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## EQB Water Availability Project Technical Focus Group DRAFT Survey #2 Results Compiled

### Framework Development

**What elements would you want to see in a framework for considering the near-term effects and long-term implications of proposed water uses? If you have ideas on different scales, please list them.**

- The basic elements are an understanding of atmospheric input of water over time balanced by an accounting of water loss. This requires better resolution of the movement of water as controlled by geologic materials. Water storage must be maintained over the long term to preserve the aquatic features and habitats we value. I see the framework changing over time from an emphasis on monitoring the effects of use to an increasing role of modeling in predicting the effects. The transition is dependent on the development of geologic, hydrologic, and climate data to create meaningful and effective models.
- I believe that most of what is needed for a framework already exists and that the state already has the authorities it needs through rules & Statute. What is needed at this time is a better communication and evaluation tool that puts all of the pieces together in a meaningful way and can communicate this information to a large group of different users, most of whom have varying needs. The challenge is putting all the data we have together in a meaningful format.
  - A framework really needs to offer reviewers, industry, and the public a perspective. A stand-alone pumping rate is not meaningful to many people. However, a comparison of a proposed water use to that of all uses in a zone of influence or within an MCD, county, watershed or whatever scale offers a reference. We need to do a better job of addressing proposed future use. That is a requirement in environmental review and it's in Statute (103G.265 or water plan requirements) as well as a number of other references to future needs and future projections. We need to establish a systematic and quantitative way of doing this for short-term and long-term needs. They may be estimates, but they can help guide decisions. We can also use this information to run development scenarios, quite similar to the scenario work Met Council is doing with Metro Model II.
  - The framework needs to incorporate water quality and its protection and preservation. There needs to be a way to consider the quality of the water resource being proposed for use with the ability to compare that to the needs of the proposed water user. There also need to be better means of ensuring that water use/pumping won't lead to degradation of the source water. Again, much of this data exists or is understood by a small handful of technicians, but it needs to be incorporated into a framework for many users.

- A framework needs to be easily adapted and modified to new and expanded data. It also needs to be iterative. A framework needs to have strong statewide leadership and interagency coordination. These issues impact so many departments, that strong communication and coordination is needed. The current work activities have been a great step, and with proper long-term support and funding, continuing some EQB-led work on this makes sense.
- The framework needs to consider aquifers, their locations & boundaries, and more data about their features & parameters.
- The framework needs to evaluate and quantify surface water.
- The framework should be adaptable to run scenarios based on possible future climate change impacts.
- The framework needs to evaluate future populations and projected industrial growth.
- The framework needs to have an educational component. Much information already exists, but that needs to be easily shared with the larger community. Currently too much knowledge and data is bottled up and not well integrated.
- The data framework needs to be GIS-based. It needs to link to what we know about aquifers and their characteristics. It should tie into the SWUDS database and link to the water level monitoring program.
- Regional scale: If you want sustainability, you cannot allow unlimited growth! Growth causes additional demands to be placed on existing natural resources. Regional planning should direct growth to the least sensitive areas. Statewide: Water law as it currently exists in Minnesota does not allow the permitting agency to 'zone out' new water users. If that is a goal, we'd need to create some kind of modified prior appropriation water law. Right now, equal priority users all have the same right to use water. We can restrict how much they get within that particular class of user, but if spread too thin, water use for an individual user becomes uneconomical. Which is why prior appropriation is the doctrine out west where water is frequently limiting. Senior users are satisfied first, junior users must be prepared to suffer the consequences of a limitation. There is a way under prior appropriation for the user to evaluate the risk of a dry year - and that is not possible in Minnesota's context. Local: How about matching crops to climate and soils to minimize water use? Or how about determining what protective thresholds are required to maintain natural resources within the community (lake, stream, wetland, spring, etc.) and determine how the threshold parameter responds during the 'dry' or 'wet' year. If it is a local effort, political will to constrain use for protection may be found.
- Establish goals. Assess the quantity and quality of the current water resources and then be able to document trends. Have regulatory authority to achieve the goals.
- The focal point of policy framework should be on water conservation and efficiency in order to have sustainable water supply for human and ecological services for indefinite time. An example of conservation are: conserve irrigation water, price water, use "virtual water", adapt low-water sanitation, eventually moving to no-water sanitation, decouple fresh water supplies from sanitation systems, develop technology for efficient use of water in industry, etc. The following elements should be in this policy framework: 1. The integration of land use and water use planning in relation to society's uses of water and land. That means the integration for land and water requirements for human needs, food and feed, fiber, biofuels and infrastructure as well as ecological services, etc. € rather

than pretending that each need can be analyzed separately 2. Develop a price for the use of water resources and degradation of water quality and depletion of water quantity beyond renewable supply. Break the addiction that water is free and pass the laws that encourage the industry to use either less water or to replace water use with other substance. For example, in the past 30 years Congress passed laws requiring toilet manufacturing to use less water. 3. To make a shift from non-sustainable use (storage and renewable supplies) to sustainable use (only renewable supply). This sustainable supply must be shared by human and ecological services. Surface and ground-water system (blue water) should be treated as one source. The storage of surface and ground water should be left intact. That way the resilience and feedback of the hydrologic system will be intact. The storage can be used only in emergency situation (similar to national oil reserve or drought situation). 4. Pollution must be stopped to secure usable raw water sources and protect ecosystems services, in the long term moving toward a water pollution veto. For example, it is inadvertent misuse of science and technology in using herbicides, pesticides, antibiotics and others as manifested in their side effects. 5. Awareness and quantification of depletive water use involved in plant production. Therefore, there is a need to incorporate green water resources (soil moisture) and green water use (evaporation).

- Site specific water availability analysis (pumping tests, etc). Impacts to nearby water users Projections for water demand in area Regional impacts on water source - short and long term
- Elements would include: 1). Existing and new data networks for monitoring streamflow, weather data, ground water level data, water use by humans for various activities such as industry, municipal, food/fiber/fuel production, and water use by nature for biomass production. 2). Data mining and data analysis to quantify the links between the various forcing functions in the system, and the effects of those forcing functions on the state (quantify, quality) of the surface water and ground water resource. The analysis would involve not only looking for explaining what has been and is being observed, but also to forecast ahead. I think of this system as being similar to what is already done by climatologist/weather bureaus in forecasting future conditions (near and far time scales). The analysis tools would include for example, statistical tools (time series analysis, factor analysis, etc.), and physically-based models (MODFLOW for instance) for the modeling of the temporal and spatial distribution of various relevant state variables (water levels, fluxes, quality). 3). Economic model that uses information about the current and forecast physical conditions about the water resources and arrives at the cost and benefits of alternative water resource allocations. 4). A policy decision mechanism for allocating water uses that is responsive to the currently perceived state and future forecast state of water resources and ecological services. Monitoring systems would be designed for a nested system so that information can be derived about physical processes occurring at various spatial and temporal scales. Of course those nested systems will be designed to optimize/maximize the information value of the data acquired. Models will then follow suit with the nested monitoring systems; there will be models that cover the very large scale, and these will be directly linked to the models developed at increasingly refined scales.
- Start with codifying the term "sustainable yield" as a replacement of "safe yield." Explicitly recognize in law how "reasonable" use is dependent on: a) a need test, b) the

short term sustainability test, and the long-term sustainability test. Also introduce the concept of priority sustainability management areas, building off of the aquifer management zone authority, except that these areas would address surface and ground water as one system, and be triggered by any land and water uses or expected future uses, and quality concerns, that indicate a system approaching a sustainability crisis or threat (something less than "crisis," say heading toward a crisis more long term). I also would explicitly require local, regional and state governments (all agencies) to build these concerns into their planning and development considerations, even to the point where a state agency (broader than DNR) could be required to approve decisions that would precipitate additional deterioration of a system's sustainability status. This also would require establishment of a routine, interdisciplinary monitoring and assessment program, and routing reporting of sustainability indicators based upon it. These would drive or trigger the whole process, or at least that component of the process beyond that driven by reaction to individual permit requests. We must get beyond reactionary approaches to managing water. I also would introduce the concept of permit trading as a legitimate part of the modified riparian water law in Minnesota, with conditions and subject to the same tests outlined here.

- My overriding concern in the framework is how it is administered. I am concerned about the conflicts and lack of cooperation between agencies who are involved in water resource management.

### **How could this framework be applied?**

- Water allocations are made and the effects closely monitored. Effects are evaluated, and thresholds on acceptable changes are identified. As better modeling is created from better geologic and hydrologic input models can improve our ability to predict effects and minimize investment in uses that are not sustainable.
- This framework could be one part of a decision-making tool. Just like current Environmental Review depends on a broad team, all members having different responsibilities and answer different data questions, this framework could help inform one part of this activity. It could add to put much of the individual pieces of information together in a way that makes sense.
- Regionally and locally
- 1, 2, 3. This knowledge based framework will require information on renewable capacity of surface and ground water system at spatial and temporal resolution (i.e. unit in volume of water per unit of land). This approach needs a multi-scale level. It will require developing land-based mapped synthetic hydrologic units at the state, regional, county and local levels. The human use (water appropriation) and ecological services needs should be reported by parcel of land, not aquifers and compared with sustainable supply at a county level or watershed or any unit of land. Initially, this framework should be in parallel with present framework (by aquifer). As new mapping unit will be developed the old system by aquifer could be disbanded. At the site specific level presently it will require pumping test. Eventually, when the information of the land based hydrologic units will be developed the need for pumping test could be eliminated. 3. Pollution must be stopped with economic and policy incentives. 4. Intelligent decision in agricultural policy and land use.

- I don't see a way around the need for case-by-case analysis. Maybe I just don't get it.
- It would be completely interactive. Data acquired from the monitoring network would be analyzed for the various spatial scales to derive measures/indices of current conditions, and responses would be applied for corrective actions (for instance to allow additional water uses or to cut back in water use at a given location). The framework will need to be managed by one government entity, but it will need to be serviced/interacted with by the various existing agencies. For the functioning of the framework to succeed it will be necessary for the various responsible agencies to cooperate effectively with each other. The challenges will be great, as we saw for the creation of the national office of homeland security; getting various agencies to cooperate is not easy.
- We must be willing and ready to change from the current reactionary approach to a preventive one at each level, even with less than ideal information. We should define system limits with the best available methods (e.g., the watershed characteristics method for statewide determination of long term system capacities), but let them be refined as needed on a region or aquifer by aquifer basis.
- As in other states, I think we should consider water management districts.

### **How should this framework be modified or improved in the future?**

- Better data and resolution will lead to improved predictability.
- Through an interagency coordinating team. A data framework will likely have to be housed in a single location, but leadership and oversight could be put in place through a coordinating team, similar to the current EQB-led structure.
- The framework should be iterative so that better decisions can be made based on additional information.
- The modification and improvement of this framework for a finer resolution will require improved information to understand and quantify the hydrologic cycle and its spatial and temporal interactions with the natural and built environment. Development of the monitoring network to measure water resources sustainability. This network must be built to integrate stream flow and water level information based on the multi-scale maps land-based hydrologic units. Advanced cyber infrastructure should be developed to understand and use diverse data sets about the spatial and temporal interactions with the natural and built environment. Development of capabilities of satellite remote sensing and GIS to measure water balance components (precipitation, soil moisture, evapotranspiration, air and surface temperature will provide a finer resolution of water balance characteristics. This will improve the information on spatio-temporal variability of these components to improve the framework. Development of water information system based on web-based services for decision support needs that includes water appropriations, ecological services needs, maps of land-based hydrologic units, intelligent monitoring network to measure sustainability.
- Framework should be flexible enough to be able to incorporate new data and knowledge as it is created. New geologic and water resource data and information, better water use data, new data on projected water demands and demographics
- This framework would be evolutionary. As additional data are collected the initial models developed with preliminary data would be modified and updated, and the monitoring systems set in place would also be modified to account for the improvement in the

models. Presumably, as the models are improved it will be discovered that some monitoring will be redundant and therefore efficiencies in monitoring will be increased by dropping or moving monitoring sites.

- The framework should be consistent, but the information, methods and tools we use to implement it should evolve as we learn more how to better assess short- and long-term sustainability, and get the institutions of local, regional and state government to integrate sustainability into their decision processes.
- Evaluation of state agency roles in water management.

## **Supporting data**

When we evaluate water availability and sustainability, we rely on many sources and types of data. In this section we hope to get your views on the importance of these data and address their adequacy or opportunities for growth and expansion.

## **Climate**

### **What publicly available data do you use?**

- Little or none
- Precipitation.
- Precipitation
- Data from the high-density precipitation network and from the Weather Service network.
- Precipitation
- Evapotranspiration, precipitation, surface and air temperature
- State Climatology Office data on precipitation, temperature, etc.
- Precipitation, temperature, solar radiation, wind speed, relative humidity.
- Very little

### **Can it be easily accessed?**

- Yes, we have a good database and that excellent regional coverage.
- Online from DNR Climatology.
- Yes
- No
- Yes.
- It is relatively easy to access the data from NOAA and from local/state networks (such as the University of Minnesota's network of weather stations).

### **What do you need this data for?**

- Recharge and trend analysis for water level fluctuations.
- Compare to water use and to water levels to try to sort out impacts from climate and impacts from changes in water use.
- Calculating recharge, for evaluating water quality for shallow wells, evaluating time of travel to the aquifer

- To quantify water resources sustainability at a multiple scales
- To evaluate antecedent conditions to particular hydrologic observations.
- For the quantifying spatial and temporal distribution of precipitation (rainfall, snowfall), and quantifying evaporative demand.

### **How is this information important to decisions you or others have to make about water?**

- Recharge data and evaluation s critical to long term groundwater management.
- Have to understand cause and effect to be able to change what is in our power to change in order to prevent an impact or to minimize and impact.
- Very
- If this data would be available from satellite remote sensing we have a better chance for finer resolution to define and map hydrologic units.
- The information is essential to put observations tied to a given time into context.
- Water resource systems will be sustainable only if we can quantify how much water is flowing through the hydrologic system. The base for this water flow is the precipitation, and in terms of fluxes the evaporation is only subordinate to the precipitation quantity itself.

### **What do you see as its value?**

- Precipitation is the input to the hydrologic system. That component must balance with true withdrawal (evaporation, transpiration). Ground water discharged after use may return to the aquifer it was taken from, to another aquifer, or to surface water. This must also be accounted for to calculate availability.
- Intelligent management of groundwater resources is not possible without a comprehension of recharge to aquifers.
- Can't do without it.
- If the values upon which as analysis is made are not correct, the solution will not be correct. The decision will be based on incorrect assumptions.
- Determine the effect of climate change, land use change or other climatic features. Time series analysis and spatio-temporal variation at a multi-scale will allow to measure possible impact on water resources sustainability. Develop the water information system for decision making in order to address the water resources sustainability
- Its completeness, ease of use, and the extreme helpfulness of those managing the data.
- It is absolutely critical. Without the climate/weather data you do not know how much water you are working with.
- Climate change is the 800 lb gorilla in the room that no one seems to want to recognize. Still, we cannot wait until we have complete information and understanding before we act and before we establish a prospective, forward-looking management system.

**What additional data needs do you perceive (i.e. what additional data would you like collected or made available)?**

- No opinion for additional data.
- The precip/temp network is pretty good - other parameters such as barometric pressure and Potential Evapotranspiration and solar radiation not so dense.
- Evapotranspiration, precipitation, surface and air temperature
- Continue to support the State Climatology office. Insure that they continue to have the tools they need to keep doing what they are doing. Do not skimp on administrative support for the offices operations.
- There is a need to be able to better interpolate precipitation amounts between current monitoring sites. Radar systems and other remote sensing systems are needed for this purpose. There are additional data needs along this line, and there needs to be improvement in the analysis of the remote systems data to more accurately predict the precipitation quantities spatially and temporally.

**How would they be applied?**

- NA
- All help
- All water balance components will be quantified by linkage to landscape components per parcel of land at a multiple scales and multi-scale maps will be compiled for practical application on sustainable water supply
- To predict spatial and temporal distribution of surface runoff, transpiration by vegetation, evaporation, and ground water recharge.

**Have recent higher precipitation trends masked the impacts of increased water consumption? Explain your response.**

- Possibly. There are other processes such as septic systems that discharge ground water from depth to the shallow subsurface. One would expect that this artificially creates a wetter near surface environment. Agricultural drainage serves to lower the water table and increase river flow at certain times.
- It's definitely possible.
- This question is irrelevant for developing the framework for water resources sustainability. The temporal and spatial variability should be the issue, not just one event, drought or whatever. It is like synoptic measurement of water levels which give a specific time measure, but does not tell anything about water sustainability. Plus, it is extremely costly.
- I don't know.
- I do not believe that this can be quantified at present. Perhaps with a thorough analysis one might come to this conclusion. I believe that the current data available could be used to evaluate this question, but it has not been addressed yet.

**List any research questions you think Minnesota should address regarding climate data collection, application, etc.**

- We should start more research and policy evaluations into climate change impacts and land use (or natural resource) evolution.
- Trend analysis
- I mentioned that climate data collection should be improved by using satellite technology. The research question: spatio-temporal variability of climate characteristics and linkage with landscape components. Developing the maps and monitoring network of climate characteristics.
- Much climate data is collected already and I would like to see how satellite information could be used to more effectively utilize the information available in the on-ground climate/weather data. For example, to use thermal IR data from satellite for dynamic mapping of the spatial distribution of actual evapotranspiration.

**Do you have any general comments or recommendations regarding climate data?**

- Climate change due to human influence may be more rapid than natural climate change, but it will still be difficult to predict. Without knowing how or when humanity will change to mitigate climate change, or how effective those changes will be, I think it is difficult and probably ineffective to try to react now. Monitoring and modeling will be important. Most of our immediate actions will probably be driven more by the change in demand for water than the change in climate.
- I mentioned that climate data collection should be improved by using satellite technology. The research question: spatio-temporal variability of climate characteristics and linkage with landscape components. Developing the maps and monitoring network of climate characteristics. Do you have any general comments or recommendations regarding climate data? The challenge is to provide a mapping (mapping here means dimensions, linkage and complexity) of water resources sustainability (dealing with climate data) as a knowledge domain and to do so in ways that facilitate knowledge e-networking among interested individuals, institutions, and agencies. To address this knowledge domain requires a team effort of ecologists, hydrologists, geologists, soil scientists, social and economic science. Old approaches to study each component (ground water, surface water, climate, vadose zone) individually are not able to do this.
- I'm repeating myself, but we have one of the best, if not the best, State Climatology office in the nation. They need continued support. They have been forced to do more and more with less and less for many years. They do great work and with adequate funding they could do even better. Just that it needs to be more thoroughly utilized for the purpose of quantifying water fluxes within the landscape, and also for characterizing trends of these water fluxes over the period of record.

## **Geology**

### **What publicly available data do you use?**

- MGS is more involved in generating geologic data and interpretations and less in using it. We create, compile, and use County Well Index, geophysical data, scientific drilling, field observations, and laboratory work. Interpretation of that data allows us to make geologic maps.
- 1. Most important is County Atlases where available. 2. Next is the multitude of USGS publications, particularly those on unconsolidated surficial (sand plain and outwash aquifers) and buried aquifers. 3. County Well Index - this is a critical resource. The data bases is in dire need of an influx of money to verify well locations for the thousands of well logs that have been submitted. 4. Other geologic maps are important where atlases are not available. 5. Consultant reports on file at MPCA. 6. Regional atlas studies, where available.
- County atlases
- USGS reports and quad maps (geologic as well as topographic), MGS reports and maps
- Geologic atlases, contaminant (hazardous, petroleum, and agricultural chemical) site investigations, observation well network, county well index, soil map coverages
- Maps, well logs, publications
- MGS maps, publications, and associated data. Water Well records. DNR water level records (lake and observation well). USGS maps, publications, and associated data. Soil survey data.
- 1). Geologic maps, both hard copy and digital maps. 2). Well logs.
- MGS and USGS publications. MDH well log database.

### **Can it be easily accessed?**

- Since about 1995 all of our products are digital and web-served. As our methods and capabilities develop we are also making most of the data we generate available as well.
- Yes, again if you know where to look and how to gain access to reports.
- Yes
- Some of the data (not site specific investigative data) Not all counties have atlases and some are not electronic
- Yes, reasonably
- Yes for most. Water well records can be a bit problematic due to the huge volume and security concerns related to public water supply wells.
- Yes, very easy accessibility.

### **What do you need this data for?**

- Geologic maps (seamless coverage) are developed mostly from isolated points of information. Knowledge of geologic processes allows us to make interpretations and fill the gaps between points of known conditions.
- Any groundwater work requires a basic understanding of the geology. It starts there. You cannot perform any reasonable evaluation without this fundamental background.

- Assessing water availability (aquifers and aquitards), identifying potential contaminants (too costly to sample every well for every possible compounds, to do our job, which is identifying where public drinking water is coming from
- Mapping synthetic hydrologic units and regionalization at a multi-scale
- Hydrogeologic evaluations.
- To characterize the subsurface environment. This information is needed to be able to characterize the flow fields of ground water and shallow subsurface water, and of course these flows are related to the generation of stream flows.
- Potential well interference issues. EIS/EAW development.

### **How is this information important to decisions you or others have to make about water?**

- Other parties and processes are employed to develop ideas about how much water is available over time (sustainable). The calculation of water available in a bounded area must then be translated to the aquifers that underlie that area. Management of those aquifers requires knowledge of how (where) they recharge, where they discharge, who is pumping from them, and how surface water bodies are connected. CWI is a huge step toward identifying users when the step of relating wells to specific aquifers is accomplished. All of these parameters are portrayed in County Geologic Atlases.
- Critical to the decision making process. How deep in the water table? How deep is the nearest bedrock aquifer? What type of soils are in an area and are there potential for buried sand and gravel deposits.? Is the bedrock permeable? To perform any groundwater evaluation requires a knowledge of the geology. If anyone says this isn't important, they likely are an engineer.
- Very important
- The information is critical to define synthetic hydrologic units based on hydrologic characteristics
- It provides much of the basis for those decisions. Without knowledge of the "container", it is impossible to evaluate the water in the container.
- Certainly information about the geology and related hydrogeology is critical to quantifying the amount of water that is stored in the ground water system, and it is also critical to estimating the quantity and quality of water flowing through the subsurface and interacting with surface water.
- Provides the basis for decision making on water appropriation and well interference.

### **What do you see as its value?**

- Geologic and hydrologic mapping and associated databases bring "availability/sustainability" down to the aquifer and user level.
- Where can safe drinking water be obtained if quantity or quality become issues
- Synthetic hydrologic units at a multi-scale organization are quantified that shows the recharge and discharge rates at a multi-scale per parcel of land. That is sustainable water resources and it is critical information that unifies land and water.
- It has the same value to water resource evaluation as "Greys Anatomy" has to a surgeon.
- Needed for quantification of the fluxes of water and chemical constituents in the subsurface and interaction with surface waters. Also, determination of where land use

needs to be more critically controlled to prevent contamination of the subsurface water resources.

- Invaluable to have the data readily available.

### **What additional data needs do you perceive (i.e. what additional data would you like collected or made available)?**

- It would help immensely to have water wells assigned accurate digital locations at the time of drilling (under MDH regulation). I'd also like to see studies of recharge, particularly rates and modes of recharge to deep and confined aquifers including the effects of pumping. I'd like to see models include the transfers of water associated with septic systems, and municipal and regional sewage systems. I'd like more data that describe the quality of recharge (subsoil monitoring).
- More maps. Delineation of non-bedrock aquifers. More groundwater quality data. More groundwater level data.
- Base flow for streams, gaining and losing streams and other surface water bodies, contaminant plume mapping, stream bed resistance, aquifer thickness and hydraulic conductivity, hydraulic boundaries
- Geologists should borrow ideas from soil scientists and have classification of material they describe. For example, they should develop the matrix of geologic material, such as sand, clay, gravel, limestone, sandstone, etc and indicate the percentage or in any other units the content of material and put on a map. I know they have some of these data from different sources, but it must be on the map, so we can use the areas of different classes for more detail analysis of hydrologic characteristics. Geologists are doing now the hydrostratigraphic description, but it is not really well developed classification.
- Continued emphasis on regional scale ) geologic and hydrogeologic mapping (e.g. County Atlas, Regional Assessments). Continued expansion of water level observation well network.
- Water level data should be collected at a higher frequency at selected sites. The selection of the particular sites would be accomplished by using existing data to determine from statistical design as to where the most value would be achieved.
- State wide water level and chemistry would be nice. The vast network of geologic information and water chemistry, etc produced by monitoring well construction that is on file at the MPCA would be a huge asset if it were compiled and available to the public on-line.

### **How would they be applied?**

- We need to know if confined aquifers can recharge at rates equal to expected withdrawal rates. We also need to know the quality of water that is recharging.
- Groundwater modeling - for input parameters, finding safe drinking water sources
- They would be applied for better definition of synthetic hydrologic units and mapping of sustainable supply from those units.
- The water level data would be used with weather data and streamflow data (and lake level data) to tie together the water fluxes of these components, that is, the water level data would be used with the other data for water balance studies.

- Development of flow nets and background water quality.

**Given the reality that geologic atlases cannot be completed for the entire state in the next 2-5 years, what information or techniques do you think state and local entities as well as industry should incorporate to evaluate water availability and sustainability?**

- Pumping tests, monitoring, permitting that makes it clear that usage may be restricted in the future, education on the basics of ground water and the effects of water usage on quality and quantity.
- The state needs to spend more time considering other alternatives for defining our water resource systems.
- Water supply planning should include an evaluation of each planning entity's ground water and surface water monitoring program. [What, they don't have a monitoring program? They don't even know how their resources are faring under their current use levels? THEN START MONITORING!] What are the historic water levels in the community's wetlands and lakes? What are the trends on water levels in area wells? How effective are the community's efforts to curb use of drinking water on the landscape? Counties without geologic atlases could go one giant step toward a future atlas by taking on the task of determining accurate well locations for wells in CWI within their county - perhaps a regular summer task to keep up with what drillers have done in the past year? Training and standards for data collection could be managed by MGS - mapping grade GPS is the minimum standard, survey grade is best because elevations can be determined (better than estimating between contour lines).
- Industries should be located in areas that have the water resources to support those activities. The industry should be responsible for identifying the water resources and the industry should have a contingency plan that states how future water needs in that area will be addressed.
- First of all geologic atlases alone are NOT able to address the issue of water availability and sustainability. There is urgent need to develop water sustainability atlas program that will be able to answer this question. Meanwhile at a state, regional level and Twin Cities Metro area (TCMA) the maps of sustainable water supply are developed. These maps should be incorporated by state, East Central Minnesota and TCMA. The rest of areas must still use old pumping approach that does not address the issue of sustainability.
- Perhaps specifically targeted regional studies focusing on water availability.
- The geological atlases are really needed for improving existing published results on water resource sustainability, but the existing results should be used until they can be improved once atlases are completed.
- Heard many scenarios over the years (and involved in some) of having physical and chemical data from monitoring wells submitted to the MPCA electronically. I assume it isn't being done. It should be. At least it should be a permit requirement. In my experience, almost all forms are filled out by a permittee's consultant electronically. They should be submitted in that form.

**Can geologic atlases answer questions of sustainability? If not, what additional information needs to be collected to address water sustainability (assuming funding is not a limitation)?**

- Atlases are effective at describing the system in which water moves and is stored. They don't predict future input of water (atmospheric delivery) or future withdrawal rates. Aquifers are a "savings account" which will only be maintained if withdrawals (pumping) are balanced by deposits (recharge). Atlases allow us to recognize the boundaries of the aquifers, the users, and connections to surface water. The additional information is prediction and measurement of inputs, accounting of all withdrawals including the ultimate fate of water withdrawn.
- No. We need much more information on aquifer characteristic and boundary conditions.
- Not alone. trend analysis, well interference research, local information
- Absolutely not! It is a myth; even the title suggests that it is only characterization of geology. Water sustainability issue can be resolved only by quantifying water balance characteristics of entire hydrologic cycle and their linkage with landscape components. Geologic Atlas is only one component of terrestrial hydrologic system. Furthermore, geologic atlas program does not even consider the hydrologic characteristics in a way that can address the water resources sustainability. There is a need to incorporate not only geologic reservoir but also all other components of hydrologic cycle and human interaction: atmosphere, hydrosphere, lithosphere, pedosphere, biosphere and antroposphere. In particular, surface water system and vadose zone. In addition to stream flow there is a need to quantify precipitation, evapotranspiration, soil moisture, surface and air temperature, recharge and other hydro-climatic characteristics to map their spatio-temporal variability. In other word, the entire hydrologic cycle must be studied in unity. System approach to quantify all component of terrestrial hydrologic system well suited if this information is available. To move into the 21 century we need to use satellite technology.
- Demographic projections, climate change projections, and site-specific water availability investigations.
- Not by themselves. The atlases provide information about the capacity of aquifers but do not provide information about the renewable supply of water passing through the geological systems. It is this renewable supply that needs to be quantified in order to address water sustainability.
- We must extend the analysis of geologic atlases to ensure they define water in the system and the amounts that can be pulled from the system while conforming to near and long term sustainability limits. This should not be a local design option in the atlas program. Atlases should build in and, perhaps, modify the information generated about long-term sustainability by the watershed characteristics and other methods.
- Not as they exist. Aquifer mapping needs to take place and aquifer testing for the given aquifer needs to be added, interpreted and presented. Not sure the atlas is the best vehicle. The aquifers cross political boundaries. If no budget limitations, there should be hydrologic atlases developed that are based on the aquifer boundaries.

**List any research questions you think Minnesota should address regarding geologic data collection, application, etc.**

- See data needs above
- The format for saving the data should be easy to share. All information collected from a water well should be identified by the unique number for that well.
- Geologists should borrow ideas from soil scientists and have classification of material they describe. For example, they should develop the matrix of geologic material, such as sand, clay, gravel, limestone, sandstone, etc and indicate the percentage or in any other units the content of material and put on a map. I know they have some of these data from different sources, but it must be on the map, so we can use the areas of different classes for more detail analysis of hydrologic characteristics. Geologists are doing now the hydrostratigraphic description, but it is not really well developed classification. The quantitative information on hydrologic parameters includes transmissivity, permeability, specific storage, diffusivity and other characteristics. Again the key they should be in map format in the atlas, but such information is not available in present format of atlas. This should be a systematic multi-scale component of atlas. It must be in GIS map format. We are dealing with Earth data and thus all data has geographical significance. Without maps in GIS it does not serve the need of the state in useful way.
- We need to know more about what knowledge about the hydrogeological systems can be gained from water level data. Are there climate change signals embedded in the water level data? What frequency of water level reading is necessary to get a sufficient picture of water level variability? What spatial distribution of water level reading is sufficient to get a sufficient picture of water level variability?
- The above requires the refinements that added research could bring.
- Compile the existing data that is on file at the various agencies before you develop new research questions. You may only need to fill in gaps.

**Do you have any general comments or recommendations regarding geologic data?**

- The economic impact of water availability would suggest that these fundamental steps toward aquifer management (geologic atlases) should have a larger and more stable funding stream.
- Geologic data design should be tailored to the need of water resources sustainability as well as broadly to environmental sustainability. Geologic data should be a part of integrative analysis relating to water resources sustainability. Geologists should be part of team. Presently they design the data collection as this fit to the specific narrow need of agencies. The challenge is to provide a mapping of water resources sustainability (dealing with geology) as a knowledge domain and to do so in ways that facilitate knowledge e-networking among interested individuals, institutions, and agencies. To address this knowledge domain requires a team effort of ecologists, hydrologists, geologists, soil scientists, social and economic science. Old approaches to study each component (ground water, surface water, climate, vadose zone) individually are simply not able to do this.
- A study should be performed to determine what level of detail of geological data is necessary to support water resource sustainability estimation.

## **Water quality**

### **What publicly available data do you use?**

- MPCA's GWMAP, USGS's NAWQA/STORET; MnDNR's County Geologic Atlas and Regional Hydrogeologic Assessment Programs; MDH's various programs; MDA's Agricultural Chemical Monitoring and Assessment Programs
- Impaired waters
- Don't use much that would be publicly available, we get the quality info from the permit applicant when it has a bearing on the usability of the water for a specific purpose. The ambient network for ground water chemistry at PCA has been an orphan child but is coming back, I hope.
- Site investigation reports, public water supply water quality,
- Maps and data on major and minor parameters of ground water.
- N/A.
- Sometimes data from public wells on general water quality. Often go to MPCA and look at paper files on contaminant plumes.

### **Can it be easily accessed?**

- This task is much easier than it used to be because generally it's provided over the Internet. The main problem for most of these data sets is to relate them back to a MN water well unique identifier number. Typically, the data sets do not include this number and identification requires contacting someone within the agency.
- Surface water data is readily available. Ground water data does not seem to be.
- No - not currently. The information in site investigation reports is not available electronically.
- No
- Yes

### **What do you need this data for?**

- We use water quality data to help trace the movement and residence time of ground water.
- Where is groundwater contaminated and with what constituents.
- To answer water resources sustainability issue dealing with water quality.
- Receptor evaluation. See if agency staff actually has all the data generated by a permittee.

### **How is this information important to decisions you or others have to make about water?**

- It is very important.
- Providing safe drinking water supplies
- It provides quantification of what quality of water should be sustainable. The goal is to eliminate pollution and eventually veto it.
- Determine what actions will likely be taken to address a real or potential release.

### **What do you see as its value?**

- As a tracer, water quality data provides information that can help calibrate or improve conceptual or mathematical models of ground-water flow.
- Life - plants, animals, humans depend upon water resources - as well as industrial uses for community development
- The information could be used for water sustainability management and planning.

### **What additional data needs do you perceive (i.e. what additional data would you like collected or made available)?**

- 1.) Whenever possible, water quality data should be collected from a well with a geologic record and construction information (has a unique well number). 2.) Often times a single target analyte is sampled for (i.e. nitrate, tritium, or pesticide). It has proven helpful to have data on major and minor cation and anion concentrations in addition to these target analytes, so filling a cation and anion bottle while in the field would be useful. Stable isotopes are also useful tracers; oxygen and deuterium are most common but others are becoming available as analytical methods improve. Finally, measurements of physical characteristics, such as conductivity, temperature and pH have minimal costs and often can be collected in real time via data loggers.
- We need more dedication to sampling & analysis & data sharing related to ground water quality.
- The chemical and biological parameters include major and minor elements, nitrates, pesticides and other biological parameters of interest should be collected. There is lot of data that MAgD, MPCA and MHD collects, but nobody synthesizing these important data and nobody disseminates in usable form. Table is NOT enough. About this part I did hydrogeochemical maps while at MGS. For example M-61, but nobody in the state is doing this. All information must be in GIS and map form.
- Needs to be electronic and searchable.

### **How would they be applied?**

- With regard to the first point, ground-water quality data needs to be interpreted in the context of the geologic formation it has come from in order to draw useful conclusions. As for the second point, the costs of analyses for major and minor cations/anions along with isotopes are decreasing, and detection limits are lowering â€ making collection of these data more reasonable.
- This data would be applied to develop water sustainability tool dealing with water quality issue based also per parcel of land using system analysis as was done for water quantity. The synthetic hydrologic units will serve as the point of departure to develop this new tool.
- As the system exists now, you generally need to know what data collection sites exist by observation. Historic sites can be easily missed and state staff who may have knowledge of the area may not be available or cooperative for a variety of reasons.

**Do you have suggestions on how we can better incorporate water quality when we try to answer questions of water quantity?**

- We need a better sense of where water quality is impacted either by anthropogenic or natural conditions. Mapping the distribution by aquifer of contaminant plumes, saline water intrusions, or elevated arsenic levels are examples of how this can be accomplished.
- This needs to be part of the framework.
- Yes, see answer above.
- We must recognize both the effects of quality on quantity and vice versa (where pumping affects quality). We need a systematic integration of quality, quantity (both timing and quantities) and land use information through information systems geared to address the full aspects, short- and long-term, of sustainability.
- If a limitation for economic growth is low quality water, we should provide economic incentives for industry to use low quality water with necessary treatment over appropriating higher quality water.

**List any research questions you think Minnesota should address regarding water quality data collection, application, etc.**

- Water quality data is important because it can show changing conditions over time. This can be on the scale of decades to look at long term trends over large areas, or on the scale of days to hours (real time data logging) to look at changing conditions relevant to contaminant transport typical of flow in fractured rock. Applied research topics include land use, well head protection and aquifer characterization (extent, permeability distribution)
- We need a much greater emphasis on ground water.
- Develop water sustainability atlas that includes also water quality as well as water quantity. Data collection should be tailored to this need.
- Need to develop an ambient conditions map for each aquifer in the state.

**Do you have any general comments or recommendations regarding water quality data?**

- Water quality data compliments hydraulic data such as aquifer tests and interpretive data such as ground-water flow models.
- Surface water quality data needs to be made more easily available. We also need to do a good job of document trends, not just making people look up old reports and do the comparisons on their own. There is a place for condition reporting, but trend reporting has great value.
- Water quality data should be linked to the source (unique numbers for groundwater wells and a system for identifying surface water sampling locations needs to be developed.)
- The challenge is to provide a mapping of water resources sustainability (dealing with water quality) as a knowledge domain and to do so in ways that facilitate knowledge e-networking among interested individuals, institutions, and agencies. To address this knowledge domain requires a team effort of ecologists, hydrologists, geologists, soil

scientists, social and economic science. Old approaches to study each component (ground water, surface water, climate, vadose zone) individually are not able to do this

- The data is not readily accessible.

### **Fisheries data and ecosystem needs**

#### **What publicly available data do you use?**

- Very little
- I am not an expert in this area, but this information is absolutely urgently needed to address water resources sustainability. I could answer below questions, but it will not do a justice because I am not expert in this area. However, the last question is applicable to any section and this section as well.
- N/A.
- None

#### **Can it be easily accessed?**

- Not sure, never access it.

#### **What do you need this data for?**

- NA

#### **How is this information important to decisions you or others have to make about water?**

(No responses given)

#### **What do you see as its value?**

(No responses given)

#### **What additional data needs do you perceive (i.e. what additional data would you like collected or made available)?**

- We need more research to look at the practicality of Q10 or whether some other metric is needed.

#### **How would they be applied?**

(No responses given)

#### **Do you think additional ecosystem protections are needed? If so, what would you propose?**

- Possibly. This goes back to researching the applicability of Q10 for MN's ecosystem needs.

**List any research questions you think Minnesota should address regarding fisheries data collection, application, etc.**

- We need a concerted research agenda to ascertain the variable flow and quality requirements of ecosystems and their key indicator species. Michigan should be a good model for this.

**Do you have any general comments or recommendations regarding fisheries and ecosystem needs data?**

- We need to do a better job of documenting trends in our fisheries data. There is a place for condition reporting, but trend reporting has great value.
- The title of this section is too narrow and does not represent all the needs of ecosystem services. The “ecosystem services” is a correct definition. It refers to functions of ecosystems that underpin human and ecosystem well-being, including land, water, terrestrial biota for human needs, water flow, detoxification and purification of soil, water and air; nutrient cycling; soil formation and maintenance; control on the population and distribution of pests and pathogens, pollination of flowers and crops; maintenance of biodiversity, including fish and others; and regulation of climate ( thorough, e.g. evapotranspiration, reflectivity and carbon sequestration). The challenge is to provide a mapping of water resources sustainability (dealing with ecosystem services) as a knowledge domain and to do so in ways that facilitate knowledge e-networking among interested individuals, institutions, and agencies. To address this knowledge domain requires a team effort of ecologists, hydrologists, geologists, soil scientists, social and economic science. Old approaches to study each component (ground water, surface water, climate, vadose zone) individually are not able to do this.

**Land Use**

**What publicly available data do you use?**

- Very little
- Parcel coverages, wetland designated lands, flood plains
- The data bases available on the DNR data deli.
- Very little to none

**Can it be easily accessed?**

- Yes

**What do you need this data for?**

- To estimate parameters for land surface hydrologic models.

**How is this information important to decisions you or others have to make about water?**

- The calculation of surface water budget, the partitioning of rainfall into runoff and infiltration, and infiltration into recharge and ET, is critical to knowing about the fate of the water resource and the flux of water through the hydrologic system.

**What do you see as its value?**

- To quantify the water flux through the landscape is needed to be able to know how much water is available for human use and for ecological services.
- Land use drive water use and water quality. We must integrate our approached to managing land use with those for water, even as we recognize the different roles of state and local government in each.

**What additional data needs do you perceive (i.e. what additional data would you like collected or made available)?**

- I think there is a reluctance to do work that relates land use to water quality effects. Subsoil monitoring and also monitoring of drainage water quality are important and don't receive the attention they deserve.
- No recommendation at this time.
- We need routine and rigorous monitoring of land use change, and the effects of this change on water quality and quantity (again, meaning timing and quantity both).

**How would they be applied?**

- When the effects of land use practices are measured and understood we can make informed decisions about the public benefit and real economic impact of these practices.
- N/A.
- Through a system of tracking sustainability and estimating the effects of prospective new uses or changes on sustainability.

**Do you think additional ecosystem protections are needed? If so, what would you propose?**

- We do need to better understand the sensitivity of ecosystems to human impacts; minimizing human impacts is essential sustaining of the services from those systems.
- Yes; we need a more refined understanding of ecosystem needs, both quality, quantity and variability.

**List any research questions you think Minnesota should address regarding land use data collection, application, etc.**

- Are there certain land areas of high natural resource value that need to be preserved? How can we better quantify the impacts of tile drainage, ditching, impervious surfaces etc. on recharge quantification?

- We need research into system responses to various land uses in various places in the watershed and over aquifers. We need to make sure we understand the effects of land use on all aspects of the hydrologic system, including possible disruptions of system interconnections.

**Do you have any general comments or recommendations regarding land use data?**

(No responses given)

**Linking data sets**

**Are there other data sets with an important role in addressing water quantity that we should consider? If so, please list them.**

- Water level program. We need to start looking at and reporting regional trends for water level measurements. We also need to commit to continuous measurements in strategic areas.
- To my surprise the surface water data are left out. Surface water data are the most critical to water resources sustainability. This applies to both water quality and quantity. The unity of surface and ground water should be a centerpiece to study of water resources sustainability. In the framework I underline the need to study blue water and green water. It is absolutely critical to study vadose zone. The knowledge of vadose zone is essential component to define and quantify synthetic hydrologic units as well as important part of the water for production of food, feed, biofuels as well as ecosystem services. It is part of the critical zone for interaction of land, water and terrestrial biota. This also applies to water quantity and quality. Topography, land cover, geomorphology and watersheds should be a part of study. Human land use for housing, commerce, infrastructure, agriculture, recreation, etc. should be critical data set to determine the land use changes, climate change or other changes.
- Remote sensing data is a vast resource for studying the hydrologic cycle. But, not enough is done with remote sensing data. I have not been up on what the state of current satellites are in, but I have recently read about one or two satellites that will be decommissioned and a valuable resource will be lost as a result. Somehow we need to get support (political) for NASA/Feds government to provide more remote sensing resources for water resource related data.
- NRCS data

**Linking data sets can be challenging since data is often collected for purposes other than for what they are applied. Please outline any suggestions you have for making data sets more compatible.**

- A centrally-supported data clearinghouse makes sense. However, in the past these efforts have failed because work has been done to try to house the data centrally. That doesn't work. In most situations, data needs to be maintained by the entity generating the data. However, having a central location that maps to all these independent data sources makes sense. For example, we could start with a web-based central data site. From there, data

could be sorted by type (e.g. quality, surface water, etc.). Under each of these categories, there would be links to the agencies

- All data related to wells need to be stored with the unique well number as one of the fields. This applies to water quality info, too!
- To make the data sets compatible we must treat water resources sustainability as a knowledge domain and facilitate this knowledge e-networking among interested individuals, institutions, and agencies, both nationally and internationally. Again, it requires the team effort from different agencies dealing with specific data sets.
- While there are general ideas/principles about what is needed to make data compatible, I do not believe that it is well known how this is done for the type of data we need for water resource quantification. A system is needed not only for quantification but also continued monitoring. Data system designs should be developed to determine what would be the optimum or near-optimum set of data systems to address the current and future needs for water resource quantification.
- We need to construct an information system geared to support prospective and sustainable water and land management. It must be patterned after the hydrologic cycle and directly applicable to permit and system wide decisions.
- The baseline data should be compatible: well logs, water quality chemistry, etc. I don't think you can viably make the datasets compatible given the programmatic independence of the various agencies requesting the data.

## **Modeling**

### **When dealing with models, what are the most sensitive parameters?**

- Recharge, permeability distribution
- I'm not sure because I don't have this expertise, but I definitely believe this needs more attention. There are many statistical tools that can be used to quantify error/variability and to also pinpoint where data can be strategically collected to minimize future error/variability.
- You can use the model itself to try to figure that out.
- With respect to water quantity issues, the most sensitive parameters are generally the aquifer properties (hydraulic conductivity, storativity/specific storage, and porosity). Also important are recharge rate and rates of leakage between adjacent materials. A key concern is the degree to which parameters vary in space.
- All parameters are sensitive depending on the scales and all have uncertainty. With respect to ground-water the most sensitive parameter is recharge/discharge.
- This all depends on what models one refers to. Surface water models, subsurface water models? Anyway some sensitive parameters are: soil hydraulic conductivity, aquifer conductivity, aquifer thickness, conductance of stream/lake - aquifer interfaces, vegetation rooting depths. While these are important parameters, an even bigger issue are the boundary conditions for models. In many situations these boundary conditions are not known with certainty, so one needs to estimate them through calibration. So for instance, while ground water models are great tools when the geometry of aquifers are known, when they are not well-known (such as the poor knowledge about ground water - surface

water interface interaction geometry for instance) the model will not perform well at all, and will in fact be misleading.

### **How might we best refine those parameters?**

- By having a better understanding of the path water follows once it enters the ground.
- Through statistical research to define them. From there we can offer the state strategic and focused biennial funding priorities in the area of data collection.
- Increasing numbers of points where real values are known is a good idea. Problem is, the database of known aquifer physical parameters is not getting larger very fast and the information that's being added is typically not from large scale long duration aquifer tests. So, I vote for some much really good aquifer tests and some really attentive sampling during well drilling when deep wells are planned. Our chance is coming up with the recently funded bonding and LCCMR projects that will drill some more Mt. Simon wells for monitoring. Perhaps we can pay similar attention to the PCD-Jordan next biennium - Olmsted County has already commented that we ought to protect the Jordan for them the way we protect the Mt. Simon in the Metro area.
- Support general mapping (i.e., county atlases, regional hydrologic assessments, quad-scale mapping efforts) and basic data collection activities (i.e., ob well program, stream flow stage and discharge measurements, regional water level measurement studies). It is especially important for data collection programs to be funded and maintained at consistent levels over time. Refinement of model parameters often follows a stepwise process: a) model, b) assess uncertainties and data gaps, c) collect additional data to address step b above, d) revise model, e) repeat steps B-D, as necessary to achieve model objectives. To frequently, we stop after step b.
- To refine parameters we must shift to new paradigm of integrative approach, that include three principles: spatio-temporal variability, regionalization of terrestrial hydrologic system and validity of models. The refinement of parameters will be based on multi-scale regionalization of synthetic hydrologic units.
- Field test measurements can be conducted to quantify many of the parameters mentioned. The issue about the boundary conditions for subsurface systems can only be determined by detailed geophysical work, or by guesswork. In a particular situation there might be enough field data to support an adequate representation of the boundary conditions, but to achieve this could be quite expensive. It might be necessary to go with other types of models.

### **How can we use statistics to optimize locations and parameters for future data collection?**

- Care should be taken to see that population being sampled is well-defined.
- Let's support some work at the U to investigate this and provide the state with feedback.
- Not without good geology to physically constrain the answers we let the statistics give us! If you've got at least a sound conceptual model of ground water flow and interconnectedness between systems, then use of a well-calibrated model can be used to evaluate the sensitivity of the model to calibration data at certain locations - I'm always wanting ground water level monitoring points at hypothetical ground water discharge

points, at divides and at known recharge sources. Use the model to find out which such points will be most valuable.

- Too often statistics are misinterpreted because the objectives of the study were not clearly defined or understood. For example, statistics can make it look like water quality is improving, when the real reason the water quality is better is because new wells were drilled into different aquifers to replace wells with contamination. We can use statistics to evaluate the distribution of aquifer transmissivity values (concern about the degree of variation in aquifer parameters in space).
- The optimization could be achieved if we explore the set of organizing principles that might underlie the heterogeneity and complexity. The multi-scale regionalization as described in previous paragraph is using statistics to answer this question. Other avenues for research should be explored such comparative analysis, classification, optimality principles and network theory.
- Statistical analyses are performed to determine where the estimation of system parameters is most uncertain, and it is at those locations where the additional data should be located. The additional data might mean to collect at an established site more frequently, or it might mean to establish a new sampling site altogether.
- The watershed characteristics and RRR methods must be used and integrated into modeling and decision-making, even as they are refined.

## Research needs

### Are there any research needs we should consider supporting in the short-term?

- Other means for looking at water availability or sustainability (RRR, Red River, U of M project). If it's not practical to measure all of our aquifers in the short term, let's look to other ways of quantifying our resource. We know that recharge to surface and ground water originates with precip. So, let's continue to research means to use climate, soil and hydrogeologic data to characterize our systems, while we continue to support and promote the county atlas program. Maybe we should promote research to look at trends in Minnesota's water resources - quantity and quality and policy.
- We need some fish response curves for Minnesota streams and species (see the theoretical curves represented in the Michigan report). We need to come up with methods to evaluate the impacts of dug pit withdrawals on surface water bodies and refine our tools for determining streamflow depletion from alluvial wells. Due to the lag in recovery from pumping (as the cone of depression decays) a ground water user should be told to turn off sooner than a surface water user to have the same protective value. So - how do you figure out when to shut off a given well? If the action threshold for surface water users is Q10, should it be Q15 for GW? Q20? Work through some scenarios based on past data –
- To address the water resources sustainability we must shift from traditional haphazard, narrow thinking and unintegrative approaches of surface water and ground water to integrative approach of entire terrestrial hydrologic system (surface water & vadose zone & ground water). The knowledge of water balance characteristics (described above) in regional and multi-scale organization is only the road map to quantify water resources sustainability.

- We need to support the estimation of water resource fluxes (stationary as well as non-stationary) using the integration of surface water and ground water data in conjunction with land use, topography, geology, soil, and climatic data. We need to avoid approaches that look at only one component of the hydrologic system because such approaches are doomed to failure. Aquifer/watershed mapping

**If you were on the LCCMR, what types of projects would you like to see proposed and funded this fall?**

- Phase 2 of this project. We have a strong interagency coordinating team with tons of experience and enthusiasm. Let's take what we've learned in this process and the recommendations from them and move this framework forward for the next two years. We have need for more work on both the policy & data frameworks and they are inextricably linked. The benefits can be huge for the state, public, local entities and industry.
- Springshed mapping is essential for TMDL work and for the assessment of ground water use impacts on streams and springs in the southeast. Springshed mapping - the applied program (as distinct from research being done by Calvin Alexander at the "U") - should be funded on an ongoing basis - DNR needs two full-time and two summer staff for at least the next decade. A center for Karst studies at Winona State Rochester could be created to carry out the dye trace analyses and to house the necessary analytical equipment for this and other spring/stream work. Karst geomorphic unit maps can be created at an appropriate scale and clipped to create County maps as additional plates for County Geologic Atlases. The State's ground water level monitoring network gets put on the chopping block every time we (at DNR) have funding problems. So the next appointment with the guillotine is only 11.5 months away. A solid drilling budget, predictable staffing levels and good support within DNR's infrastructure (GIS software, computers that can keep up, geophysical and video logging tools, drill rig supplies and maintenance, transducers and loggers, telemetry budget, etc). If you want to know what's up with your water, you are going to need to make real investments in the State's ability to monitor an ambient network and to assist other jurisdictions in monitoring the impacted areas.
- University of Minnesota current LCCMR project: Water resources sustainability is the process of creating a new tool of quantifying water resources sustainability based on integration of all components of hydrologic terrestrial system into well defined synthetic hydrologic units at a multiple scales. This quantification of water resources sustainability is only possible based on mapped hydrologic units. Atlas of water resource sustainability for Minnesota showing quantitative water balance characteristics will be a product from this project. Proposed project for LCCMR: Title: Monitoring regional water balance characteristics for measuring water resources sustainability This project will include the following: 1. Create the new tool for monitoring water resources sustainability based on mapped hydrologic units. 2. Mapped hydrological units at a multi-scale are the foundation of monitoring network. 3. Regime and trends of stream flow as climatologic component to ground-water regime and trends 5. Measuring (and predicting) impacts of human use and the need for ecological services 6. Atlases of water resource sustainability

for Minnesota combining mapping of quantitative units from current project and monitoring network from proposed project.

- LCCMR should be more open to continuation support for ongoing projects involving data collection, rather than always looking for new, sexy projects. The importance of basic, un-glamorous, data gathering is often overlooked.
- 1). Work related to the water resource needs of ecosystem services to be sustained. 2). Estimation of the effect of scenarios of climate change on water resources quantification. 3). Multi-scale mapping of water quality for both surface and ground water within Minnesota. 4). Development of and test an interface for utilizing remote sensing data with land based water resource data systems in the quantification of water resources.
- I'd make sure we set up a program for continuous improvement of our estimations and understanding of short and long term sustainability.
- Defining ambient and current conditions of major growth corridors on nonpolitical boundary basis.

### **Local involvement and education**

#### **How can we better educate local water supply planners & citizens to water supply planning concerns? How do we bring it home that it can be a fragile system?**

- Effort is needed at all levels including the public education curriculum. While education related to events draws a crowd (ex: plant proposal) the polarization undermines the education effort effectiveness. The challenge is to draw in people to learn about ground water in a non-confrontational setting. I could visualize required training sessions for water planners and other local staff provided by the State.
- A framework would help.
- Find out what they care about and show them how water matters. Even those who place themselves first in every way will realize that induced recharge brings water quality changes and that water quality changes might impact their number one priority (themselves).
- The focus of this survey is only physical processes dealing with water resources sustainability. However, sustainability of human and environmental systems (i.e. sustainable society) rest on three pillars: environmental conditions and processes, sociopolitical conditions and processes; and economic conditions and processes. Just as three leg-stool falls down if any leg fails, so integrity of any of these domains fails. Therefore, for better education( and motivation) we need to have an integrative research program where all three pillars will be studied as a team effort to address multiple interaction of environmental condition (in our case water resources sustainability), sociopolitical conditions and economic conditions. Only based on such integrative analysis we will be able to motivate government, public and industry, in other words entire society. One note more, it is not only the education of planners and citizen, but more importantly to shift laws and regulations toward conservation and efficiency. The integrative analysis of a team where physical, social and economic scientists are working together will provide meaningful information for education, information, motivation and capacity building. The fragility of the human-environmental system and indeed our own existence requires building the knowledge on all aspects of sustainable society. That

knowledge must be based on science of sustainability that I outlined in Section “General”. The challenge is to bring all components into integration and demonstrate that standard of living cannot be maintained if we will degrade environment. It is much broader issue than simply the education of local water supply planners & citizens. Again, this question demonstrates unintegrative thinking with respect to water sustainability. The fragility of the system education requires building the knowledge on all aspects of sustainable society. That knowledge must be based on science of sustainability that I outlined in Section 1. The challenge is to bring all components into integration and demonstrate that standard of living cannot be maintained if we will degrade environment. It is much broader issue than simply the education of local water supply planners & citizens. Again, this question demonstrates unintegrative thinking with respect to water sustainability. To encourage users to save water: as often happens when people exploit a natural resource, few worry about waste if a commodity is so cheap that it seems almost free. So, the pricing of water could be a tool to educate citizens, but again, we must have information to develop that price. Like in any commodity we need to know sustainable supply and sustainable demand. The challenge is to bring all components into integration and demonstrate that standard of living cannot be maintained if we will degrade environment. It is much broader issue than simply the education of local water supply planners & citizens. Again, this question demonstrates unintegrative thinking with respect to water sustainability. To encourage users to save water: as often happens when people exploit a natural resource, few worry about waste if a commodity is so cheap that it seems almost free. So, the pricing of water could be a tool to educate citizens, but again, we must have information to develop that price. Like in any commodity we need to know sustainable supply and sustainable demand.

- We need to educate the public about the hydrologic cycle, and to illustrate examples of cases where man helped to keep the balance in order and cases where man has pushed the balance to a dire situation for both man and nature.
- We should mandate that they address water sustainability (quality and quantity, both) as they relate to land use, for which local government holds principal responsibility.
- Move it out of the state level into a more local water management district

### **Should we mandate local participation in ground water level monitoring?**

- I would prefer that monitoring be left to professionals and those without a stake in the outcome. I would like to see more and better reporting of water level data to locals.
- There are definite advantages, but "mandate" is a strong word. Then again, there needs to be accountability for our water resources by the users.
- An excellent idea. With appropriate standards and targeted assistance, monitoring networks could be greatly expanded. Data could be submitted by the local/regional (communities or user groups may choose to band together to accomplish monitoring) specialist and the DNR web page would display the submitted data - making it quickly available for local, regional and statewide use. DNR's data systems are being upgraded during this fiscal year to plan for almost unlimited capability to assimilate and digest data.
- This is irrelevant question based on presently unsustainable management of water resources. Why only ground water? What about surface water, etc. It is a question that

comes from old paradigm of unintegrative thinking. The question should be: how we can design the intelligent monitoring system to monitor sustainability of water resources?

- Perhaps rather than mandate we should first try providing adequate incentives.
- No. We have volunteer systems for river systems as well as for weather systems. Why can't we get volunteers to help with ground water monitoring? It is only a matter of education, awareness, and statement of purpose.
- Yes.
- No. Too much error involved in the data collection.

## **General**

### **Do you have any questions you would like asked of the group or discussed at the final meeting?**

- First of all, this survey is missing two critical components: SURFACE WATER SYSTEM AND VADOSE ZONE SYSTEM. The sustainability of water resources requires integration of all systems: atmosphere, hydrosphere, lithosphere, pedosphere, biosphere and antroposhere. Secondly, I want to educate the group on the need to understand the importance of integrative thinking. One meeting that I attended clearly showed to me that this group is lacking that thinking. This is significant barrier preventing effective access to large bodies of knowledge dealing with water resources sustainability. Sustainability (as ontology) requires the need to think more outside your normal area of specialization as well as about the interconnections of your specialty to other domains (in our case hydrologic cycle) and even borrow from sister science. The issue of sustainability also requires the system thinking in broad sense; we argue for environmental systems to demonstrate balance and resilience; economic activity to exhibit efficiency and equity; governance to show participation and responsiveness; and institutions to demonstrate adaptation and feedback. We can address the environmental systems via system approach described above, but I believe it is critical to have an integrative team of researchers from all above fields to work together. The I on E is the right place to have this team.
- N/A.