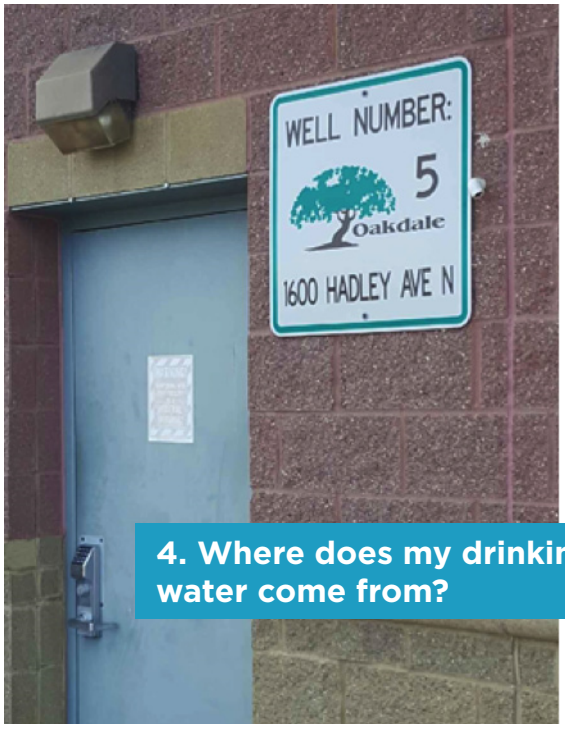
Minnesota's Groundwater Education Gap Preparing Students to Effectively Manage our Groundwater Resources in the Future

MINNESOTA GROUND WATER ASSOCIATION
White Paper 02
DECEMBER 2016

1. Is my well water safe to drink? For what contaminants should I test my well water?

2. Who provides groundwater expertise for teachers?

3. What teaching resources are available?



4. Where does my drinking water come from?

The pictures on the covers represent questions about groundwater that groundwater professionals indicate the public often asks or which professionals ask about groundwater education. These questions can be used to update or improve classroom curricula as well as to further define statewide strategies for improving public knowledge about groundwater. The Minnesota Ground Water Association (MGWA) has identified gaps in groundwater education that are presented in this white paper that can be used as a starting point for improving citizen knowledge about groundwater. The long-term desire is to have Minnesotans be better informed about groundwater so that they can make more informed decisions about managing and protecting one of our most valuable natural resources.

FRONT COVER

1. Water glass on a well (Source - Bruce Olsen).
2. Classroom discussion about groundwater (Source – Children's Water Festival Web page).
3. Outdoor Water Park at the Science Museum of Minnesota (Source – MGWA).
4. Municipal well house (Source – Bruce Olsen).

BACK COVER

5. Contaminated water being pumped from a monitoring well (Source - Minnesota Department of Health) with 55-gallon drum of improperly managed waste (Source - Cathy Undem).
6. Exploration drill rig (Source – United States Geological Survey).
7. Pillsbury Hall at the University of Minnesota, Minneapolis Campus (Source – Public internet image).
8. Diagram of geological and water-bearing characteristics at neighboring wells (Source – Bruce Olsen).

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Minnesota's Groundwater Education Gap:
Preparing Students to Effectively Manage Our Groundwater Resources in the Future

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EXECUTIVE SUMMARY

Approximately three million Minnesotans who live in communities rely on groundwater for drinking and the 1.3 million who live elsewhere have wells. Furthermore, groundwater recharges many lakes and streams, supports habitat for many plants and animals, and is a more dependable source of water supply than surface water. Pumping to meet the water supply demands of communities, industry, agriculture, and mining is having an increasing impact on sustaining the amount of groundwater that is available locally. About 83 percent of community public water supplies derived from groundwater require some level of water-quality treatment (Minnesota Department of Health oral communication, November 2016). The natural quality of groundwater often requires community water suppliers and well owners to add treatment to reduce its hardness and to remove iron, manganese, arsenic, radium and other such contaminants. Human-caused contamination such as from fuel, solvents, and nutrients has impaired groundwater quality in some areas to the point that treatment is required to meet state and federal drinking water standards. Yet, with the statewide dependence that Minnesotans have on groundwater, many lack the basic knowledge about it to make informed decisions that will protect its quality and quantity for future generations.

Wise management of Minnesota's groundwater resources relies on a citizenry that is knowledgeable of basic groundwater principles and on groundwater professionals that start their careers with adequate postsecondary training. To this end, the Minnesota Ground Water Association (MGWA) has assessed potential gaps in groundwater education in Minnesota. Specifically, this assessment looked into deficiencies in, 1) the curriculum taught in grades K-12, 2) postsecondary graduation requirements for entry-level groundwater- related jobs, and 3) education goals about groundwater that are contained in water resources management strategies. Overall, improvements made in all three areas would better prepare future generations of Minnesotans to play more active roles in wisely using and managing their groundwater resources.

Currently, Minnesota's academic standards relating to K-12 education about groundwater only require that the hydrologic cycle be taught in the fourth and eighth grades. Schools must focus their curricula on meeting Minnesota academic standards and testing requirements so that in many schools, teaching about groundwater is limited to the hydrologic cycle and nothing more. The limitations of having only this academic requirement is reflected in a MGWA survey of groundwater professionals which indicates that the general public lacks knowledge about groundwater quality and what groundwater resources are available to them locally. Also, adults are uncertain about the roles that local, state, and federal government play in groundwater resource management and protection. Revisions to Minnesota academic standards for science that are scheduled for the 2017-2018 school year could narrow gaps in groundwater knowledge so that today's K-12 students may become tomorrow's groundwater literate adults and better prepared to solve problems relating to groundwater.

A MGWA survey of public sector and private sector employers indicates that no formal mechanism is in place for them to communicate to Minnesota's postsecondary institutions the knowledge, skills, and experience that they require of candidates for entry-level groundwater jobs. Furthermore, the survey indicates that only three of the twelve Minnesota colleges and universities that were selected for review offer coursework relating to groundwater beyond the introductory level. This translates into many postsecondary graduates from Minnesota facing stiff competition from better prepared graduates for entry-level groundwater jobs. MGWA, in consort with other professional organizations, has the opportunity to improve communication between employers and postsecondary institutions to help reduce these hiring problems.

Planning strategies that include education about water resources are documented by several organizations in the public sector and private sector, but either do not provide sufficient detail about groundwater education efforts for all of Minnesota's residents or focus on target groups related to a management objective. Also, there is limited coordination described between these strategies to promote a statewide approach to groundwater education. Furthermore, implementation of strategy goals promoting statewide education about groundwater to all Minnesotans ranges from partially complete to none. MGWA has an opportunity to assist with developing a statewide strategy for improving groundwater education that builds upon previous efforts and the experience gained by attempting to implement them.

Findings suggest that increasing knowledge about groundwater could be accomplished through several avenues, such as changing Minnesota's academic standards or expanding teacher access to education resources that are approved by school boards and are applicable to cross disciplinary teaching methods. Support for filling the current education gaps appears to be widespread and MGWA could play a significant role by coordinating and engaging technical experts, elected officials, and educators within its membership. Furthermore, MGWA could help improve communication between employers and postsecondary institutions so that undergraduate degree requirements may better reflect employer hiring requirements as much as is practical.

Finally, there are opportunities available to organizations, such as MGWA, that are consistent with their missions relating to groundwater education. In particular, MGWA could participate in revising Minnesota academic standards for science, mathematics, and social studies and demonstrate how groundwater principles or management issues can be incorporated into classroom lessons for meeting these standards and their benchmarks. Also, the experience gained by developing this white paper can be shared with other professional organizations to broaden the discussion about current gaps in groundwater education and to develop approaches for eliminating them.

GLOSSARY OF TERMS AND ACRONYMS

Academic standard: a requirement that specifies the learning goals by grade level for five core areas of learning (arts, language arts, math, science, and social studies). Academic standards are defined in Minnesota Statutes Chapter 120B.021.

Aquifer: any water-bearing bed or stratum of earth or rock capable of yielding groundwater in sufficient quantities that can be extracted (as defined in Minnesota Rules 6115.0630)

Benchmark: specific academic knowledge and skills that K – 12 students need to achieve in order to meet a statewide academic standard. Benchmarks are legislatively defined in Minnesota Statutes Chapter 120B.023.

Cross-disciplinary teaching: including two or more academic standards and associated benchmarks in a lesson so that students may achieve proficiency in multiple standards simultaneously.

Curriculum: courses offered by an educational institution.

Entry-level professional-groundwater position: a job which includes payment for at least 1040 work hours annually to perform any or all of the following activities relating to Minnesota's groundwater resource – 1) evaluate its potential as a source of water, 2) manage and protect its quality or quantity, 3) describe lateral and vertical changes in water chemistry and rates of recharge, 4) identify or estimate flow direction and pathway within an aquifer and the hydraulic connectivity with surface water or other aquifers, or 5) educate others about groundwater and actions that they can take to preserve its quality and quantity for future generations. The position would 1) have minimal authority to make a final decision by the employer that affects groundwater resources and 2) be supervised by a groundwater-related position whose professional work responsibility affecting groundwater is recognized by either 1) licensure or 2) education and work experience.

Finding: a statement that summarizes the facts about a concept or situation and was developed by a consensus of workgroup members.

Implication: a possible future effect that may occur by addressing a finding.

K-12: a student who is enrolled in kindergarten through the twelfth grade.

Postsecondary: any education that is received beyond high school.

Statewide strategy for groundwater education: an individual strategy or a collection of coordinated strategies that support groundwater education throughout the state or within a geographic area that includes a significant portion of the state's population and which may be implemented elsewhere.

White Paper: an article that gives an unbiased evaluation and treatment of a topic for informational and educational purposes. Ideally, a white paper will positively influence future quantity or quality of Minnesota's groundwater resources, interrelated resources, and their users. Typically, a white paper presents the technical aspects for the evaluation in summary form, but includes references to sources of more detailed information.

AGI: American Geosciences Institute
AWWA: American Water Works Association
BSWR: Board of Soil and Water Resources
E STEM: School programs that use Environmental projects to emphasize Science, Technology, Engineering, and Mathematics
MDA: Minnesota Department of Agriculture
MDH: Minnesota Department of Health
MGS: Minnesota Geological Survey
MGWA: Minnesota Ground Water Association
MDNR: Minnesota Department of Natural Resources
MPCA: Minnesota Pollution Control Agency

Project WET: Water Education for Teachers. It is a program that provides training, interactive classroom materials, and technical support about water resources to classroom teachers and other educators. It is an international effort that is coordinated in Minnesota by the Minnesota Department of Natural Resources.

STEM: An interdisciplinary approach to education that uses a curriculum which is based upon four disciplines – Science, Technology, Engineering and Mathematics.

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

1. Problem Statement and Definition

A workgroup was established by the MGWA Board of Directors to investigate the extent to which, 1) Minnesotans lack general knowledge about Minnesota's groundwater resources, and 2) employers and postsecondary educational institutions in Minnesota identify the core curriculum needed for graduates to fill entry-level professional-groundwater jobs. Given the dependence that Minnesotans currently have on groundwater and the likelihood that it will become even more important in the future, it would be prudent to ensure that today's students, who will become tomorrow's decision-makers and property owners, gain better insight into how to properly manage and protect our groundwater resources.

In particular, this white paper has the following objectives-

- Identify the basic level of knowledge about groundwater that high school graduates should have to function as informed citizens when groundwater management issues may impact them.
- Describe the gap in current K-12 education requirements that limit a high school graduate's ability to meet the above objective and identify potential options for filling this gap.
- Identify the core curriculum and skills that a postsecondary student who is majoring in a groundwater-related field should have to meet the needs of public sector and private sector employers.
- Describe the gap in postsecondary education that hampers Minnesota's college graduates from being hired for in-state entry-level professional-groundwater positions.
- Incorporate the findings from the other four objectives into a discussion of alternatives that may be used individually or incorporated into a statewide strategy for closing the groundwater education gap in Minnesota.

The primary audiences for this white paper are K-12 and postsecondary educators, decision makers who affect natural resources education, and the general public.

2. Background Research

Approximately three million Minnesotans who live in communities rely on groundwater for drinking and the 1.3 million who live elsewhere have wells. Furthermore, groundwater recharges many lakes and streams, supports habitat for many plants and animals, and is a more dependable source of water supply than surface water. Pumping to meet the water supply demands of communities, industry, agriculture, and mining is having an increasing impact on sustaining the amount of groundwater that is available locally. About 83 percent of community public water supplies derived from groundwater require some level of water-quality treatment (Minnesota Department of Health oral communication, November 2016). The natural quality of groundwater commonly requires community water suppliers and well owners to add treatment to reduce its hardness and to remove iron, manganese, arsenic, radium and other such contaminants. Human-caused contamination such as from fuel, solvents, and nutrients has impaired groundwater quality in some areas to the point that treatment is required to meet state and federal drinking water standards. Yet, with the statewide dependence that Minnesotans have on groundwater, many lack the basic knowledge about it to make informed decisions that will protect its quality and quantity for future generations.

Although K-12 and postsecondary students are the principal focus groups for this white paper, gaps in adult education and opportunities to address them were often identified by subject area experts, education and strategy documents, and the results of the two surveys conducted by the workgroup. Therefore, the following discussion includes some mention of gaps in adult education as well as the availability of a statewide strategy for educating Minnesotans about groundwater.

K-12 Education

Identifying what gap exists in current K-12 education about groundwater was accomplished by determining what students are currently taught about Minnesota's groundwater resources and comparing these results to questions adults commonly ask about groundwater. If today's students are receiving the information to answer questions asked by adults, then these questions may largely disappear when today's students become adults.

Academic Standard "Understand That"	Grade Level	Benchmark
In order to improve their existence, humans interact with and influence Earth systems.	4	Describe how the methods people utilize to obtain and use water in their homes and communities can affect water supply and quality.
Water circulates through the Earth's crust, oceans, and atmosphere in what is known as the hydrologic cycle.	4	Identify where water collects on Earth, including atmosphere, ground and surface water.
	8	Describe the location, composition and use of major water reservoirs on the Earth, and the transfer of water among them.
		Describe how the water cycle distributes materials and purifies water.

Table 1. Minnesota academic requirements that include groundwater

Table 1 summarizes the current Minnesota academic requirements for teaching K-12 students, specifically as the requirements pertain to groundwater. Although state requirements to teach students about groundwater are limited to understanding the hydrologic cycle, teachers and school boards have the discretion to use it as a focus in cross-disciplinary teaching. For example, the hydrologic cycle could be used to show its effects upon fishing, water purification, or groundwater quality and availability. The first academic standard listed in Table1 provides an example of an opportunity for cross-disciplinary teaching using groundwater.

Educators have access to a large amount of groundwater-oriented educational materials, workshops, and teaching programs that are offered by the public and private sectors. Appendix 2.1 presents a listing of these teaching assets which could provide a foundation for increasing K-12 student understanding of groundwater.

The teachers who were interviewed indicated that a lack of lesson plans or teaching aids are not reasons why more subject matter about groundwater is not taught. Rather, groundwater-related teaching resources are currently used only when a specific teacher or school decides to use them because most of the subject matter contained in them is not required to be taught in the classroom. More commonly, teachers indicate that they teach to the standard (i.e., focusing on the water cycle) because that is all they have time for.

Survey of Questions Adults Ask about Groundwater

In the fall of 2015, an online survey was offered to MGWA members as well as others whose jobs include answering questions from the public about groundwater. Appendix 2.2 presents the questions posted to respondents and the criteria that were used to assess the responses. Figure 1 shows survey results relative to the four principal groups in which the questions were presented. Overall, respondents indicated that questions regarding groundwater quality were the most frequently asked, followed by questions about data collection and research and general questions. Respondents indicated that questions about groundwater quantity were asked least frequently.

The interest in groundwater quality that is shown in Figure 1 is also reflected in the types of questions that the public asks staff from the MDH and the MPCA at the Minnesota State Fair (MDH 2014, oral communication). Many of these questions indicate a lack of knowledge about groundwater quality and the impacts of contamination on drinking water. Therefore, it appears that future efforts to expand K-12 education about groundwater could start by emphasizing groundwater quality and potential impacts on it from land- and water-use.

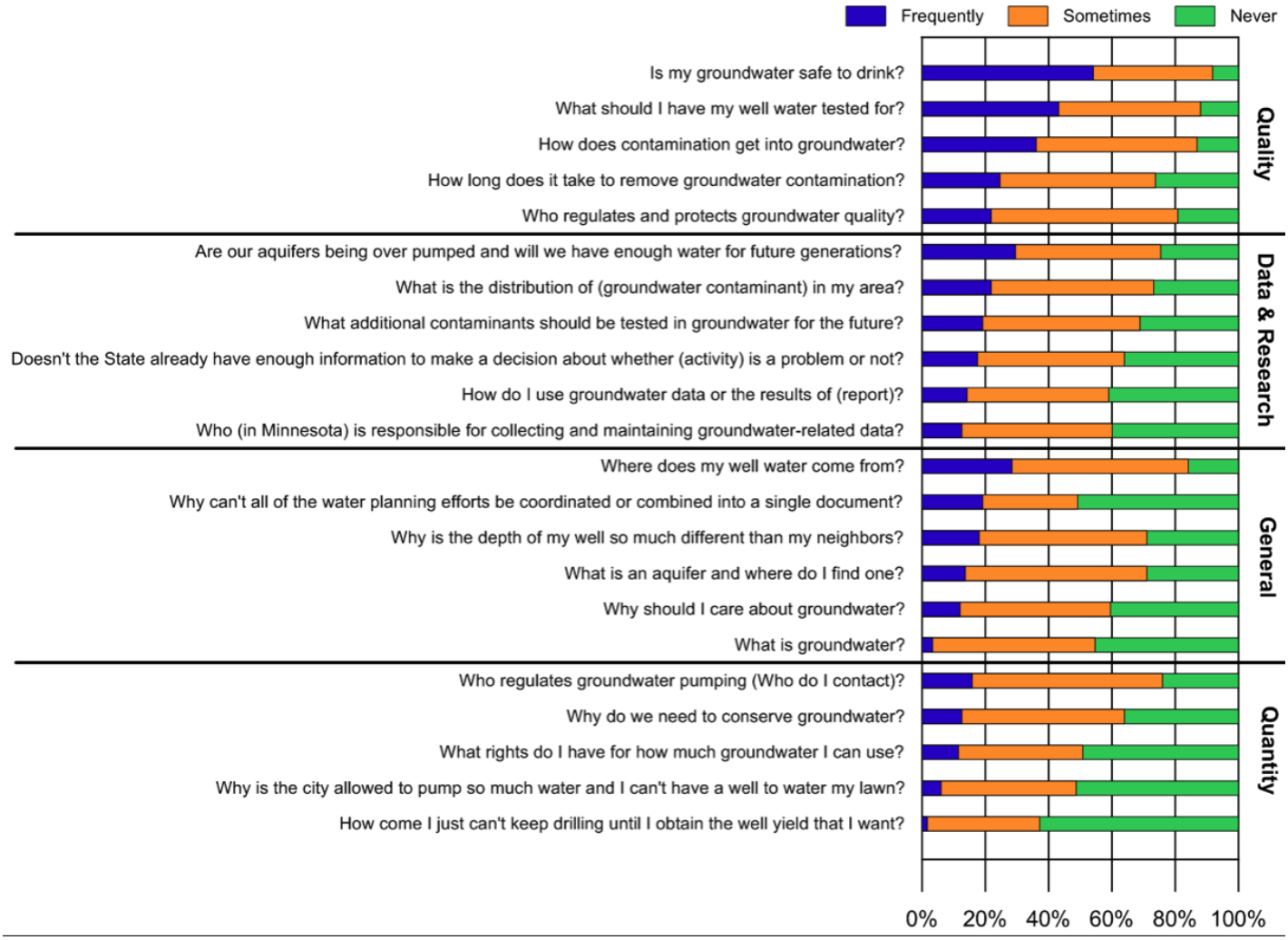

Figure 1. Summary of how often groundwater professionals are asked by the public the listed questions

Postsecondary Education

Table 2 summarizes the number of groundwater-related courses and degrees that are offered by the Minnesota's colleges and universities which were selected to be representative of undergraduate groundwater education. The information sources used to prepare it are described in Appendix 3.1. Some of the postsecondary institutions in surrounding states are shown for comparison, but the number is limited because a comprehensive assessment was beyond the scope of this effort. Only earth science, geological engineering, or environmental science degrees were selected due to time constraints for preparing the white paper. It is noteworthy that St. Cloud State University has recently expanded its emphasis on coursework and has established a hydrology degree option.

Postsecondary School	Number of Groundwater-Related Courses Offered	Degree Offered
Minnesota Institutions		
Carleton College	2	Geology
Gustavus Adolphus College	1	Geology
Macalester College	1	Geology
Mankato State University	1	Geology
Moorhead State University	None	Geosciences
St. Cloud State University	5	Hydrology
University of St. Thomas	2	Environmental Science or Geology
Winona State University	2	Geology
University of Minnesota		
Duluth	4	Environmental Sciences or Geology
Crookston	1	Natural Resources
Morris	2	Environmental Science
Twin Cities	6	Earth Science, Environmental Engineering, or Geoengineering
Selected Schools in Surrounding States		
Iowa State University	7	Civil Engineering, Environmental Science or Geology
North Dakota State University	1	Geology
South Dakota School of Mines and Technology	1	Geology or Geological Engineering
University of Iowa	7	Civil Engineering, Environmental Engineering, Environmental Science, or Geology
University of North Dakota	5	Environmental Geoscience, Geology, or Geoengineering
University of Wisconsin		
Eau Claire	3	Geology
Madison	5	Geology or Geological Engineering

Table 2. Comparison of postsecondary coursework and degree programs in minnesota and selected surrounding states

Nine of the twelve postsecondary schools in Minnesota listed in Table 2 offer a limited number of groundwater related courses for undergraduate student degrees. The other three are on par with the number of courses that are offered by the seven representative schools in surrounding states.

For some industries, such as water-well contractors, there are no postsecondary institutions from which they obtain candidates for entry-level professional-groundwater positions. Employees learn by on-the-job training and the skills they learn are set by the needs of the individual employer. This training pathway was not addressed by this white paper.

Survey of Employer Hiring Requirements

An online survey of the coursework, training, or skills that employers require for entry-level professional-groundwater positions was offered by the white paper work group to public sector and private sector employers. Details of the survey are provided in Appendix 3.2. Groundwater-related positions at colleges and universities generally require advanced degrees (typically a PhD) and advanced training or experience. As such, academic institutions do not hire entry-level professional-groundwater positions as defined in this white paper and were not included in the list of potential employers to whom the survey was distributed.

Figure 2 summarizes the course work, skills, and experience responses from employers. Appendix 3.2 presents the details regarding the survey and the significance of the survey data. Fifteen responses from an estimated 70 potential candidates were received (eight from the private sector and seven from the public sector). Despite the low response rate, the results provide insight into the current employer hiring requirements for entry-level professional-groundwater jobs.

Survey responses indicate:

- Nearly three quarters of the respondents (73%) said that a bachelor's degree is required compared to a master's degree;
- Skills relating to data collection, interpretation, processing, and presentation are as important as those relating to the physical sciences and mathematics; and
- Report writing skills are essential and ranked fifth behind general hydrology, groundwater theory, general chemistry, and physical geology.

The 11 topics that at least half of the employers identified as required knowledge or skills were compared to the coursework descriptions obtained from the 12 Minnesota colleges and universities chosen for this assessment (Table 2). Although most schools address employer requirements for undergraduate degrees, there are some potential gaps which may affect hiring:

- Teaching database data entry skills could not be determined from online course descriptions so it was not possible to determine whether a gap exists without further investigation;
- Only five of the 12 postsecondary schools specifically mention teaching groundwater flow modeling; and
- Only three of the 12 postsecondary schools specifically mention teaching well-data collection and verification.

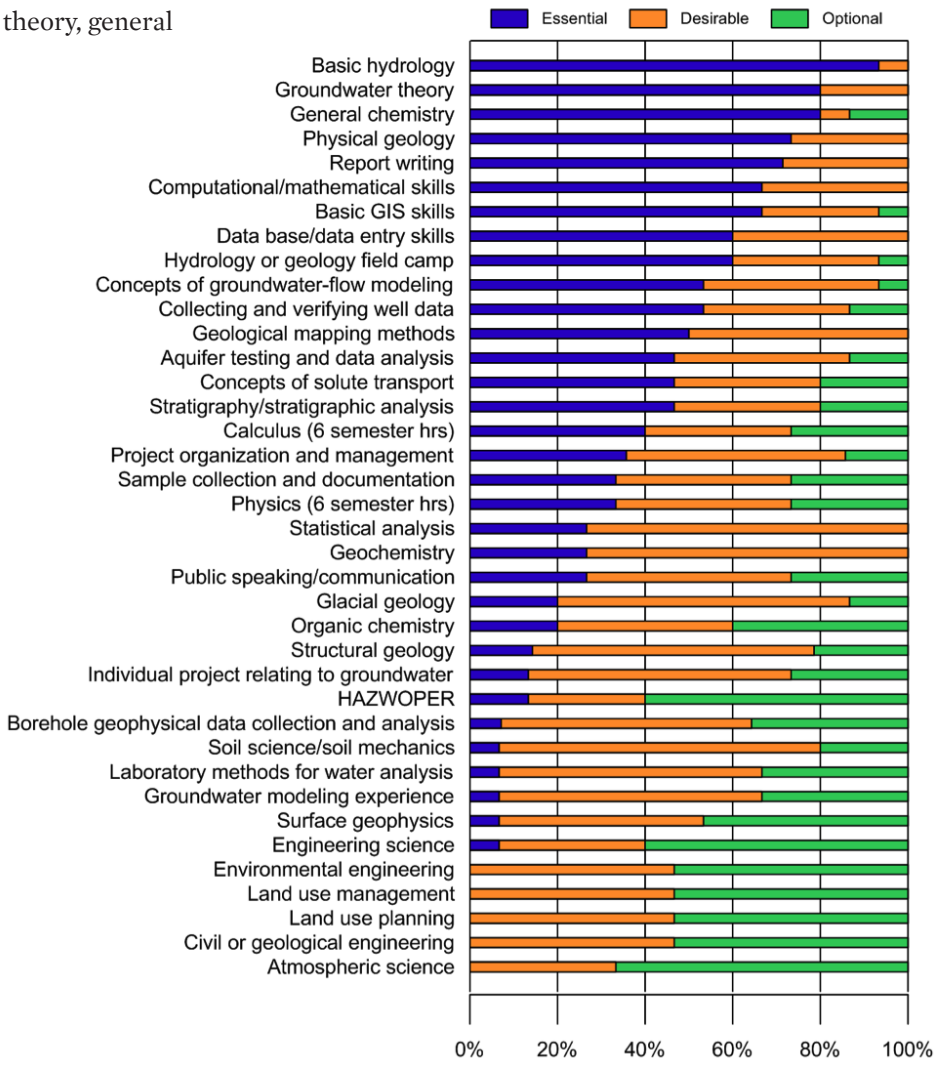

Figure 2.
Employer survey respondents' ranking of skills required for entry-level professional-groundwater jobs

Employers indicated the following regarding communication with postsecondary institutions:

- A slight majority (53%) of the employers indicated that they have at least some communication with postsecondary institutions primarily through alumni organizations or job postings; and

- Of the communication options offered to respondents, meeting face-to face (53%) and forums (47%) were preferred over conducting a survey (33%) or to other ideas presented by the respondents (27%).

Statewide Groundwater Education Strategy

Strategies were researched from several state agencies and water-related organizations to better understand interests and planned actions for groundwater education. Education strategies identify various groups of people using different technical material, as detailed in Appendix 4.2. Figure 3 summarizes documented statewide strategies for groundwater education based upon the, 1) criteria listed in Appendix 4.1, 2) range of student types, and 3) approximate population identified.

The University of Minnesota Water Sustainability Framework addressed all criteria targeting K-12 students, citizens, and professional students, but the strategy remains to be implemented. No formal policy changes have occurred to improve water education and public engagement since the release of this document. However, the University of Minnesota Water Resources Center held an all-day workshop in 2013 for Minnesota legislators. This workshop focused on issues and policies to increase the understanding about groundwater by our decision makers (University of Minnesota, 2013). Several strategies are fully implemented, but focus on specific audiences. The MDA Nutrient Management Plan focuses on nutrient-fertilizer applicators. The partnership between the MDH and the Minnesota Section of the American Water Works Association partnership focuses on K-12 teachers, and the Science Museum of Minnesota focuses on K-12 students and the public. Many strategies, however, have limited descriptions specifically for groundwater education and have not been fully implemented. Detailed information for all strategies is included in Appendix 4.2.

Several local organizations addressed groundwater education directly for adults that did not meet the measures for inclusion in Figure 3. Examples included programs for watershed and conservation districts, and Twin Cities Metropolitan conservation groups (Appendix 2.1).

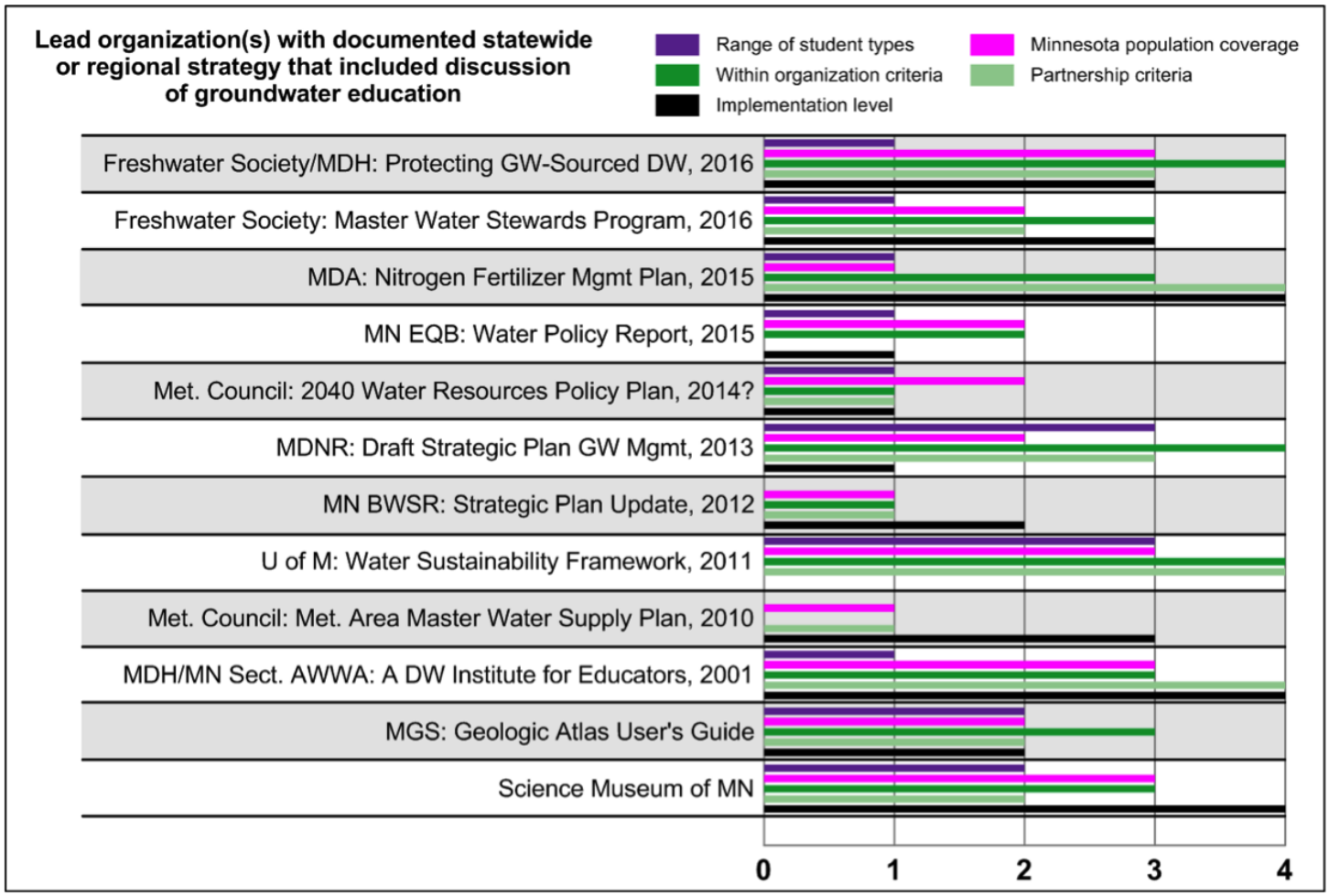

Figure 3. Summary of documented statewide strategies for groundwater education. [A relative score, in which 4 is the highest, is used to indicate the degree to which the review criteria have either been implemented or address all strategic goals. For example, a strategy that targets k-12, teachers, and adults would score 3. A strategy that targets about half of Minnesota population, such as greater Minnesota, would score 2. The number of strategy-attainment criteria for within organization and partnership (4 of each defined in appendix 4.1) Is reflected by the score. A strategy that is fully implemented in function and funding would score a 4]

3. Findings

Findings of this white paper were developed from a synthesis of public information or by the workgroup through online surveys. They are presented according to the three main focus areas of the white paper.

K-12 Education

1. Minnesota's state education standards require that fourth and eighth grade students understand the hydrologic cycle, but require nothing else be taught about groundwater at any grade level. Therefore, K-12 students receive limited groundwater education because teaching priorities are set to meet statewide academic standards.

2. Assessment testing of K-12 students (the Minnesota Comprehensive Assessment) is based upon Minnesota academic standards and is limited to evaluating whether students understand the hydrologic cycle. Therefore, there is no statewide requirement or incentive for students to understand other aspects about groundwater beyond the hydrologic cycle in order to graduate from high school.

3. MGWA survey results indicate that the public has the most questions about groundwater quality. Therefore, it may be beneficial if future educational initiatives start with expanding knowledge about groundwater quality and the impacts that result from land and water uses.

4. Although individual teachers or schools have access to some very good teaching resources that can be used for expanding groundwater education in school curricula (Appendix 2.1), these resources may be unknown or unavailable if not approved by the school district. Each of these teaching resources has a different "twist" on groundwater and surface water which may provide the diversity needed to meet individual teacher needs and the school district expectations. A centralized clearinghouse could allow easier access to these resources for teachers and school boards to evaluate and use.

5. Any effort to expand student understanding about groundwater in Minnesota schools must be integrated with state education standards and benchmarks that are defined in state statute. Education-expansion efforts must recognize the challenges that teachers and school boards face to meet all of the state education standards and benchmarks as well as meeting achievement testing goals that are defined by state and federal governments. These challenges greatly affect the time and resources that can be allocated to teaching each subject in the classroom. Also, the curriculum that is offered within a school district is based, in part, on the subject matter and teaching methods emphasized by individual school boards.

6. Gaps in science education occur across Minnesota and the science classes offered and curriculum taught vary dramatically from district to district, as well as from school to school. Science classes meet the minimum standards in most schools but some schools teach science at every grade level with an environmental or STEM focus. School resources (i.e., teachers and funding) are inconsistent between districts. Schools in larger districts appear to have more resources and offer greater variety and depth of subject matter in science curriculum.

7. There is a persistent shortage of science teachers (KARE 11, 2016) which may contribute to the groundwater education gap (i.e. a lack of teachers who are comfortable with the subject matter may limit teaching of that subject). However, cross-disciplinary teaching was stressed by several of the topic area experts as well as classroom teachers who were interviewed. Developing lessons and classroom materials that have groundwater as the focus may be a means to incorporate groundwater education in the classroom. For example, groundwater management and technical analysis of groundwater data are conducive to being incorporated into lessons that address Minnesota academic standards in Science and Engineering, Mathematics, and Social Studies. Cross-disciplinary teaching that includes groundwater could first be developed for the fourth and eighth grades but could be expanded to include all grade levels.

8. Many schools and districts are presented with issues larger than groundwater or science education gaps, such as transient students, English as a second language, inconsistent education levels, private-public discrepancies, poverty, lack of technology and internet access, homelessness, and hunger. Therefore, future efforts to prepare materials relating to groundwater education must reflect these educational challenges as well as draw from student experiences with groundwater such as with home wells, youth group projects, news about local groundwater contamination or water-supply problems. It will require the involvement of a broad spectrum of expertise to be successful in developing or expanding educational materials relating to groundwater.

Postsecondary Education

1. Review of the undergraduate degree requirements for the 12 Minnesota colleges and universities that were selected for assessment shows that nine offer limited coursework related to groundwater. The other three are on par with the number of courses offered by the seven colleges and universities from surrounding states that were selected to be representative of external undergraduate degree requirements.

2. Three quarters of the employers who responded to the MGWA survey indicated that a bachelor's degree is the minimum required for an entry-level professional-groundwater position at their organizations. Therefore, it benefits students, postsecondary schools, and employers to have undergraduate graduation requirements reflect the curriculum and skill requirements that are specified by employers to the extent that this is practical.

3. Hiring requirements for entry-level professional-groundwater positions in Minnesota stress report writing and data management skills as much as those relating to the physical sciences and mathematics. Potential gaps in Minnesota undergraduate degree programs are, 1) only five of the 12 schools offer groundwater flow modeling, 2) only three schools offer instruction in collecting and verifying well data, and 3) no schools mentioned developing student skills in database development and data entry, although this may be reflective of the level of detail provided by online course descriptions.

4. Undergraduate degree requirements are a primary factor in determining the skills developed by students during their postsecondary education. As such, graduation requirements that go beyond the skills required by employers to include some of the desired skills, as suggested by employer feedback for this white paper, may increase a graduate's competitiveness in the job market. Additional dialogue with those hiring entry-level professional-groundwater job candidates would help ensure that the required and desired skills of a broader community of employers are identified.

5. There does not appear to be a formal mechanism in place for employers to communicate their coursework, skills, or experience requirements for entry-level professional-groundwater positions to Minnesota's colleges and universities. Approximately half of the survey respondents indicate that they do not directly communicate hiring requirements to postsecondary institutions. Those that do indicated that they communicate mostly through alumni organizations or by providing job postings to educators or staff. Employers prefer either meeting face-to-face or convening a forum to discuss hiring requirements with postsecondary institutions over conducting a survey or other options such as relying on job postings.

Statewide Groundwater Education Strategy

1. Review of Minnesota state agency strategic or policy plans indicated that, 1) they recognize the need for water education, and 2) mention educational methods or tools available to the public. However, specific mention of groundwater education goals and target audiences is limited, especially for K-12 and postsecondary students.

2. A review of statewide strategies prepared within the past decade (Figure 3 and Appendix 4.2), shows that either groundwater education is mentioned in insufficient detail to specify the needs of K-12 students, postsecondary students, and adults or they have not been implemented. The Interagency Groundwater Drinking Water Group includes in their charter (Appendix 4.3) the need for statewide strategies for protecting and managing drinking water derived from groundwater, but groundwater education is not stated as part of this need.

3. State agency efforts for educating adults about groundwater currently are focused on either, 1) aspects of individual programs such as the County Geologic Atlas Program (MDNR, MGS), the Source Water Protection Program (MDH), and the Nutrient Management Program (MDA), or 2) educating local agency staff and land use managers to better utilize the results of these programs (MDNR, MDH, and Freshwater Society). Although very good in content and presentation, these strategies do not address the entire adult population in a consistent, statewide effort to improve public knowledge about groundwater.

4. Generally, there is little coordination between the statewide strategies relating to groundwater education with some exceptions, 1) coordination between the Drinking Water Institute Program and Project WET that targets science teachers, and 2) the Minnesota Water Sustainability Framework referred to recommendations in Greenprint for Minnesota: State Plan for Environmental Education, 3rd edition.

5. The level of understanding and knowledge needed about groundwater is not significantly different between the adults and K-12 students. Therefore, education materials that are developed to close current gaps in groundwater knowledge could serve adults as well as students.

4. Implications of Findings

Development of this white paper was met with cooperation, encouragement, and support from all of the individuals or organizations that provided input. As such, the MGWA views the findings of this white paper as a means for focusing future efforts to expand the level of groundwater education in Minnesota. In particular, the following implications build upon the findings:

- The limited scope of the current Minnesota academic standards and benchmarks relating to groundwater education provides for a wide variety of options to increase K-12 student education about groundwater. Essentially, there is a clean slate on which to develop expanded academic requirements.

- Providing additional accredited training for teachers or a forum for review of educational curricula could increase teacher and school board support for expanding the scope of groundwater education in the classroom. For example, MGWA members and those from other professional organizations could form a pool of needed expertise, especially if some of the time that they spend can be applied to their continuing education requirements for licensure.

- The interest expressed by employers to improve communication regarding the hiring requirements for entry-level professional-groundwater position may ultimately improve the likelihood that postsecondary students in Minnesota will be better qualified to fill in-state job openings.

- The development of a statewide strategy for groundwater education can build upon the content of existing water resource management strategies as well as the experience gained by efforts to implement them. Much is already known regarding the educational needs of adults regarding groundwater. A comprehensive strategy can use this knowledge to identify and close the current gaps.

5. Opportunities for Advancing Groundwater Education

The following discussion focuses on what MGWA can do to help address Minnesota's current gaps in groundwater education. Acting upon these opportunities will likely involve MGWA cooperating with other professional organizations, teacher and citizen groups, legislators, and government agencies. Opportunities that may develop over the next several years are:

- The Minnesota Department of Education will be revising state academic standards for science in 2017-2018 which provides MGWA an excellent opportunity to communicate the findings of this white paper to the public and to those involved with standards revision.

- Pending the development of state academic standards that expand upon knowledge of groundwater, organizations such as MGWA could work with the Minnesota Department of Education and other interested parties to develop examples that demonstrate the incorporation of groundwater principles or management issues into academic standards for Science, Mathematics, and Social Studies. Presenting these examples at conferences or teacher workshops would be an effective means for generating support for cross-disciplinary teaching using groundwater as the focus.

- The information obtained for this white paper can be used by others to better identify the groundwater education needs of K-12 students, postsecondary students, and the adult population. Although the time constraints and resource limitations faced by the workgroup may have limited the scope of the surveys and their analyses, these and other surveys of a broader audience by professional organizations provide insight that can be used to refine future efforts to assess improvement in groundwater education in Minnesota.

- Presentation of the white paper to other professional organizations may help MGWA better develop its role regarding groundwater education and to expand member involvement in supporting educators. Furthermore, contact with other professional groups regarding groundwater education identified potential collaborators for MGWA to partner with and increase the base of support for closing education gaps.

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Appendix 1.1
Workgroup Organization and Operation

Given the one-year timeframe for completing the white paper and the broad range of issues that could be covered, the workgroup organized into three teams, each of which was responsible for leading efforts to collect information and formulate findings for its assigned subject area –

The K-12 Team focused on, 1) identifying whether there is a lack of knowledge about groundwater experienced by K-12 graduates, 2) identifying whether any gaps exist in state K-12 education standards that hinder teaching students about groundwater, and 3) evaluating potential options for reducing or eliminating any groundwater education gaps that are identified.

The Postsecondary Team focused on, 1) defining the course-work, skills, and experience needed by a postsecondary graduate seeking an entry-level professional groundwater job in Minnesota, 2) identifying how Minnesota colleges and universities determine the educational requirements for students who wish to graduate with an undergraduate degree that focuses on groundwater, and 3) assessing whether any gaps exist between the education requirements for public or private sector entry-level professional-groundwater jobs versus current Minnesota college and university course work requirements for graduation.

The State Groundwater Strategy Team focused on, 1) compiling a listing of current studies, reports, or statewide strategies that specify groundwater education in Minnesota, 2) assessing whether these documents provide sufficient detail to identify the groundwater education needs of K-12 and postsecondary students or mention adult education, and 3) assessing whether these documents identify gaps in groundwater education for Minnesota K-12 and postsecondary students.

The teams met either face-to-face or via teleconference calls and a chairperson was appointed for each team who reported progress and results at monthly workgroup meetings. In addition, a Technical Review Team was established to assist the lead writer with organizing and editing the draft white paper document. One member from each of the other three teams, the workgroup chair person, and the lead writer comprised the Technical Review Team. A document termed Findings, Observations, and Questions (FOQ) was created in which all members of the white paper workgroup could add potential content for the white paper or provide comment regarding the input from the teams or other workgroup members. The representative from each team would notify the lead writer what wording from the FOQ document they wanted to be included in the working draft of the white paper.

Several topic area experts visited with the workgroup to discuss issues and present information that was incorporated into the white paper. The MGWA is very appreciative of their willingness to assist the workgroup and in their actions to educate others about Minnesota groundwater. The following table summarizes the input provided by these individuals.

Appendix Table 1.1 Summary of white paper workgroup meetings with invited guests

Date	Guest (s)	Topic
September 21, 2015	John Olson and Doug Paulson, Minnesota Department of Education	Minnesota Department of Education perspectives on K-12 science education
October 22, 2015	Darrell Gerber, Freshwater Society	Update of Freshwater Society Groundwater Framework Report
November 16, 2015	Terry Doud, Heritage Environmental (E)-STEM Middle School Science Teacher	Science-teacher perspectives and examples of hands-on lessons
January 7, 2016	Stew Thornley, Minnesota Department of Health	American Water Works Association (AWWA) Drinking Water Institute Program for teachers
January 7, 2015	Janine Kohn, Project Coordinator, Minnesota Department of Natural Resources Project WET (Water Education for Teachers)	Project WET guidelines and activities in Minnesota
January 7, 2016	Benji Kohn, Trout Unlimited	How Trout Unlimited use trout in classroom (TIC) as a vehicle to teach about contaminants, water and groundwater-fed streams.
January 14, 2016	Dr. Fred Finley, University of Minnesota,	Discussion of research activities at the STEM Research Center

Appendix 2.1
Teaching Assets and Resources Relating to Groundwater Education in Minnesota

Appendix Table 2.1 Examples of groundwater-education assets and resources grouped by primary user. [Information discovered through research for this white paper, such as from a January 5, 2015 meeting of water conservation task force at mdnr, or groups or resources without a published minnesota statewide strategy for education that have or could have value to educators and students.]

Lead Organization or Resource for Groundwater Education with Internet link or other source of information	Education Recipient(s) identified	Comments specific to groundwater education
K-12 Students		
Hamline University Center for Global Environmental Education (http://www.hamline.edu/education/cgee/youth-resources.html)	K-12	Hamline's Center for Global Environmental Education (CGEE) has been an internationally recognized pioneer in creating thematic learning projects for K-12 students around the globe.
H2O for Life Race2Reduce program (http://www.h2oforlifeschools.org/)	K-12	H2O for Life educates, engages and inspires youth to learn, take action and become global citizens. We provide students with a unique and valuable learning experience through service-learning opportunities focused on the global water crisis.
Resource Action Programs (Franklin Energy Company) http://www.resourceaction.com/	K-12	Develops the WaterWise kits which are used in schools to educate about water conservation.
Science Museum of Minnesota, Big Backyard (https://www.smm.org/bigbackyard)	K-12	Learn how nature changes the landscape, the importance of groundwater aquifers, and wander our gardens full of local plant life.
Sharing Environmental Education Knowledge (SEEK) (http://www.seek.state.mn.us/)	K-12	SEEK works as a clearinghouse for all types of environmental education resources, from articles to lesson plans, from performances to displays, and many more. These resources come from a variety of organizations throughout Minnesota, including schools and colleges, government agencies, libraries and businesses.
Trout in the classroom (MNDR, Trout Unlimited and Nielson Foundation) (http://www.dnr.state.mn.us/vnr/trout.html)	K-12	A component of this hands-on awareness of trout habitat includes teaching about the value of groundwater to cold-water fisheries. They work with water works institute to target 5th through 12th grade physics and chemistry teachers to bring groundwater into classes. Targets area is mainly Metro classrooms and trout streams, but Bemidji and Rochester are potential future targets. (Benji Kohn, oral communication, January 7, 2016)
Public (including users interested at the local county, watershed or conservation District levels)		
Anoka County Water Resources Management task force (https://www.anokacounty.us/1421/Water-Information-and-Management)	Public	Anoka County's natural resources, environment, education and public health agencies and organizations have established a Water Resources Task Force that monitors local water resources and collaborates with state and local agencies and organizations to address water protection and management issues.
East Metro Water Resource Education Program (Angie Hong, oral communication June 2016)	Public	A Water Resource Education Specialist is jointly funded by local watershed districts/organizations and county conservation districts. This public water-education program, which includes groundwater, represents in the eastern Twin Cities Metropolitan Area Brown's Creek, Carnelian Marine - St. Croix, Comfort Lake - Forest Lake, Middle St. Croix, Ramsey -Washington Metro, Rice Creek, South Washington and Valley Branch Watersheds, Cottage Grove, Dellwood, Forest Lake, Grant, Lake Elmo, Hugo, Newport, Oak Park Heights, Oakdale, Stillwater, St. Paul Park, Willernie, West Lakeland, Woodbury, Washington County and the Washington Conservation District. In addition to making presentations to local public forums and providing resources for local water events, the education process is also accomplished through a weekly blog written by the specialist www.eastmetrowater.areavoices.com
Groundwater Foundation, Lincoln, NE (http://www.groundwater.org/)	Public, K-12	A primary goal is to educate people and inspire action to ensure sustainable, clean groundwater for future generations.
Dakota County Environmental Education Program https://www.co.dakota.mn.us/Environment/EducationResources/Pages/default.aspx	Public	The Dakota County Environmental Education Program (DCEEP) provides citizens and organizations with educational materials and programmatic support for water resource education projects. The Program coordinates projects such as the Wetland Health Evaluation Program, Project Wet, storm drain stenciling projects, and the Vermillion River Watch Program. The DCEEP is coordinated through the Dakota County Soil and Water Conservation District, the University of Minnesota - Extension, and Dakota County.
Metro Watershed Partners (http://fmr.org/metro-watershed-partners)	Public	The Watershed Partners is an innovative, dynamic coalition of over 60 public, private, and non-profit organizations in the Minneapolis/Saint Paul, Minnesota metropolitan area. Through collaborative education and outreach, we promote a public understanding that inspires people to act to protect water quality in their watershed.

Public (including users interested at the local county, watershed or conservation District levels)		
Non-point Education for Municipal Officials (http://www.mnerosion.org/)	Public	Non-point Education for Municipal Officials, or NEMO, is an educational program for land use decision makers that addresses the relationship between land use and natural resource protection.
Ramsey Conservation District (https://www.ramseycounty.us/residents/environment/ramsey-conservation-district)	Public	The Ramsey Conservation District is the bridge between Ramsey County citizens, conservation agencies and government to sustain our natural resources through partnerships, technical services and education.
Rice Creek Watershed District (http://www.ricecreek.org/)	Public	The purpose of the RCWD is to conserve and restore water resources of the District for the beneficial use of current and future generations.
Stearns County Soil & Water Conservation District (http://www.stearnscountyswcd.net/pages/Home)	Public	The Stearns County Soil & Water Conservation (SWCD) District is a local unit of government that manages and directs natural resource management programs at the local level. The SWCD works in both urban and rural settings, with landowners and with other units of government, to carry out a program for the conservation, use, and development of soil, water, and related resources.
University of Minnesota Water Resources Center (http://www.wrc.umn.edu/)	Public	Training and certification for water management professionals, educators and city and rural leaders.
Groundwater Professional and Teacher Development		
American Geological Institute http://www.americangeosciences.org/	Professional and teacher development,	A federation of geosciences professional organizations that has a wealth of education resources and tools which others may find useful relative to GW education. Their educational resources network aggregates geoscience education resources from a variety of providers. The goal is to provide visitors with the widest possible collection of curricula, classroom activities, teacher professional development opportunities, science education standards, virtual field trips, teaching ancillaries and much more. They encourage visitors to review the collections, suggest other resources, and let them know when items are out of date or problematic for other reasons.
American Geophysical Union AGU education, student programs, and career center: Helping to prepare the next generation of earth and space scientists:http://www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education/ AGU Talent Pool programs can help students with next career steps: https://eos.org/agu-news/agu-talent-pool-programs-can-help-students-with-next-career-steps	Public, K-12 educators, middle and high-school students, post-secondary, and early-career scientists	AGU is focused on building partnerships and collaborations that will increase the effectiveness of its outreach efforts related to education. As an international science organization of over 60,000 members, geosciences is the broad education target, which can include groundwater sciences. AGU has identified two specific strategic objectives, along with tactics, as an organizational priority under its talent-pool goal. These are, (1) Focus on transition points in the workforce development pipeline at which students tend to leave earth and space sciences, and (2) Increase the recruitment, retention, and degree completion of underrepresented populations of undergraduate students in earth and space sciences.
Geological Society of America (http://www.geosociety.org/index.htm) (http://www.geosociety.org/educate/)	Professional development	Provides resources for study and practical field experiences in the broad topic of geosciences, some of which may include groundwater topics. Includes GeoTeachers workshops and America's Teacher Advocate Program (TAP) where the goal is to promote geoscience to school students and their families through active and enthusiastic teacher advocate. Also provides up-to-date, curriculum-linked, engaging geosciences teaching resources to school teachers across the USA and beyond which are developed by people with recent classroom teaching experience, and provides teacher activities in which they experience the importance, relevance, and wonder of geosciences through first-hand contact with geosciences in the field or laboratory.
Minnesota Earth Science Teachers Association http://mnearthscience.weebly.com/	K-12 (earth-science) educators	MESTA is a group of teachers who are passionate about Earth Science Education. Participate in annual workshops with invited geoscience professionals. There is no mention of teacher resources and presentations about groundwater on the Web site.
Minnesota Minerals Education Workshop (http://www.d.umn.edu/prc/MMEW/index.html)	K-12 educators	MMEW is a three-day workshop held annually for K-12 earth science educators that offers short courses and field trips focused on the geology and mineral resources of Minnesota. The workshops have been held in various locations throughout Minnesota since its inception in 1997.

Groundwater Professional and Teacher Development		
National Groundwater Association (http://www.ngwa.org/Pages/default.aspx)	Professional development	A national professional organization that provides or sponsors a long list of conferences and training workshops meant for professional-development education. Some of the conferences give opportunity for student presentations. They also provide resources for public outreach support, such as for "groundwater awareness week" and "protect your groundwater day" each year.
Project WET (Water Education for Teachers National portal: http://portal.projectwet.org/ MDNR sponsor link: http://www.dnr.state.mn.us/projectwet/minnesota.html	K-12 educators	Project WET supports the Department of Natural Resources Waters mission of providing leadership in the cooperative management of activities that affect Minnesota's water resources in order to promote resource protection while allowing reasonable use. Typical educator workshops last 6 hours, and during the workshop individuals are exposed to the Project WET Curriculum and Activity Guide through hands-on activities. The workshops vary from a standard workshop that deals with water on a variety of levels, to a workshop that may have a theme such as groundwater, wetlands, social issues pertaining to water, water and the arts, and/or the history of water in Minnesota.
University of Minnesota Extension Water Resources Center (http://www.wrc.umn.edu/)	Professionals	Training and certification for water management professionals, educators and city and rural leaders.
Varied users from K-12 through Professionals		
Minnesota Digital Water Research Library https://water-research-library.mda.state.mn.us/pages/application/publicRecordSearch.xhtml (Minnesota Department of Agriculture, 2016)	Water managers, professionals, engaged citizens	The Minnesota Water Research Digital Library is a user-friendly, searchable inventory of water research relevant to Minnesota, with emphasis on publications from 2000 forward. The Library provides one-stop access to all types of water research, enabling water managers, researchers, engaged citizens and others to easily find, share, and coordinate research to support their efforts to protect, conserve, manage and restore water in Minnesota. From a base of over one thousand peer-reviewed and non-peer-reviewed articles, the Library is expected to grow steadily in quantity and quality as partner organizations begin curating collections of scientific-technical articles in their areas of expertise.
U.S. Environmental Protection Agency https://www.epa.gov/ground-water-and-drinking-water **Region V** (includes Minnesota) https://www3.epa.gov/watersense/about_us/index.html http://sourcewatercollaborative.org/	Public, including middle school grades, post-secondary students, Professional development	A federal agency with a wealth of information about groundwater drinking water rules, standards, regulations and water quality from the federal perspective: Safe Drinking Water Act, Safe Drinking Water Information System, National Primary Drinking Water Standards, Drinking Water Health Advisories The Water Sense Partnership Program helps people save water with a product label and tips for saving water indoors and out Also available is information about drinking water from groundwater sources and protecting those sources.
United States Geological Survey http://water.usgs.gov/edu/mearthgw.html http://water.usgs.gov/ogw/pubs.html	Public, including middle school grades, post-secondary students, and Professional development	A national science agency that has a number of publications written with the intent to education lay audiences about the concepts of groundwater, water quality, interactions with surface waters, and human effects on groundwater. Numerous groundwater data sets are readily available through the Internet for students to use in practical problem solving. They also produce reports of educational value to college students and other scientists. Some example introductory papers are listed below: • Ground Water • The Water Cycle • Basic ground-water hydrology • Ground Water and the Rural Homeowner • What Is Ground Water • Ground Water And Surface Water: A Single Resource • Aquifer Basics Examples of Circulars: • Estimated Use of Water in the U.S. in 2010 (Circular 1405) • Streamflow Depletion By Wells -- Understanding and Managing the Effects of Groundwater Pumping on Streamflow (Circular 1376) • Report to Congress: Progress Toward Establishing a National Assessment of Water Availability and Use (Circular 1384) • Ground-Water Availability in the United States (Circular 1323) • Estimated Withdrawals From Principal Aquifers in the United States, 2000 (Circular 1279) • Ground Water in Freshwater-Saltwater Environments of the Atlantic Coast (Circular 1262) • Heat as a tool for studying the movement of ground water near streams (Circular 1260) • Evolving issues and practices in managing ground-water resources - Case studies on the role of science (Circular 1247) • Water in storage and approaches to ground-water management, High Plains Aquifer, 2000 (Circular 1243) • Assessing Ground-Water Vulnerability To Contamination: Providing Scientifically Defensible Information For Decision Makers (Circular 1224) • Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data (Circular 1217) • Estimated Use of Water in the United States in 1995 (Circular 1200) • Sustainability of ground-water resources (Circular 1186) • Land Subsidence in the United States (Circular 1182) • Estimating Areas Contributing Recharge to Wells -- Lessons from Previous Studies (Circular 1174)

Appendix 2.2 Review Criteria and Analysis of Questions the Public Asks About Groundwater

Poll provided to MGWA membership
Please select the category that most closely describes your organization: Private sector, State agency,

Federal Agency, Local agency, Education, Other (Please specify).

For each of the following questions, indicate whether you receive this question from the public Frequently, Sometimes, or Never:

General Questions
1. What is groundwater?
2. What is an aquifer and where do I find one?
3. Why should I care about groundwater?
4. Where does my well water come from?
5. Why is the depth of my well so much different than my neighbors?
6. Why can't all of the water planning efforts be coordinated or combined into a single document?

Groundwater Quantity
7. How come I just can't keep drilling until I obtain the well yield that I want?
8. What rights do I have for how much groundwater I can use?
9. Who regulates groundwater pumping (Who do I contact)?
10. Why do we need to conserve groundwater?
11. Why is the city allowed to pump so much water and I can't have a well to water my lawn?

Groundwater Quality
12. Is my groundwater safe to drink?
13. How does contamination get into groundwater?
14. What should I have my well water tested for?
15. Who regulates and protects groundwater quality?
16. How long does it take to remove groundwater contamination?

Data Collection and Research
17. Who (in Minnesota) is responsible for collecting and maintaining groundwater-related data?
18. Doesn't the State already have enough information to make a decision about whether (insert the name of the activity) is a problem or not?
19. How do I use groundwater data or the results of (insert the name of report)?
20. What additional contaminants should be tested in groundwater for the future?
21. Are our aquifers being over pumped and will we have enough water for future generations?
22. What is the distribution of (insert the name of the groundwater contaminant) in my area?
23. Option to enter as many as three of your own most frequently received questions not addressed above:

Criteria and Methodology Used for Analysis
The following criteria and methodology were used to evaluate the Survey Monkey Poll that was sent mostly to the MGWA membership regarding commonly-received questions about groundwater from the public. Twenty-two questions were provided, and respondents were given the opportunity to provide up to three questions which they commonly received from the public.

1. Determine the most common group (General, Quantity, Quality, or Data Collection/Research) of questions asked, based upon the total number of times the questions within each group were assigned each of the frequency classifications listed in the survey. Also note the total percent response for each frequency classification for all of the questions within a group, i.e., frequently, sometimes, never, (no response was interpreted as "never").

2. Calculate the frequency with which the questions within each group are most often asked, i.e., frequently, sometimes, never, no response (interpreted as "never").

3. Review the unique questions offered by respondents in response to question no. 23 on the poll (respondents were given the opportunity to list up to 3 of the questions they commonly receive from the public).
   i. Discard questions that have little relevance to the objectives of the White Paper.
   ii. Identify whether a question is just a rewording of one of the 22 survey questions or unique. A reworded question will be treated as indicative of the survey
   question to which it is matched.
   iii. Determine whether the "non-reworded" unique questions fall into one of the four designated categories (General, Quantity, Quality, or Data Collection/Research) or represent new category(s) and assign the unique questions to those categories accordingly.

iv. After aggregating the unique questions into question categories, re-calculate the frequency with which categories of questions and individual questions are asked.

Survey Findings

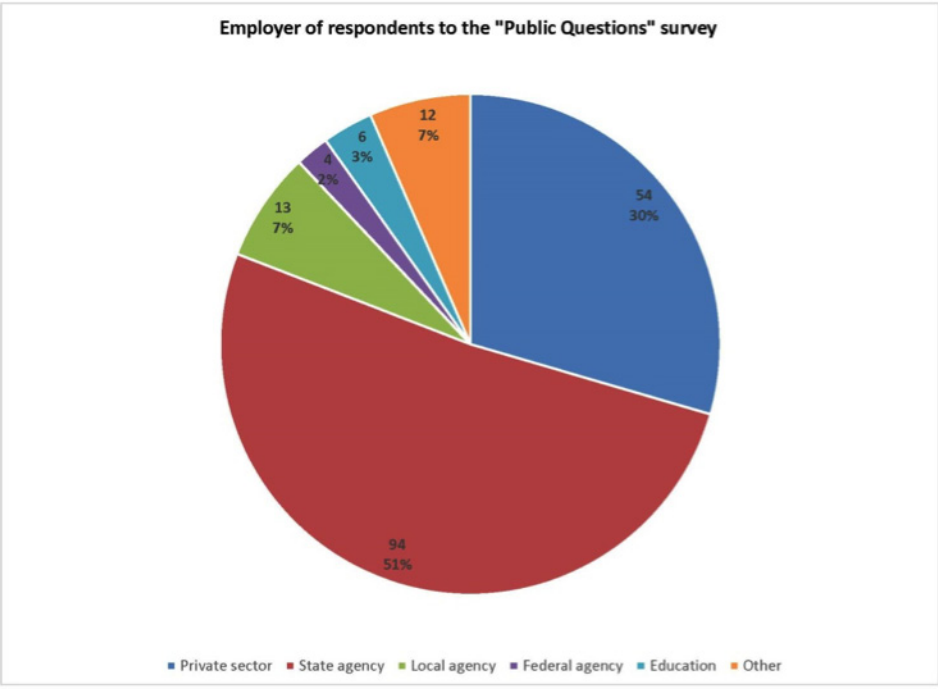
Key findings of the "Public Questions" survey are summarized as follows:

- 183 people responded to the poll (Appendix Figure 2.2_1). 51% of respondents worked for state agencies, 30% worked in the private sector, 7% worked for local agencies, 2% worked for federal agencies, and 3% worked for educational institutions. 7% identified their employer as "Other".

- Overall, questions regarding Groundwater Quality were the most frequently asked, followed by questions about Data Collection and Research and General Questions (respectively). Respondents indicated that questions about Groundwater Quantity were asked least frequently.

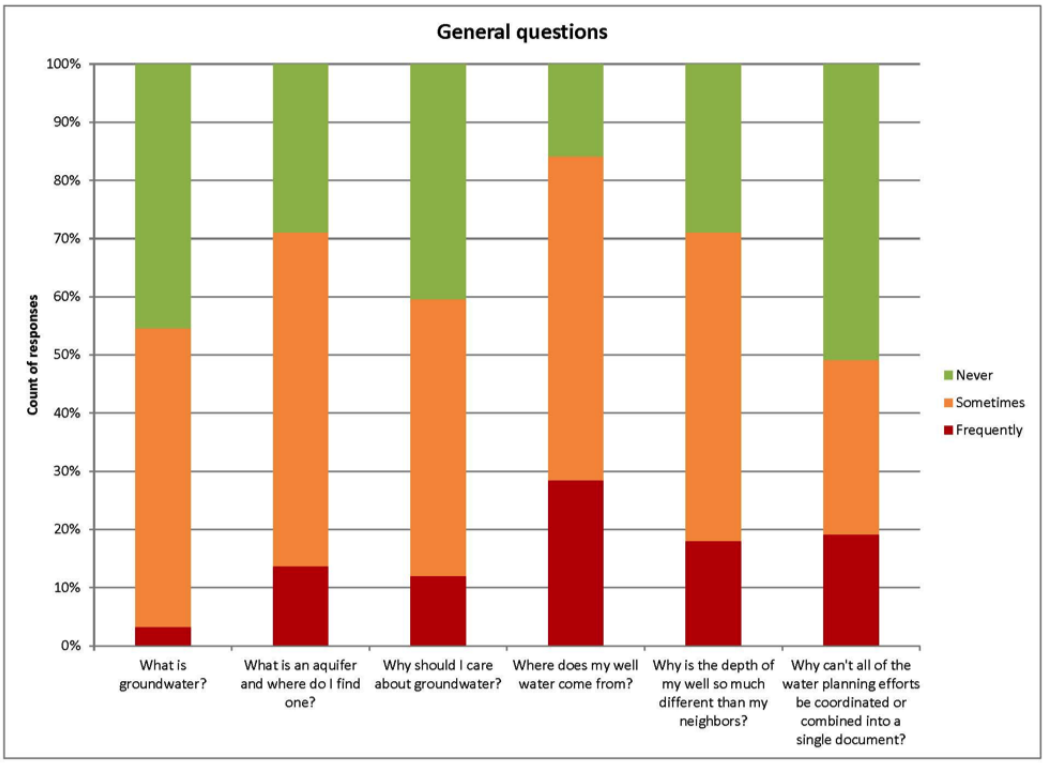
- Of individual questions, the question "Is my groundwater safe to drink?" was asked most frequently. The questions "How does contamination get into groundwater?" and "What should I have my well water tested for?" were asked the second-most frequently, according to respondents.

- The least-asked question was "How come I just can't keep drilling until I obtain the well yield that I want?". The second-least asked questions were: "What is groundwater?", "Why is the city allowed to pump so much water and I can't have a well to water my lawn?", "What is groundwater?", and "What rights do I have for how much groundwater I can use?"

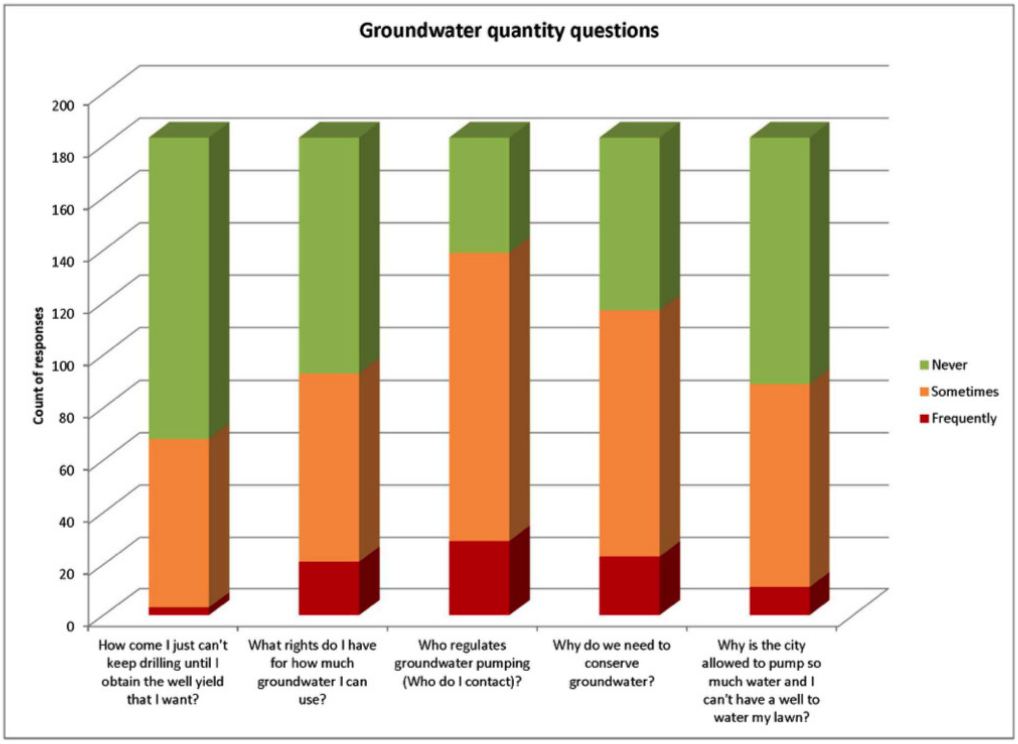


Appendix Figure 2.2-1 Employer of Respondents to the "Public Questions" Survey

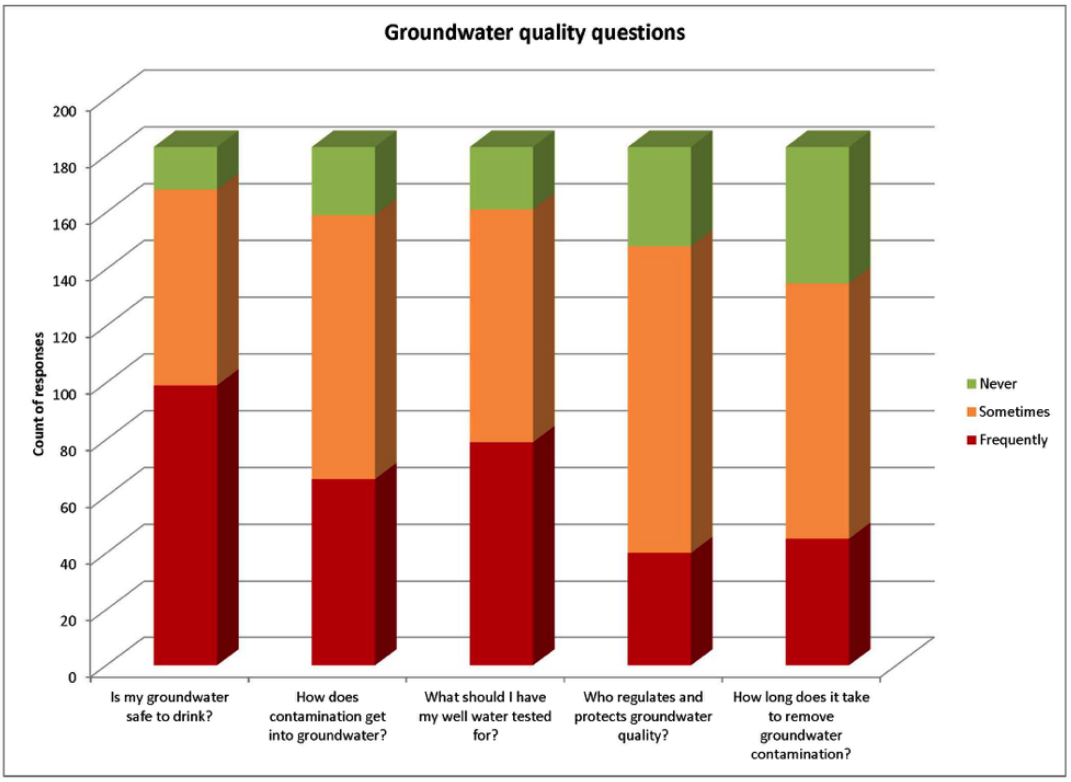
The following diagrams summarize responses to questions within one of the four categories:



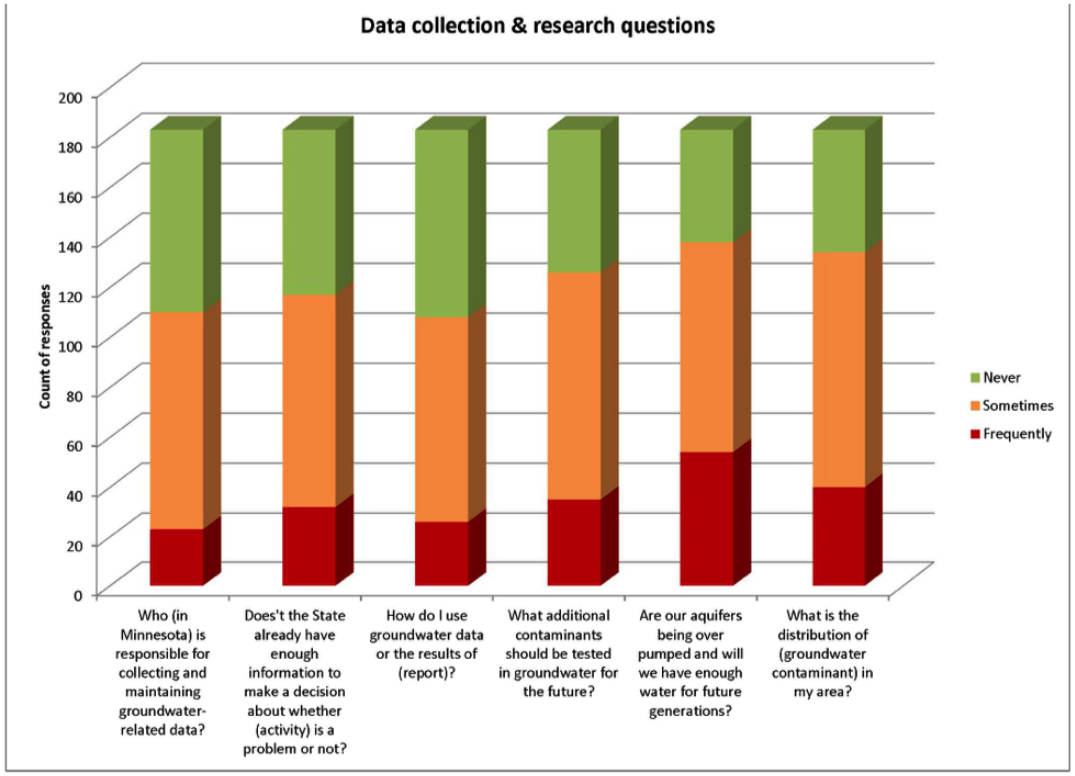
Appendix Figure 2.2-2 General Questions about Groundwater



Appendix Figure 2.2-3 Questions about Groundwater Quantity



Appendix Figure 2.2-4 Questions about Groundwater Quality



Appendix Figure 2.2-5 Questions about Data Collection and Research

Appendix Table 2.2 indicates the frequency of responses for the 22 questions provided. "No Response" as interpreted as "Never". Results of the survey are shown graphically on the preceding figures.

Question Category	Count of responses		
Question	**Frequently**	**Sometimes**	**Never**
General Questions			
What is groundwater?	6	94	83
What is an aquifer and where do I find one?	25	105	53
Why should I care about groundwater?	22	87	74
Where does my well water come from?	52	102	29
Why is the depth of my well so much different than my neighbors?	33	97	53
Why can't all of the water planning efforts be coordinated or combined into a single document?	35	55	93
Groundwater Quantity			
How come I just can't keep drilling until I obtain the well yield that I want?	3	65	115
What rights do I have for how much groundwater I can use?	21	72	90
Who regulates groundwater pumping (Who do I contact)?	29	110	44
Why do we need to conserve groundwater?	23	94	66
Why is the city allowed to pump so much water and I can't have a well to water my lawn?	11	78	94
Groundwater Quality			
Is my groundwater safe to drink?	99	69	15
How does contamination get into groundwater?	66	93	24
What should I have my well water tested for?	79	82	22
Who regulates and protects groundwater quality?	40	108	35
How long does it take to remove groundwater contamination?	45	90	48
Data Collection and Research			
Who (in Minnesota) is responsible for collecting and maintaining groundwater-related data?	23	87	73
Doesn't the State already have enough information to decide about whether (activity) is a problem or not?	32	85	66
How do I use groundwater data or the results of (report)?	26	82	75
What additional contaminants should be tested in groundwater for the future?	35	91	57
Are our aquifers being over pumped and will we have enough water for future generations?	54	84	45
What is the distribution of (groundwater contaminant) in my area?	40	94	49

Appendix Table 2.2_2--Summary of Responses to Questions 1 through 22

Appendix 3.1
Survey of Employers with Entry-Level Courses and Related Degree Requirements from Minnesota Colleges and Universities

Minnesota College and University Web-based Sources of Information.

Institution	Website Reference
Carleton College	https://apps.carleton.edu/curricular/geol/
Gustavous Adolphus College	https://gustavus.edu/general_catalog/current/geology
Macalester College	http://www.macalester.edu/academics/geology/courses/
Mankato State University	http://cset.mnsu.edu/chemgeol/programs/geol/curriculum.html
St. Cloud State University	http://www.stcloudstate.edu/programs/hydrology/ http://www.stcloudstate.edu/programs/earth-science/
St. Thomas University	http://www.stthomas.edu/geology/majors/
Winona State University	http://www.winona.edu/geoscience
University of Minnesota	
Crookston	https://www.crk.umn.edu/academics/agriculture-and-natural-resources-department/natural-resources
Duluth	http://www.d.umn.edu/catalogs/current/
Morris	http://www.catalogs.umn.edu/documents/MorrisCourseDescriptions2015.pdf
Twin Cities	http://www.cege.umn.edu/current/undergraduate https://www.esci.umn.edu/Undergraduate-Studies-Program

Web-based Sources of Information from Selected Colleges and Universities in Surrounding States

Institution	Website Reference
Iowa State University	http://catalog.iastate.edu/collegeofengineering/civilengineering http://catalog.iastate.edu/collegeofliberalartsandsciences/geology http://catalog.iastate.edu/collegeofagricultureandlifesciences/environmentalscience
North Dakota State University	https://www.ndsu.edu/geosci/curricula/course_planner/
South Dakota School of Mines & Technology	http://www.sdsmt.edu/Academics/Departments/Geology-and-Geological-Engineering/
University of Iowa	https://clas.uiowa.edu/envsci/undergraduate-program/track-hydrosciences https://clas.uiowa.edu/ees/undergraduate-program/bs-geoscience http://catalog.registrar.uiowa.edu/courses/cee/
University of North Dakota	http://und-public.courseleaf.com/courseindex/
University of Wisconsin	
Eau Claire	http://www.cege.umn.edu/current/undergraduate
Madison	https://www.engr.wisc.edu/department/civil-environmental-engineering/ http://geoscience.wisc.edu/geoscience/

Note: Courses were included if the description identified that groundwater was either 1) the principle focus of the course, or 2) a significant portion of the subject matter. The time limits and resources faced by the workgroup did not permit a direct conversation with a representative of the postsecondary institution listed. Therefore, it is possible that some courses are not shown that may apply because they could not be assessed beyond the course description that is referenced on the postsecondary institution's website.

Groundwater-related Coursework Offered by
Minnesota Colleges and Universities

Postsecondary Institution	Number of Groundwater Courses	Degree Offered	Class Name	Credits
Carleton College	2	Geology	Hydrology Geochemistry Natural Waters	6 6
Gustavus Adolphus	1	Environmental Science	Hydrogeology	4
Macalester College	1	Geology	Surface/Groundwater Hydrology	not listed
Mankato State University	1	Geology	Hydrogeology	3
St. Cloud State University	5	Hydrology	Physical Hydrology Chemical Hydrology Groundwater Modeling Water Resource Mgmt. Surface Hydrology	4 4 2 3 4
University of St. Thomas	2	Geology Environmental Science	Hydrogeology Environ. Geochemistry	4 4
Winona State University	2	Geology	Applied Hydrology Geochemistry	4 4
University of Minnesota				
Crookston	1	Natural Resources	Hydrology and Water Quality	4
Duluth	4	Environmental Science or Geology	Physical Hydrology Environ. Hydrology Aqueous Geochemistry Well Hydraulics	4 4 4 3
Moorhead	None	Geology	None	None
Morris	2	Environmental Science	Hydrology Groundwater	4 4
Twin Cities	6	Environmental Engineering, Geology, or Geoengineering	Aqueous Geochemistry General Hydrogeology Field Hydrogeology Groundwater Mechanics Groundwater Modeling Hydrologic Design	3 4 5 3 3 4

Groundwater-related Coursework Offered by
Postsecondary Institutions in Surrounding States

Postsecondary Institution	Number of Groundwater Courses	Degree Offered	Class Name	Credits
Iowa State University	7	Geology Civil Engineering or Environmental Science	Groundwater Hydrology Hydrology Field Methods in Hydrology Applied Groundwater Flow Modeling Hydrologic Modeling and Analysis Environmental Geochemistry Watershed Hydrology	3 4 3 3 3 3 3
North Dakota State University	2	Geosciences	Hydrogeology Geochemistry	3 3
South Dakota School of Mines	1	Geology Geological Engineering	Groundwater	3
University of Iowa	7	Civil Engineering Environmental Engineering Environmental Science Geoscience	Hydrogeology Field Methods in Hydrologic Science Isotope Geochemistry Groundwater Groundwater Modeling Hydrology Water Resources Sustainability	3 3 3 3 3 3 3
University of North Dakota	5	Environmental Geoscience, Geology, or Geoengineering	Hydrology Hydrological Methods GW Monitoring & Remediation Groundwater Modeling Geochemistry	3 2 3 3 3
University of Wisconsin				
Eau Claire	3	Geology	Physical Hydrogeology Contaminant Hydrogeology Geochem of Natural Waters	4 4 3
Madison	5	Geoscience or Geological Engineering	Hydrogeology Principles of Geochem. Contaminant Hydrogeology Groundwater Hydraulics Groundwater Flow Modeling	4 3 3 3 3

Appendix 3.2
Survey of Employers with Entry Level Professional Groundwater Positions

A survey was provided to employers with entry-level professional-groundwater positions to identify the skills required for such positions and any means by which those requirements are communicated to Minnesota postsecondary educational institutions.

Survey Recipients

The survey was distributed to Minnesota-based organizations in the public and private sectors. Public-sector organizations included state government agencies. Private-sector organizations, including consulting and engineering firms, were identified from the MGWA membership roster. Some survey recipients in both the public and private sectors were identified as volunteers during the Spring 2016 MGWA meeting and the 2016 MGWA member survey.

Public-sector employers at the Minnesota state agencies were identified by the Interagency Groundwater Drinking Water Group. These survey recipients include the supervisors and managers within the agencies that engage in groundwater-related activities. It is estimated that the survey was delivered to approximately 25 recipients at the state agencies through this method.

Private-sector employers were identified from the MGWA membership roster. For the purpose of this evaluation, private-sector employers include those organizations with a primary focus on groundwater services that are not drilling contractors or laboratory analytical services. The survey URL was delivered directly to an individual at each private-sector organization with at least five MGWA members and most organizations with three or more MGWA members. In some cases, the survey was provided to more than one contact at an organization with high MGWA membership to allow broad participation. The survey was delivered to 45 contacts at 34 private-sector organizations.

Survey Questions

The survey was developed and delivered using the SurveyMonkey.com online service. Survey recipients were emailed a link to the survey and a follow-up reminder email several weeks after the initial request. The survey consisted of the questions listed below. Questions offering an open-ended response are indicated.

1. What general type of organization do you represent?
    - Private Sector
    - Public Sector
    - Academic
    - Non-Profit
    - Other (please specify) (Open-ended response)

2. What coursework or skills are essential or desirable for a candidate for an entry level professional groundwater position? (Ranked by necessity: Essential, Desirable, Optional)
    - Aquifer testing and data analysis
    - Basic GIS skills
    - Basic hydrology
    - Borehole geophysical data collection and analysis
    - Collecting and verifying well data
    - Concepts of groundwater-flow modeling
    - Concepts of solute transport
    - Data base/data entry skills
    - Environmental engineering
    - General chemistry
    - Geological mapping methods
    - Groundwater theory
    - Hydrology or geology field camp
    - Individual project relating to groundwater
    - Laboratory methods for water analysis
    - Land use management
    - Land use planning
    - Organic chemistry
    - Physical geology
    - Project organization and management
    - Public speaking/communication
    - Report writing
    - Sample collection and documentation
    - Surface geophysics
    - Stratigraphy/stratigraphic analysis
    - Statistical analysis
    - Glacial geology
    - Soil science/soil mechanics
    - HAZWOPER
    - Groundwater modeling experience
    - Calculus (6 semester hrs)
    - Physics (6 semester hrs)
    - Engineering science
    - Structural geology
    - Civil or geological engineering
    - Geochemistry
    - Atmospheric science
    - Computational/mathematical skills
    - Other (please specify additional skills) (Open-ended response)

3. Do you have any further expectations or qualifications of an entry-level groundwater-professional job candidate that you could not specify under Question 2? It would be very helpful if you would add your thoughts and ideas here. (Open-ended response)

4. What is the degree level that a candidate for an entry level professional groundwater position needs for your organization?

- Vocational-Technical degree
- Associate's degree
- Bachelor's degree
- Master's degree
- Ph.D. degree

5. Do you communicate your hiring needs to the educational institutions from which you hire? If so, how? (Open-ended response)

6.How could communication between employers and educational institutions be enhanced? Check all that apply.

- Meeting face-to-face
- Periodically convene a forum to discuss
- Periodically repeat this on-line survey
- Other (please specify) (Open-ended response)

Survey Results and Analysis

Fifteen respondents participated in the survey. A summary of the key findings of the results is included below. Responses to open-ended questions and our interpretation of such responses are listed in Table 2.2.

Key findings of the Employer Survey include:

- 53% of respondents (n=8) worked for private-sector organizations and the remaining 47% (n=7) worked in the public sector. No respondents worked for academic, non-profit, or "other" organizations.
- The skills identified as Essential/Desirable/Optional are shown on Figure 2 of the paper, listed in decreasing order by the percentage of "Essential" responses. Those skills that are most basic to an understanding of groundwater were more frequently selected as "Essential": "Basic hydrology" and "Groundwater theory" top the list. Skills not listed in the survey, but indicated by respondents as being essential or desirable include mineralogy and inverse optimization.
- Nearly two-thirds of respondents (73%) indicated that a Bachelor's degree is the degree level required for entry-level groundwater positions at their organization.
- A slight majority of respondents (53%) communicate their hiring needs with Minnesota educational institutions, primarily through either direct/personal communication or by providing job postings for distribution among students.
- Respondents indicated a desire for improved communications between employers and postsecondary educators through direct/personal means, including face-to-face meetings and a periodic forum. A desire for an enhanced role by professional organizations such as MGWA in brokering this communication was also expressed.

Appendix 4.1
Criteria for Evaluating Components of a Statewide Strategy for Groundwater Education in Minnesota

I. The following criteria were used to assess existing groundwater education strategies primarily by government agencies, but also for individual educational institutions, or private-sector organizations. The strategy includes:

a. An organization or public need and timeframe for implementation is stated for improving education about groundwater throughout Minnesota;

b. The primary recipient(s) of specific groundwater education efforts is identified;

c. For each primary recipient, at least one of the following specific topics of groundwater education were included in the strategy:

i. Basic groundwater concepts (aquifers physical characteristics and distribution, water use rights, Minnesota laws or regulations, and sources of technical assistance)

ii. Groundwater quantity (pumping limits from wells, pumping interference with other groundwater users, recharge rates, estimated age of groundwater, and relations to surface water)

iii. Groundwater quality (drinking-water standards, sources of pollution, natural or manmade contaminants, and options for protection or remediation)

iv. Groundwater data (sources, types, and access; technical assistance for using data, and data collection efforts or targeted areas) and;

d. An assessment of education results and when this is to be conducted.

II. The following criteria were used to assess through coordination or partnerships among organization the likelihood of advancing a statewide strategy to promote improve groundwater education. The strategy includes:

a. Specific reasons are given for the need to collaborate with similar or other entities involved in increasing student or public understanding about water-resources or management and protection; At least one other entity that is implementing another strategy is identified that could help improve coordination or the development of a partnership;

b. Added value to primary recipients of groundwater education through improved coordination;

c. The educational effort(s) of another strategy is clearly identified as well as the potential areas of overlapping effort between the two strategies.

d. An assessment of the perceived improvement in educational results through coordination is developed for sustaining or evolving the strategy;

See Appendix 4.2, Summary of Statewide Strategies that Include Groundwater Education, for how the workgroup applied the above criteria to various organizations.

Appendix 4.2
Summary of Statewide Strategies that Include Groundwater Education

["x", means addressing criteria was implied]

Lead Organization(s) in alphabetically order and Strategy document with Internet link or other source of information	Strategy criteria within organization				Strategy criteria for coordination or partnerships				Comments specific to groundwater education and level of implementation
	Ia. GW Education need stated	Ib. Education Recipient(s) identified	Ic. At least one of these four GW topics addressed (i) Concepts; (ii) Quantity; (iii) Quality; or (iv) Data	Id. Assessment of education results	IIa. Reasons stated for collaboration	IIb. Coordination adds value to student needs	IIc. Strategies of two or more organizations are compared/contrasted	IId. Assessment of education results of coordination	
Freshwater Society and Minnesota Department of Health, 2016. Protecting groundwater-sourced drinking water: Assessment of needs and barriers faced by local management professionals. Freshwater Society: 45 p. http://freshwater.org/wp-content/uploads/2012/07/MDHNeedsAssess_FINAL2.pdf (Pradhananga and others, 2015)	p.1	Local water-management professionals (specifically SWCDs)	i,ii,iii,iv	p.18	p.1	p.5, 15	p.4, 20		MDH engaged the Freshwater Society to conduct a qualitative needs assessment with the primary research question: "How can state-level agencies best match resources with local needs in order to accelerate the adoption and implementation of groundwater and drinking water protections?" Focus education in hydrogeology and agronomy. Acknowledged potential roles of many state and academic organizations and comparison to MDH Groundwater Restoration and Protection Strategies (GRAPS), mention of results evaluation. High need expressed in workshops, funding obstacles noted relative to implementation.
Freshwater Society Master Water Stewards program, 2016. http://masterwaterstewards.org/become-a-master-water-steward/	x	Public	iii		x	x			Although Internet site does not explicitly mention groundwater education, the Master Water Stewards (MWS) program was developed in 2013 to equip citizens with the knowledge and skills to help improve (watershed) water quality at the grassroots level. In 2016 the program engaged seven watershed districts and one municipality, and is now expanding statewide (and included education about rain gardens. Modeled after successful Master Gardener programs, volunteer community leaders will participate in a 50-hour program of courses and projects. Certified Master Water Stewards will volunteer 50 hours of community service in the initial year of certification, up to 25 hours each subsequent year and ongoing education in order to maintain their certification. Good implementation progress.
(Metropolitan Council, 2010). Metropolitan Area master water supply plan, 134 p. https://metrocouncil.org/Wastewater-Water/Publications-And-Resources/WATER-SUPPLY-PLANNING/MASTER-WATER-SUPPLY-PLAN-2015/Master-Water-Supply-Plan,-Chapters-1-8.aspx					pp. 7-9				Guiding Principle 2: An understanding of the region's long-term [25 years] water supply availability and demand is necessary to identifying a specific community's or sub-region's water sources. In order to maintain a current and appropriate level of guidance, this plan will be updated as new technology emerges and as analyses are revised with new data. Aquifers are defined under Water Sources section. Metro Model 2 used as an analysis tool. Partner with MDNR and MDH. This strategy, rich in data base, analysis and management strategies, does not mention the need for groundwater education. Mostly implemented.

Metropolitan Council, 2015. 2040 Water Resources Policy Plan. 101 p. Metropolitan Council: https://metrocouncil.org/Wastewater-Water/Planning/Water-Resources-Management-Policy-Plan/WATER-RESOURCES-POLICIES/Water-Resources-Policy-Plan.aspx		Twin Cities Metropolitan Area citizens (7 counties)			p.11				Although not a statewide strategy, but the region grew by over 975,000 people in the past four decades and the overall population of about 3 million is about three-fifths of the overall Minnesota population. This document is a framework for building [planning and management] strategies that integrate wastewater, water supply, and surface water as related areas of a comprehensive water picture. The Council is committed to collaborating with our partners, including federal, state, local and regional agencies and organizations, to promote the long-term sustainability of the region's water resources for surface and groundwater quality and to learn from each other, develop and lead region-wide sustainability strategies [including groundwater]. This strategy does not specifically mention the need for groundwater education rather the need for proper management and planning for regional water resources including groundwater. Initial implementation for long term.
Minnesota Board of Water and Soil Resources 2007 strategic plan 2012 update, 2012. Minnesota Board of Water and Soil Resources: http://www.bwsr.state.mn.us/publications/Strategic_Plan.pdf (Minnesota Board of Soil and Water Resources, 2010. One watershed, one plan: State strategies).			I, iv					pp. 8-9	Considerable mention of value of partnerships with local government units, state, and federal organizations and results assessments to improve and sustain water and soil resources. No mention of need for groundwater education. The [Board] is committed to collaborating with our partners, including federal, state, local and regional agencies and organizations, to promote the long-term sustainability of the region's water resources for surface and groundwater quality and quantity and wastewater collection and treatment. To promote sufficient and high-quality ground, the [Board] will: Collaborate with our partners to save dollars, share expertise and accomplish more. Work with external partners on climate change and sustainability to learn from each other, develop and lead region-wide sustainability strategies. Promote the wise use of water at the community level through optimizing surface water and groundwater use, conservation, reuse, and aquifer recharge. Partly implemented.
Minnesota Department of Agriculture, 2015. Minnesota nitrogen fertilizer management plan, 2015. Minnesota Department of Agriculture Pesticide and Fertilizer Management Division, 131 p.: http://www.mda.state.mn.us/~/media/Files/chemicals/nfmp/nfmp2015.pdf	p.1, 55, 61-63	Nitrogen fertilizer appliers	i,ii,iii,iv		p.61	p.62	p.62	p.62, 66-69	Document lists several state, local, agricultural and university of Minnesota partners under acknowledgments. For agricultural areas, oversees groundwater contamination and vulnerable areas using state maps by other agencies. Includes general geomorphology, water-table sensitivity, recharge to surficial aquifers. Monitor nitrate conditions and trends in Minnesota Groundwater. Applies guides from Comprehensive Groundwater Protection Act of 1989 for the prevention, evaluation and mitigation mostly of fertilizer contamination in state groundwater. Prevention activities focus on promoting nitrogen BMPs to protect groundwater from nitrogen fertilizer from leaching into the most hydrogeological vulnerable areas. Prevention activities within Nitrogen Fertilizer Management Plan are ongoing regardless of the status of mitigation for nitrate in groundwater. These efforts will be coordinated through a new statewide Nitrogen Fertilizer Education and Promotion Team. Implementation of education, outreach and demonstration activities will be accomplished through existing programs. Fully implemented.

Minnesota Department of Health and Minnesota Section of American Water Works, 2001. A Drinking Water Institute for Educators: http://health.state.mn.us/water/institute/index.htm	x	K-12 Teachers	i,ii,iii		x	x	x	x	Partners with Minnesota Section of the American Water Works Association and SMM have been conducting a series of "Drinking Water Institutes" for Minnesota teachers since 2001. Middle-school and high-school teachers learn about drinking water [which includes GW], along with ways to develop the subject into inquiry-based curriculum, at these Institutes. They also have opportunity to write curriculum to take back to their classrooms. The overall goal of this program is to have an ongoing group of high-school graduates in the state who are well versed on the subject by being provided with subject matter curriculum as a key part of their education at various grade levels. Instructors assess number of students impacted with follow-up to teachers. MDH Internet sites show many strategic plans for health-related topics, but difficult to find one specific to GW education. Plans for contaminant-specific plans (such as for nitrate, pesticides, PFC, and AS) drinking water, climate-change adaption and environmental health tracking/biomonitoring have connections to GW. Fully implemented with budget issues as pending obstacle (Stew Thornley, oral communication January 2016).
Minnesota Department of Natural Resources draft strategic plan for groundwater management, October 2013. Minnesota Department of natural Resources: http://files.dnr.state.mn.us/waters/gwmp/gwsp-draftplan.pdf Also to ""Evaluation of Models andTools for Assessing Groundwater Availability and Sustainability": http://files.dnr.state.mn.us/publications/waters/modelsandtools.pdf in which education and technology transfer was recommended for citizens and local governments as part of the management strategy.	p.8	Groundwater users, stakeholders, partners, and the general public	i, ii, iv	p.10	p.7	p.8	p.7-8		Through many partnerships, improve communication and **education** about the importance of groundwater resources and challenges of groundwater management: (a) develop and implement a communication plan to increase understanding of groundwater resources and groundwater issues, (b) improve the distribution and utility of County Geologic Atlas information in order to increase understanding of aquifers and hydrogeology, (c) continue to work with partner organizations (e.g., MPCA, MDA, MDH, BWSR, Metropolitan Council, Tribal councils and others) to develop important information on groundwater, (d) more actively engage users, stakeholders, partners, and the general public in discussions about Minnesota groundwater resources Draft Strategic Plan for Minnesota DNR's Groundwater Management Program October 2013, and (e) work with land use authorities and other partners to adopt policies and practices and procedures that preserve groundwater recharge areas, minimize risk of groundwater contamination and that ensure plentiful supplies of high quality groundwater. Initial implementation.
Minnesota Environmental Quality Board, 2015. Beyond the status quo: 2015 EQB water policy report, 43 p.: https://www.eqb.state.mn.us/sites/default/files/documents/WaterReport_091715_FINAL_R.pdf,		Legislators	iii, iv						This five-year mandated report to the Minnesota Legislature suggests water policy for the future. Although limited on specific education points, the report does imply groundwater-education needs by identifying issues, such as, groundwater use, tends in levels, nitrate concentrations, and need for additional water research and data. Report also states value of Minnesota's innovative water technology industry and the associated links to post-secondary education. Initial implementation.

Lead Organization(s) in alphabetically order and Strategy document with Internet link or other source of information	Strategy criteria within organization				Strategy criteria for coordination or partnerships				Comments specific to groundwater education and level of implementation
	Ia. GW Education need stated	Ib. Education Recipient(s) identified	Ic. At least one of these four GW topics addressed (i) Concepts; (ii) Quantity; (iii) Quality; or (iv) Data	Id. Assessment of education results	IIa. Reasons stated for collaboration	IIb. Coordination adds value to student needs	IIc. Strategies of two or more organizations are compared/contrasted	IId. Assessment of education results of coordination	
Minnesota Geological Survey; Setterholm, D.R., 2014. Geologic Atlas User's Guide: Using Geologic Maps and Databases for Resource Management and Planning: Minnesota Geological Survey Open-File Report OFR-12-1, 22 p. http://conservancy.umn.edu/handle/11299/166713	p.1	County and local groundwater managers and the public	i,ii,iv		p.2	p.2			Partners with MDNR. Although not a specific strategy document for groundwater education, the guide can be used for local groundwater education. The purpose of the guide is to explain, through reference to County Geologic Atlas products, where water comes from, how geology and climate control its distribution, and how we can manage water to maximize its availability at the highest quality. The purpose of the Guide is to explain in simple terms where our water comes from, how geology and climate control its distribution, and how we can manage water to maximize the availability of high quality water for ourselves and the habitat we live in. Implemented by motivated local water managers.
Science Museum of Minnesota Internet site **https://www.smm.org/** and Patrick Hamilton, oral communication May 2016	x	Mostly grade 2-6, K-12 educators	i, ii		x	x			Mission: We impact over a million people from around the world every year through trips to our museum, school visits, our traveling exhibitions, and Omnitheater films. For mostly grades 2-6: • SciEd is science education support and programs for teachers. Working with teachers, we strive to advance science literacy through dynamic resources: field trips to the museum, in-school visits, curriculum support, Science House lending library, and professional development. • Field trips to the museum: • PROGRAMS AT SCHOOL: Our programs at your school are a great way to energize your science curriculum. Our cross-curricular team of 20 teachers and presenters travel throughout Minnesota and western Wisconsin. [Every Minnesota County is considered] For educators: • Resources and professional development: This full service circulating library and professional development center has over 2,000 of the coolest hands-on items you can borrow for use with your students. • SMM has direct support for what is taught in the classroom through a **data base** to connect exhibits, programs, and resources to Minnesota Academic Standards by grade level. Fully implemented. The Big Backyard has been a successful attraction for several reason; (1) kids like to play in water, (2) adults have places to sit in the shade, and (3) the camera obscura also is a great draw. Opens June 18 (summer months). GROUND WATER PLAZA: Water is life. Learn about the importance of groundwater aquifers and enjoy a refreshing drink of pure water you pump from 300-feet under the earth.
University of Minnesota, 2011. Minnesota Water Sustainability Framework, 2011. University of Minnesota Water Resources Center, 140 p. https://www.wrc.umn.edu/sites/wrc.umn.edu/files/minnesota_water_framework.pdf (Kennedy and Stromme, 2008)	p. 104	Minnesota citizens, K-12, and professionals	i	pp. 103 - 104	p. 103	pp. 104-105	pp. 103-105	p. 106	Water and environmental education needs in general, recommendations and potential strategy for implementation are described in the chapter "Citizen Engagement and Education" (pp. 101- 106). Some mention of groundwater. Recognizes Minnesota Association for Environmental Education and "A Greenprint for Minnesota: State Plan for Environmental Education, 3rd Edition" (http://www.seek.state.mn.us/publications/p-ee5-01.pdf). This comprehensive strategy for citizen engagement through water literacy/knowledge with stated benchmarks related to measuring behavior change has yet to be implemented.
Total of 12:	8	11	10	3	10	8	5	4	

Appendix 4.3
Charter of the Interagency Groundwater/Drinkingwater Group

Charge/scope:
Coordinate statewide groundwater and drinking water protection and management efforts.

The team will identify priority groundwater and drinking water protection and management issues that may affect Minnesota's public health, welfare, and environment, and develop strategies for addressing them. The team will focus on activities that affect groundwater and drinking water sustainability (quality and quantity) including issues related to the interaction between groundwater and surface water, and ecosystem protection. The team will also provide a forum for presentation and discussion of activities, research, and reports on Minnesota groundwater and drinking water.

Team members will provide a level of support that reflects their resource capabilities. All work shall be conducted cooperatively with the team members responsible collectively for the work and success of the team. The team may form subgroups to carry out its tasks. All decisions and products shall be developed by consensus of the agencies.

Membership:
- Randy Ellingboe, Tannie Eshenaur, Jim Kelly, Steve Robertson, MDH
- Katrina Kessler, MPCA
- Jason Moeckel, Brian Stenquist, Stephen Thompson, DNR
- Jeff Berg, Larry Gunderson Dan Stoddard, MDA
- Don Buckhout, Eric Mohring, BWSR
- Ali Elhassan, Lanya Ross, Met Council

Meeting Frequency:
Monthly.

Tasks:
- Prepare joint presentations on ground water and drinking water activities as needed.
- Use the Minnesota Groundwater and Surface Water Protection Strategies to prioritize work and develop interagency budget proposals.
- Coordinate and promote enhanced data coordination.
- Charge and monitor activities of interagency subgroups working on
  - development of Groundwater Restoration and Protection Strategies reports for local planning and implementation; and
  - coordination and development of statewide capacity for using groundwater models integrated with other quantitative data assessment tools.

- Identify interagency coordination needs on issues regarding contaminants of emerging concern, and recommend a plan to address those needs.
- Coordinate the interagency review of plans and reports on groundwater and drinking water.

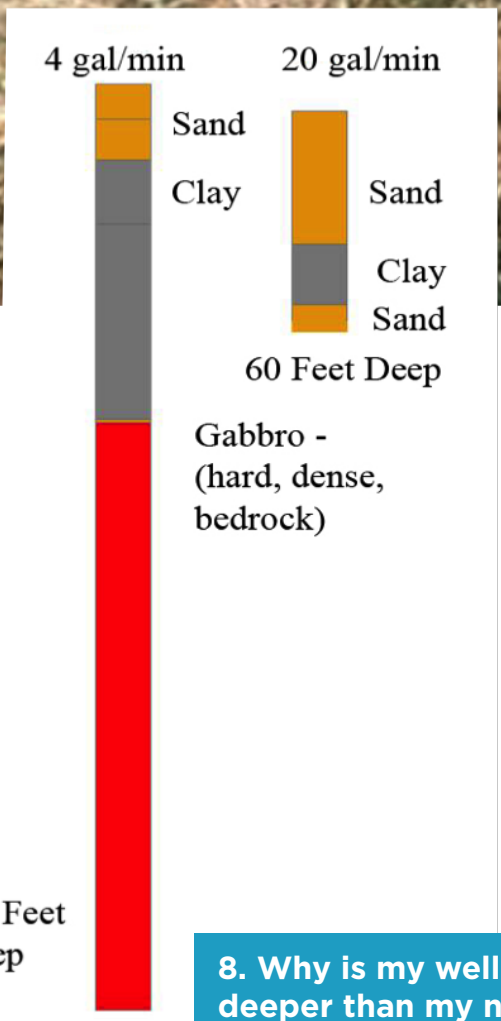
Measures:
Team continues to monitor groundwater and drinking water measures included in the Clean Water Performance Report, and develops new measures as needed.

Draft outcomes:
- Statewide drinking water protection and groundwater sustainability efforts are coordinated and effective.
- Drinking water protection issues that affect the health and welfare of Minnesotans will be prioritized and strategies that effectively address the barriers to successful implementation of drinking water protection efforts in Minnesota will be developed.
- Groundwater protection issues that affect ecosystem services, sustainability and surface water quality/quantity will be prioritized and strategies that effectively address the barriers to successful implementation of groundwater protection efforts in Minnesota will be developed.

Additional outcomes that relate to interagency coordination (given the multi-agency approach Minnesota has to groundwater protection), groundwater monitoring/mapping/information gathering, and groundwater-surface water interactions will be developed as needed.

5. How does groundwater become contaminated?

55-gallon drum containing waste.



6. Are our aquifers being over pumped? Will we have enough groundwater for future generations?

7. Do undergraduate degree requirements reflect employer hiring requirements?

8. Why is my well so much deeper than my neighbor's well?