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HISTORY OF OHIO'S OIL- AND GAS-WELL LOCATION MAPS AND THEIR CONVERSION TO DIGITAL FORM

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INTRODUCTION

The Ohio Division of Geological Survey has just completed a project to digitally capture the locations and basic attributes of all the located oil and gas wells in the state of Ohio. The project began in April 1996 and was completed when the final data were released to the public on September 15, 1997. Three significant products resulted from this project: new digital oil- and gas-well location maps for all townships in the state, a computer database containing all the oil and gas well locations and other basic information, and a new digital base map for the state of Ohio complete with all original land subdivisions. Included in these products are 1,355 digital township well-location files containing approximately 211,000 individual well locations. This project is part of an overall plan to convert most of the geologic data at the Survey into a geographic information system (GIS).

At the start of this project, the staff of the Geological Survey thought we knew all there was to know about these maps and data records. However, through the course of the project we were constantly surprised to discover additional types of discrepancies and errors in the maps and data files. This discovery prompted us to further research the original sources for the data and maps, which we have long taken for granted. Thus, in addition to the planned products of this project, we also have a new understanding of the history of the Division of Geological Survey's oil and gas well spot maps. Some aspects of this project are still underway, including the documentation of the history of oil- and gas-well records in Ohio. Therefore, this paper is the first summary of this project; when complete it is our intention to publish a final detailed publication for reference by future generations working with what is now new digital oil- and gas-well data.

There are many benefits to having the oil- and gas-well information in digital format. It allows for faster and more efficient archival, access, and analysis of the data. These reasons are a driving force in the conversion of the well-spot maps from paper/mylar to digital representations. However, there was also a near-desperate need to convert the existing well-spot maps into the digital realm. The well locations have been spotted on paper and mylar base maps since the 1950's. These maps have been deteriorating over time owing to constant use and are becoming brittle and developing folds, creases, and tears. As new information is added to the maps, older information is erased to ostensibly ensure cartographic readability (fig. 1). However, many of the original maps are becoming unreadable. The Survey has, in the past, recreated some maps, by hand, at a great expense of labor. Therefore, the conversion of the township well-spot maps had to occur fairly soon or we would have had to re-draft many more of these maps.

Prior to the initiation of this project, a consistent set of coordinates locating all the oil and gas wells in the state did not exist. Between 1860 and 1996, approximately 266,069 wells have been drilled in the state (Ohio Division of Oil and Gas, 1996). The location information we have on these wells ranges from almost none to very accurate information. The quality of the location information varies from well record to well record. Some wells have very accurate coordinate location information in the form of footage calls surveyed from the original land subdivisions. A large subset of those wells with footage calls have State Plane Coordinates that were measured from the paper U.S. Geological Survey 1:24,000-scale topographic maps. In large portions of the state, there is no good coordinate information available for the wells located on the township well-spot maps. For example, in the northwestern portion of the state, an estimated 76,000 wells were drilled prior to 1920 (Wickstrom and others, 1992), before permits and location maps were required by the state to locate a well. Only 20,000 of these wells were found on our maps as part of this project. As another example, the Ohio Division of Oil and Gas has a database of wells permitted since 1983. Querying the database shows that of the approximately 100,000 wells in the system, only 60,000 have surveyor's footage calls. Another query shows that only 45,000 of the 100,000 well records contain State Plane Coordinates. As a result of the well-digitization project, we now have a consistent set of coordinates for all wells that are spotted on our township well-spot maps. Additional work will be required to try to locate wells for which we have completion records in our files but no location on our maps.

A complete, accurate base map was critical for the successful digitization of the oil and gas wells. It is important to have an accurate base map so that a well's true location is represented correctly relative to other features on the base map. Wells must be accurately located on the base map to insure spacing requirements are met. Over half the wells on the well-spot maps are located using the surveyor's footage calls measured from land subdivision boundaries.

We feel that the digitizing project has correctly transferred each well's spacing relative to surrounding wells. The new digital base-map files should serve the needs of the oil and gas industry in Ohio well for the location and management of the oil- and gas-well information. The base maps will also be useful to many other agencies and constituent groups.

Anyone using the Division of Geological Survey's township oil- and gas-well spot maps has probably noticed a large variety of permit number types identifying the wells. To research an oil and gas well, one must take the well-permit number found on the township well-spot map and find the well cataloged in the Geologic Records Center files by county, civil township, original land subdivision, and permit number. As the Division and the industry move into the computer age, it becomes necessary to give unique identifiers to all the oil and gas wells to allow proper indexing within the relational databases. The most widely used standard for assigning unique well identifiers is the schema employed by the American Petroleum Institute (API). This coding scheme is the standard for reporting all wells in North America. Permit numbers issued by the Division of Oil and Gas are API compliant. Unfortunately, the Division of Oil and Gas only came into existence and began to issue permit numbers since 1965. Wells prior to 1965 were either not given a permit number, given a permit number by the Ohio Division of Mines, or given a project number by either the Ohio Division of Geological Survey or the U.S. Geological Survey. There are many cases where these well numbers are not unique. In the future, these wells with non-API-compliant permit numbers will be given unique API numbers so they can be entered into the database. For now, the original permit number that identifies the well on the map must be maintained, because this number ties the well-spot location on the map back to the Geologic Records Center well card. These original permit numbers also will be stored in the new database system to provide a cross reference to earlier work. Understanding the origin of the permit number associated with each well helps the Division in its task of assigning unique API numbers to each oil and gas well.

HISTORY OF THE TOWNSHIP MAPS

Prior to this study, there has never been a published history of Ohio's oil-and-gas well-spot maps. To allow proper conversion into a GIS, it is important to understand the history of these maps. We need to know the data sources and the completeness of the well information used. We also need to understand the different type of well-identification numbers on the maps. As we move the map series into a geographic information system, we must have unique identifiers for each well location. The evolution of the regulations governing oil- and gas-well operations in Ohio has much to do with the history of this map series.

Information on the spot maps comes from at least four sources: the Ohio Division of Mines, the Ohio Division of Oil and Gas, the Ohio Division of Geological Survey, and the U.S. Geological Survey. There may be other sources of information for the well locations, which we are continuing to research.

It was of particular interest for this project to know when surveyed locations (plat maps) began to be required for well locations and when and how permit numbers were first issued in Ohio. Three summaries of regulations concerning oil and gas operations have been found during this investigation. These summaries are from Wilson (1951), DeBrosse (1994), and a 1979 internal memo from the staff attorneys of the Division of Oil and Gas. Unfortunately, there are conflicts among these summaries concerning certain regulations. For example, there are serious conflicts for the date when plat maps were first required for the location of a well. Additional research was necessary to resolve these conflicts.

The locations of the wells on the spot maps are primarily derived from plat maps submitted to the state. These maps are required as part of the permit for drilling an oil and gas well. Plat maps for oil and gas wells were first required by the state in 1898 to protect coal-mining operations. The plat map was submitted to the Chief of the Division of Mines for all wells drilled in coal-bearing townships. This requirement was changed in 1951 so that plat maps were required for all wells drilled in the state. This change in 1951 was a significant development. Between, 1898 and 1951, only wells in the coal-bearing townships of eastern and southeastern Ohio had plat maps submitted for them. This requirement left out the significant drilling activity northwestern, central, and central-northern Ohio. These well locations would not have been filed with the state; hence, their locations had to have been gathered from other sources. Thus, the locations for many of these wells are of questionable accuracy; many can not be located better than placing them in the proper land subdivision, and some must be considered lost at this time.

There are several different types of well-identification numbers on the well-spot maps. The majority of the well-identification numbers have been issued by two State agencies as part of the permitting process. The former Division of Mines in the Ohio Department of Industrial Relations had regulatory control over oil- and gas-well operations between 1880 and 1965. After 1965, regulatory control over oil and gas operations was shifted to the newly created Division of Oil and Gas within the Ohio Department of Natural Resources. There are other well-identification numbers located on the well-spot maps. The most numerous types of nonstate well-identification numbers come from a study done by the U.S. Geological Survey on the Bedford Shale and Berea Sandstone in the Appalachian Basin (Pepper and others, 1954). The U.S. Geological Survey needed a method to identify well locations and well logs for this study. Two other types of well-identification numbers are the "D" numbers and the "L" numbers. Both of these numbering schemes were created by the Ohio Geological Survey for projects that they were conducting in the late 1950's and early 1960's. These three projects form the bulk of the nonregulatory-assigned well-identification numbers.

The Division of Mines assigned "A" numbers to all wells in coal-bearing townships drilled prior to 1936. These numbers were not unique; all the wells drilled within a lease were given the same number, followed by "–A" at the end of the number (fig. 2a). Permit numbers were first

issued by the Division of Mines in 1936; these were almost unique. Permits were issued per application rather than per well. A permit application with one well was issued a unique permit number. If an application had two or more wells in it, then the permit number applied to all wells. To differentiate individual wells, they would add the well number to the end of the permit number (fig. 2b).

In 1965, the Ohio Division of Oil and Gas was created for the specific purpose of the regulation of oil and gas wells in the state. The Division of Oil and Gas issues a unique permit number per well sequentially per county following API recommendations. The Division of Oil and Gas began the number series with the last permit number issued by the Division of Mines in each county. These unique permit numbers correspond to the American Petroleum Institute's numbering scheme for all wells in the United States and Canada (fig. 3). The Ohio Division of Oil and Gas also began to issue new "A" number permits for old wells that they discovered in their regulatory investigations and for storage wells drilled between the time periods around 1960-1963 and 1966-1967. The new "A" series permit numbers are issued for only one well, unlike the older "A" series permit numbers issued by lease or application. These maps and different permit-numbering schemes are only the official part of the locations on the township spot maps.

The U.S. Geological Survey conducted a project to locate wells as part of an effort by the U.S. government to discover strategic petroleum resources needed to conduct U.S. participation in World War II. James Pepper was placed in charge of the study to look at the Bedford Shale and Berea Sandstone in the Appalachian Basin (Pepper and others, 1954). For this study, drillers' logs were collected from various sources and the corresponding well locations were plotted on a map and assigned numbers. In Ohio, the U.S. Geological Survey geologists first plotted the locations of the wells on township well-spot maps provided to them by the Ohio Fuel Gas Company (predecessor to Columbia Natural Resources). After they had plotted the locations on the township base maps, the locations and their identifiers were transferred to U.S. Geological Survey 15-minute topographic maps. The well-identifier scheme is based upon the 15-minute topographic maps. Each well identifier is created using a state code, a 15-minute topographic quadrangle code, and a 5-minute quadrangle subcode. The unique number for Ohio is 1000. Figure 4 shows all the 15-minute quadrangles used in the study for Ohio. Each 15-minute quadrangle was assigned a unique number. Each quadrangle was subdivided into nine 5-minute rectangles by latitude and longitude, and each rectangle was assigned a number (fig. 5). The wells were assigned numbers sequentially within each 5-minute rectangle as they were located in the U.S. Geological Survey offices. These 15-minute topographic maps with the well locations are called the Pepper maps and the well identifiers are called Pepper numbers. The Ohio Division of Geological Survey has copies of all the Pepper maps for Ohio that were created as part of that study.

The current township-base oil-and-gas well-spot maps were created by the Ohio Geological Survey between 1957 and 1961 under Ted DeBrosse. The basic work plan for the project involved gathering county engineer tax maps from each of the counties that had reproducible tax maps. The maps that were gathered were generally at the scale of 1:15,840. Some of the maps were at a larger scale. For example, the Mahoning County tax maps were at a larger scale, each covering an area of one quarter-township. These county tax maps were photographically reduced to the 1:15,840 scale and then assembled to create a single township map. Unfortunately, the original quarter-township maps were either not at the correct scale or there were mistakes in the assembly process. The assembled township maps have overlaps and gaps along the quarter-township boundaries. While some counties maintained up-to-date tax maps for their county, other counties' maps were very out of date. For example, the tax maps for Adams County date back to the 1880's! The variable age and scales of the tax maps made the process of transferring the well information difficult. Once the Survey obtained the tax maps for a county, the oil- and gas-well plat maps from the Ohio Division of Mines were collected and their well locations and attributes were transferred to the tax maps. The ownership information on the plat maps was an aid in the transfer to the tax maps.

When the Division of Oil and Gas was formed in 1965, Mr. DeBrosse became part of that division. Photographic reproductions of the Survey's township spot maps were provided to the new division and became the standard base upon which it spotted wells. For many years each division hand-spotted the same wells on their respective copies of the same maps, the Division of Oil and Gas for regulatory usage and the Division of Geological Survey for release to the public. This duplication inevitably led to differences in the two map copies. As part of the current computerization project, the differences between the maps are being resolved and both divisions are now using the same digital maps.

The township well-spot maps were created at a scale of 1:15,840, which is more commonly known by the verbal scale of 1 inch to 1,320 feet or 4 inches to a mile. There are many problems in using these maps as a base for spotting well locations. The land-ownership information on the maps is out of date by anywhere from 30 to 50 years or more, and keeping this information current is well beyond the means of either the Division of Geological Survey or the Division of Oil and Gas. Some maps, which were photographically compiled, show edge-matching errors. Many of the maps are greatly out of scale in both the x- and y-axis from years of being pulled through various copy machines. Finally, the largest problem with the township well-spot maps is that many of them do not have the land subdivisions drafted correctly. The tax maps are not legal documents and are not required by law to be accurate. They were assembled by the county engineer to serve as an <u>index</u> to parcel ownership only and are not the legal means by which parcel ownership is represented and conveyed. On many of the maps it appears that the draftsmen idealized the land subdivisions. For example, the draftsmen drew orthogonal, 1-mile square sections, when in reality the section is not a square mile in area nor are the corners at 90° angles (fig. 6). For the digitization phase of this project, rectifying these inaccuracies of the township maps was the biggest challenge.

BUILDING A DIGITAL BASE MAP

To produce any sort of accurate product in this digitization effort, it was necessary to register our inaccurate paper and mylar township spot maps to an accurate representation of the land subdivisions for Ohio. This process is known as "rubber-sheeting." Via a process called *digitizer setup,* the operator registers a number of points on the mylar map (minumum of four points) to corresponding points on the digital map. The computer program then stretches and squeezes the input to minimize error over that area. The setup program reports error statistics that allow us to judge how accurate our representation will be. Our accuracy requirements for spotting wells on a base map must be less than 100 feet. Some of the mylar townships were so distorted that a digitizer setup had to be run on each section/subdivision in the township.

Therefore, the success of this project largely depended on the accuracy of the digital base map that we used. There have been a number of previous efforts to build a digital base map for Ohio, the first started in the early 1980's by the Ohio Department of Transportation (ODOT). Between 1980 and 1985 ODOT digitized the following elements from the U.S. Geological Survey 1:24,000-scale topographic maps: 7.5-minute quadrangle boundaries; political boundaries such as state, county, township, and municipal boundaries; Public Land Survey System (PLSS) boundaries (sections); roads and railroads; airport locations; and hydrography (streams and lakes). Another effort to build a contiguous statewide base map was initiated by the Public Utilities Commission of Ohio in the late 1980's. These files did not include the PLSS section lines, which were of critical importance to our project. There are other small-scale digital base maps that are available for use, such as the U.S. Bureau of the Census TIGER files and the U.S. Geological Survey 1:100,000-scale digital line graph (DLG) files. Both the TIGER files and the 1:100,000-scale DLG files were considered to be too inaccurate for spotting the locations of the oil and gas wells. In addition, the TIGER files did not include the PLSS section lines, and the 1:100,000-scale DLG files did not completely cover the entire state.

The Survey had been using ODOT's digital base maps since 1987 for smaller scale mapping projects and, therefore, we were familiar with their structure. When we started this project we thought these files would be sufficient for us to build upon. Unfortunately, we discovered a number of problems associated with these files. First, although ODOT did perform quality control on the layers that were of importance to their mapping, the PLSS lines were not a priority so did not have very rigorous quality control performed. Initial comparison of the PLSS lines between the paper 1:24,000-scale-topographic maps and the digital files showed errors ranging up to 500 feet. The PLSS layer was one of the most critical features needed for our project. We had hoped that by using ODOT's section lines, we would only have to digitize the irregular subdivisions in the state. The second major problem discovered in the ODOT files was the Ohio State Plane Coordinate System zone boundary. By law, the Ohio State Plane Coordinate System zone boundary falls along a specified set of county lines (Ohio Revised Code, 1985). When ODOT digitized those counties and quadrangles that fall along the zone boundary, they introduced a distortion so that neighboring counties in different zones could be merged seamlessly together without a coordinate transformation. This distortion ranges anywhere from 0 to 200 feet for those boundary counties, depending upon distance from the principal meridian. This distortion affected elements within those county files, rendering them useless for our needs.

Luckily, several Ohio state agencies, including ODNR, are involved in a cooperative agreement with the U.S. Geological Survey (USGS) to convert all the USGS 1:24,000-scale topographic maps to digital line graph (DLG) files. The resultant DLG files are very accurate digital representations of the elements comprising the 7.5-minute quadrangles. The contractor for the project was The Ohio State University's Center for Mapping. The project is known as Generating Information from Scanning Ohio Maps (GISOM) (Ramirez, 1997). The DLG files, when complete, will represent the most accurate, contiguous, and consistent set of digital base maps available across the state of Ohio.

Using the new DLG files was considered to be our best solution for a number of reasons. These data conform to the National Map Accuracy Standards for 1:24,000 scale, which translates to an accuracy of (40 feet (U.S. Bureau of the Budget, 1947), which meets our accuracy needs. Another reason for using the U.S. Geological Survey DLG maps is because they include the hypsography (topographic contours). No other map series in the United States has as detailed hypsography as this map series. The final, and most compelling, reason to use the DLG files is the accuracy of the PLSS features. Although the USGS does not claim legal responsibility for the accuracy of the PLSS data, it was discovered that considerable effort was made to recover the PLSS section corners for Ohio. According to the specifications used to create the topographic maps (U.S. Geological Survey, 1980), all efforts must be made to recover the PLSS section corners so that the PLSS lines can be represented accurately. Examination of the original source materials stored at the USGS offices in Rolla, Missouri, revealed that the mapmakers and surveyors collected, in the field, the locations of the original section corners. The surveyors used copies of the original survey plats from 1786 to 1820 to survey and recover the section corners. These copies of the plats came from the National Archives in Washington, D.C. This effort to accurately recover and represent the section corners gave us confidence that this map series would meet the needs of the oil and gas industry to locate wells throughout the state of Ohio.

Unfortunately, the GISOM project was not completed by the time we needed the base map for this project. After we had finished capturing well locations and attributes for the western half of the state, we discovered that the ODOT base map we were using was not accurate enough for our purposes. We then had to start over again and build the base map using the DLG files. But, because the GISOM project was not completed at that point, we had to digitize some of the political boundaries and PLSS section lines from the 1:24,000-scale topographic maps. The quality-control checking of our digitizing of the political boundaries and PLSS

lines indicates that our work is within National Map Accuracy Standards. We plan to go back and substitute in the newly released DLG files for those quadrangles we had digitized. Because our digitizing conforms to the National Map Accuracy Standards, replacing our digitizing with the DLG data will not degrade the accuracy of the digitized well locations.

In addition, the DLG files were supplemented by adding the original, irregular land subdivisions. Ohio was the first state in which the federal government subdivided the land before it was sold. This process started in 1785, right after the end of the Revolutionary War. Between 1786 and 1838, many different schemes were used to subdivide the land. In Ohio, nine major schemes were used, along with many different minor subdivisions (Sherman, 1925). Eventually, the federal government settled upon the scheme that is now known as the Public Land Surveying System (PLSS). This system was first applied in the United States in northwestern Ohio. The PLSS layer in the DLG files does not include the irregular land subdivisions of Ohio. These irregular subdivisions occur in the following surveying districts: Virginia Military District, Ohio Company Purchase, Donation Tract, Connecticut Western Reserve, and U.S. Military District. There are also numerous other small surveys in which irregular subdivisions occur, such as the French Grants, Refugee Grants, the Twelve-Mile-Square Tract; these divisions are well described in Sherman (1925). There are many wells located by footage calls in these areas of irregular land subdivisions. Therefore, it was important that we add the irregular land subdivisions to the PLSS layer of the DLG files.

We needed to capture the irregular land subdivisions for our work to accurately digitize the well locations. The process that we used involved digitizing the irregular land-subdivision lines from the county engineer tax maps. In some cases, the irregular land-subdivision lines were not reliable or could not be read from the tax maps. In those cases, we used alternative sources for the irregular land subdivisions. These sources included Ohio Fuel Gas township-well-spot maps, Ohio Division of Geological Survey county base maps, county plat books, Pure Oil Company township well-spot maps, larger scale subdivisions from Sherman (1925), Sherman's (1922) map (used as a secondary source of Virginia Military District lots), and the Quaker State Oil Company base maps (used especially as a tertiary source for the Virginia Military District lots). We would do a digitizer setup of a township tax map to the digital base map assembled from the DLG's. If the misclosure between the township map and the digital base map was greater than 50 feet, then a digitizer setup was performed on a smaller area of the tax map. Once an acceptable digitizer setup was established, the operator digitized the irregular land-subdivision lines into the graphics file.

Our resultant digital base-map series now contains new county, township, section and irregular subdivision lines either captured from DLG files or digitized at the Survey. The digital ODOT files have been rectified to fit these new bases to allow us to use their hydrography and textual labelling. In the near future we plan to bring in the hypsography, hydrography, and roads from the new DLG files. We then plan to add major roads and streams to the new digital township well-spot maps. We also intend to offer 7.5-minute quadrangle well-spot maps, complete with topographic contours, in the near future.

DATA CAPTURE AND QUALITY CONTROL

Capture of the oil- and gas-well locations and attributes was accomplished via a contract from the Ohio Department of Natural Resources with the Ohio Penal Industries (OPI). OPI acted as the data-capture contractor for the project by supplying inmate labor from within the Ohio prison system. While the inmates provided the labor for the project, OPI's subcontractor, Lockwood, Jones, and Beals, Inc. (LJB), provided project management, oversight, inmate training, and software programming. The Ohio Division of Geological Survey provided clean master well-location maps and copies of the well-location maps, the digital base-map files, and final quality control of the submitted product. This division of labor worked quite well and enabled the successful completion of the project.

Lockwood, Jones, and Beals, Inc., provided software to help automate the data-capture process. The first program supplied was designed to facilitate digitizing the well symbols at the specified location. LJB designed a menu of well symbols that the operators were to use when digitizing the well locations. The menu contained all 34 permissible well symbols found on the Survey's spot maps (table 1). It also contained a special well symbol for an unknown well status. The second program enabled editing of the well symbol and the attributes surrounding the well symbol. The final program supplied by LJB loaded the database with the information contained in the graphics files.

The Ohio Division of Geological Survey provided rules for the prisoners to use when capturing the well locations and the limited set of attributes surrounding the well. Many different people have maintained the well-spot maps for over 40 years. This diversity created an environment for a lot of variability on the maps. The rules given to the operators at OPI and LJB helped reduce the variability of both the number of well symbols and the attributes surrounding the well location. Another reason for establishing data-capture rules is that the project management team and the operators were unfamiliar with the oil- and gas-well information that they were required to capture. The rules successfully constrained the data-capture process and avoided many data-interpretation errors.

One of the most critical components of this project was to conduct quality-control tests to check whether the well-spot maps were converted accurately. The basis for these quality-control checks was for the checkers to overlay the original mylar well-spot maps on the new plots of the digital well-spot maps. The quality-control checks were performed a number of different times along the way to acceptance. First, the contractors at OPI had an operator perform quality-control checks on the finished graphics file. If any problems occurred, the corrections were done at the OPI facility. LJB then picked up the graphics files for an area and performed their own quality-control checks. Finally, the graphics files along with the original source materials were delivered to the Ohio Division of Geological Survey. At

the Survey, college interns did quality-control checks on all the township maps returned by the contractor. If the interns found a map that had a high percentage of unacceptable well locations and attributes, then the original maps, along with the changes to be made, were returned to the contractor for correction. The files corrected by the contractor were returned to the Ohio Division of Geological Survey for further quality-control checks. The quality-control loop continued until the Ohio Division of Geological Survey accepted the new digital map.

Once we had accepted a graphics file from the contractor, there were still edits that needed to be made at the Survey. After the final edits using the rules applied to the contractor were made, further edits were done using a new set of rules. The second set of rules was made so that the maps conveyed information that the Ohio Division of Oil and Gas needed to conduct their work.

RESULTS

Many results will come from this project. We are moving away from mylar and paper well-spot maps that had been the traditional product used by the oil and gas industry for over 100 years. One major advantage of the new digital well-spot maps is that they will not decompose over time, as do the paper maps. The mylar township-well-spot maps suffer from readability problems. As wells are spotted on the mylar maps, original information is erased to accommodate new information, and is lost forever. The new computer-plotted well-spot maps are much more readable than those they replaced (fig. 7). Plus, additional elements such as roads, streams, etc. can be added and, using sophisticated visualization and plotting techniques, this information can be faded and screened to enhance readability and avoid the loss of ancillary information on the plotted maps. The new base maps are far more accurate than the 30- to 50-year-old county engineer tax maps that were being used as base maps. The digital data will enable the rapid update of the well-spot maps and enable the public to perform analyses that are more complex. The graphics that symbolize the well locations are attached to an initial database that will grow over time as data are added from the Division of Geological Survey well cards and records from the Division of Oil and Gas. The data files obtained from this project will allow the Division of Oil and Gas to inventory wells with nonstandard permit numbers and issue API-compliant numbers for all these wells. The data files will also form a skeletal database for over 211,000 wells that can now be merged with the new Risk-Based Data Management System (RBDMS) which the Geological Survey and the Division of Oil and Gas are now implementing. These new digital well-spot maps are the beginnings of an integrated geographic information system for the Division of Geological Survey and the Division of Oil and Gas. The well-data files and graphics files from this project are all freely available to the public via the ODGS World Wide Web site or on magnetic media.

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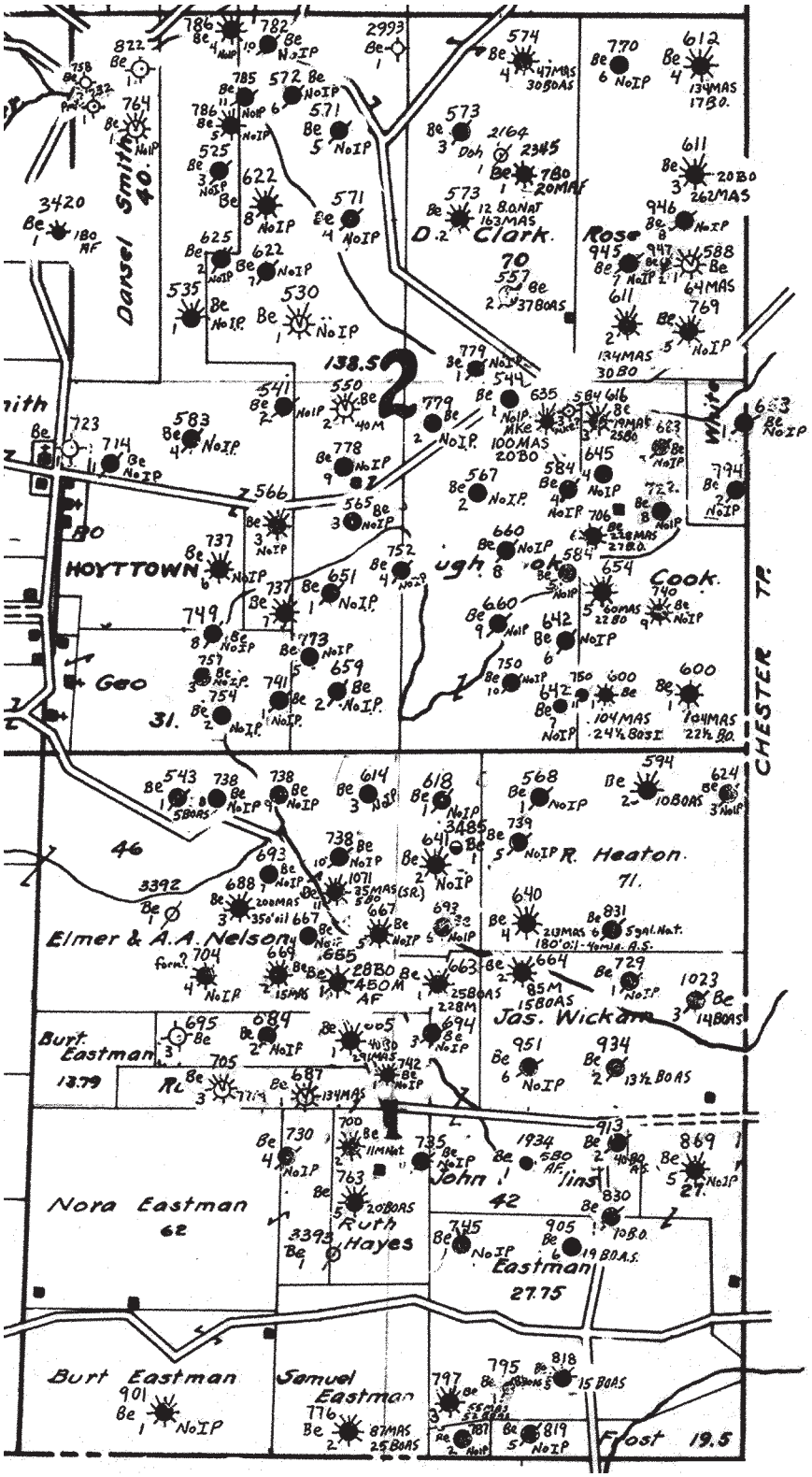


FIGURE 1.—A portion of the old township-based well-spot map for Bedford Township, Meigs County. Note the very cluttered, hard-to-read nature of the well information. Note also how much of the background information (lease names, roads, streams, even subdivision numbers) has been erased to make room for the well information. Compare to figure 7 for readability. See table 1 for well-symbol explanation.

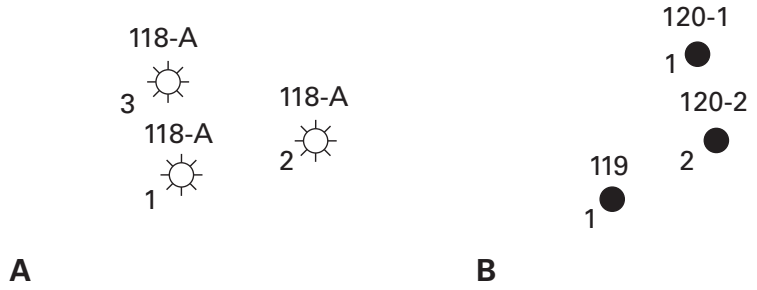


FIGURE 2.—Examples of different "A" numbering schemes. **A**, pre-1936 scheme; all wells on a lease given same number followed by "–A." **B**, 1936-1965 scheme; all wells on an individual application given same permit number followed by well number.

1 2 3 4 5 6 7 8 9 0

where:

1-2 = State ID code, Ohio = 34

3-5 = API County, Parish, or offshore Area code, alphabetical: in Ohio Adams Co. = 001, Wyandot Co. = 175

6-0 = Well code/spatial data ID
Division of Oil and Gas assigns permit numbers for wells serially by county following the guidelines of:
Historical wells = 00001 - 20000
Current wells = 20001 - 60000

Many states follow API's suggestion of assigning wells serially, by county, by year (e.g., first permitted well in a county for the year 1991 = 91001).

Under Ohio's current use of the API system, the well code numbers in the range 60001 - 99999 could be assigned to other data categories.

State Codes 01 - 89 are reserved by API for identifying states, offshore areas and Canadian provinces. Numbers 90 - 99 are reserved for internal use by companies. If needed, 90 - 99 could be utilized to identify other categories of data in Ohio.

FIGURE 3.—American Petroleum Institute basic 10-digit well-identification scheme.

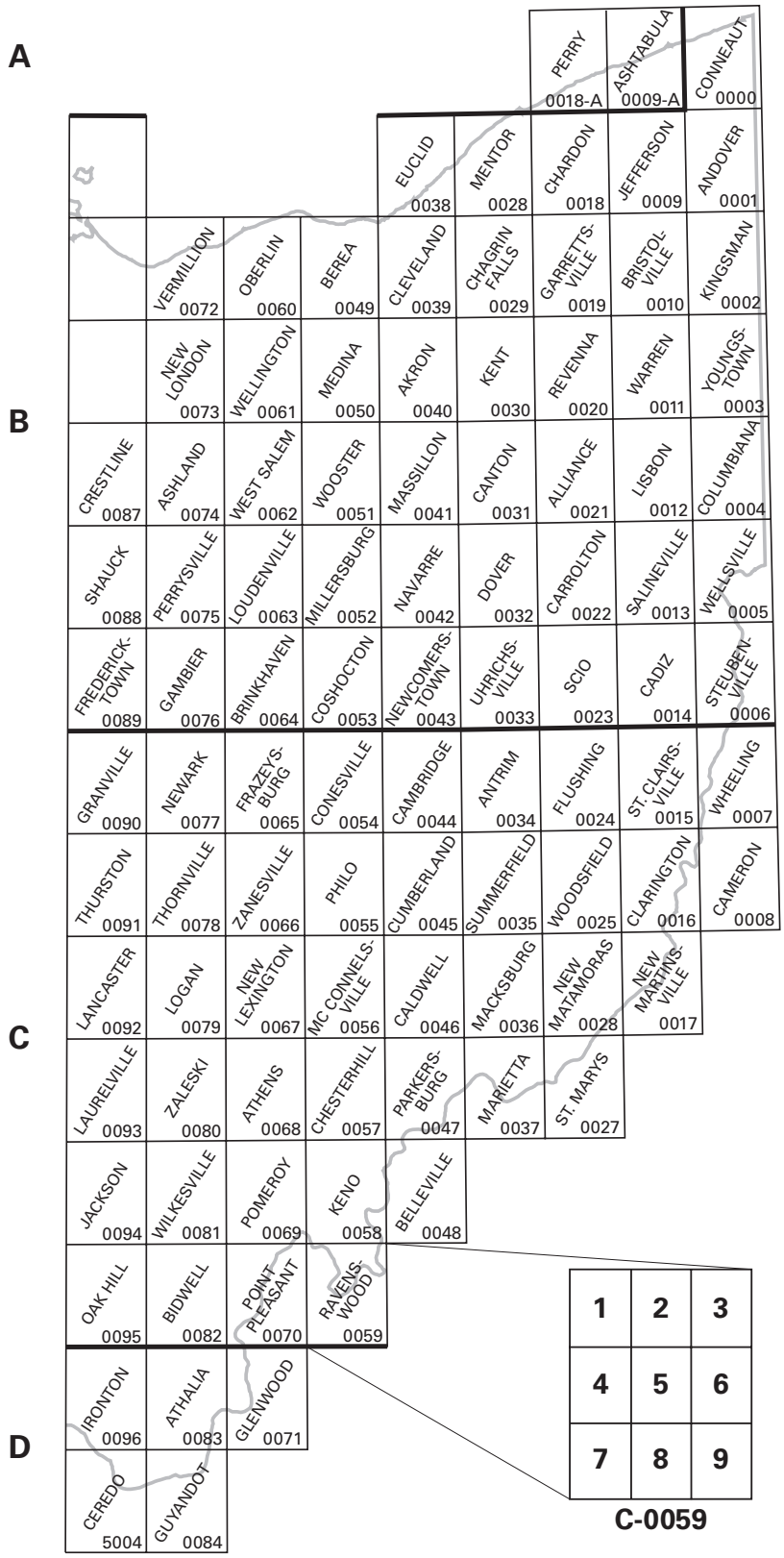


FIGURE 4.—Index map showing the location, name, and number of all the 15-minute USGS quadrangles on which Pepper and other USGS workers located wells in Ohio.

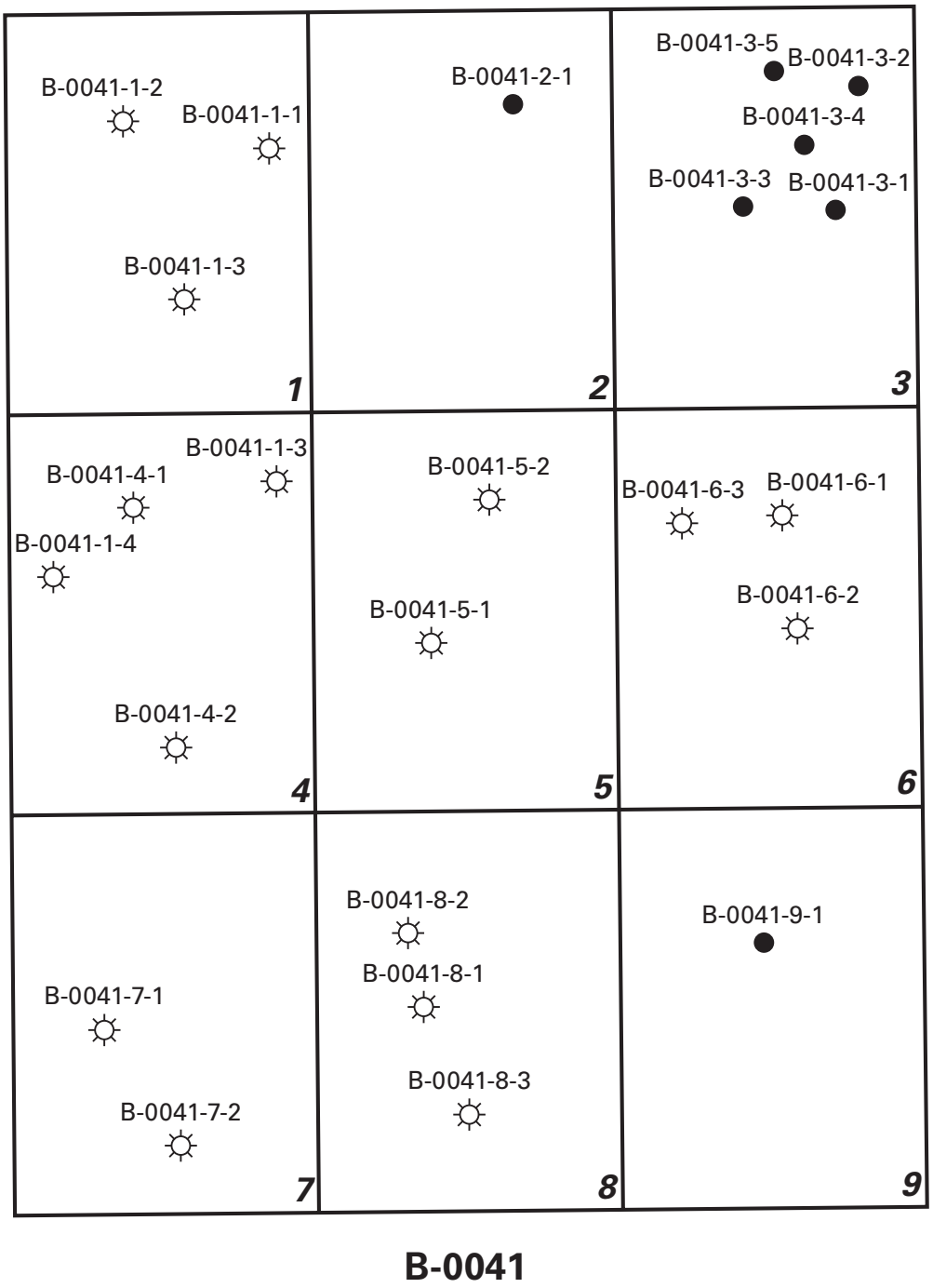


FIGURE 5.—Example of the subdivision of a Pepper 15-minute quadrangle and how wells were sequentially numbered within each 5-minute subquad.

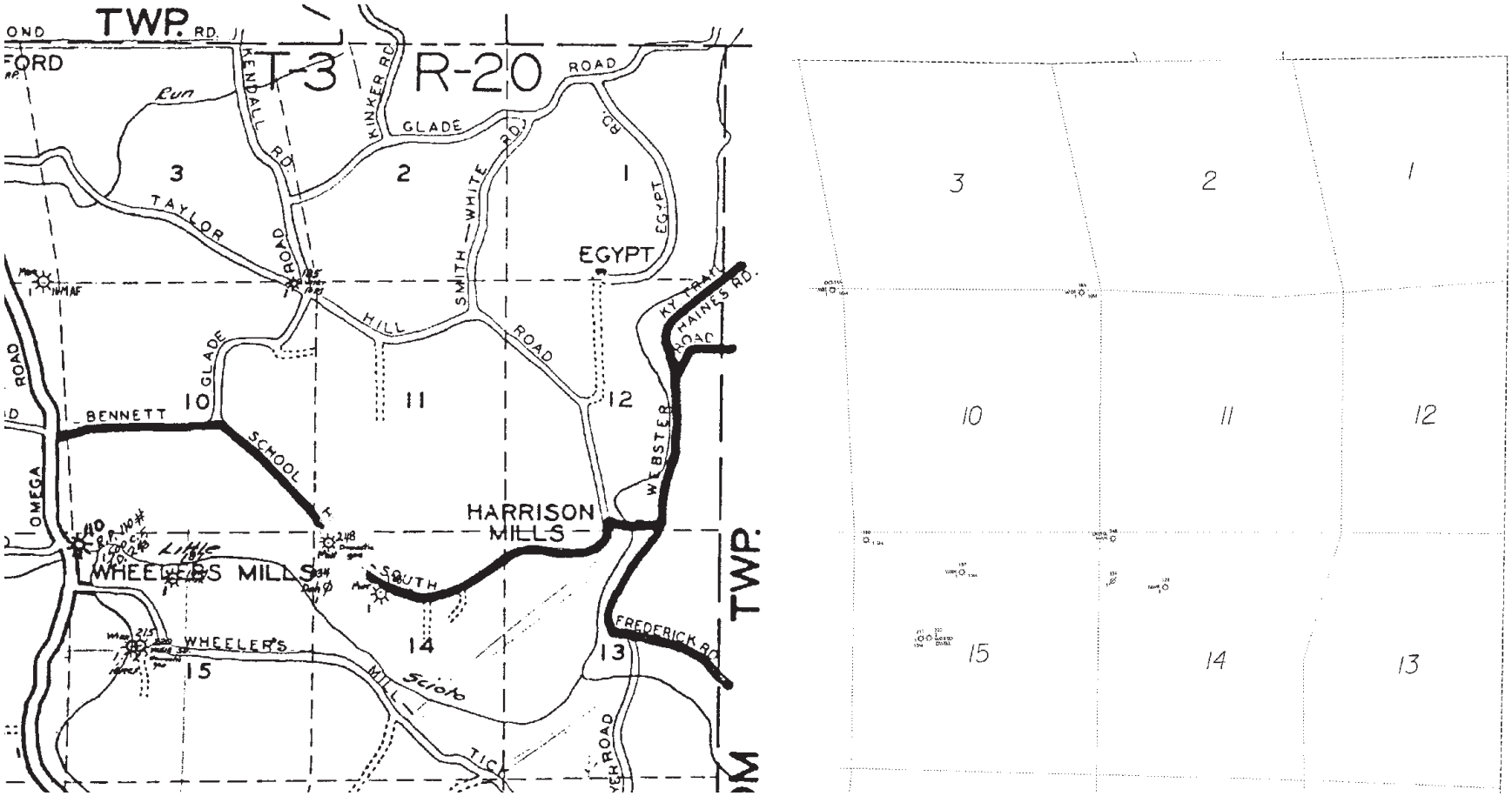


FIGURE 6.—Maps of a portion of Harrison Township, Scioto County, showing **A**, the land subdivisions as depicted on the old township well-spot map, and **B**, the same land subdivisions from the new digital base map compiled from USGS 7.5-minute quadrangle DLG's. Note the different shapes and sizes of some of the subdivisions. Note particularly how the eastern boundary line of section 14 jogs to the northeast in figure 6b but is straight on figure 6a. There is over 300 feet of misclosure between the two maps at the northeast corner of section 14. See table 1 for well-symbol explanation.

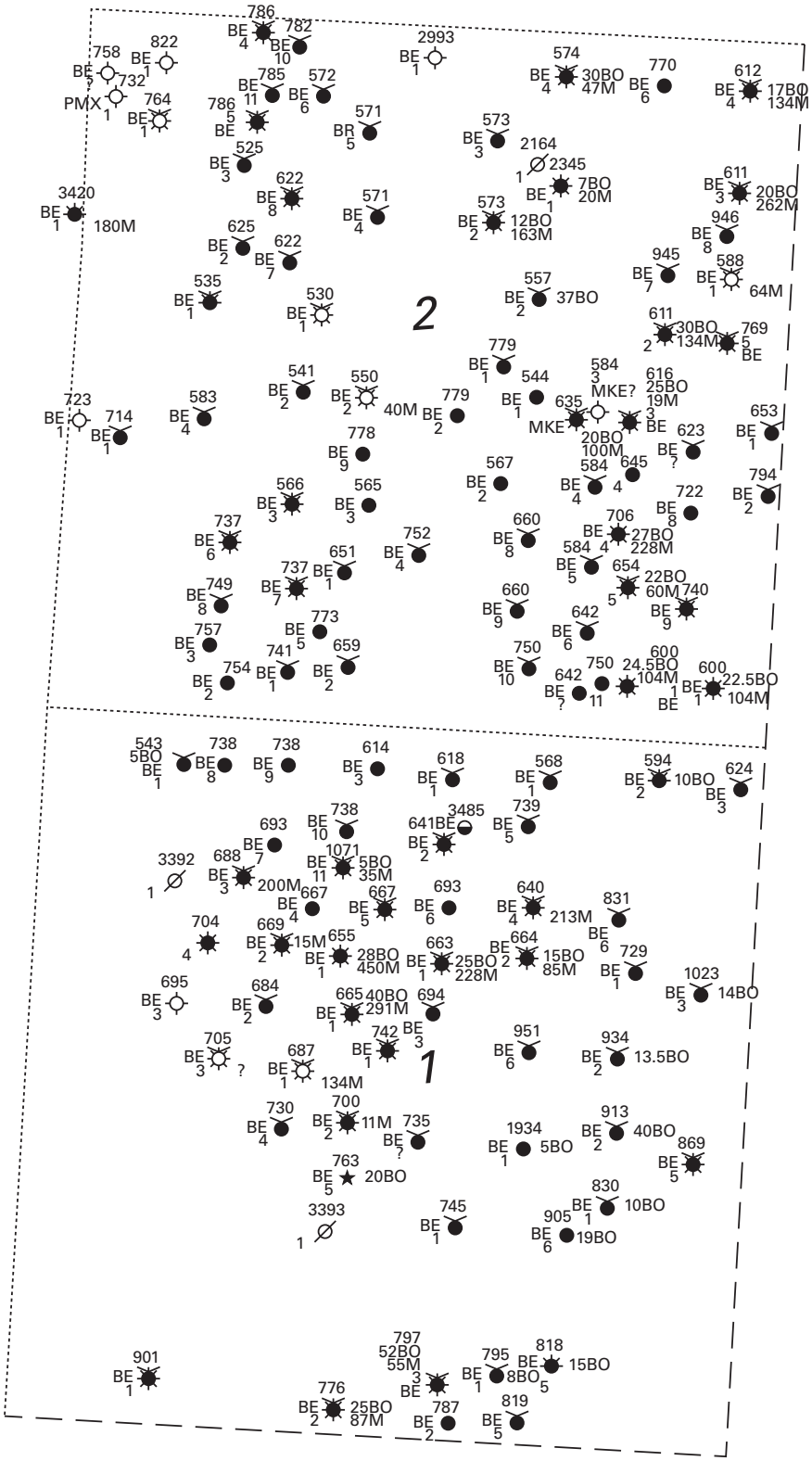
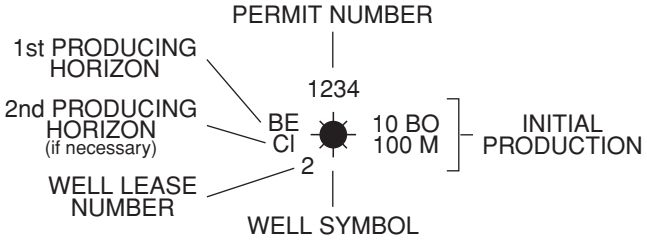


FIGURE 7.—A portion of the new digital township well-spot map for Bedford Township, Meigs County. Compare to figure 1 for readability. Background information (roads and streams) will be added to these maps in the near future.

TABLE 1.—Well symbols shown on township well-spot maps.

	Permitted location
	Expired permit location
	Gas show
	Gas well
	Plugged gas well
	Gas and oil show
	Plugged gas and oil show
	Oil show
	Oil well
	Plugged oil well
	Gas well with oil show
	Oil well with gas show
	Plugged oil well with gas show
	Oil and gas well
	Plugged oil and gas well
	Plugged gas well with oil show
	Dry hole
	Dry hole with gas show
	Dry hole with oil show
	Dry hole with oil and gas show
	Injection well
	Plugged injection well
	Well producing oil and gas from multiple horizons
	Plugged well that produced gas from multiple horizons
	Well producing gas with a show of oil from multiple horizons
	Well producing gas from multiple horizons
	Well producing oil from multiple horizons
	Plugged well that produced oil with a gas show from multiple horizons
	Plugged well that produced oil from multiple horizons
	Well producing oil with a gas show from multiple horizons
	Plugged well that produced gas with an oil show from multiple horizons
	Plugged well that produced oil and gas from multiple horizons
wwell	Well originally drilled for oil and gas, but converted to a water well
wwell	Plugged water well
	Unknown status