Mapping Bedrock: Using models to determine bedrock depth across a large area

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The history of groundwater quality issues and the high prevalence of karst features in Northeastern Wisconsin were major factors in the formation of the Northeast Wisconsin Karst Task Force. The mission of the task force was to examine existing scientific data and make recommendations on land management and technologies to reduce agriculture's impact on groundwater quality. A report summarizing the findings and conclusions titled “Final Report of the Northeast Wisconsin Karst Task Force” was developed and released in February of 2007. After this report was distributed, the UW - Discovery Farms Program published “Review and Comment on the NE Wisconsin Karst Task Force Report” stating that:

“although much useful information was provided by the Karst Task Force, the report was inadequate in the identification of sources that impact water quality and that it overstated the soil risks. Discovery Farms recommended further evaluation to more accurately identify the depth of unconsolidated surface materials over the carbonate bedrock.”

In response to the need for accurate and practical information, the UW - Discovery Farms Program developed a pilot mapping program to identify the thicknesses and distribution of soils and unconsolidated materials in Calumet County. This is the second fact sheet in a short series providing information on the various aspects of this project and provide an overview of how these technologies can be utilized to better determine depth to bedrock.

Existing information on depth to bedrock

In Wisconsin, soil surveys were/are conducted to provide information on materials from the land surface to a depth of 5 - 8 feet. Surveys began in the early 1900’s, and from that time until the present, soils data has been collected and continually updated based on more recent surveys. Today, 100% of the land in Wisconsin has been surveyed and has soils information. However, the age of the most recent soil survey can vary significantly between counties (some from 1961). Soil survey information for each county can be found at: http://soils.usda.gov/survey/printed_surveys/state.asp?state=Wisconsin&abbr=WI

From soil surveys, information can be obtained on where bedrock is likely to exist if it is within 5 - 8 feet of the soil surface. Much of the soils information, especially relating to older soil surveys, was obtained using a combination of topographic maps (to read land features), and bucket augers to take soil samples (Figure 1). Although the bucket auger method provides a good representation of the soil profile, the refusal of the auger to dig further can result from large rocks imbedded in the soil profile or from densely packed glacial till. In some instances, the refusal of the bucket auger to dig further was annotated as coming in contact with bedrock; when instead the auger encountered a large rock or glacial till. If an erroneous judgment was made on bedrock contact, the depth of unconsolidated materials above the bedrock could be significantly underestimated.

In Northeastern Wisconsin, glacial geologists have done an extensive job of mapping the glacial materials that cover the landscape, usually at scales of 1:100,000, as a part of their effort to understand the region's glacial history. These maps provide insights into the textures and thickness of the unconsolidated materials covering the carbonate bedrock in that part of the state. Although extremely valuable, this information is not detailed enough for field-specific use by agricultural producers.

Figure 1. Bucket auger (foreground) and other tools used to identify soil for soil surveys.
Determination of the depth to bedrock as well as the composition of the unconsolidated materials using a Geoprobe®

The UW - Discovery Farms Program purchased a skid-steer equipped with a Geoprobe in the fall of 2008 to assist producers with their nutrient management planning by providing more detailed information on the unconsolidated materials covering the carbonate bedrock. Since the Geoprobe is mounted on a skid-steer it can be moved easily across farm fields, and it uses the tractor’s hydraulic system to drive a probe quickly through unconsolidated materials to the bedrock surface.

The probe can be used to determine the depth to bedrock, the types of un lithified materials over bedrock (Figure 2), or in certain circumstances it can be used to install groundwater monitoring wells. The Geoprobe also has the capability of taking samples at selected depths or coring the entire depth of the hole; these samples provided information on the composition and texture of the unconsolidated materials (Figure 3).

The Geoprobe was initially utilized to check the depth to bedrock on selected farms in Northeastern Wisconsin. These farms were selected because the producers had discrepancies (both deeper soils and shallower soils) with the established depths provided in their county’s soil survey.

These preliminary test plots indicated that in some cases, the depth to bedrock as established in the soil survey were accurate. In other cases the depth to bedrock in the soil survey indicated that bedrock was within 5 feet of the soil surface, while the Geoprobe showed depths of 12 to over 20 feet.

Figure 2. Geoprobe® boring to determine depth to bedrock

Figure 3. Geoprobe® cores of soil and unconsolidated material

Determination of the depth to bedrock using well construction reports and Geographic Information Systems (GIS) data

Although the data collected by performing borings with the Geoprobe proved invaluable for accurately determining the depth to bedrock in a small test area, using this method on a larger scale would be expensive, time consuming and invasive. An alternative method of determining depth to bedrock was developed through a cooperative effort between two UW - Extension programs, Wisconsin Geological and Natural History Survey and the Discovery Farms Program.

Utilizing well construction reports as surrogate geologic logs, the depth to bedrock can be determined at any location assuming that there are sufficient drilling records. Calumet County was selected as the pilot area to initiate this study because of the high land area prone to karst feature development; and a history of elevated nitrate and bacterial well contamination. In addition, accessibility of land records as well as high resolution topographic maps aided our ability to conduct this project.

The initial phase of the project began with the creation of a database of well construction report information. Well construction report geology was entered for the different layers of material as identified by the well driller. Specific attention was given to the depth at which bedrock was encountered. The well construction reports were then
spatially referenced using a variety of techniques to identify the specific location that these wells reside on the landscape.

Using a Geographic Information System (GIS), a digital elevation model (DEM) was queried at the location of each well to obtain an elevation of the well at the surface. The depth of the bedrock, obtained from the well construction reports, was subtracted from the surface elevation to give an elevation of the bedrock. This was completed for each well in Calumet County that had drilling records that could be spatially referenced and had bedrock depth properly annotated on the drilling records.

Once the database for all the wells in Calumet County was completed, a bedrock topography map was completed with GIS using interpolation to define areas between wells. The output is a topographic map that approximates how the surface would look if everything above the bedrock was removed. After the bedrock topography is subtracted from the original DEM, the final output is the depth to bedrock map seen in Figure 4.

As can be seen in the map and in the legend in Figure 4, some of the output values were 0 or a negative value, meaning that the modeled bedrock elevations were higher than DEM elevations. When these areas were assessed on a countywide basis, it was observed that these areas either had very shallow soils, often “holding” water at the surface; or in some instances had bedrock exposed at the soil surface. Analysis of wells that tested high in nitrate or bacterial contamination were usually more prevalent in these areas and areas of shallow soil depth (annotated in clear or red shades on Figure 4).

When the depth to bedrock maps are viewed at a smaller scale, these features become very visible. The wetness features observed in the aerial photography coincide quite well with the areas that were determined to be shallow depth to bedrock (Figures 5 and 6). In addition, these areas are often left as woodland because the shallow soils are not conducive to crop production. Figure 6 also shows well contamination information; red dots are wells that have tested high in nitrate or bacterial contamination and green dots are wells that have not. In areas with shallow depth to bedrock, the contaminated wells are much more prevalent. In areas with deeper soils, well samples typically show less nitrate or bacterial contamination.

Selected areas that were prone to high variability in interpolated bedrock depth maps, were ground-truthed...
More in-depth procedures on how to perform this type of mapping program can be found in the reports developed through this project: Mapping Bedrock - Models and field tools to identify loss potential in vulnerable landscapes; Mapping Bedrock - Identifying the Depth of Bedrock at a Large Scale using Well Construction Reports; Mapping Bedrock - Verifying Depth to Bedrock in Calumet County using Seismic Refraction.

This fact sheet can be found on the web at: www.uwdiscoveryfarms.org or by calling the UW-Discovery Farms Office at 715-983-5668. (June 2013)