MANURE AND GROUNDWATER: THE CASE FOR PROTECTIVE MEASURES AND SUPPORTING GUIDELINES.

Karl Czymmek[1], Harold van Es[2] and Larry Geohring[3]
PRO-DAIRY[1], Department of Crop and Soil Sciences[2] and Department of Biological and Environmental Engineering[3]
Cornell University

Concerns about groundwater contamination relating to manure application have been on the increase over the past few years. Large dairy farms are increasingly being scrutinized because of the sights, sounds and odors associated with handling significant amounts of liquid manure each year. When manure is handled on a large scale, the intensity of equipment use, coverage of large acreage in a matter of hours, and odors can draw attention to field activities that typically were ignored in the past. The high visibility of manure related agricultural activities and increasing awareness of drinking water quality may cause neighbors to think more about the quality of their own water supply and to test their water for nitrate or bacteria.

Some residential water supplies do not meet modern health standards in terms of the physical condition of the well. Clearly the homeowner should bare responsibility for this. However, many homeowners are unaware of where their water comes from and little information is provided during real estate transactions. Dug wells are shallow and can be easily contaminated directly by surface activities or conditions, especially when poorly located. Some drilled and driven wells are shallow too and may also be improperly or inadequately installed or maintained. These shallow wells are prone to contamination from improper activities around the wellhead or from nearby on-site septic systems, and possibly manure spreading in certain circumstances as well.

Typically, the contamination concerns are fecal coliform bacteria (E. coli) or nitrate. Although there remains a great deal to learn about how these materials move below ground, much is already known about the characteristics of these contaminants. Nitrate is highly water-soluble and thus moves readily through the soil as water drains. E. coli bacteria are not water soluble, but because of their small size, can move through larger soil pores such as cracks or wormholes and so generally require a more direct physical connection to a well to cause problems. The high water content and organic nature of liquid manure may enhance movement of some contaminants under some conditions.

Research reported in 1980 by Bouldin and Porter indicated that most *surface* waters in Upstate New York were substantially below the EPA drinking water standard of 10ppm. This is still largely the case today. However, Bouldin and other USGS scientists reported that some groundwater sources were experiencing increasing nitrate concentrations over time, and this trend has continued in some circumstances where nitrate levels have been tracked.

While more investigation is required, drinking water well vulnerability may be associated with on-site septic systems in some cases and farming activities in others. In gravel valley aquifers and perhaps well-drained upland areas, the vulnerability of a particular well depends on the activities taking place on the land over or near it in relation to the amount of groundwater recharge from woodland and abandoned fields that may mix with it, a so-called “dilution” effect. Some research has shown a strong positive correlation to the number of on-site systems or intensity of agricultural land use with increased nitrate concentrations in groundwater.

In limestone bedrock areas, especially where soil is less than 3 feet over bedrock, the processes can be quite different. Limestone often has vertical cracks that may lead deep into the ground. Once water reaches and fills these cracks, it flows downward very quickly, with minimal filtration or adsorption, and may then move laterally along horizontal cracks. Since limestone is water soluble, over time, water flow increases channel size, thereby increasing the rate of water passage. In some cases, rather large amounts of water and associated contaminants, such as E coli or nitrate, can be moved long distances underground. If these underground pathways are connected to a well, the contamination potential is clear. At this time, however, it appears that some individual or clusters of wells in New York may be vulnerable, but we do not have reason to believe that the concern is widespread over a great number of wells. Nevertheless, a small number of wells may be seriously impacted, so developing more protective measures are important.

In response to these issues, a groundwater protection working group was formed in 2003 to begin to assess current knowledge and to update field guidelines where appropriate. This group consists of Cornell researchers, extension and PRO-DAIRY staff, USDA and USGS scientists and NYS Departments of Health and Agriculture and Markets personnel. The following draft guidelines briefly describe the NY Nitrate Leaching Index and limitations, as well as set forth draft groundwater protection guidelines that will begin to show up in CAFO plans in NY over the next few years.

PRELIMINARY DRAFT: GUIDELINES FOR AGRICULTURAL OPERATIONS IN SENSITIVE GROUNDWATER AREAS

Karl Czymmek, PRO-DAIRY, Harold van Es, Department of Crop and Soil Sciences and Larry Geohring, Department of Biological and Environmental Engineering

Developed in consultation with the Groundwater Working Group:

Bill Kappel, USGS
Dave Eckhardt, USGS
Steve Indrick, NRCS
Steve Page, NRCS
Jerry Smith, NRCS
Tibor Horvath, NRCS
Jeff Ten Eyck, SSWCC staff
Paul Kaczmarczyk, NY-DOH
Ron Entringer, NY-DEC, formerly NY-DOH

The Preliminary Draft Guidelines for identifying and protecting sensitive groundwater resources are designed to reduce the risk of groundwater contamination posed by manure applications. These guidelines are based on available knowledge of processes contributing to groundwater contamination. Manure handlers must understand that there are inherent risks associated with manure application. These guidelines cannot be expected to eliminate all risk of groundwater contamination because there are conditions and combinations of circumstances that are difficult or impossible to predict or evaluate.

The Nitrogen Leaching Index (NLI) for New York State utilizes annual and seasonal rainfall and the soil hydrologic group to provide an estimate of the relative risk of nitrogen leaching out of the plant root zone for each field. The NLI does an excellent job of flagging well and excessively well-drained soils that are at increased risk for leaching. For fields that receive an NLI rating of 10 or more, guidelines are provided for improving nitrogen conservation practices and management in "The New York Nitrate Leaching Index" (http://nmsp.css.cornell.edu/publications/nleachingindex.pdf).

The NLI is designed to consider soil characteristics in the top few feet of the earth's crust and to generally reduce nitrate loading to groundwater resources. Presently, the NLI is not designed to evaluate vulnerability of specific groundwater resources such as wells or springs. The NLI does not consider pathogen or phosphorus transport, nor was it designed to evaluate underlying geologic features such as bedrock type and condition, water storage capacity, or conductivity.

Since groundwater issues in agricultural areas are on the rise, planners will be increasingly called upon to provide site-specific evaluations and recommendations regarding manure rates and spreading setbacks, especially where liquid manure is applied. While researchers develop improved risk indicator tools, the guidelines below are suggested for planners to begin to evaluate the landscape more carefully for potential contamination risks.

There are three general conditions that can present an increased risk for the contamination of specific groundwater resources: 1) Soils less than 40 inches deep over carbonate bedrock; 2) glacial outwash and some well drained alluvial soils; and 3) soils less than 20 inches deep over other bedrock types. Since the features and processes involved in each situation are somewhat different, guidelines are delineated separately below. To get a general idea of the geology of NYS and to estimate the bedrock type that lies beneath a farm, see: http://geology.about.com/library/bl/maps/newyorkmapmid.jpg?once=true& and http://geology.about.com/library/bl/maps/nylegend.jpg.
Also, regional scale surficial and bedrock geology maps can be obtained as arc files at : http://www.nysm.nysed.gov/gis/. GIS based aquifer maps for NYS can be found at: http://www.nysgis.state.ny.us/inventories/health.htm

1) Limestone areas. A significant portion of prime agricultural soil in NY was deposited over Carbonate bedrock. "Carbonate" includes Limestone, Dolomite, and other carbonate-like sedimentary bedrock that can create enhanced fracture pathways due to groundwater flow. Bands of Carbonate bedrock run roughly parallel to the NYS Thruway from Albany to Buffalo, along the western side of the Hudson River, and also in Northern New York. Some of the bedrock is rather soluble, and results in "Karst" topography; where sinkholes and closed depressions and dissolved caverns and fractures (zones of rapid flow) are often exhibited. These Karst areas are at high risk for groundwater contamination and special care must be taken. Karst groundwater flow systems exist across New York; usually weakly developed in the Onondaga Limestone in the western part of the State, while more intense (i.e., more or larger interconnected channels) karst development can be found in the Onondaga and Helderberg units in the eastern part of the State. Limestone and some dolomite units may have weakly developed karst systems and may present a moderate to high risk of groundwater contamination. Limestone and dolomite bedrock can also be highly fractured, providing rapid drainage pathways for surface runoff to reach groundwater. The fractures are important pathways between the surface and the ground water flow system providing rapid groundwater recharge, even when filtered by a few feet of soil. As water seeps into the cracks, the carbonate material is slowly dissolved causing further bedrock erosion (widening of fractures) and increasing the capacity of such areas to accept shallow groundwater recharge. These characteristics make carbonate areas some of the more vulnerable to rapid surface water recharge and to changes in water quality, especially when large quantities of manure may be moved offsite during periods of heavy rainfall or snow melt. Either type of event can cause rapid surface water runoff and subsequent infiltration into the bedrock.

- In karst areas (where carbonate bedrock is present), ask producers to identify:
    - areas where bedrock limits tillage or drain tile installation or drainage ditch depth.
    - presence of sinkholes, springs, closed depressions in or near fields that may fill and drain rapidly.
    - areas where runoff water or tile discharge disappears into the ground.
    - known or potential locations of abandoned wells or cisterns.
    - locations of wells used for any private, homeowner or public water supply (i.e., municipal, trailer court, roadside restaurant, etc.) within 1 mile from fields that may receive manure.
    - historical water quality problems in the area, such as leaky underground fuel storage tanks, short- and long-term water quality/quantity problems related to the ground-water system (unconsolidated or bedrock aquifers), etc.
- Using the soil survey, determine if any soils on the farm overlie carbonate bedrock at a depth of 40 inches or less (see Appendix A) and visually evaluate and map fields for bedrock limited areas.
- Visually evaluate and map fields for sinkholes, springs, and closed depressions. These areas may not be represented in the soil survey. depending on the date and level of detail in place during the survey period
- The following practices should be applied to soils less than 40 inches deep over limestone where appropriate:
    - Generally limit liquid manure application rate to 10,000 gallons/A/year or less, depending on nutrient content and crop requirement.
    - Do not spread manure within 100 feet of any well or spring.
    - Manure should not be applied to lands that drain to a sinkhole or closed depression, unless it can be incorporated before the next rainfall or snowfall. Special care is needed when soils are frozen, unless injected or immediately incorporated through “frost tillage”.
    - When applying liquid manure to living sod, consider adopting methods of shallow incorporation or injection to break up soil pores and reduce runoff and leaching potential.
    - For annual crops, incorporate manure (especially liquid manure) whenever possible to mix with soil and reduce the potential for runoff and leaching through preferential flow. Consider fate of conserved ammonia-N.
    - When rotating sod to annual crops, do not kill sod in the fall by tillage. Fall chemical sod kill should be delayed as long as possible. Delaying sod kill until spring may require changes in weed control programs.
    - Fall applied manure should be limited or eliminated.
    - Adopt other N conservation practices such as cover crops.

2) Glacial outwash (and certain well drained alluvial soils over sand or gravel deposits). Outwash soils and surficial, unconsolidated aquifers are often found on Southern Tier valley floors and around the base of the Adirondacks, but

smaller deposits are also found in other upland positions around NY. The soils are typically made up of relatively coarse sand, gravel, cobble, etc and are often well to excessively well drained. Since these soils have high specific water yield or “drainable porosity”, water and soluble materials such as nitrate rapidly move out of the root zone. Many public water supply systems are located in these areas. Consequently, these soils may present a moderate to high water quality risk.

- In outwash areas, ask producers to identify:
  - location and description (if possible) of all farm and neighboring wells within 1000 feet of fields that may receive manure, if known.
  - known or potential locations of abandoned wells or cisterns.
  - locations of wells used for any public water supply (i.e., municipal, trailer court, roadside restaurant, etc.) within 0.5 miles from fields that may receive manure.
  - awareness of historical water quality problems in the area, such as leaky underground fuel storage, etc.
- Determine if the farm lies within a sole or primary source aquifer boundary (see http://www.epa.gov/region02/water/aquifer), your consultant should be able to access a more detailed NYS aquifer map at: http://www.nysgis.state.ny.us/inventories/health.htm).
  - Do not spread manure within 100 feet of any: a) well; b) direct connection to an aquifer; or c) spring.
  - Carefully evaluate and implement the NLI risk score and N management recommendations.
  - Monitor and improve the uniformity of manure spreading equipment and practices.
  - See Appendix B for a list of soil types.

3) Soils less than 20 inches to bedrock. These soils can be found anywhere in NYS and are often situated on shale or other layered bedrock, though fractures can occur in any type of bedrock. When the soil is less than 10-20 inches deep over fractured bedrock, there is a high potential for local groundwater impact. It is difficult to know if there are critical fractures present, and, once in a fracture, the contaminant can move great distances depending on the gradient of the water table, and water uses in the region. Therefore, shallow soils will be treated as though fractures are present in the bedrock and guidelines are similar to those for the karst system described in section 1 above. In some circumstances, past manure spreading experience may be used to guide what practices below need to be adopted.

- In shallow and very shallow soil areas, ask farm operators to identify:
  - areas where tillage is restricted by bedrock
  - areas where runoff water or tile discharge disappears into the ground.
  - location and description (if possible) of all farm and neighboring wells within 1000 feet, if known.
  - known or potential locations of abandoned wells or cisterns.

    - locations of wells used for any public water supply (i.e., municipal, trailer court, roadside restaurant, etc.) within 0.5 miles from fields that may receive manure.
    - locations of nearby ponds that are bedrock limited.
    - awareness of historical water quality problems in the area, such as leaky underground fuel storage, etc.
    - See Appendix C for a list of soil types.
- The following practices should be applied to soils shallow or very shallow over sedimentary bedrock:
    - Generally limit manure application rate to 10,000 gallons/A/year or less, depending on nutrient content and crop requirement. Little or no manure should be applied to sod in the fall, winter or spring before it is to be rotated to corn
    - Do not spread manure within 100 feet of any well or spring.
    - When rotating sod to annual crops, do not kill sod in the fall by tillage. Fall chemical sod kill should be delayed as long as possible. Delaying sod kill until spring may require changes in weed control programs.
    - Fall applied manure should be limited or eliminated.
    - Adopt other N conservation practices such as cover crops.
    - Carefully evaluate and implement the NLI risk score and N management recommendations.
    - Monitor and improve the uniformity of manure spreading equipment and practices.

Additional suggestions for producers:

- When new land is acquired, talk to previous operators, if available, about abandoned wells, shallow bedrock, sinkholes or places where water disappears into the ground.
- Meet owners of adjacent properties before spreading manure at new sites, explain manure management practices and ask about well types and locations so that pro-active steps can be taken to reduce groundwater contamination risk.
- Keep manure application rates low at first when spreading at a location that is new to the operation and/or has had little or no recent manure history.

Protecting groundwater may demand improved manure management and additional farm resources in the coming years. These guidelines should be a good start toward reducing farm business risk associated with the potential for contaminating a drinking water well.

Appendix A

New York Soil Series, Variants, and Miscellaneous units that are less than 40 inches deep to carbonate bedrock (e.g. limestone, dolomite):

Benson
Chaumont
Chippeny
Farmington
Galoo
Galway
Gouverneur
Groton Variant (Jefferson Co.)
Guff*
Guffin*
Joliet
Kings Falls
Madalin Variant (Montgomery and Schenectady Co.)
Matoon*
Neckrock
Nehasne
Newstead
Ogdensburg
Rockland, limestone
Ruse
Summerville
Sun Variant (Monroe Co.)
Wassaic
Wilpoint

* In some areas these glaciolacustrine soils are over non-calcareous rock. These areas are indicated at a small scale on the bedrock geology map (Adirondack sheet) from the New York State Geological Survey.

The following soils are typically over calcareous shale, but may be over limestone in areas where shale and limestone bedrock formations are in close proximity. In addition, the calcareous shale may be porous enough in places to allow rapid infiltration, creating an increased risk of groundwater contamination.

Aurora
Brockport
Camillus
Lairdsville
Lockport
Palatine
Riga
Varick

Appendix B

New York Soils with Glaciofluvial or Alluvial Parent Material
and Sandy or Sandy and Gravelly Substratum:

Adams
Agawam
Allagash
Allard
Allard Variant
Altmar
Alton
Atsion
Au Gres
Barbour
Berryland
Bonaparte
Carver
Castile
Champlain
Chenango
Colonie
Colosse
Colton
Constable
Copake
Covert
Croghan
Deerfield
Deford
Deinache
Deposit
Duane
Duneland
Duxbury
Elnora
Enfield
Fahey
Fluvaquents
Fredon
Gougeville
Granby
Grattan
Groton
Halsey
Haven
Hempstead
Hinckley
Homer
Hoosic
Howard
Jebavy
Junius
Kars
Knickerbocker
Linlithgo
Middlebury
Mooers
Naumburg
Ninigret
Oakville
Occum
Occum Variant
Olean
Ondawa
Otisville
Palmyra
Pawling
Phelps
Philo
Pipestone
Pits, Gravel and Sand
Plainfield
Plymouth
Podunk
Pompton
Pootatuck
Raypol
Rippowam
Riverhead
Rumney
Scarboro
Sciota
Searsport
Stafford
Sudbury
Suncook
Trestle
Trout River
Tunkhannock
Udifluvents
Udipsamments
Waddington
Wainola
Wallace
Walpole
Wampsville
Wappinger
Wareham
Windsor
Wyalusing

Appendix C

New York Soil Series, Variants, and Miscellaneous Units that are less than 20 inches to non-calcareous bedrock:

Abram
Arnot
Canaan
Couchsachraga
Glover
Halcott
Hannawa
Hawksnest
Hogback
Hollis
Holyoke
Insula
Irona
Kearsarge
Knob Lock
Lordstown Variant (Cortland Co.)
Lyman
Nassau
Quetico
Ricker
Rock Land
Rock Outcrop
Skylight
Taconic
Topknot
Tor
Torull
Tuller
Woodstock
Wotalf