Assessment of the Geology and Hydrogeology of Two Sites for a Proposed Large Dairy Facility in Jo Daviess County Near Nora, IL

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Introduction

This report is an update of two previous reports sent to the Jo Daviess County Board on February 8, 2008 (Panno, 2008a, 2008b) concerning the "Notice of Intent to Construct" application for two 6,850 animal unit capacity dairy facilities, released by the Illinois Department of Agriculture. The notice proposes two sites in Jo Daviess County referred to as Traditional North (S. 31, T. 29 N, R. 5E) and Traditional South (S.6, T. 28 N., R.5E). This report, and the previous two reports are the result of an investigation of the available information on the geology and hydrogeology of the Traditional North and Traditional South sites located approximately 0.9 miles west of Nora, IL. The Traditional South site is located 1,375 feet south of Traditional North site (Figure 1). Because both sites are in such close proximity, they were treated as one location in this report.

Geology and Hydrogeology of Jo Daviess County

Jo Daviess County lies within the Driftless Area of northwestern Illinois and is so-called because of the lack of glacial drift overlying bedrock in the area that is present throughout the Midwestern U.S. Bedrock in the area of the proposed dairy consists of Middle Ordovician-age (from 488 to 444 million years before present) carbonate rocks of the Galena-Platteville Group (Figure 2). Carbonate rocks of the Galena Group overlie those of the Platteville Group and are composed of fine-grained limestone and dolomite. Thin remnants of Ordovician-age Maquoketa shale overlie these carbonate rocks in many places (McGarry 2000). The carbonate bedrock of the proposed dairy sites and of most of Jo Daviess County constitutes an important aquifer for municipal and private wells in the county.

Karst Areas

The Livestock Management Facilities Act identifies karst areas as environmentally-sensitive. A "karst area" is defined by the Livestock Management Facilities Act as "an area with land surface containing sinkholes, large spring, disrupted land drainage, and underground drainage systems associated with karstified carbonate bedrock and caves or a land surface without these features by containing a karstified carbonate bedrock unit generally overlain by less than 60 feet of unconsolidated materials." "Karstification" is defined by the U.S. EPA (2002) as "the process of solution and infiltration by water, mainly chemical but also mechanical, whereby the surface features and subterranean drainage form a karst topography…" The term "karstified carbonate bedrock" refers to carbonate bedrock (limestone and/or dolomite) that contains solution-enlarged fractures (secondary porosity) that are typically greater than 1 cm wide (White 1988).

Caves, sinkholes and carbonate bedrock were mapped in the Jo Daviess County area as part of a preliminary estimate of the extent of karst terrain in the state of Illinois by Panno et al. (1997a) and as a map by Weibel and Panno (1997). Carbonate rock (limestone and dolomite) is present as bedrock throughout the county. Caves occur primarily in the Galena Group, are found all over the county, and consist of solution-enlarged crevices and form network-type caves (tall, near-vertical passages, often at right angles to one another (Figures 2 and 3). One of the mapped caves is located less than 3 miles southwest of the proposed dairy facility, although, not all caves in the county have been mapped and many more may be present. Initial mapping of cover-collapse sinkholes in Jo Daviess County suggested that they were more localized and found near Chestnut Mountain Resort, just south of the town of Galena, and in Mississippi Palisades State Park just south of Jo Daviess County in Carroll County, in soil cover overlying Silurian-age dolomite (Figures 2 and 4). It is important to understand that an area does not have to contain sinkholes to be classified as karst; the term "karst" does not just refer to surface features such as sinkholes and large springs, and cave openings. Whereas, these surface expressions are indicators of karst areas, if an area is underlain by karstified carbonate bedrock, then the area is classified as karst even through no sinkholes are present (Figure 5). It is the karstification of bedrock that transforms it into a prolific aquifer that is key. Groundwater flowing through a karst aquifer can travel miles per hour, whereas, groundwater flowing through a sand and gravel aquifer may travel feet per year. In a karst aquifer, surface-borne pollutants (e.g., a spill or seepage of animal waste) can contaminate wells miles away from the source in a matter of hours. Consequently, based on the bedrock geology map of Jo Daviess County (McGarry 2000) that shows most of the county having carbonate bedrock (Figure 2) and a relatively thin sedimentary overburden, we would classify the entire county as karst. Exceptions to this generality would include the Mississippi River Valley and areas where there are thick sequences of Maquoketa shale that might afford protection to the underlying karst aquifer. However, shale thickness should probably be at least 10 feet or more to avoid movement of water through fractures and/or macropores (e.g., root pathways of vegetation, animal burrows).

Well Log Data

Based on bedrock geology, the occurrence of caves in the area of the proposed dairy facility near Nora, IL, and the above discussion, the site overlies karstified bedrock which serves as a karst aquifer when it is saturated. An examination of drill logs (obtained from the ISGS Records Library) from the area suggest that there is about 20 feet of soil and loess (wind-blown silt) overlying bedrock. Some drill logs suggest that thin (5 feet or less) of Maquoketa shale may be present in the area with water levels ranging between 16 and 70 feet below the surface (based on water well records). These unconsolidated sediment data are supported by 30 soil borings of the sites drilled and logged by Terracon, an engineering firm hired by the developers, and a report on the soil boring information by Johnson (2008). Boring logs of the two proposed sites reveal relatively thin (from 5 to 20 feet thick) unconsolidated materials overlying weathered limestone bedrock. Because most borings did not extend more than a depth of 10 feet, the average thickness of the unconsolidated materials at the sites is unclear, but the thickest sediment is less than 20 feet with little or no shale protecting the underlying aquifer. This is considerably less than the 60 feet of unconsolidated material overlying karstified carbonate bedrock recommended in Section 10.24 of the Livestock Management Facilities Act. Further, the proposed site area is clearly within an environmentally-sensitive area based on an aquifer sensitivity map prepared by McGarry and Riggs (2000).

Aerial Photographs

An examination of recent aerial photographs (2005) of the proposed site and vicinity revealed no sinkholes in the area, either due to an absence of sinkholes or to their being obscured by crop residue cover (Figure 6). However, an older (1947) aerial photograph revealed an area slightly less that 0.5 square miles, located just south and southwest of the Traditional North site, that appears to be a pasture containing circular to elliptical features with dark centers and dark rims, and similarly-shaped light colored features (Figure 7). These features are about 300 or so feet in diameter and appear to be cover-collapse sinkholes. These features are nearly identical to sinkholes found in Illinois' sinkhole plain in southwestern Illinois (Figure 8). Other circular to elliptical features to the west and south of that area are present in the 1947 photograph, but are more subtle. Only a few of these features, characterized as sinkholes herein, are still, although just barely, discernible in the 2005 photograph of the same area (Figure 6).

Given the history of mining in Jo Daviess County, the possibility that these circular to elliptical features (Figure 7) might be exploration pits or mine shafts was investigated. To test this hypothesis, the locations of the suspected sinkholes were compared to a map of the mined areas of Jo Daviess County. There was no record of any mining within a mile of the proposed site and the suspected area (Figure 9). Further, the known mined areas in the vicinity of Nora and Warren were examined in 1947 aerial photographs to see if similar patterns were observed. Again, no such patterns were seen in the mined areas. The question then arises about why these features do not appear on a USGS 7.5 minute topographic map. It is suggested that because of the relatively thin layer of unconsolidated materials that overlie bedrock, the sinkholes must be fairly shallow features (within the 10 foot contour interval), and as such, would not show up on a topographic map.

Consequently, in the absence of any evidence to the contrary, it must be assumed that these are natural features and are probably sinkholes that have since been obscured by activities associated with row crop agriculture. A worst-case (and likely) scenario would be that the proposed sites and their surroundings contain similarly obscured sinkholes. Implications for the presence of obscured sinkholes on the proposed sites would then have to be considered under Section 13a-5 of the Livestock Management Facilities Act. It is important to note that the area containing sinkholes is characterized in the bedrock geology map (McGarry 2000) as Maquoketa Group, and suggests that the thickness and/or effectiveness of shale as an aquitard in this area is inadequate to protect the underlying aquifer from surface-borne contaminants.

Potential Contamination from Large Animal Facilities

Groundwater quality can be easily affected by spillage and/or seepage of animal waste into an aquifer. This is particularly so in a karst aquifer where there is little or no chemical or physical retention and/or degradation of contaminants. Animal waste contains nutrients (e.g., ammonium, phosphorous, potassium), salts (particularly sodium and chloride), as well as bacteria, viruses, and pharmaceuticals (e.g., Panno et al. 1996, Panno et al. 1997b, 2006b; Hackley et al. 2007). Surface-borne contaminants in groundwater are typically stratified so that the greatest concentrations are nearest the surface and the concentrations of the contaminants decrease with depth (e.g., Hackley et al. 2007). This is best seen in nitrate concentrations plotted against depth for the data in Table 1 (Figure 10).

Groundwater Quality of the Area

Groundwater quality of the karst aquifer underlying the proposed sites, and in the vicinity of the proposed site, should be an indication of the susceptibility of the aquifer to surface-borne contaminants. The Illinois State Water Survey maintains a database of water quality data for the state of Illinois which was accessed for this investigation. The ions chloride (a major component of road salt) and nitrate (a byproduct of nitrogen fertilizers, livestock waste, and effluent from private septic systems) were used as indicators of aquifer susceptibility in the vicinity of the proposed sites. Although no data from wells within the sections of the proposed sites were available, water quality data from wells surrounding the sites were examined. Because of the paucity of water quality records in the area, some of the wells are located just across the boarder to the east in adjacent Stephenson County (this area has the same bedrock geology and aquifer, but a thicker sequence of unconsolidated materials) (Figure 1).

In order to determine if the karst aquifer is contaminated, it is imperative to know the background (naturally-occurring) concentrations of the ions of interest (nitrate and chloride). Background is the concentrations of these ions that would be there without any contamination (e.g., concentrations that would be found in pre-settlement days). Elevated concentrations of nitrate (greater than 2.5 mg/L, as nitrogen), and chloride (greater than 15 mg/L) would indicate groundwater contamination in Illinois (based on work by Panno et al. 2006a and Panno et al. 2006b, respectively). Another indication of background concentrations can be found in wells from State Parks (areas that usually approach pristine conditions).

The available data (Table 1) contain wells at a variety of depths ranging from 72 to 420 feet below the surface. In some cases, the data represent multiple sampling of the same well in different years. In Illinois, private wells in creviced carbonate rock (limestone and dolomite) are usually cased through the soil zone and left open several feet below the top of bedrock (Panno et al. 1996). This is done to take advantage of multiple zones of groundwater inflow. Consequently, even the deepest wells can receive groundwater from the shallow part of the aquifer. Municipal wells can be cased and grouted to selected horizons or left open similar to private wells. Most of the available well water data were predominantly from municipal wells in the town of Apple River and Apple River State Park in Jo Daviess County, and the towns of Winslow and Lena in

Stephenson County. Pumping of the wells in a karst aquifer typically draw groundwater from shallower depths where it mixes with groundwater from deeper parts of the aquifer.

Chloride concentrations in these well water samples ranged from less than 1 mg/L to 55 mg/L. Elevated chloride concentrations (greater than 15 mg/L) in this part of the state typically originate from road salt, and chloride concentrations exceeded background in 24% of the samples in Table 1. Road salt in Illinois is applied to roadways at a rate of between 45 and 160 kg of salt per lane mile per snow/ice event, and reapplied, as needed (Panno et al. 2005). Nitrate concentrations (as nitrogen) ranged from less than 1 mg/L to 31 mg/L (as nitrogen). Nitrate concentrations at levels greater than 2.5 mg/L (as nitrogen) indicate that the aquifer is open to surface runoff and is not being protected by an aquitard (e.g., the Maquoketa shale). Nitrate concentrations exceeded background in 15% of the samples in Table 1. Elevated nitrate concentrations in this area are probably due to row crop agriculture (nitrogen fertilizers) which dominates the land use. Well-water samples with exceptionally high concentrations of both chloride and nitrate (e.g., a well from the Apple Canyon Utility that has 54 mg/L chloride and 31 mg/L nitrate) are probably associated with livestock waste or possibly waste from private septic systems. Livestock waste and effluent from private septic systems contain high levels of nitrogen (initially as ammonium in the waste, and later as nitrate in groundwater or surface water) and chloride (Panno et al. 2006b; 2007; Hackley et al. 2007).

Consequently, the presence of nitrate and chloride, particularly at depths of hundreds of feet, indicate that groundwater contamination is occurring in the karst aquifer surrounding the proposed dairy sites. Based on the available data, groundwater from shallow wells would probably contain concentrations of these indicator contaminants well in excess of background concentrations. The water quality data, plus the thin cover of unconsolidated sediment, and the likelihood of sinkholes in the area support the likelihood that groundwater in the karst aquifer underlying the proposed dairy sites could easily be contaminated by surface-borne pollutants.

Conclusions

In general, most of Jo Davies County could be characterized as karst given the dominance of carbonate bedrock (limestone and dolomite) and the karst aquifer throughout the county. The proposed sites for the dairy facility are underlain by a karst aquifer that, in turn, is overlain by typically less than 20 feet, and as little as 5 feet of unconsolidated materials. Aerial photographs of the sites taken in 1947 indicate that there are sinkholes immediately adjacent to the proposed sites, and possibly within the perimeters of the proposed sites. Further, contamination of the aquifer from road salt and nitrogen-fertilizers at depths of hundreds of feet (based on available water quality data in the area of the proposed sites) suggest that the karst aquifer is highly susceptible to surface-borne pollutants, contains a well-connected fracture system, and has rapid groundwater travel times (as are all karst aquifers). Given the thin nature of the overlying sediment and the likelihood of sinkholes on the sites, the karst aquifer underlying the proposed sites would be highly susceptible to groundwater contamination by spills/seeps of animal waste.

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Table 1. Chloride and nitrate concentrations in groundwater samples collected from municipal and private wells in the vicinity of the proposed dairy faciltiy near Nora, IL (ND = No Data).

Location:Township,Range,Section			Date	Well No.	Depth	Project	Lambert X	Lambert Y	Source Type	Site Name	Cl	NO3-N
Township	Range	Section	Sampled		(Feet)						(mg/L)	(mg/L)
28N	04E	04	11/13/1973	1	200	IEPA - HISTORICAL	2851470	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	44	4.3
28N	04E	04	7/15/1975	1	200	IEPA - HISTORICAL	2852130	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	37	3.4
28N	04E	04	8/4/1976	1	200	ISWS - HISTORICAL	2852130	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	34	2.9
28N	04E	04	4/26/1977	1	200	IEPA - HISTORICAL	2852130	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	30	2.6
28N	04E	04	10/23/1979	1	200	IEPA - HISTORICAL	2852130	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	31	2.3
28N	04E	04	7/1/1940	1	72	ISWS - HISTORICAL	2851470	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	1	ND
28N	04E	04	8/4/1976	3	72	ISWS - HISTORICAL	2851470	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	4	< 0.1
28N	04E	04	10/23/1979	3	72	IEPA - HISTORICAL	2851470	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	3.5	< 0.1
28N	04E	04	9/18/1972	3	150	IEPA - HISTORICAL	2851470	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	54	31
28N	04E	04	11/13/1973	2	150	IEPA - HISTORICAL	2850150	3427178	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	3	0.1
28N	04E	04	7/15/1975	4	150	IEPA - HISTORICAL	2850150	3427178	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	4	1.3
28N	04E	04	9/18/1972	4	190	IEPA - HISTORICAL	2850150	3427178	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	3	ND
28N	04E	04	8/4/1976	4	190	ISWS - HISTORICAL	2850150	3427178	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	4	0.1
28N	04E	04	4/26/1977	3	190	IEPA - HISTORICAL	2851470	3426518	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	1.3	< 0.1
28N	04E	04	4/7/1980	4	190	IEPA - HISTORICAL	2850150	3427178	PUBLIC WELL	UTL INC APPLE CANYON UTL CO	5.1	1.3
28N	04E	04	8/4/1976	2	100	ISWS - HISTORICAL	2851470	3427178	PUBLIC WELL	APPLE RIVER CANYON STATE PARK	6	0.2
28N	04E	04	4/26/1977	2	150	IEPA - HISTORICAL	2851470	3427178	PUBLIC WELL	APPLE RIVER CANYON STATE PARK	5.6	0.2
28N	04E	04	10/23/1979	2	100	IEPA - HISTORICAL	2851470	3427178	PUBLIC WELL	APPLE RIVER CANYON STATE PARK	4.6	0.2
28N	04E	04	9/5/1985	542	100	IEPA - HISTORICAL	2851470	3427178	PUBLIC WELL	APPLE RIVER CANYON STATE PARK	3.1	0.15
28N	04E	04	4/26/1977	4	150	IEPA - HISTORICAL	2850150	3427178	PUBLIC WELL	APPLE RIVER CANYON STATE PARK	4.3	0.2
28N	04E	22	7/1/1970	ND	120	ISWS - HISTORICAL	2858462	3413901	PRIVATE WELL	ND	1	0.1
28N	04E	34	7/1/1940	ND	146	ISWS - HISTORICAL	2857953	3399971	PRIVATE WELL	ND	7	ND
28N	05E	31	7/1/1940	ND	146	ISWS - HISTORICAL	2870568	3399839	PRIVATE WELL	ND	2	ND
29N	04E	19	9/1/1940	ND	380	ISWS - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	1	ND
29N	04E	19	9/1/1940	ND	380	ISWS - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	1	0.2
29N	04E	19	12/1/1946	1	380	ISWS - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	6	0.4
29N	04E	19	9/19/1972	1	395	IEPA - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	5	< 0.1
29N	04E	19	3/24/1975	1	385	IEPA - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	4	0.1
29N	04E	19	4/21/1977	1	385	IEPA - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	7.8	< 0.1
29N	04E	19	3/10/1980	1	385	IEPA - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	3.8	< 0.1
29N	04E	19	11/30/1981	1	385	IEPA - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	5.6	< 0.1
29N	04E	19	3/7/1984	1	380	IEPA - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	5	< 0.1
29N	04E	19	7/10/1985	11728	380	IEPA - HISTORICAL	2841131	3445821	PUBLIC WELL	HOFFER PLUMBING CO	4.4	< 0.1
29N	04E	18	9/23/1987	11729	488	IEPA - HISTORICAL	2840208	3449815	PUBLIC WELL	HOFFER PLUMBING CO	6.3	0.11
28N	06E	16	9/5/1985	552	216	IEPA - HISTORICAL	2912567	3417625	PUBLIC WELL	LAKE LE-AQUA-NA STATE PARK	4.1	0.28
28N	06E	17	12/18/1973	1	215	IEPA - HISTORICAL	ND	ND	PUBLIC WELL	WINSLOW	38	6.9
28N	06E	16	8/4/1976	1	215	ISWS - HISTORICAL	2912567	3417625	PUBLIC WELL	WINSLOW	2	0.4
28N	06E	16	10/18/1977	1	210	IEPA - HISTORICAL	2912567	3417625	PUBLIC WELL	WINSLOW	20	2
28N	06E	17	6/11/1973	2	270	IEPA - HISTORICAL	2911280	3414990	PUBLIC WELL	WINSLOW	54.8	0.03
28N	06E	17	10/8/1975	2	265	IEPA - HISTORICAL	2911280	3414990	PUBLIC WELL	WINSLOW	1	0.1
28N	06E	16	8/4/1976	2	270	ISWS - HISTORICAL	2911907	3416965	PUBLIC WELL	WINSLOW	< 1	0.5
28N	06E	16	10/18/1977	2	260	IEPA - HISTORICAL	2911907	3416965	PUBLIC WELL	WINSLOW	0.9	0.1
28N	06E	17	7/3/1973	3	190	IEPA - HISTORICAL	ND	ND	PUBLIC WELL	WINSLOW	7	2.8
28N	06E	17	10/8/1975	3	165	IEPA - HISTORICAL	ND	ND	PUBLIC WELL	WINSLOW	37.8	< 0.02
28N	06E	17	8/4/1976	3	185	ISWS - HISTORICAL	2909300	3417630	PUBLIC WELL	WINSLOW	0	0.1
28N	06E	17	10/18/1977	3	160	IEPA - HISTORICAL	2909960	3417630	PUBLIC WELL	WINSLOW	0.8	< 0.1
28N	06E	17	8/4/1976	4	320	ISWS - HISTORICAL	2908640	3418290	PUBLIC WELL	WINSLOW	1	0.1
28N	06E	17	9/20/1976	ND	306	IEPA - HISTORICAL	2909300	3418290	PUBLIC WELL	WINSLOW	1.7	< 0.1
28N	06E	17	10/18/1977	4	306	IEPA - HISTORICAL	2909300	3418290	PUBLIC WELL	WINSLOW	5.3	< 0.1
28N	06E	17	9/18/1978	4	320	IEPA - HISTORICAL	2909300	3418290	PUBLIC WELL	WINSLOW	< 1	ND
28N	06E	17	8/4/1976	5	216	ISWS - HISTORICAL	2907320	3414990	PUBLIC WELL	WINSLOW	16	9.3
28N	06E	16	8/4/1976	6	225	ISWS - HISTORICAL	2913227	3417625	PUBLIC WELL	WINSLOW	28	3.7
29N	06E	22	8/1/1918	ND	355	ISWS - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	4	2.3
29N	06E	22	5/1/1937	ND	355	ISWS - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1	ND
29N	06E	22	11/1/1945	ND	355	ISWS - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	5	ND
29N	06E	22	11/1/1947	1	355	ISWS - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	2	ND
29N	06E	22	10/7/1975	1	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1	< 0.1
29N	06E	22	10/19/1977	1	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1.1	< 0.1
29N	06E	22	12/6/1982	1	200	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	< 1	< 0.1
29N	06E	22	7/9/1973	2	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	< 1	< 0.1
29N	06E	22	10/14/1980	2	320	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	47.6	< 0.02
29N	06E	22	7/15/1980	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1.5	< 0.04
29N	06E	22	7/23/1985	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	< 1	< 0.1
29N	06E	22	2/13/1990	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	< 1	< 0.1
29N	06E	22	1/13/1994	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1.1	< 0.01
29N	06E	22	12/8/1994	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1.92	< 0.01
29N	06E	22	12/17/1996	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	< 1	< 0.01
29N	06E	22	12/9/1998	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1.6	< 0.01
29N	06E	22	12/18/2000	11891	355	IEPA - HISTORICAL	2921257	3442015	PUBLIC WELL	WINSLOW	1.51	< 0.09
28N	06E	22	10/1/1963	ND	240	ISWS - HISTORICAL	2919846	3410378	PRIVATE WELL	ND	2	ND
28N	06E	33	11/1/1947	ND	380	ISWS - HISTORICAL	2912624	3401838	PRIVATE WELL	ND	26	ND
28N	06E	33	1/1/1913	ND	420	ISWS - HISTORICAL	2911964	3401838	PUBLIC WELL	LENA	11	0.3
28N	06E	33	5/1/1931	ND	340	ISWS - HISTORICAL	2911964	3401838	PUBLIC WELL	LENA	30	1.9
29N	06E	33	3/1/1964	ND	132	ISWS - HISTORICAL	2911971	3430895	PRIVATE WELL	ND	27	25
29N	06E	33	3/1/1964	ND	132	ISWS - HISTORICAL	2911971	3430895	PRIVATE WELL	ND	17	17

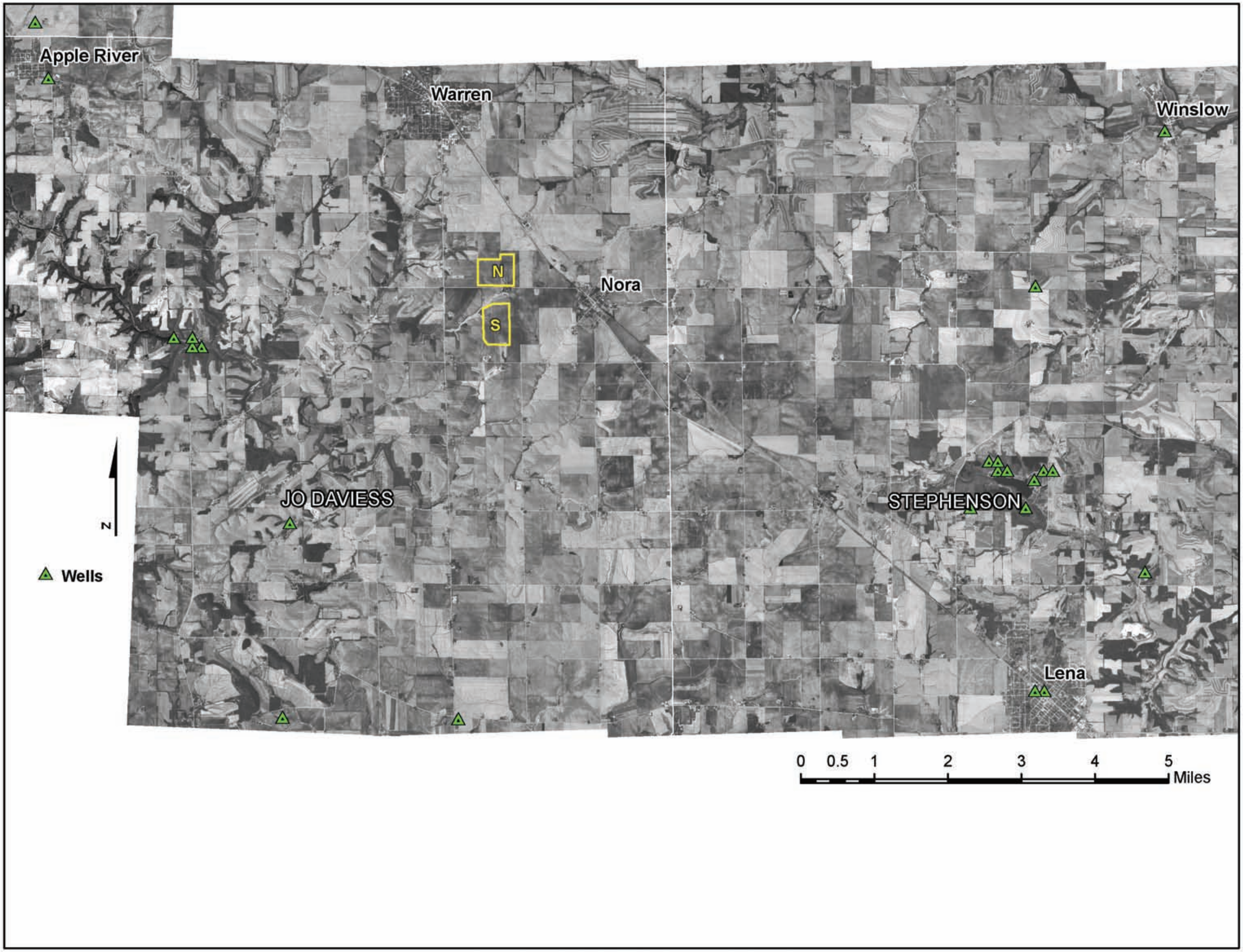

Figure 1. Site location map/aerial photograph showing the proposed Traditional North (N) and Traditional South (S) Sites just west of Nora, IL. Well locations for water quality data from Table 1 are included as green triangles

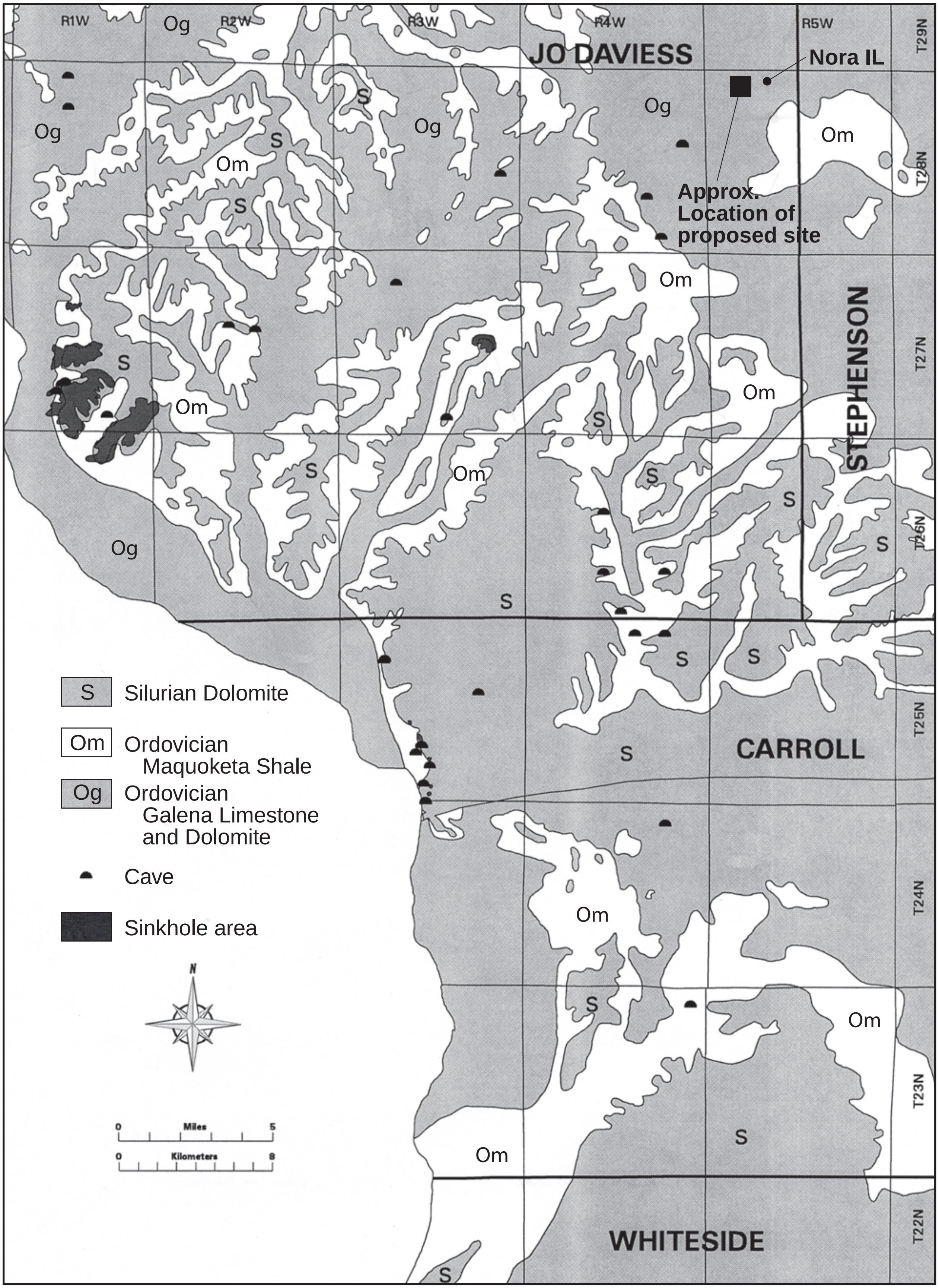

Figure 2. Karst map of the northeastern part of Illinois including parts of Jo Daviess, Stephenson and Carroll Counties (from Panno et al. 1997a).

Figure 3. Passages about 3 feet wide in a cave located along Route 20 in western Jo Daviess County near Long Hollow Scenic Overlook. The cave was formed in carbonate rock of the Galena-Platteville Group.

Figure 4. Sinkhole located in Mississippi Palisades State Park just south of the county line in Carroll County. The cover-collapse type sinkhole formed in unconsolidated sediments overlying Silurian-age dolomite.

Figure 5. Creviced carbonate rock of the Galena-Plattville Group exposed along Route 39 just south of Rockford, Illinois.

Figure 6. Aerial photograph of proposed Traditional North (N) and Traditional South (S) sites taken April 3, 2005. The topography of the area and the outline of the proposed sites have been superimposed on this photograph. The sites and surrounding area are dominated by row crop agriculture.

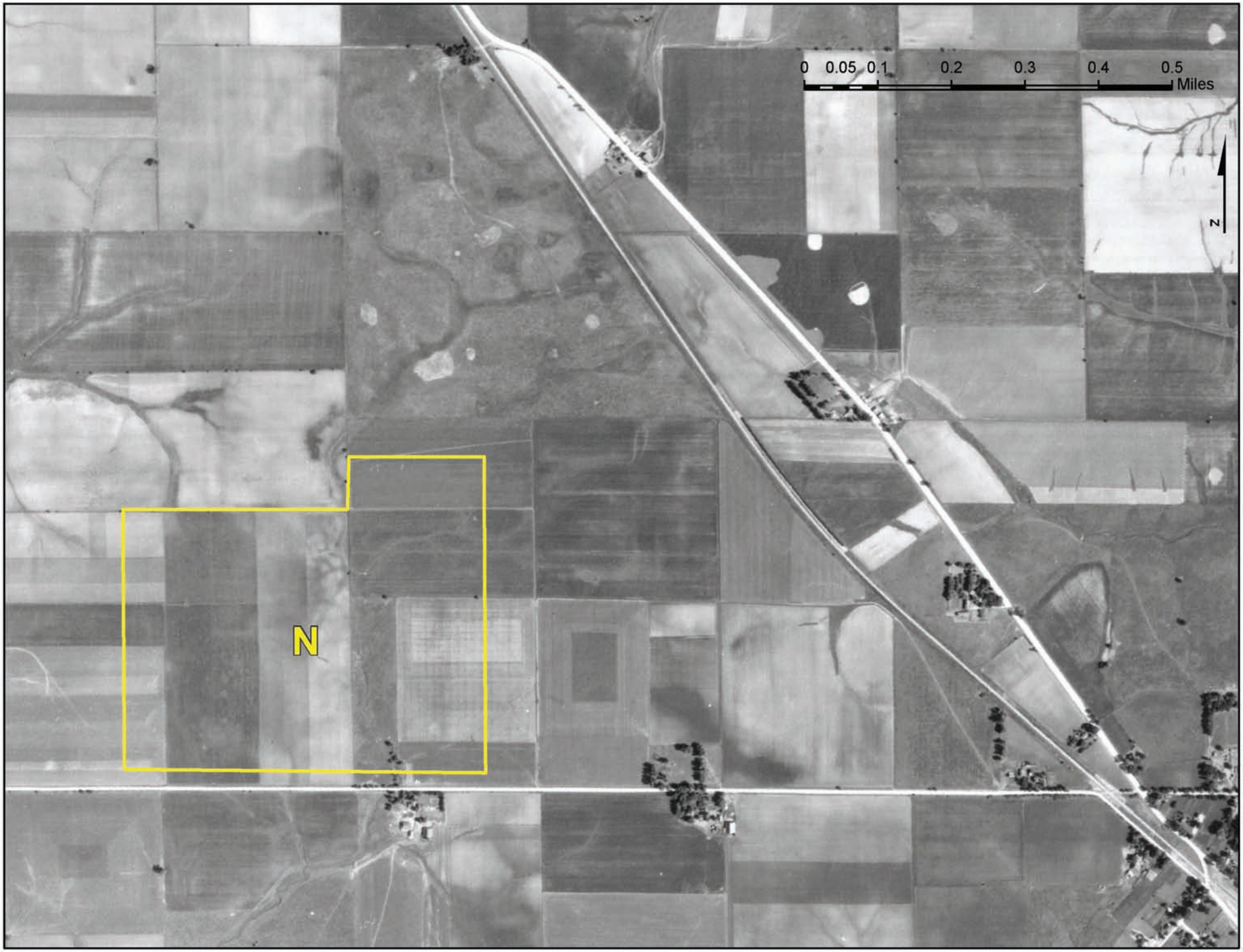

Figure 7. Aerial photograph in vicinity of the site for the proposed dairy facility taken July 1, 1947. The area near the top center part of the photograph shows what appear to be sinkholes in a pasture located just north to northeast of the Traditional North (N) site. In the 2005 aerial photograph, the pasture has been converted to row crops and almost all traces of the sinkholes have been obscured (Figure 6).

Figure 8. Aerial photograph of a farm field in St. Claire County, southwestern Illinois, showing cover-collapse sinkholes similar to those seen in Jo Daviess County (Figure 7). From Panno et al. (2008).

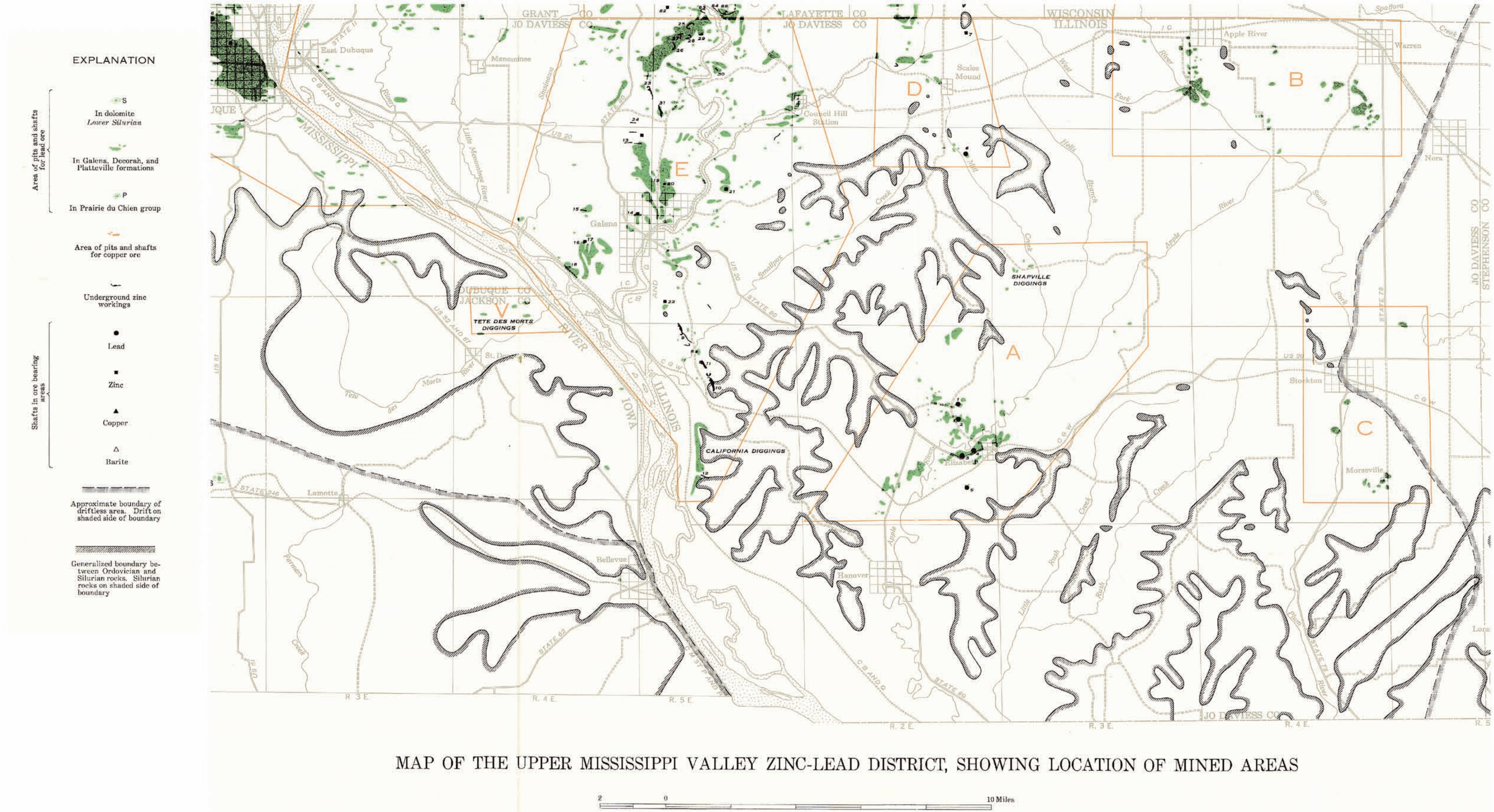

Figure 9. Map of the Upper Mississippi Valley zinc-lead district showing the location of all mined areas in Jo Daviess County. The north-south trending dashed line near the eastern boarder of Jo Daviess County represents the approximate boundary of the driftless area (from Heyl et al. 1959).

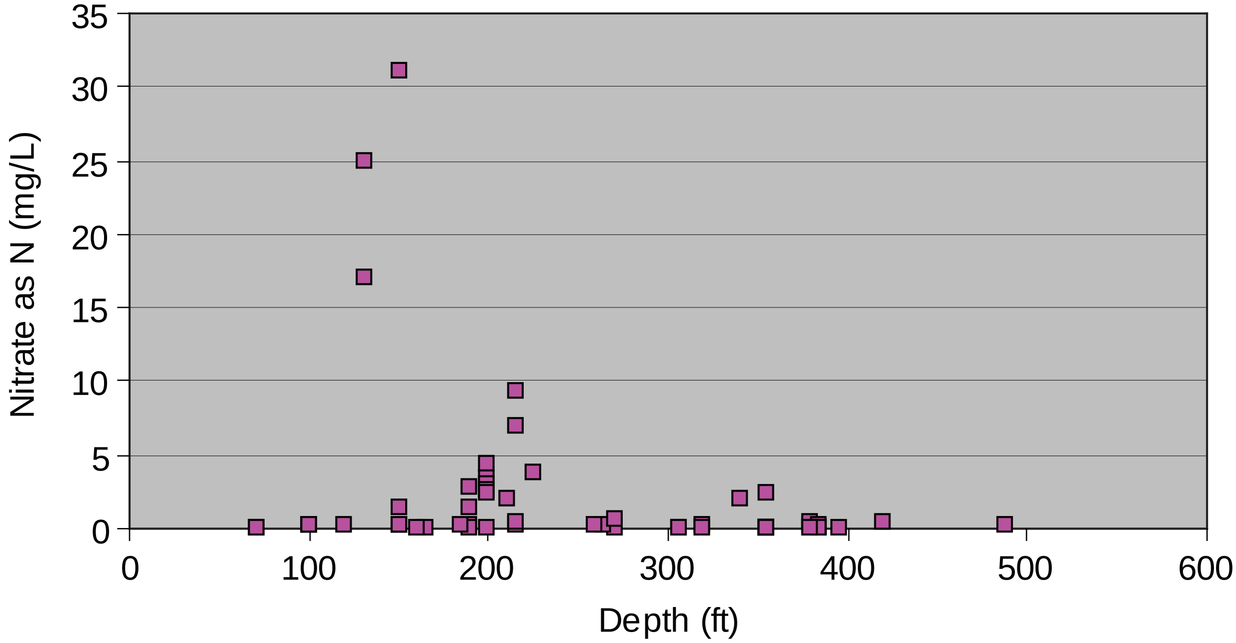

Figure 10. Nitrate concentrations in well water samples plotted against depth of the wells in feet showing stratification of nitrate (from Table 1). Nitrate concentrations are elevated in some of the shallower wells.

Supplemental Materials

A site visit on March 25, 2008 was part of this investigation. The trip was made by S.V. Panno, S.J. Taylor (Illinois Natural History Survey), L. Johnson (Soil and Water Conservation District), and B. Baranski (Jo Daviess County Board). The trip included a visual inspection of Traditional North and Traditional South from roadways because we didn't have permission to go onto the sites. In addition, we examined bedrock exposures in road cuts, outcrops and quarries, as well as reported sinkholes and a large spring located within five miles of the proposed sites.

The locations of each of the points visited are identified on a bedrock geology map prepared by C.S. McGarry (2000) (Figure S1). Photographs and descriptions of each of the sites are presented on subsequent figures (Figures S2 to S12). Additional karst features such as large springs and small caves have been described by residents of the area, but were not examined during our visit. In general, most outcrops and quarries yielded a clear view of the Galena Group carbonate rock, and strongly suggested that karst features are ubiquitous in the carbonate rock throughout the area. These descriptions and photographs add additional evidence to our conclusion that the bedrock made up of Galena Group carbonate rock is replete with karst features in Jo Daviess County and that the Galena Group carbonate rock constitutes a karstified bedrock unit and a karst aquifer.

Regarding a question from Aaron Chambers (Statehouse Bureau Chief, Rockford Register Star) on April 4, 2008 about the feasibility of trying to determine if a rock body contains karst features by relying solely on drilling, the lead author stated that it was not surprising that in an area where the carbonate rock (limestone or dolomite) having vertical or near vertical fractures or crevices (somewhere between an inch and six inches wide) every 10 to 40 or so feet, that vertical drill holes would miss these fractures with 3 inch diameter boreholes. For example, if one assumes two sets of vertical fractures 3 inches wide (between 1 and 6 inches), 25 feet apart (between 10 and 40 feet), and intersecting at 90 degrees, and assume randomly distributed boreholes 3 inches in diameter, then the entire area can be divided into 3x3 inch squares and a comparison of the areas (intact rock vs fractures) should yield the probability of intersecting a fracture with a borehole in the area near Nora, IL. A comparison of the areas of intact rock vs fracture indicates that the probability of intersecting a fracture with a 3-inch borehole in this scenario would be 2% or 1in 50. Angled holes would improve the chances of hitting a fracture or crevice; however, the actual probability would depend on the depth and angle of the borehole and the number of boreholes.

Finally, it is important to realize that it only takes one fracture or crevice to transport a contaminant into the underlying carbonate aquifer. Based on what is known of the area (it is difficult to find a road cut or quarry within the carbonate rock that does not have abundant karst features) and the limitations of drilling, it seems that one would want to err on the side of caution and assume the proposed sites are lying over karst features and invest in a containment system that would not be so easily compromised.

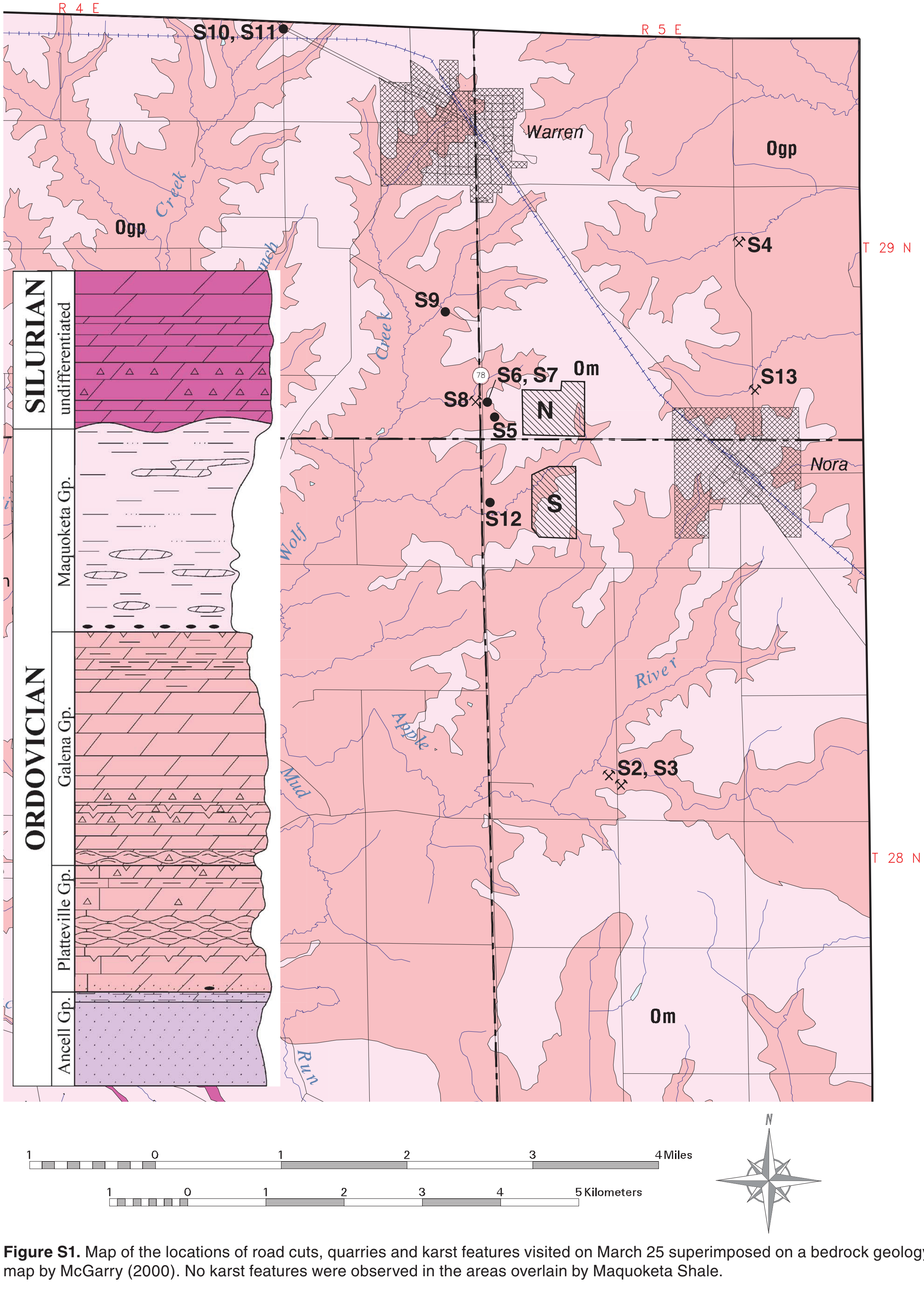

Figure S1. Map of the locations of road cuts, quarries and karst features visited on March 25 superimposed on a bedrock geology map by McGarry (2000). No karst features were observed in the areas overlain by Maquoketa Shale.

Figure S2. Exposure of Galena Group carbonate rock in a quarry located 1.5 miles south of the proposed dairy (Traditional South site). Two sets of solution-enlarged crevices are visible in this photograph, one set are fracture planes parallel to the quarry face and the other set are fracture planes nearly perpendicular to the quarry face. All are vertical or nearly so, have a width of several inches, and show evidence of dissolution on their surfaces.

Figure S3. Panoramic photograph of the opposite wall of the same quarry showing two prominent solution-enlarged fractures (one a the far left and the other about 2/3 of the exposure to the right. Additional vertical fractures are visible to the far right of the photograph. Other vertical features along the wall include drill holes used to blast the face of the quarry.

Figure S4. Exposure of Galena Group carbonate rock in a quarry located about 1.5 miles north of Nora, IL. The walls of the quarry are craggy and badly weathered. A racoon and birds were seen entering and exiting the openings.

Figure S5. A nearly circular, snow-filled depression located on Todd Sargent's farm. The snow overlying this depression was about 3 feet deep with a diameter of about 10 feet. Bedrock in the area was Galena Group carbonate rock.

Figure S6. Road cut about 100 feet northwest of Todd Sargent's farm showing a solution-enlarged crevice about 6 inches wide.


Figure S7. Road cut near Sargent's farm showing a solution-enlarged crevice about 2-3 inches wide.

Figure S8. A small quarry across the road from site S6 and S7 showing karst features.

Figure S9. A large springs located about 1.5 miles north-northeast of the proposed sites. The spring was contained by the land owner who used a large conduit (cattle were digging at the spring and causing erosion). The spring flows year around and discharges about 50 gallons per minute. Specific conductance of the water suggests a chloride concentrations ranged from 30 to 40 mg/L (elevated above background levels of <1 to 15 mg/L).

Figure S10. A panoramic view of a 300 foot exposure of Galena Group carbonate rock along a road cut near the IL-WI boarder located just northwest of Warren, IL along Rt. 78. The exposure reveals a fault and numerous crevices along its length. Crevices range from 10 to 50 feet apart.

Figure S11. A closeup of the above road cut showing numerous crevices betwen 1 to 6 inches wide. Bedding planes were prominent throughout the exposure.

Figure S12. A small depression about 5 feet in diameter in a cultivated field, and located in a field just west (about1.5 miles) of Nora, IL, appears to be a sinkhole. Fragments of carbonate rock littered the field indicating that the soil overlying bedrock was relatively thin in this area.

Figure S13. A small quarry containing the remnants of butchered deer. The quarry walls were small and so overgrown that a clear view of the rock was not possible.