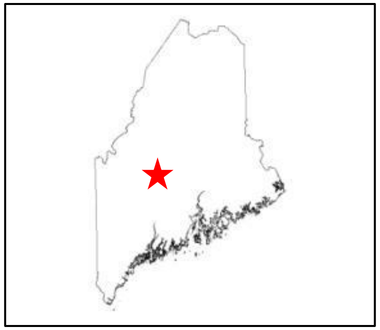
Geologic Site of the Month

December, 1998

Hydrogeology of the Bingham Water District Well



45° 2‘ 40.92“ N, 69° 52‘ 54.25“ W

Text by
Andrews L. Tolman
Maine Geological Survey

Introduction

Where does the water you drink come from? If you have a municipal water supply, and live in a small to medium-sized city or town, the chances are good that your water comes from a well. Water in wells is called **ground water** which moves differently from water in lakes and streams, called **surface water**. In contrast to surface water systems that obey the familiar rule that "water flows downhill", it is much more difficult to understand the movement of ground water.

The MGS Wellhead Delineation Program

The management and conservation of ground water supplies requires an understanding of the area contributing water to wells. This fact was brought home forcefully by the several incidents of Methyl Tert Butyl Ether (MTBE) contamination of public water supplies in the spring of 1998. The Maine Geological Survey, in cooperation with the Drinking Water Program of the Maine Department of Human Services, is conducting an evaluation of public water supplies judged to be the most sensitive to potential contamination. This program is part of the work authorized by the 1996 Safe Drinking Water Act Amendments, and is funded by the U.S. Environmental Protection Agency (EPA).

The goal of this evaluation is to assess the areas contributing significant recharge (the surface area supplying water to a well) to selected municipal wells. This project is part of the Source Water Assessment Program (SWAP), which is evaluating the risk of contamination of ground and surface water sources. It is not feasible to assess threats to ground water sources without a reliable understanding (delineation) of the land area providing water to a well.

The MGS Wellhead Delineation Program

Of the 143 wells in sand and gravel aquifers (as opposed to wells in bedrock) serving more than 250 people, 62 sources already have the land area contributing to the well identified, including an estimate of the time it takes for water to flow from the recharge area to the well. The project is reviewing the existing delineations, refining them where appropriate, and performing delineations on the remaining sources. The time of travel is important to evaluate because it provides a measure of the response time between a contamination incident on the ground surface and actual contamination of the well.

Recharge areas are being delineated using existing hydrogeologic, well testing, and pumping rate information. A new standardized simulation method is being tested on four pilot systems, before we apply this method on all the systems. For water supply systems that need new field data, the Drinking Water Program will be contracting with consultants for the data collection. Since the amount of data available for the delineations may be limited, the project will also identify data gaps so the water system would know how to improve the accuracy of the delineation in the future. We are not developing management plans, ordinances, or contingency plans based on the delineation, although we provide the water system operators with copies of the delineation for their use in developing such plans.

The MGS Wellhead Delineation Program: Bingham Water District

As an example of our work, we used the Bingham Water District well as one of our pilot sites (Figure 1). The Kennebec River Valley is filled by glacial sands and gravels. Wells in these "buried valleys" can yield large quantities of water. The Bingham Well is located in an esker, the channel of a glacial stream, where very coarse gravel was deposited by fast-moving water. These deposits can be good locations for municipal wells if local land use is compatible with maintenance of water quality.

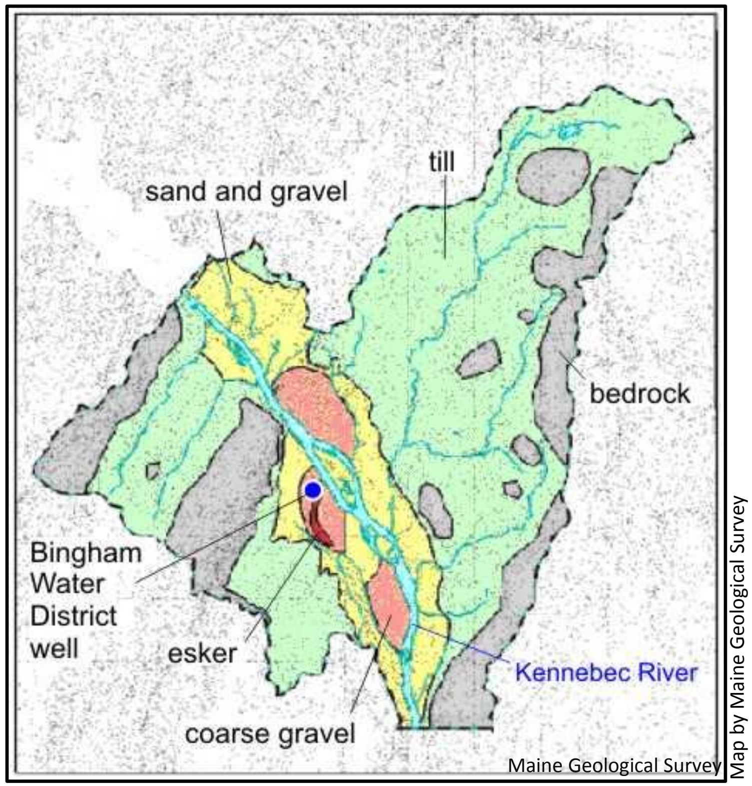


Figure 1. This map shows the surface geologic units in the area around the Bingham Water District Well.

The MGS Wellhead Delineation Program: Bingham Water District

Sand and gravel aquifers in Maine are generally discrete bodies bounded laterally and vertically by surface water and less permeable glacial materials. The most productive aquifers are coupled to surface water, and generally contain coarse sands and gravels. Eskers occupying river valleys, like the Bingham esker, are the most common source of municipal ground water supplies. Under natural conditions, ground water in the aquifer flows upward and discharges into the river or stream. The geometry of these deposits gives them a good source of induced recharge. During pumping, wells may draw water from a nearby river or stream into the aquifer, providing more water than would be available from recharge under normal conditions. Most high-capacity wells are located to take advantage of that recharge while still providing adequate filtration for surface-water pathogens.

The MGS Wellhead Delineation Program: Bingham Water District

These rivers and streams provide water over and above that available from storage and natural recharge (Figure 2).

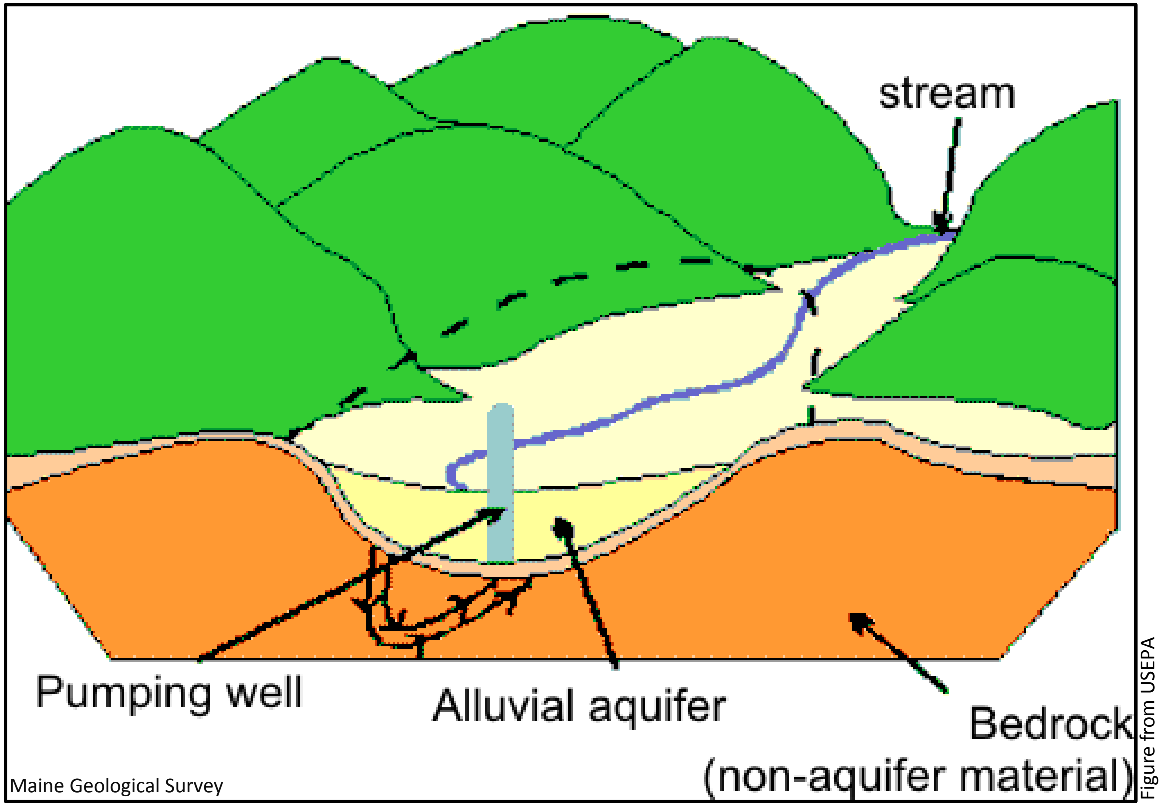


Figure 2. This schematic block diagram shows a typical valley fill aquifer in mountainous terrain, like Bingham. The till and bedrock uplands may also provide some water to the well, both through ground water flow and from induced infiltration of stream flow from the uplands

The MGS Wellhead Delineation Program: Bingham Water District

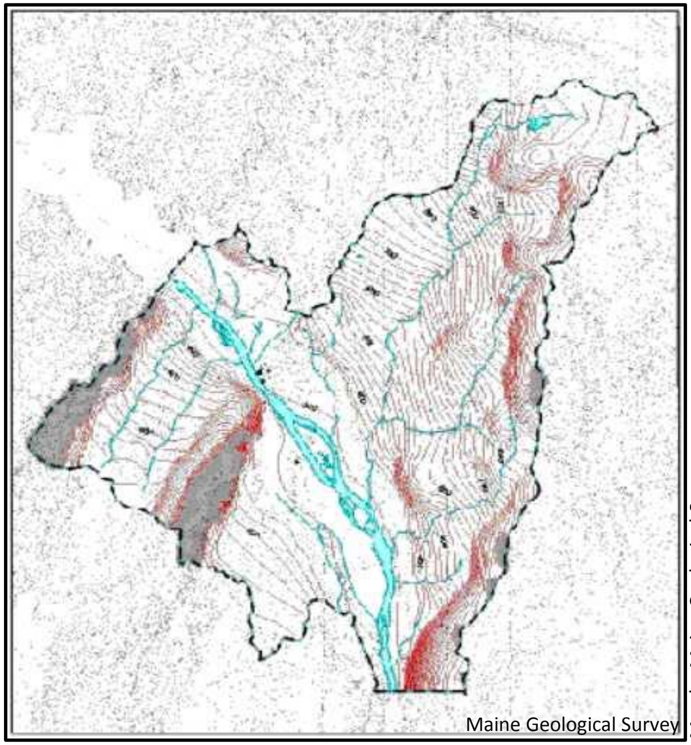
Delineation is the process of using the information about the hydrogeology of the aquifer and the properties of the well to estimate the area on the ground surface that contributes recharge to the well. For this project, we estimate the area that contributes water for two zones: that area with a travel time (ground water residence time from the recharge area) of less than 200 days, and the area with less than 2,500 days travel time. Because ground water flows at different speeds in different materials, the path of water movement at various places around the well makes a complex pattern. We calculate a flow field around the well and evaluate the flow velocities towards the well.

Developing a numerical model (a series of equation matrices that are used to calculate velocities and volumes of flow through the aquifer) allows for the simulation of boundary conditions (like rivers or drainage basin boundaries) as well as different geologic materials within the aquifer. Numerical modeling is appropriate for this project for sites where there are clear indications of near-field boundary conditions or large variation in the aquifer materials. Numerical modeling offers a more precise delineation of travel times, which may also be more accurate if the aquifer and boundary condition types are well-defined.

The MGS has developed a set of ARC Info coverages of Sand and Gravel Aquifers from their on-going mapping project. These data, together with computer digitized streams, topography, and drainage divides from USGS topographic maps, form the base of our analysis (Figure 3). These data are geo-referenced, which means that they are tied to real-world coordinates. The well location is also geo-referenced. The Drinking Water Program has just completed a project that located all public water supply wells using Global Positioning System technology. That data is posted at the OGIS website.

The MGS Wellhead Delineation Program: Bingham Water District

In Figure 3 we simulated a large regional ground water flow system in order to provide realistic flows to the aquifer near the well. Using a large area, with drainage basin divides as model boundaries, helps to make the contributing area delineation more realistic. Note the darkened areas of the map. These represent "dry cells" in the model. These are areas where the simulation predicts that the till and shallow bedrock will not be saturated with ground water. Generally, they correspond to areas of steep slopes where bedrock is exposed at the surface.



Map by Maine Geological Survey

Figure 3. This map shows the simulated ground water level contours for the model area.

Results

Using the digital information, well pumping data, and geologic mapping, we constructed a MODFLOW (a finite-difference model developed by the U.S. Geological Survey) model of the river valley using GMS, the Groundwater Modeling System. This model simulates ground water flow through the geologic materials around the well, and provides a flow field, represented here as a water table contour map (Figure 3). MODPATH, a particle-tracking computer program used with MODFLOW, calculates contributing (recharge) areas and estimates time of travel to the well (Figure 4).

In Bingham, we found that the water district was not the only entity pumping water from wells in the valley. A local fish hatchery, located upstream of the Bingham well, also pumps large volumes of water from the aquifer. We conducted simulations both with and without pumping at the fish hatchery wells to see whether their use would change the area contributing water to the Bingham well. In this case, the hatchery wells, located on the opposite side of the river, do not alter the area providing water to the municipal well.

Results

In Figure 4 the time travel zones are divided into an area of less than 200 days travel time to the well, and of less than 2,500 days travel time to the well. The 200-day zone was selected based on survival of virus and other infectious agents in ground water. Generally, disposal of human or animal wastes (septic systems) should be avoided within this zone. The 2,500-day zone represents the time it has historically taken to respond effectively to leaks and spills of hazardous chemicals. Storage and large-scale use of such chemicals should be avoided within this zone, unless the uses are very carefully managed.

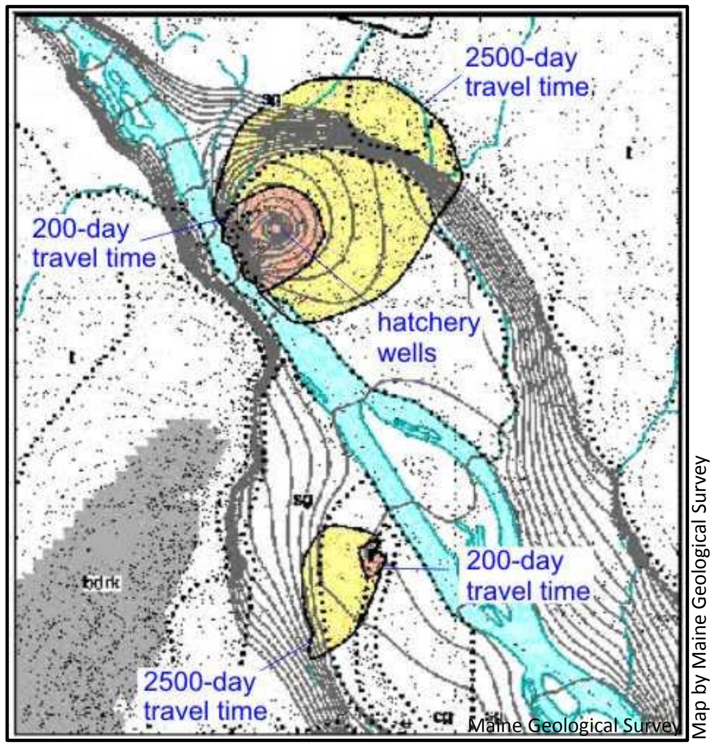


Figure 4. Travel time zones for both the Bingham Water District Well and the Bingham Fish Hatchery Wells.