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Illinois Pollution Control Board Responses Regarding Proposed Amendments to 35 Illinois Administrative Code Parts 501, 502, and 504

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Introduction

Following the hearings of 2012 regarding the Illinois Environmental Protection Agency's Concentrated Animal Feeding Operations: Proposed Amendments to 35 Illinois Administrative Code Parts 501, 502, and 504, the Illinois Pollution Control Board (IPBC) expressed concerns about testimony by Panno with regard to the lack of definitions of "karst" and "karst terrain". They also expressed interest in understanding the effectiveness of an aquitard overlying a karst aquifer particularly in areas where the siting of CAFOs in karst regions of Illinois is an issue. The following was prepared to address the IPCB questions.

Carbonate Rock

Carbonate rock (limestone and dolomite) comprises approximately 25% of the bedrock surface of Illinois (Weibel and Panno 1997) and ranges from Ordovician to Mississippian in age. Glacial drift and loess overlying carbonate bedrock range from 0 m to more than 100 m and in thickness and is thinnest beyond the glacial limit in Illinois' Driftless Areas of northwestern Illinois and in far southern Illinois. Carbonate bedrock is exposed and/or closest to the surface along the margins of the Illinois Basin and along major structural features like the LaSalle Anticlinorium. Where carbonate rock is at or near the surface (overlain by 0 m to less than 15 m of unconsolidated, fine-grained sediment), karst features may be observed at the surface.

Carbonate rock is a major source of groundwater in Illinois and throughout the world with the most productive aquifers having secondary porosity (fractures and bedding plane partings) that permits the transport of water into and through the rock. Because of the generation of carbon dioxide by plant root respiration and microbial activities in soils overlying carbonate rock, infiltrating water (rainwater and snow melt) becomes acidic prior to entering fractures, joints and bedding planes in carbonate rock. Small amounts of calcite and/or dolomite (the dominant minerals of carbonate rock) dissolve releasing calcium, magnesium and bicarbonate ions until the water approaches saturation with respect to calcite and/or dolomite (White 1988). Slow dissolution over thousands to hundreds of thousands of years gradually enlarges joints, fractures, and pathways along bedding planes through which groundwater moves. Some solution-enlarged pathways become large conduits through which groundwater flows to points of discharge (e.g., springs). The solubility of carbonate rock is responsible for the development of karst aquifers and karst terrains.

It is important to thoroughly characterize the geology and hydrogeology of areas underlain by carbonate rock in order to identify karst terrain. Knowing where karst terrain is and the degree of karstification present is important for land use planning, water-resource protection and regulatory purposes.

Karst Terrain

"Karst" has been defined by numerous internationally-recognized experts in the areas of karst geology and karst hydrogeology. White (1988) in his classic book "Geomorphology and Hydrology of Karst Terrains" defines "karst" in a very broad sense and in keeping with the European definition, stated that "East Europeans and particularly Soviet writers…consider all landforms produced by the solution process to be karst - regardless of scale, surface expression, or rock type." White also stated that when crevice widths within carbonate rock approach 1 cm, the aquifer can include a turbulent flow regime and may be considered to be a karst aquifer. Jennings (1971) in his book "Karst" stated that "Karst signifies *terrain with distinctive characteristics of relief and drainage arising primarily from a higher degree of rock solubility in natural waters than is found elsewhere*. The word is also used adjectivally to refer to rock, water, streams, caves and other features making up such landscape." Ford and Williams (1992) in their book "Karst Geomorphology and Hydrology" stated that "Karst is terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well developed secondary porosity. Considerable rock solubility alone is insufficient to produce karst. Rock structure is also important. The key to karst is the development of its unusual subsurface hydrology. The 'engine' that powers its natural processes is the hydrologic cycle. Soluble rocks with extremely high primary porosity usually have poorly developed karst. Yet soluble rocks with negligible primary porosity that have later evolved a very large secondary porosity support excellent karst. The distinctive landforms above and below ground that are a hallmark of karst result from solution along pathways provided by the structure." The *Karst Waters Institute* (http://www.karstwaters.org/) defines karst as "…a special kind of landscape that is formed by the dissolution of soluble rocks, including limestone and dolomite. Karst regions contain aquifers that are capable of providing large supplies of water. More than 24 percent of the world's population either lives on or obtains its water from karst aquifers. In the United States, 20 percent of the land surface is karst and 40 percent of the groundwater used for drinking comes from karst aquifers. Natural features of the landscape such as caves and springs are typical of karst regions. Karst landscapes are often spectacular scenic areas. Examples include the sinkhole plains and caves of central Kentucky, the large crystal-clear springs of Florida, and the complex, beautifully decorated caves of New Mexico. Common geological characteristics of karst regions that influence human use of its land and water resources include ground subsidence, sinkhole collapse, groundwater contamination, and unpredictable water supply." Finally, C. Alexander, hydrogeologist and karst expert from the University of Minnesota stated that the apparent absence of karst features on the ground surface (e.g., sinkholes) in no way precludes the presence of an underlying karst aquifer. This is because sinkholes are end-members of a continuum that extends from large-scale sinkhole drains down to nano-scale macropores.

The late Dr. J. Quinlan, a foremost expert in karst hydrogeology, often stated that if the bedrock of an area is composed of carbonate rock, the area should be considered karst and underlain by a karst aquifer unless proven otherwise. Of those areas within Illinois that are underlain by carbonate rock, 35% (9% of the state) is included in five regions that contain karst features at and near the surface (Weibel and Panno 1997; Panno et al. 1997; Panno and Weibel 2010). Berg (2001) stated that "Karst areas are the most sensitive of any geologic setting because contaminants can be transported very rapidly." Recharge and groundwater movement within karst terrain are extremely fast and these aquifers are highly susceptible to groundwater contamination from surface-borne contaminants.

Work by Lindsey et al. (2010) has shown that sinkhole density can be related to aquifer vulnerability. They develop three categories for sinkhole density using karst areas from four states in the eastern United States: low (less that 1 sinkhole/100 km^2); medium (1-25 sinkholes/100 km^2); and high (greater than 25 sinkholes/100 km^2). Lindsey et al. (2010) also determined that nitrate concentrations, indicative of anthropogenic (typically agricultural lands) contamination, were significantly greater in high and medium sinkhole density areas than low sinkhole density areas. The relatively large interconnected solution-enlarged pathways present in fissured or karstified carbonate rock allow rapid movement of water into and through the rock bodies. These rock bodies often constitute locally important aquifers in Illinois, but are highly susceptible to surface-derived contamination (e.g., Panno et al. 1996, 2001; Hackley et al. 2007). Recharge to the karst aquifers often is rapid and carries with it materials (often macroscopic) from the land surface that can include human and animal wastes, agricultural chemicals, urban runoff, and other waste products associated with the land use of a region. In contrast, recharge to non-karst aquifers in most of Illinois typically undergoes a slow migration through the matrix of fine-grained materials (e.g., thick, silt- and clay-rich glacial diamicton) that generally provide sufficiently slow transit time and geochemical environmental conditions suitable for chemical, biological, and physical degradation and retardation of pollutants. Schilling and Helmers (2008) suggested that water movement through karst aquifers is analogous to movement through agricultural drainage tiles (i.e., flow through open conduits rather than minute pores), which are commonly contaminated with high levels of agrichemicals (e.g., nitrate, phosphorous, pesticides).

Combining these definitions and other information, we propose the following comprehensive definition for karst and karst terrain within and in unconsolidated materials overlying carbonate rock of Illinois. *"Karst" refers to both the geology and hydrogeology of an area with bedrock that has a major component of soluble rock (i.e., limestone and/or dolomite). Secondary porosity formed by fractures in the rock bodies that has resulted from tectonic stresses on crustal rocks provides the pathways for movement of recharge water and groundwater into and through the rocks. The walls of the fractures are subject to dissolution by mildly acidic rainwater, snow melt and soil water containing carbonic acid that forms from carbon dioxide in the air and soil being dissolved in water. These slightly acidic recharge waters react with the carbonate rock and dissolve fracture walls, progressive widening of those fractures. The result is the formation of an enlarged connected porosity through which groundwater can, under a normal range of hydraulic gradients, flow rapidly. This connected porosity makes up the relatively high permeability of the carbonate rock aquifers of Illinois. When the fractures of the aquifer are widened to about one centimeter or more, the aquifer can include turbulent flow and the aquifer may be referred to as a "karst aquifer." Under such circumstances, groundwater flow can be rapid and, in some cases directional, that is, following fracture orientation and leading to crevice/conduit development. Combining an open karst aquifer such as this with relatively thin overlying cover sediment (less than 50 feet) at ground surface can enhance the formation of macropores and sinkholes that can provide pathways to the aquifer. Consequently, the susceptibility of such an aquifer to the infiltration of surface-borne contaminants can be high and groundwater quality can be adversely affected. Surface features that may be present in carbonate rock exposures and fine-grained sediments overlying a karst aquifer include creviced bedrock containing cutters and grikes (vertical and subvertical fissures developed by solution along a joint), cover-collapse sinkholes* *(closed depressions), sinkhole ponds, caves, cave-collapse sinkholes (karst windows), and losing or disappearing streams. However, the absence of any or all of these features at the surface does not preclude the presence of an underlying karst aquifer.*

Aquitard Overlying Karst Aquifers

Carbonate aquifers are sometimes protected by overlying shale that is of low hydraulic conductivity (an aquitard) in which case the aquitard may protect the underlying aquifer from rapid infiltration of surface-borne contaminants. However, the aquitard must be continuous throughout a region to be effective in protecting the underlying aquifer. For example, the proposed CAFO in Jo Daviess County was sited on Maquoketa Shale that might have protected the underlying karst aquifer. Unfortunately, the site was on an erosional remnant of shale in an area where carbonate rock was exposed along streams on site and cover-collapse sinkholes were present within a few feet of the site boundaries. Because there was overland discharge from the site prior to operations and because the owners planned to apply the manure off site and directly onto karst terrain, the geographically limited nature of the aquitard underlying the CAFO vitiated the protective qualities of the aquitard.

Protocols to Land Application Livestock Waste

There is concern that regulations regarding soil thickness over fractured bedrock and sand and gravel, and seasonal water table fluctuation may result in prohibitively high costs. Given that minimum soil thicknesses are less than 0.91 m, less than 1.52 m and less than 0.61 m (Sections 502.620(h, i), the determinations of soil thickness should be straight forward. For example, we use a five foot long soil probe (standard length) to determine soil depth over bedrock for those areas where soil zones can be less than 1.52 m thick. The "instrument" is low tech and relatively cheap (less than $20) and is nearly indestructible. A field can be probed in a very short period of time and if the prober has a GPS or smart phone app, the survey may be done very quickly. For example, we probed a field in Jo Daviess County and mapped the soil depth (with the use of a GPS) in less than one hour. Most of Illinois has soil thicknesses well in excess of 1.52 m and for those areas a NRCS soil survey would suffice. In those areas with thin soils, a point density probably doesn't need to be more than 10 locations per field (i.e. as a grid). This effort, combined with drill log data from the Illinois State Geological Survey (available on line) and an NRCS soil survey, should yield a representative estimate of soil thickness. Seasonal water table monitoring is slightly more difficult (Section 502.620 k); however, with a water table 0.61 m below ground surface, a couple of short 0.76 m long drive point wells could be driven into the ground at the perimeter (corners?) of the fields and monitored during wet periods of the year to determine if the field exceeds the regulatory limit. In any case, the determinations of these parameters do not appear to be prohibitively expensive given the costs of site characterization.

References

Berg, R.C. (2001). Aquifer sensitivity classification for Illinois using depth to uppermost aquifer material and aquifer thickness. Illinois State Geological Survey Circular 560.14 p.

Ford, D. and P. Williams. (1989). Karst geomorphology and hydrology. Chapman & Hall. 601 p.

Hackley, K.C., S.V. Panno, H.H. Hwang, and W.R. Kelly. 2007. Groundwater quality of springs and wells of the sinkhole plain in southwestern Illinois: Determination of the dominant sources of nitrate. Illinois State Geological Survey *Circular* 570. 39 p.

Jennings, J.N. 1971. Karst. The M.I.T. Press, Massachusetts. 252 p.

Lindsey, B.D., B.G. Katz, M.P. Berndt, A.F. Ardis and K.A. Skach. 2010. Relations between sinkhole density and anthropogenic contaminations in selected carbonate aquifers in the eastern United States. Environmental Earth Science, v. 60. p-. 1073-1090.

Panno, S.V., Krapac, I.G. and Weibel, C.P., 1996. Groundwater contamination in karst terrain of southwestern Illinois. Illinois State Geological Survey *Environmental Geology Series* 151, 43 p.

Panno, S.V., Weibel, C.P. and Li, W.B. 1997. Karst regions of Illinois. Illinois State Geological Survey *ISGS Open File Series* 1997-2, 42 p.

Panno, S.V., Hackley, K.C., Hwang, H.H. and Kelly, W.R., 2001. Determination of the sources of nitrate contamination in karst springs using isotopic and chemical indicators. *Chemical Geology*, v. 179, no. 1-4, p. 113-128.

Panno, S.V. and C.P. Weibel. 2010. Karst Terrain, in Geology of Illinois, Illinois State Geological Survey. p. 432-442.

Schilling, K.E., and M.J. Helmers. 2008. Tile drainage as Karst: Conduit flow and diffuse flow in a tile-drained watershed. *Journal of Hydrology* 349: 291-301.

Weibel, C.P. and Panno, S.V. 1997. Karst terrains and carbonate bedrock of Illinois. Illinois State Geological Survey, *Illinois Map Series* 8, 1:500,000 Scale.

White, W.B. 1988. Geomorphology and hydrology of karst terrains. Oxford University Press, New York, 464 p.