area. Because the water well database for Lake County is so large, few, if any, municipalities have a complete record of the wells. Using our well records and analyses of selected data, we will be able to provide county, municipal, and other governmental entities information that is vital to their understanding of the current and future status of aquifer utilization in Lake County.

Surficial Geology

This map (Stumpf and Barnhardt, 2005) which shows geologic materials at land surface, is derived, in part, from the digital soil survey for Lake County (Paschke and Alexander 1970;

digital update in press). The individual soil series are grouped initially into similar parent material classes, and then each class is reviewed and recoded into one of our surficial mapping units. The recoded mapping units are presented in the map legend. They are based on our fieldwork and an examination of the descriptions of sediment derived from supplemental boreholes including ISGS PowerProbe test holes, shallow engineering borings from construction sites, power transmission towers, highway and bridge construction, and major utility excavations.

A variety of derivative products can be prepared using this data set because the original soil database remains as an underlying component of this map. It can be queried for information on texture, drainage, and engineering capabilities of the upper five feet. It displays the uppermost geologic materials, which are critical for construction of derivative maps (or a GIS coverage) of aquifer sensitivity and potential for contamination. When used in conjunction with other coverage themes such as population and land development, these maps are a valuable source of data for planning purposes. The surficial geology map and its database can be used to develop derivative engineering soils maps (Santi and Martens 2003), which show conditions suitable for shallow foundations and excavations and for regional evaluations of potential aggregate resources. The surficial geology map also displays areas classified in our peat and organic-rich sediment mapping unit (Grayslake Peat). These areas contain all wetlands but not all mapped units are wetlands; some areas are wet depressions on uplands or just poorly drained soils with high organic content. Our classification is less stringent than that used to delineate wetlands. An advantage of this is that the surficial geology map displays land that may be suitable for wetlands to exist or where wetlands existed in the past. These marginal lands could be areas of interest to county and local agencies seeking areas that are potential candidates for preservation or conservation of wetlands or for low density/low impact development.

Bedrock Topography

Developed using the subsurface geologic data, this map shows the topography of the bedrock surface (Dixon-Warren and O'Malley, 2004). The bedrock surface of this map and that generated by the 3-D model are similar, but not identical because different data points and algorithms were used. A general paucity of data points, especially in the north-central part of the quadrangle, influences both of these deliverables. A relatively shallow, broad channel traverses the southern part of the quadrangle in a NNE-SSW direction. The location and orientation of subsurface channels is important because these low-lying areas on the top of bedrock can be areas with extra thick accumulations of glacial sediment. If this sediment is aquifer-bearing, a valuable piece of information is available for planning and resource utilization. A potential example of this situation is illustrated in the Beach Grove Rd. geophysical transect run by the project geophysicists (see Beach Grove Rd. graphic in Appendix). Here, the preliminary data suggest a filled channel/tunnel. Additional fieldwork and drilling is needed to confirm this feature and the character of the fill. The bedrock topography map can be produced much sooner than the 3-D model and is useful in planning for additional drilling by the Coalition and for exposing gaps in the data where additional effort should be made to acquire new stratigraphic data through drilling or by applying downhole geophysical methods. This map is a standard byproduct of our mapping and is a step in the development of the 3-D model.

Drift Thickness

The drift thickness map is developed somewhat concurrently with the map of bedrock topography (Dixon-Warren and O'Malley, 2004). It often uses the same data points, although a few additional points may be added to control the minimum depth to top of bedrock. Drift thickness ranges from about 195 to 330 feet. In the absence of substantial relief in bedrock topography, the areas of thickest and thinnest drift generally coincide with the areas where the top of bedrock is lowest and highest, respectively.

1939 Historical Aerial Photography Map

Historical aerial photography is available for most areas in Illinois with some areas having periodic coverage that spans more than 65 years. For this Pilot Study, we collected, scanned, and geometrically corrected almost 300 individual aerial photographs to produce digital orthophotography, and then joined them to form a seamless image map that has a variety of uses (Luman et al., 2005). The 1939 map shows subtle surface geological features (now obscured by development) that provide a clue to understanding the geology. This map provides a dramatic visualization of rapid urbanization. Either this map or its companion map, 1998-1999 Digital Orthophotography Map (Luman, 2005), can be used as a base upon which the data points, surficial geology, or other thematic coverage can be overlain. Prior to these photos being geometrically corrected by our team, they were limited to use as single photos; now they can be imported into GIS-based systems and used in a variety of analyses. Using this map as a base greatly increases our ability to interpret the landscape and understand and identify environmental problems.

1998-1999 Digital Orthophotography Map

The digital orthophotography map is the most commonly used base for producing maps for our fieldwork because it combines the planimetric qualities of a topographic map with the visually rich qualities of a photograph. This map is used for verifying well locations, plotting wells to be located in the field, and for producing custom maps for fieldwork (Luman, 2005). We also use more recent high-resolution (6-inch) photography for the same purposes, but their extremely large data files limit the size of the geographic area that can be displayed or plotted. Both the 1939 and 1999 maps are used to track changes in land use and land cover (Luman et al., 2005; Luman, 2005).

Well Location Map

This map displays the complete file of data points located on the Antioch Quadrangle classified as either verified (green) or non-verified (red) following our protocol (Stiff and Barnhardt, 2005; see Table 1). Slightly more than one-half of the 7000+ boreholes available were verified, but far fewer were actually used in the construction of the various maps and 3-D model. The verified wells, and the level of confidence we have in the accuracy of their location are available to be queried from our database such that future researchers will be able to avoid time-consuming searches of the archival database or will be able to selectively extract boreholes and their information for more detailed site analyses. We also have created a common working database for the Coalition team to use in developing and demonstrating derivative products to interested agencies and to the public.

Continuing Research

❖ Derivative Maps and Outreach Activities

With the completion of the primary objectives, our focus now is communicating our results to the various agencies and private users to obtain feedback regarding additional products, interpretations on how to apply our information, and incorporating proprietary information into our research.

- We will schedule meetings to discuss how our data can be better integrated with county and municipal databases and how this information can best be presented to address the critical issues that are currently being discussed.
- Work has begun on derivative maps that require the completed working database as input. In the near future, maps on aquifer sensitivity and recharge areas will be prepared and overlays of thickness and depth to top of aquifer material, well density/aquifer unit, and other themes will be available. Their preparation and need will be developed in consultation with local and county agencies.

❖ Additional Fieldwork

As part of an expanded program of fieldwork, in 2003 we began installing monitoring wells at each site where we drilled a stratigraphic borehole. We also began coordinating geophysical fieldwork which included shallow surface seismic transects and downhole geophysics. A report on these activities and a discussion of a new landstreamer technology developed by ISGS geophysicists is included in the Appendix to this report, along with a paper discussing our borehole natural gamma logging technique and program.

- The ISGS is purchasing portable equipment for downhole natural gamma logging that will be used in an expanded program of logging new water wells and other boreholes of opportunity. This will significantly increase our archive of logged wells and provide additional information on the signatures of different types of sediment. Our program has been developed in consultation with, and following the model developed by, Coalition geologists from the Indiana Geological Survey.
- A second portable downhole logger and a GPS unit will be dedicated to the drill rig. This will eliminate the need to closely coordinate the field schedules of the drilling and logging teams.
- Additional transects using shallow surface seismic reflection and borehole geophysics are planned for the current Coalition quadrangle (Fox Lake) and adjacent quadrangles to help develop the regional 3-D model. Included in the Appendix to this report are examples of the various geophysical techniques used and developed for this pilot study and how we are integrating these techniques to support our mapping and groundwater research.

❖ **Groundwater Products**

Monitoring Wells. In summer 2003 we drilled three testholes in the Antioch Quadrangle using the wireline sampling method. A natural-gamma log was run for each testhole. Because favorable hydrogeologic conditions were found at only one site, a monitoring well was constructed in that testhole. Five additional monitoring wells were installed in boreholes we drilled in the Fox Lake (1), Wauconda (1), and the Grayslake Quadrangles (3). Water levels in these six wells have been measured periodically since their installation.

- We have modified our drilling protocol to accommodate the drilling of an additional testhole at each site in order to install a monitoring well when the hydrostratigraphic conditions warrant. Because we initially select a drill site to provide information on the lithostratigraphy, a site may not necessarily be the optimum for assessing the hydrostratigraphy.

- In the future, we will consider installing monitoring wells in selected areas where information about the hydrostratigraphy is needed more than about the lithostratigraphy.
- We will increase the variety of monitored hydrostratigraphic units to better understand localized variability in aquifer conditions.

❖ **Hydrostratigraphic Modeling.** Using RockWorks 2002, data obtained from the records of water wells located in the Antioch Quadrangle, plus a one-mile buffer, are being processed and interpreted within a hydrostratigraphic framework. The dataset of wells being used include most of those we used to develop the 3-D stratigraphic model. The final dataset will include wells/boreholes with both lithostratigraphic and hydrostratigraphic interpretations. Anticipated deliverables for the Antioch Quadrangle include maps showing:

- groundwater availability
- aquifer conditions
- potentiometric surfaces
- potential for groundwater contamination
- a 3-D hydrostratigraphic model

A series of similar maps and a 3-D hydrostratigraphic model will be developed for the Fox Lake, Wauconda, and Grayslake quads, following the methodology used to develop these maps for the Antioch Quadrangle.

❖ **Engineering Geology Mapping**

Earth materials are, literally, the foundation for man-made structures. The success or failure of the stability of these structures is dependent upon many characteristics of the soil or rock and their possible impact from geologic hazards. Suitability of geologic materials for support of construction activities, including ease and stability of excavation for utilities and basements, adequate bearing strengths to support structures, and drainage conditions are major concerns of contractors. It is important to identify geological hazards, including compressible peat and muck deposits, poorly drained soils, shallow artesian conditions, unstable slopes, areas with high susceptibility to freeze/thaw, high shrink/swell characteristics, and soils that would amplify ground shaking from earthquake activity.

- To date, this project has added almost 5000 new engineering records to our archival database for the Antioch and adjacent quadrangles.
- Many are records from highway and power transmission tower construction projects whose alignments intersect many different surficial geology mapping units and soil series.
- These points of intersection can be used to establish relationships between the mapping units, soil series, and engineering capabilities.
- Our database of selected engineering properties and interpretations can be queried to produce derivative maps and digital products.

Acknowledgments

Funding for this program was made available through three annual Federal appropriations to the CGLGMC through the USGS. Each annual $500,000 appropriation was apportioned among the four state surveys and the USGS for use in their respective mapping projects. The Illinois Antioch Quadrangle Pilot Study was allocated $96,400, $105,100, and $104,882 for the three-year project. This money funded one full-time geologist and one full-time support technician for data entry and database development. The remaining funds paid for part of the field expenses. The State of Illinois General Revenue Fund (GRF) and other sources paid all drilling expenses, which are billed at $5500/week for the ISGS CME 75 wireline drill rig and $2500/week for the AMS 9600 PowerProbe. We drilled 31 boreholes (8-wireline/23-PowerProbe) in the Antioch Quadrangle and an additional 44 boreholes (17-wireline/27-PowerProbe) in the adjacent quadrangles in support of STATEMAP and EDMAP mapping projects. These were paid in part through funding supplied by those mapping projects, but General Revenue Funds were also used for drilling and field expenses and for most of the geophysical fieldwork (natural gamma logging and surface seismic reflection). Data from the STATEMAP and EDMAP projects was used to develop the Antioch Quadrangle 3-D model and assisted in developing support maps. With the exception of the

single geologist and the support technician, the General Revenue Funds paid for all of the geologists and support staff involved with this Pilot Study.

A conservative estimate of the revenue support contributed by the State of Illinois to this project is 3 to 4 full-time equivalent scientists-technical support personnel/year (approx. $260,000/yr) and 26 weeks of drilling for a total of about $119,000 (about $40,000/year) with most of this drilling occurring during the last two seasons. We now use the CME 75 rig exclusively to drill boreholes and to install monitoring wells in the very thick layer of sediments found throughout the mapping area. The lack of exposures in the mapping area requires us to drill and apply geophysical methods to obtain data for our modeling and mapping. A week of drilling and installing monitoring wells costs about $7000 and a week of geophysical fieldwork costs about $2400. Additional GRF and contract funds were used to purchase equipment and field supplies.

Our continuing success in drilling and retrieving high quality core samples is the result of the drilling procedures and equipment developed or modified by the ISGS drilling team (Jack Aud-Lead Driller; Joe Hutmacher-Driller; Steve Wildman-Driller; Chris Wilson-Driller's Assistant; and Matt Thompson-Driller's Assistant). Their work under often difficult conditions greatly assisted this project and their efficient workflow allows us to complete both a stratigraphic and monitoring well borehole within a 3 to 4 day period.

STS Consultants, Ltd., Vernon Hills, IL, and the ISGS signed a Memorandum of Understanding for which the ISGS obtained access to more than 1600 proprietary engineering records for projects in the study area. The ISGS, in turn, digitized the locations of the boreholes and entered into our archival records and project working database the engineering data and descriptions for these boreholes. We used these data primarily for the development and verification of the surficial geology map. We also supplied STS with copies of the digital files and maps.

The GIS and Mapping Division of the Department of Information and Technology for Lake County, IL provided critical digital products including raster and vector files of subdivisions, transportation networks, corporate boundaries, county forest preserves, and tax parcels through a Memorandum of Understanding signed with the ISGS. They continue to contribute to our mapping effort through periodic meetings and discussions on project status. Through an agreement with the McHenry County Information Technology Department, we were allowed internet access to the digital tax parcel data we needed to verify land ownership and water well locations.

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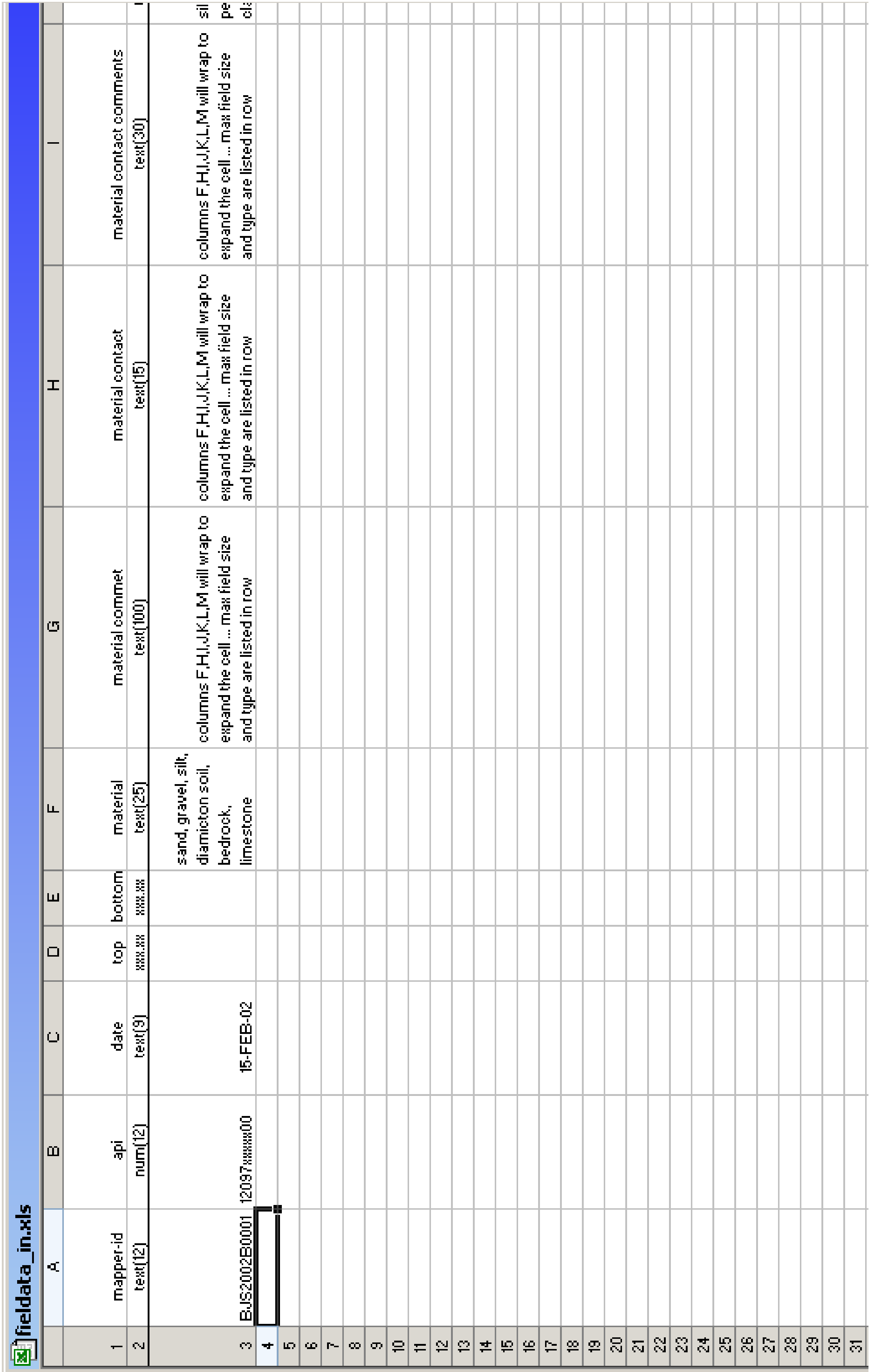

fieldata_in.xls

	A	B	C	D	E	F	G	H	I
1	mapper-id	api	date	top	bottom	material	material commet	material contact	material contact comments
2	text(12)	num(12)	text(9)	xxx.xx	xxx.xx	text(25)	text(100)	text(15)	text(30)
3	BJS2002B0001	12097######00	15-FEB-02			sand, gravel, silt, diamicton soil, bedrock, limestone	columns F,H,I,J,K,L,M will wrap to expand the cell ... max field size and type are listed in row	columns F,H,I,J,K,L,M will wrap to expand the cell ... max field size and type are listed in row	columns F,H,I,J,K,L,M will wrap to expand the cell ... max field size and type are listed in row

Figure 3. Part of Excel-based template used for data entry.

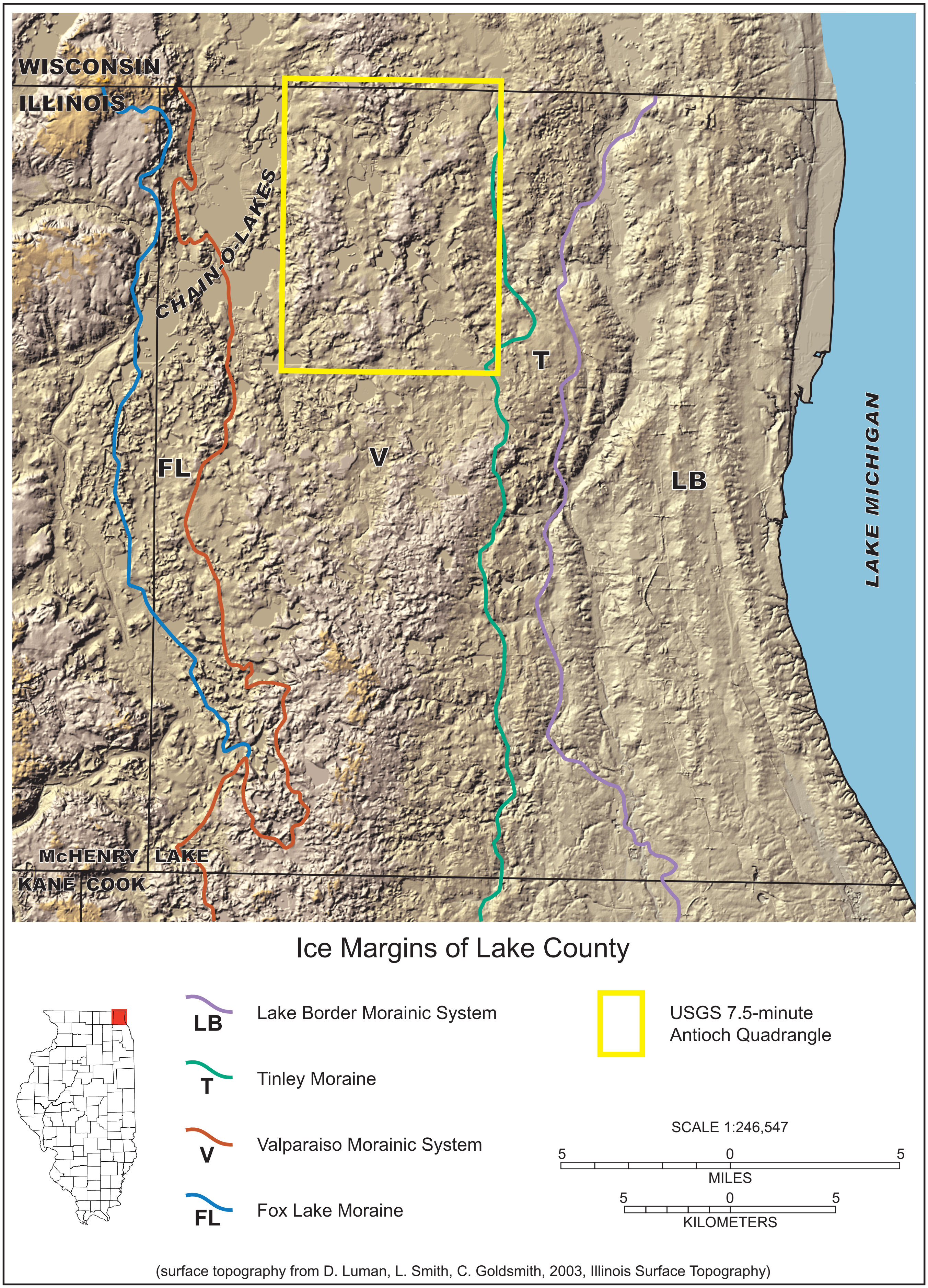

Figure 1. Ice Margins of Lake County

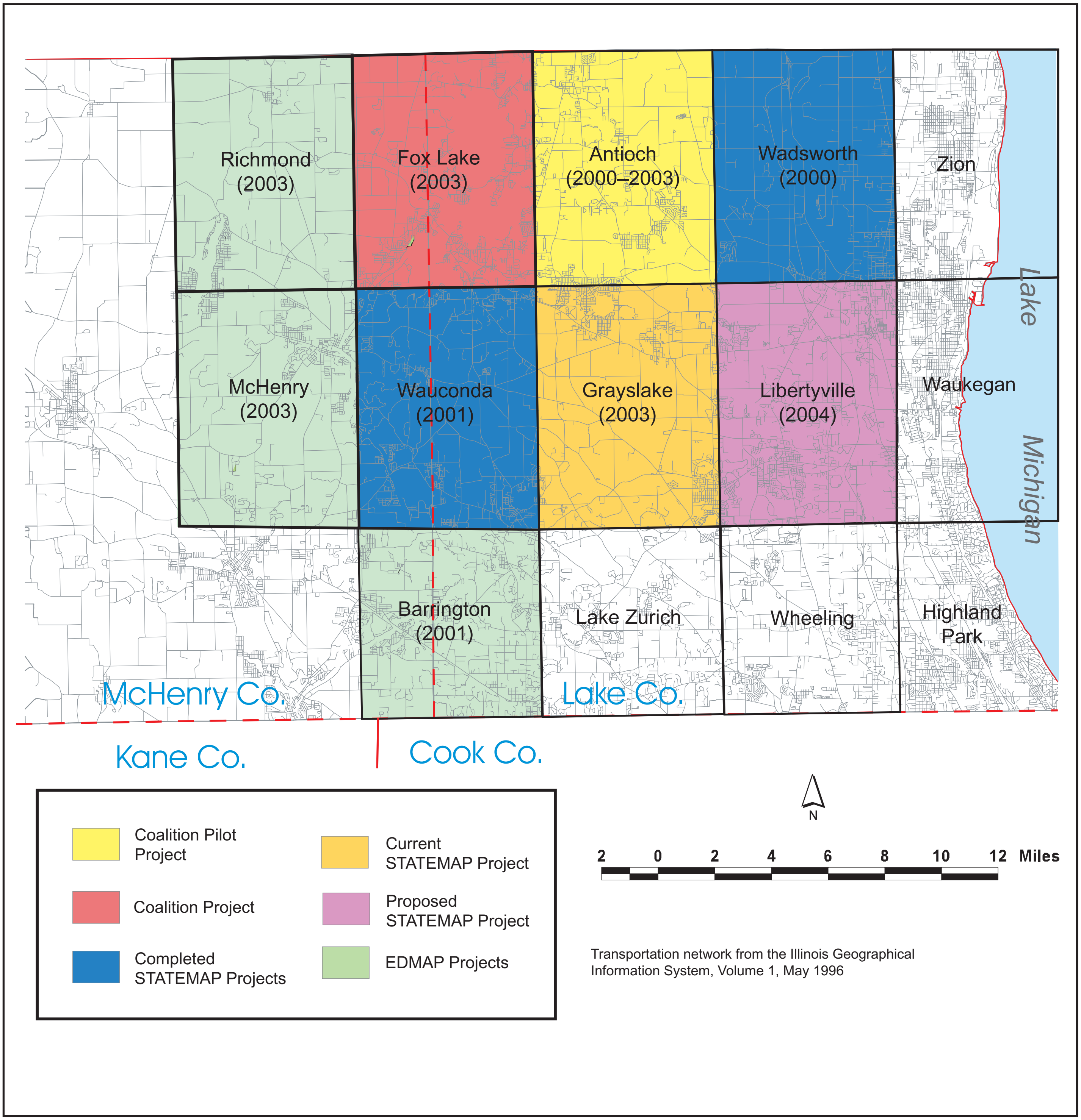

Figure 2. Status of Geologic Mapping in Northeastern Illinois

Table 1. Totals of records entered into digital database, by category and quadrangle.

4/00-5/03 Quad	New Water	Old Water	New Eng.	Old Eng.	New SS/C	Old SS/C	Gamma	ISGS	TOTAL
Antioch	292	1999	589	2	0	116	22	19	**3039**
Fox Lake	624	329	9	17	0	0	43	4	**1026**
Wadsworth	158	676	402	4	0	0	13	22	**1275**
Zion	73	186	78	0	0	0	4	0	**341**
Wauconda	615	1241	1930	135	1	0	19	8	**3949**
Grayslake	64	73	638	80	13	0	2	3	**873**
Libertyville	59	109	635	20	1	0	1	0	**825**
Other	963	1	345	0	0	0	32	12	**1353**
Wisconsin	145	0	0	0	0	0	2	1	**148**
Project Total	**2993**	**4614**	**4626**	**258**	**15**	**116**	**138**	**69**	**12,829**

New water: Records for new water wells; entered directly into digital archival (Oracle) database

Old water: Records in paper archival storage; entered into digital archival (Oracle) database

New eng: Records for new engineering boreholes; entered directly into digital archival (Oracle) database

Old eng: Records in paper archival storage; entered into digital archival (Oracle) database

New SS/C: Records for new sample sets/cores; entered directly into digital archival (Oracle) database

Old SS/C: Records in paper archival storage; entered into digital archival (Oracle) database

Gamma: Natural gamma logs for new water wells and ISGS boreholes; entered directly into digital archival (Oracle) database

ISGS: Records of boreholes drilled by ISGS drill rig; description of location and geologic materials encountered provided by Survey project geologists; entered directly into digital archival (Oracle) database

The old water, engineering, and sample set/core records were each reviewed and edited as needed before entry into the digital database. Many of these records were incomplete and required additional verification and interpretation. Many of the engineering records were related to landfill or other environmental projects.