Geology and Groundwater

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Can my town support areas of more intense development?

Where are areas of favorable water supply?

Examples - Williston, Brandon, Hinesburg;

What areas should we protect? Example: springs in Dorset

Areas favorable for higher yield shallow aquifers? Ex. PWS Woodstock, Manchester

What are the anticipated depths and yields in my area? Helps with a cost estimate

Are there water quality issues such as arsenic, uranium, manganese?

Other WQ issues such as salt, nitrates or other contaminants and how can we avoid or mitigate these?
Water available for recharge:

Metcalf and Robbins, 2013, estimated that approximately 20% infiltrated the ground and only 1.95% of that water recharged the fractured bedrock aquifer in Connecticut.

1 inch of rain falling on 12 square feet of ground is roughly 90 gallons of water and only 0.49 gallons recharges the bedrock aquifer.
The system from above

Groundwater flow generally mimics surface water flow –
Recharges in the uplands and discharges to rivers
The System From Below

- ~36” - Soils
- Thin to thick surficial materials (most <50’)
- Average drinking water well in VT ~290’
- GW generally <3000’

Saline water (?)
**Groundwater** is water that flows or seeps downward and saturates soil or rock, supplying springs and wells.

The *water table* is at the top of the saturated zone. Below the water table all pores are completely filled with water.

Pressure surface where pore pressure = atmospheric pressure

Above the water table, in the *unsaturated zone*, pores are partly or completely filled with air.

source: K. Bradbury (Wisconsin GS) and USGS
All water is part of the water cycle...

Aquifers are geologic units (sand and gravel, sandstone, etc) that can store and transmit significant quantities of groundwater
A cone of depression occurs in an aquifer when groundwater is pumped from a well. In an unconfined aquifer (water table), this is an actual depression of the water levels. In confined aquifers (artesian), the cone of depression is a reduction in the pressure head surrounding the pumped well.
Properties of surficial materials

Secondary porosity in bedrock provides flow path

Top: Inhomogeneous glacial deposits
Bottom: Fractured bedrock
Surficial Materials

Porous, permeable sand

Less permeable clay and silt, Seaver Brook, Craftsbury
Less permeable - Silt and clay

Piping – in more porous silts/sands

Dense, compacted glacial till;
Note cobbles of red Monkton Quartzite
Surficial materials influence the rate of movement through materials (hydraulic conductivity) and infiltration.

<table>
<thead>
<tr>
<th>Depositional Environment</th>
<th>Material</th>
<th>Horizontal Hydraulic Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake-bottom and deltaic (coarse)</td>
<td>Gravel</td>
<td>150 - &gt;250 feet/day</td>
</tr>
<tr>
<td></td>
<td>Coarse sand</td>
<td>60 – 200 feet/day</td>
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<tr>
<td></td>
<td>Medium to coarse sand</td>
<td>15.9 feet/day</td>
</tr>
<tr>
<td></td>
<td>Medium sand</td>
<td>60 – 175 feet/day</td>
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<tr>
<td></td>
<td>Fine sand</td>
<td>1 – 30 feet/day</td>
</tr>
<tr>
<td></td>
<td>Sand and silt (deltaic)</td>
<td>1.1 – 56.7 feet/day</td>
</tr>
<tr>
<td>Lake Bottom</td>
<td>Fine to very fine silty sand</td>
<td>0.2 – 9 feet/day</td>
</tr>
<tr>
<td></td>
<td>Fine sand to silt</td>
<td>0.16 – 5.29 feet/day</td>
</tr>
<tr>
<td></td>
<td>Fine sand, silty sand, silt, minor clay</td>
<td>0.01 – 1.13 feet/day</td>
</tr>
<tr>
<td>Lake Bottom (fine)</td>
<td>Lacustrine silt to clay</td>
<td>0.002 – 0.029 feet/day</td>
</tr>
<tr>
<td>Mixed</td>
<td>Lacustrine sand and ablation till</td>
<td>135 feet/day</td>
</tr>
<tr>
<td>Till</td>
<td>Sandy ablation till</td>
<td>22 feet/day</td>
</tr>
<tr>
<td></td>
<td>Till</td>
<td>1 foot/day</td>
</tr>
<tr>
<td></td>
<td>Hardpan</td>
<td>0.3 feet/day</td>
</tr>
</tbody>
</table>

Porosity (open space)

Permeability (connected spaces)

Secondary porosity – bedrock structures
Vermont rocks do not generally have primary porosity.
Groundwater flow in bedrock is mainly along planar features such as fractures, bedding and cleavage.

Features are interconnected and flow paths may be complex.

Type of materials influences recharge to shallow and bedrock aquifers.
Secondary porosity in bedrock may allow water to infiltrate directly –

Fractures vary – orientation, length, aperture, intersections, depth, rock type.

Hydraulic conductivity in rock is generally much less than in surficial deposits.
Town Resource Maps

- Surficial and Bedrock Geology
- Locate Water Well Data
- Depth to Bedrock
- Flow Directions – Generalized
- Hydrogeologic Units – Bedrock
- Recharge Potential to Bedrock
- Potential Overburden Aquifer with Direct Recharge
- GW – Plan, Map, Test, Protect
The average person uses 150 gallons of water per day or 600 gallons for a family of 4.

Statewide mean (92,314 bedrock wells): 13.76 GPM; 293 ft

1 GPM is 1440 gallons over a 24 hour period.
FIGURES 2-5. WATER WELL DATA, BEDROCK TYPE, AND IDW ANALYSES

FIGURE 2. Distribution of 93,786 water wells completed in 1946-2006. Database has 76 fields including use, yield, depth, type (gravel or bedrock), and materials at various depths. Locations are suspect; ~11% had E911 or GPS locations in 2006; 17% have updated E911 or GPS locations in 2014.

FIGURE 3. Wells were selected and average yields were calculated by bedrock formation (1963 map of Vermont). Formations were then grouped to produce a generalized yield map. Moore and others (2002) discussed factors which correlated negatively and positively with well yield. Among these are year drilled, drilling method, thickness of overburden, depth, elevation, proximity to streams, and type of bedrock.

FIGURE 4. Inverse distance weighted (IDW) analyses of well depths based on 6 nearest points. Map indicates some general areas where deeper wells could be anticipated. There are large areas of no data (see Fig. 2).

FIGURE 5. Inverse distance weighted analyses (IDW) of well yield based on 6 nearest points. Map indicates some general areas where higher or lower yields could be anticipated. There are large areas of no data (see Fig. 2).

A reported well yield of 1 gpm was selected as the high value for low yield wells; actual yield may be much less. 1 gpm is 1440 gallons per day and the average person uses 75 gallons per day. The percent of low yield wells is 14% and 28% have a yield of >20 gpm.

Water Well Data and Analysis

VERMONT
AGENCY OF NATURAL RESOURCES
Vermont Geological Survey
FIGURE 13. FAVORABILITY MAP

Figure 13 (above). The favorability map for higher yield surficial aquifers is based on summing together three integer rasters derived from yields of surficial wells, depth of overburden, and the hydrogeologic classification. Breaks for the three rasters are: Yield of surficial wells: 0 = less than 20 gpm, 1 = greater than or equal to 20 gpm.
Depth of overburden: 0 = less than 50 feet, 1 = greater than or equal to 50 feet.
Hydrogeologic classification: 0 = Class 6 through 13, 1 = Class 0 through 5.
Hydrogeologic Class 6 was excluded from the most favorable category as such wells might be susceptible to contamination.

The three rasters are summed together and then ranked as follows:
1: Areas with a raster score of 0 are ranked low favorability
2: Areas with raster sums of 1 or 2 are ranked progressively higher
3: Areas with a score of 3 are highest favorability

FIGURE 14. STATEWIDE FOCUS

Figure 14 (right). The statewide map shows the 5 counties where well location projects and assignment of hydrogeologic class have been completed. Well data for 11,994 wells was reviewed for the project. Water well location projects need to be conducted in the remaining 9 counties (~35,000 wells) and hydrogeologic classes could then be assigned to located wells (~30%). The raster analysis of thickness could be refined based on the new data and the aquifer favorability maps would be developed by county.

Groundwater use data by town is available for the state and the highlighted areas show towns where growth or increase in use is projected. The map focuses attention on areas where new projects could assist in locating future water supply. The more detailed census-block analysis can also be constructed for these towns.
ANR Atlas- Well data, SPA, Water Use Data Projected to 2020 in million gallons/day

Plus maps of materials, well data, structure, and water chemistry lead to favorable/unfavorable areas
Identify geographic Areas of concern

Williston area Town planning
(Derman, Kim, and Klepeis, 2008)

Hinesburg Thrust
Williston VT
(Modified from Kim, Gale, and Derman, 2007)
WOODSTOCK

Steeply Dipping Bedrock Zone and Well Yields

Thompson, 2006
Potential Buried and Shallow Aquifers

Potential Recharge to Buried Aquifer

Woodstock

Cross-section B-B'. A cross-valley profile indicating overburden valley bottom stratigraphy.
Depth to Bedrock, DeSimone & Gale, 2009
Reported static water levels and Inferred Flow Lines

The groundwater flow lines reveal generalized, inferred directions of recharge from higher regions to regions of discharge in lower portions of an aquifer.
Hydrogeologic Units, DeSimone & Gale, 2009
I – Higher: high elevation areas with thin till or exposed bedrock

II – Moderate: permeable sediment in contact with underlying bedrock;

III – Lower: thick impermeable till mainly on lower mountain flanks; impedes infiltration

Recharge Potential to Bedrock Aquifer
Andover
Bennington
Brandon
Bristol
Cabot
Calais
Charlotte
Craftsbury
Dorset
Dover
East Montpelier
Londonderry
Manchester
Monkton
Randolph
Rutland
Wallingford
Weathersfield
Williston
Woodstock
And remember...surface water and groundwater are part of the same system

THANK YOU