Seismic Profiling Aids Well Location

By Brad Caswell

Introduction

Exploration for municipal ground water supplies in the Northeast is always a challenge because the glacial aquifers vary dramatically from place to place. Even when a site for a prospective well appears exceptionally promising, step-by-step investigation is best. Seismic refraction profiling is an excellent pre-drilling technique that helps locate the right well site. It is inexpensive, takes little time, and provides clear direction for an exploratory drilling program.

An “Obvious” Aquifer

If you are acquainted with glacial landforms, the esker ridge or "horseback" defined by the topographic contours and shown darkened in Figure 1 will be obvious. The narrow ridge of sand and gravel is a glacial stream deposit that meanders southeasterly through the village of Danforth, Maine, and then forms the western shore of Crooked Brook Flowage. A dam in the village raises the water elevation of the flowage (or lake) and thereby raises the water table within the esker. The potential for inducing plentiful recharge from the lake into the sand and gravel aquifer looks excellent. Without question, an initial appraisal establishes this hydrogeologic setting as an “obvious” aquifer with a potential for supplying all the ground water the community requires. Early water plans, in fact, had a convenient well site selected and ready for test drilling at the location indicated as “a” in Figure 1.

Discouraging News

A few years after the convenient municipal well site was selected, a single observation well was installed by the state as part of its regional aquifer mapping effort. This was the only well within thousands of feet of the selected site, yet it raised significant doubts about the suitability of the aquifer. The observation well, as illustrated by Figure 2, revealed a saturated aquifer thickness of only 4 feet, much too thin for construction of a municipal well. Was the entire aquifer so thin as to be useless, or was the single discouraging piece of data a local condition?

Test Drilling

One approach to testing the aquifer's suitability was to drive small-diameter test borings starting just south of the village and continuing southerly along the west shore of the lake in the hopes of locating a site with enough saturated thickness. A string of test borings could potentially extend for more than a mile along the esker ridge, resulting in a costly venture that might fail to find a well site. This approach was rejected.

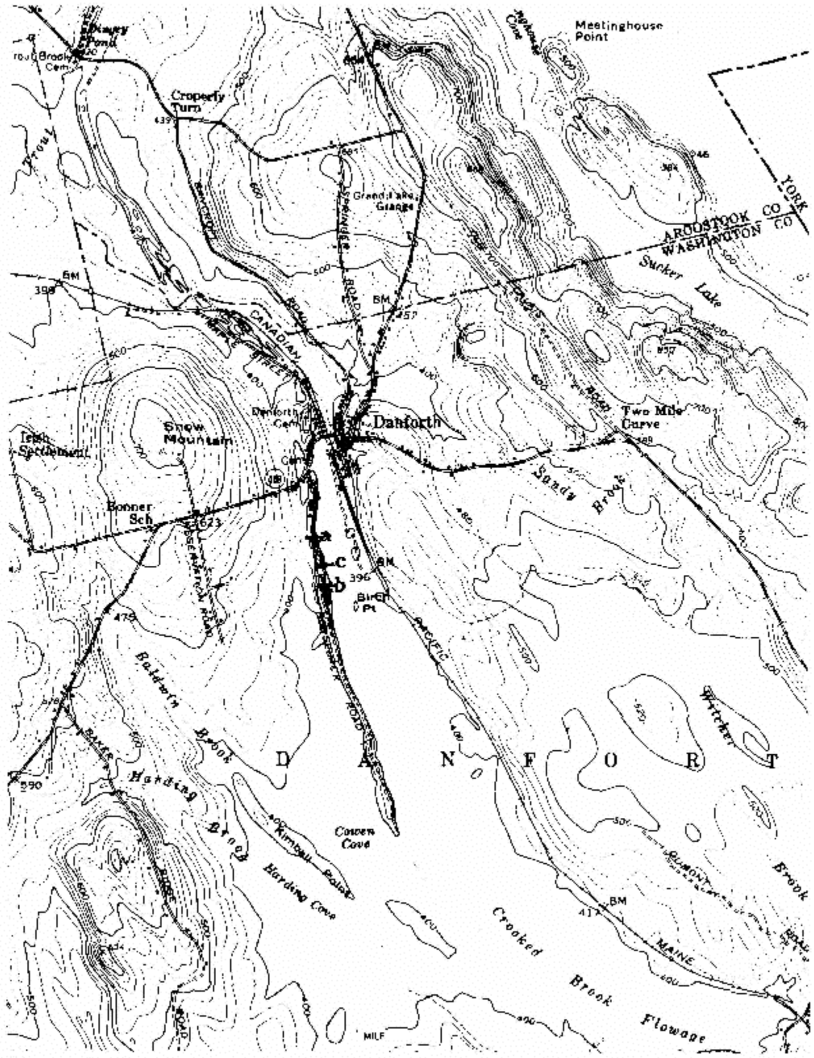

Figure 1: Topographic map showing glacial stream deposit known as an esker, or "horseback," meandering past village that is looking for a new ground water supply. A new well was originally proposed to be located at "a," but a state-installed observation well at "b" revealed insufficient saturated thickness of sand and gravel as shown by Figure 2. Seismic refraction profiling found site "c" to be suitable for construction of the municipal well. (USGS Danforth, Me Quad. 1958).

Seismic Profiling

The alternate approach to drilling a string of test wells was to complete seismic profiles along the length, and occasionally across, the esker ridge. Seismic refraction lines were run using a 12-phone, signal enhancement, refraction seismograph. Line length varied from 300 to 560 feet, depending on the terrain. Field work required less than two days.

The value of the seismic approach is demonstrated by Figure 3, which is a profile of the land surface, water table, and bedrock surface at the originally preferred municipal well site. Saturated thickness of the aquifer is only 12 to 19 feet at best in this interpretation, which required "forcing" the water table into the profile. In actuality, the seismic technique did not detect the water table because the saturated thickness is so thin relative to the aquifer thickness. Test drilling would not have been successful at this original site and the site would have been abandoned.

Most of the other seismic profiles, totaling about 3900 linear feet, revealed the same thin saturated section throughout the esker ridge. In some cases, fast seismic velocities suggested fine-grained sediments rather than permeable sand and gravel, another discouraging finding. Most of this "obvious" aquifer proved to be marginal.

The area recommended for test drilling - based on the completed seismic profiling - is illustrated by Figure 4. A local dip in the bedrock surface increases the saturated thickness of the sand and gravel aquifer to a useful 28 feet. This seismic line is calibrated on the ground water level observed in an adjacent dug well, and the saturated thickness was great enough for the water table to be detected by the seismic technique. Consequently, confidence in the seismic refraction data is high.

One other useful finding of the completed seismic profiling is that the depth to the water table at the selected test drilling site is shallow enough for test pumping using a centrifugal pump. The Figure 2 cross section through the state well shows the water table to be 27 feet below land surface, which is too deep for surface pumps. Thus, a 6-inch diameter test well would be required to pump the well and determine its yield. At the site selected for test drilling, the water table is less than 10 feet below land surface, making it possible to develop and pump test each exploratory well using surface pumps.

Conclusions

Mobilizing a test drilling rig to the esker aquifer without first defining a favorable well site using seismic refraction profiling would have been costly and failure prone. It is only by chance that random test borings would find the site defined by the seismic work. Even without the single observation well that suggested unfavorable conditions, seismic profiling would be the recommended first step of the investigation. Seismic refraction is more often than not a clear money-saving approach to glacial aquifer identification. ***WWJ***

Brad Caswell, Ph.D., is a principal of the environmental management firm Caswell, Eichler & Hill, whose corporate headquarters are located in Portsmouth, New Hampshire.

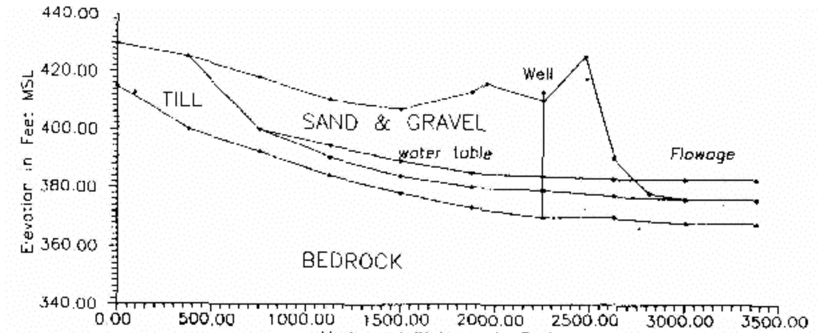

Figure 2. Schematic cross section through observation well that revealed thin saturated zone in the esker aquifer. The "Flowage" is a partially man-made lake that is hydraulically coupled to the esker aquifer.

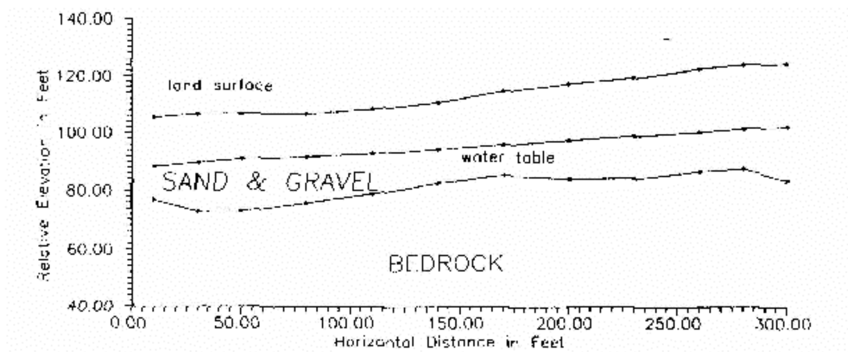

Figure 3. Seismic refraction profile through site originally selected for municipal well construction. The thickness of saturated sand and gravel (below the water table) was also too little at this site to be suitable for well construction.

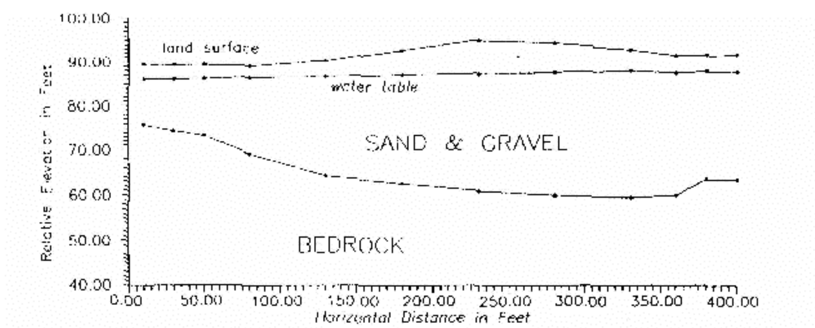

Figure 4. Seismic refraction profile through site selected for test drilling because of sufficient saturated aquifer thickness. This is the best of seven sites evaluated along the length of the esker aquifer shown on the Figure 1 topographic map.