

Proposed Regional Synthesis Report Glacial, Cambrian/Ordovician, and New England Crystalline Aquifers

Proposed Title:

The association of arsenic with depth, redox conditions, and ground-water age in selected hydrogeologic settings within the glacial aquifer system of the Northern United States

Scope (NAWQA components / constituents):

Study Units: Lower Illinois River Basin (LIRB), Upper Illinois River Basin (UIRB), Lake Erie-Lake St. Clair Drainages (LERI), White-Miami River Basins (WHMI), Western Lake Michigan Drainages (WMIC), Central Nebraska Basins (CNBR), Red River of the North Basin (REDN), Upper Mississippi River Basin (UMIS), High Plains Region (HPGW), Connecticut, Housatonic, and Thames River Basins (CONN), Hudson River Basin (HDSN), New England Coastal Basins (NECB), Delaware River Basin (DELR), and Cook Inlet Basin (COOK).

Time period: 1991 to present

Land use(s): Mixed

Constituents: Arsenic; redox indicators (dissolved oxygen, nitrate, ammonia, manganese, iron, sulfate); age-dating analytes

More than 1 Principal Aquifer? No

Expected authors – Lead: Mary Ann Thomas

Contributing: Daniel Feinstein, Chris Hoard, Ted Moran, Kelly Warner

Objectives:

OBJECTIVE 1: Document arsenic concentrations in glacial settings

- **Categorize NAWQA well networks into glacial settings based on source area and aquifer type.** An existing stratification system for the glacial aquifer system will be used to classify well networks in relation to 4 source areas and 4 aquifer types, for a total of 10-12 glacial settings.
- **Document arsenic concentrations.** Summarize arsenic occurrence in each of the glacial settings using a summary table and/or graph.
- **Select a subset of glacial settings for further analysis.** Glacial settings that lack sufficient data will not be used in tasks outlined in Objectives 2-4. Alternatively, we may “aggregate up” to more general settings to be able to include all the data. This decision will be reviewed during a conference call at near the end of FY04.

OBJECTIVE 2: Describe relations among arsenic concentrations, depth, redox conditions, and ground-water age.

- **Document redox conditions for each sample.** Redox conditions of ground-water samples will be estimated based on concentrations of selected major ions and field parameters using an automated program developed as part of one of NAWQA’s topical studies—Transport of Anthropogenic and Natural Contaminants to Public Supply Wells (TANC).
- **Document ground-water age for each sample.** Ground-water age has been shown to be an important variable related to arsenic concentrations in ground water, based on analysis of arsenic in glacial deposits in the central Midwest (Thomas, 2003) and preliminary analysis of data from the TANC topical study. For most well networks, ground-water ages are already compiled in a NAWQA spreadsheet. Samples will be grouped into two broad age categories (older or younger than 1953) related to the tritium age-dating method. (Where CFC, tritium-helium, or SF6 age dates are available, they may be used for more detailed analysis on a subset of well networks.)
- **Illustrate how relations among arsenic, depth, redox conditions, and ground-water age differ among the glacial settings.** Graphics, nonparametric statistical tests, and summary tables will be used to compare and contrast results among glacial settings.

OBJECTIVE 3: Identify the major controls on arsenic concentrations in selected hydrogeologic settings.

Determine which variables have the greatest influence on arsenic concentrations in different hydrogeologic settings using graphical and statistical analyses and simple geochemical modeling (PREEQCI). Preliminary analysis of data from the TANC study indicates that possible explanatory variables include: source area, aquifer type, redox conditions, ground-water age, well depth, and geochemical constituents such as pH, alkalinity, and other trace elements.

OBJECTIVE 4: Simulate the distribution of redox conditions and ground-water age in selected hydrogeologic settings.

Mobilization and transport of arsenic are difficult to model. However, in some hydrogeologic settings, elevated arsenic concentrations are associated with reducing and/or old ground waters. The MODFLOW-MT3DMS-RT3D suite of codes will be used to simulate the distribution of reducing and old ground water in 3 glacial type settings. Special attention will be given to the influence of stratigraphy, organic carbon content, and pumping on the distribution of redox conditions and age-mass.

Data interpretation approach & feasibility

Number of sites / components (eg: nutrients, pesticides):

- All well networks (MAS and LUS) in the glacial aquifer system with arsenic data
- Components: arsenic; redox indicators (dissolved oxygen, nitrate, ammonia, manganese, iron, sulfate); age-dating analytes.

Methods (standard? new?):

- Graphical and nonparametric statistical analyses (standard).
- TANC redox classification (recently developed).
- Simple geochemical modeling using PHREEQCI (standard).
- Simulations of redox conditions and age mass in selected glacial type settings using MODFLOW-MT3DMS-RT3D suite of codes (new).

Data availability & processing: Water-quality data will be pulled from the NAWQA Data Warehouse. Age dates will be retrieved from a spreadsheet compiled by Curtis Price.

Staff availability: The lead author is available approximately 30% in FY04, 40% in FY05, and 50% in FY06.

Complexity: This analysis is moderately complex, but it builds on previous work.

Risks / contingencies: Some well networks might not have the complete set of required information.

Other Program contacts: Sheridan Haack, Steve Hinkle, Joe Ayotte

Expected Outcome

Results of the study will be published in a USGS Scientific Investigations Report in 2006.

Why is this topic important to report on?

- The glacial aquifer system is complex and includes settings with distinctly different hydrogeologic characteristics. We need to understand which parts of this complex system are most (and least) susceptible to arsenic contamination using variables that are relatively simple and widely available.
- Redox conditions are related to the fate and transport of, not just arsenic, but other contaminants including nitrate, many trace elements, and some organic contaminants (pesticides and volatile organic compounds). Therefore, documenting how depth, redox conditions, and ground-water age differs among glacial settings provides a framework for study of these other contaminants.

Why does this topic need to be addressed now?

In 2001, the U.S. Environmental Protection Agency lowered the Maximum Contaminant Level (MCL) for arsenic to 10 µg/L. The new standard will be enforceable for public water systems in 2006. EPA's action has raised the public awareness of arsenic in drinking water, especially by water managers and private well owners. The USGS is one of the government agencies that will be increasingly called on to provide information that addresses the concerns of the public.

Why is it appropriate for this topic to be addressed by USGS? NAWQA? this regional Team?

- **USGS:** Arsenic in ground water is related to the interaction of geologic materials, water, and microbes. The USGS is the agency best-equipped to tackle this complex problem.
- **NAWQA:** (1) The glacial aquifer system is one of the largest sources of drinking water in the Nation. In parts of the glacial aquifer system, arsenic exceeds the MCL more frequently than any other contaminant. (2) Redox is an important control on the fate and transport of other constituents in addition to arsenic, including nitrate and many trace elements, some pesticides, and some VOCs. NAWQA is one of the few programs that are in position to define redox conditions over wide areas. This topic builds on work by the TANC topical study.
- **Regional aquifer team:** (1) Arsenic was identified as a contaminant of concern by scientists from NAWQA study units that span the glacial aquifer system. (2) The aquifer system is widespread and diverse and therefore has a wide range of explanatory variables for comparison and analysis. (3) The team members have the expertise, interest, and time available to devote to this topic.

Who cares and why?

- **Water managers.** In southwestern Ohio, the largest public-water supplies tap glacial valley-fill deposits that are thick (200 to 400 ft) and heterogeneous. The shallow unconfined horizons are susceptible to anthropogenic contaminants, and water managers know that they can avoid these contaminants by drilling wells deeper. However, they are unaware of how susceptible to arsenic contamination varies within the aquifer. Increased knowledge of arsenic occurrence would help water managers avoid well-siting decisions that inadvertently trade off one contaminant for another.
- **Public agencies responsible for human health.** Ideally, public funding should be targeted to areas with the greatest needs. Knowledge about which parts of the glacial aquifer system that are most susceptible to arsenic contamination would allow water-quality monitoring or education about home treatment systems to be targeted to those that would benefit the most.
- **Private well owners.** Public awareness of the issue of arsenic in drinking water has recently increased, but domestic wells are not routinely sampled for arsenic. A better understanding of arsenic occurrence in the glacial aquifer system could provide guidance to well owners regarding whether to have their water tested for arsenic. For example, in southwestern Ohio, water with low concentrations of iron is much less likely to have elevated arsenic than water with high concentrations of iron (as evidenced by dark staining).
- **Scientists.** Documenting the distribution of redox conditions in the glacial aquifer system would lead to better understanding of contaminant fate and transport of other redox-sensitive constituents, including nitrate, many trace elements, and some organic contaminants.

Budget (attached in detailed budget sheet)

FY 2004:

- Data retrieval, database compilation and QA/QC
- Categorization of glacial settings, redox conditions, and ground-water age.
- Exploratory data analysis, including summary statistics and graphics
- Conference call with NLT to review preliminary analysis

- Preparation of detailed report outline

FY 2005:

- Graphical and statistical analyses of water-quality data; creation of summary tables and figures.
- Hypothetical simulations of redox and age mass in selected glacial type settings.
- Hypothetical geochemical modeling in selected glacial type settings.

FY 2006:

- Final data interpretation and report writing
- Inhouse, colleague, and regional reviews
- Publication