Office Memorandum

DEPARTMENT: Natural Resources - Ecological and Water Resources Division

DATE: December 3, 2015

TO: Barb Huberty, Director
Legislative Water Commission
Minnesota State Legislature

FROM: Stephen Thompson, Hydrogeology and Groundwater Unit Supervisor
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MNDNR

SUBJECT: Question regarding age of groundwater in Minnesota

Introduction

This memo is in response to a question asked following a Nov. 16th Clean Water Council presentation about the DNR County Geologic Atlas (CGA) program by Stephen Thompson, MNDNR. As part of the presentation, Mr. Thompson included a brief description of age dating activities conducted by the CGA program. The question asked was, "…whether the DNR knows (or could determine) what percentage of the state's appropriated groundwater is vintage vs. recent water."

Methods for dating groundwater (groundwater residence time)

Both the DNR's CGA program and Minnesota Department of Health (MDH) sample wells for estimating water residence time (age dating). Groundwater residence time is the approximate length of time that has elapsed from the moment water infiltrates the land surface to the time it is pumped from a well or discharged at a spring. Groundwater residence time can be estimated from the amount of tritium in the sampled water. Tritium is a naturally occurring radioactive isotope of hydrogen. Concentrations of tritium greatly increased in the atmosphere between1953-1963 due to above-ground nuclear testing. Because tritium has a half-life of 12.32 years, the proportion of recently recharged water (less than 60 years) can be estimated by its tritium content.

- Tritium values of 8 or greater tritium units (TU) indicate recent aged groundwater (less than 60 years old).
- Intermediate tritium values of greater than 1 and less than 8 TU indicates a mixture of recent and vintage water
- Tritium values less than or equal to 1 TU indicate vintage aged groundwater (greater than 60 years old).

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DNR groundwater sampling and analysis shows a general relationship between the types of aquifers and the residence time of its groundwater as determined by tritium analysis:

- Recent and mixed tritium values are common in water-table aquifers.
- Vintage and mixed values are common in confined sand and bedrock aquifers.
- Groundwater can have a recent or a mixed signature where bedrock is shallow or at the surface in southeastern and east-central Minnesota or in locations where increased pumping allows younger water to migrate to deeper depths

The DNR further refines groundwater residence time of a subset of vintage tritium-age groundwater samples collected in the CGA program using carbon-14. The program estimates groundwater residence time of roughly ten vintage tritium-age samples per county. This method uses the naturally occurring carbon-14 isotope and its half-life of 5730 years to estimate groundwater residence time from roughly 100 to 40,000 years. Carbon-14 dating of groundwater residence time is primarily performed by the DNR CGA program, although previous investigations by the Minnesota Geological Survey and University of Minnesota Department of Earth Sciences have added to the statewide dataset.

Results

Aquifers are classified by type (hydrogeology and geology) and permitted use in the state's well database – the County Well Index (CWI). The following table shows that most permitted public water supply wells and commercial or industrial wells are in bedrock aquifers where vintage water is most common.

Aquifer Type				
Use Category	**Number of Wells in CWI**	**Unconfined Water-Table Aquifer (Recent & Mixed Tritium-Age)**	**Confined Sand and Gravel Aquifer (Mixed & Vintage Tritium-Age)**	**Bedrock Aquifer (Recent, Mixed, & Vintage Tritium-Age)**
Irrigation	6199	1998 (32%)	2424 (39%)	1777 (29%)
Commercial/Industrial	2426	174 (7%)	718 (30%)	1534 (63%)
Public	15,448	1100 (7%)	4702 (30%)	9646 (63%)

MDH encourages groundwater use for human consumption from confined aquifers, if possible, because these aquifer types are generally better protected from surface contamination than water-table aquifers. MDH samples public wells for tritium analysis as part of their Source Water Protection program. The public water supply wells sampled by the MDH represent nearly all of the appropriation wells for which there are tritium data available. The table below shows that from 2,538 MDH records, 45% of public water supply wells use vintage water. In addition, through the MDH well permit program, domestic well owners are encouraged to drill wells into aquifers that are confined, better protected, and commonly contain older water with vintage tritium conditions.

Groundwater residence time for Public Water Supply Wells (MDH data)	
Tritium classification	**# of wells and percentage**
Recent >8 TU	483 (19%)
Mixed >1 to <8 TU	900 (35%)
Vintage < or equal to 1 TU	1155 (45%)

The DNR chemistry database comprises data mostly from domestic wells sampled as part of the CGA program. The 2,348 DNR records suggest that most domestic water supply wells use vintage tritium-aged water.

Groundwater residence time for private, residential water supply wells (DNR data)	
Tritium classification	**# of wells and percentage**
Recent >8 TU	360 (15%)
Mixed >1 to <8 TU	656 (28%)
Vintage < or equal to 1 TU	1332 (57%)

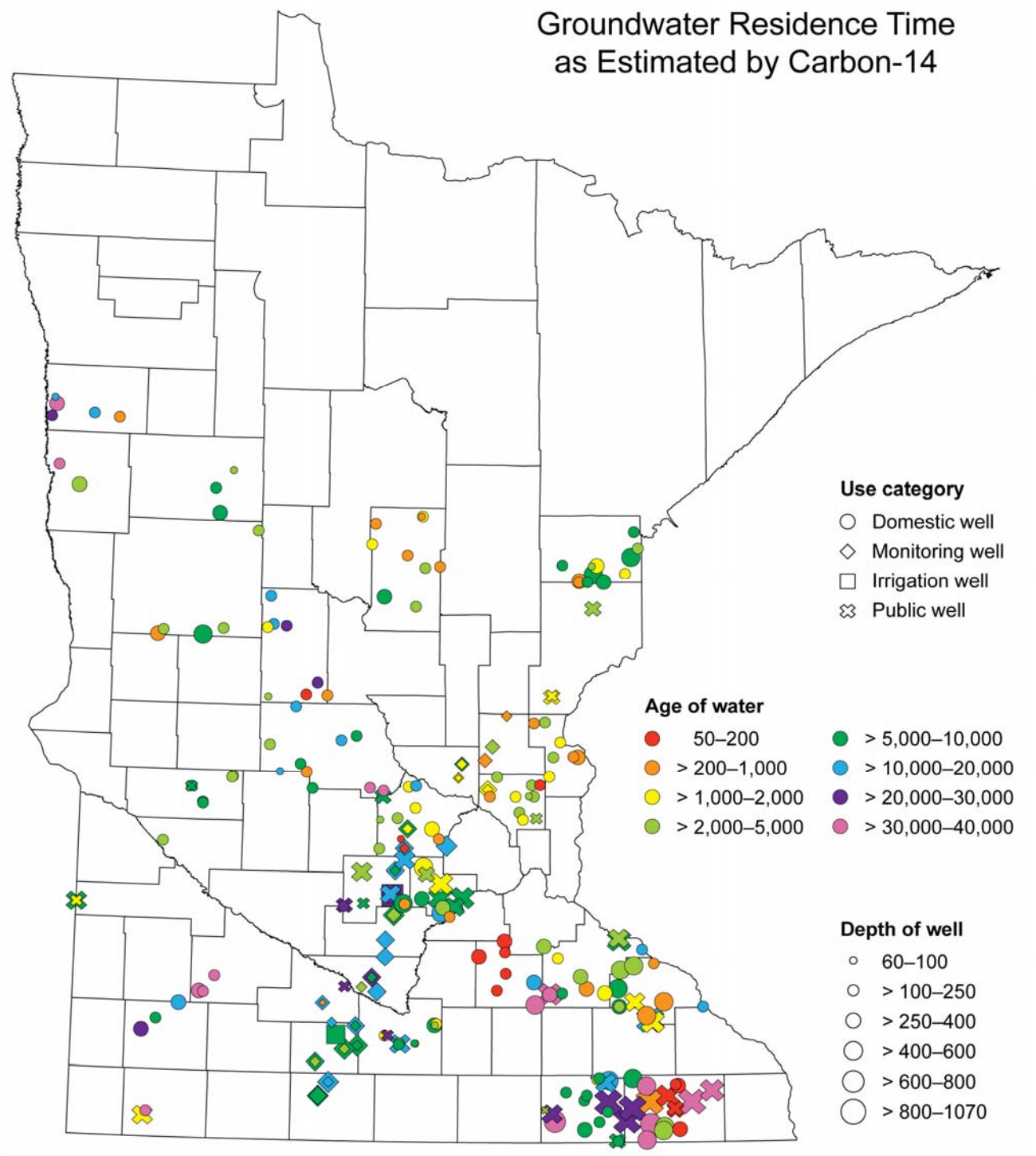
High-capacity industrial and municipal groundwater users that require a DNR permits often prefer to use deeper (and typically older) water to minimize interference with shallower domestic wells. The confining layers that separate aquifers range in their ability to protect the underlying aquifers due to differences in material properties and distribution. In addition, high-volume pumping increases groundwater gradients in the vicinity of the well (cone of depression), which in many cases allows younger water to move to depths through the confining layers.

The table below summarizes the use categories for carbon-14 ages in the DNR database. Of the 237 wells currently in the database, 97 wells are completed in unconsolidated Quaternary deposits (96 in confined sand and gravel aquifers) with the remaining 140 wells completed in bedrock aquifers. Of the use categories presented below, the public supply and irrigation uses would likely require a DNR appropriation permit. The figure on the following page presents the carbon-14 residence time data spatially, showing the distribution of data points and the range of well depths and estimated residence time per use category.

Groundwater residence time as estimated using carbon-14			
Use Category	**Number of wells in database and percentage**	**Completed well depth range (ft.)**	**Estimated residence time range (years)**
Domestic	154 (65%)	60 – 660	50 – 40,000
Monitoring	41 (17%)	70 – 718	60 – 22,000
Public Supply	4 (17%)	100 - 1070	7,000 – 30,000
Irrigation	2 (1%)	484 - 671	150 – 35,000

In the past the state has recognized that there are important aquifers that recharge very slowly and need special protection. There are special DNR restrictions regarding the use of the deep Mt. Simon/Hinckley aquifer (http://files.dnr.state.mn.us/waters/watermgmt_section/appropriations/mt_simon_hinckley_guidance.pdf).

This recognition prompted a regional investigation of the Mt. Simon aquifer recharge characteristics that extensively used tritium and carbon 14 residence time data. The reports and related videos can be found at the following link:
http://www.dnr.state.mn.us/waters/groundwater_section/mapping/projects.html


Groundwater Residence Time
as Estimated by Carbon-14
Use category
Domestic well
Monitoring well
Irrigation well
Public well
Age of water
50–200
> 200–1,000
> 1,000–2,000
> 2,000–5,000
> 5,000–10,000
> 10,000–20,000
> 20,000–30,000
> 30,000–40,000
Depth of well
60–100
> 100–250
> 250–400
> 400–600
> 600–800
> 800–1070