MTBE Drinking Water Contamination in Pascoag, RI:
A Tracer Test for Investigating the Fate and Transport of Contaminants in a Fractured Rock Aquifer

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Summary
Ever since 2001, when Pascoag's only public drinking water well was shut down because of MTBE contamination, the people of Pascoag are without a drinking water source of their own. The MTBE problem at Pascoag is one of the largest in the country and probably the largest in New England. While Pascoag is large, it has almost all common MTBE problems in the New England region: drinking water, bedrock, and river contamination. The Rhode Island Department of Environmental Management, RI-DEM, has agreed opening the Pascoag site to scientists and students from the University of Rhode Island. The overarching objective was to work towards a systematic investigation of MTBE bedrock contamination and a prognosis for remediation alternatives. In this report we describe the results of a pump test that was designed to investigate the fate and transport of MTBE. A conservative tracer test was also carried out, but it had to be terminated before tracer breakthrough at the pumping well occurred. The data generated during this pump test was amended with data from groundwater monitoring wells up-gradient from the production well and a statistical evaluation of fracture analysis data. The principal finding was that the MTBE concentration in the production well can be controlled by the pump rate. That is, the MTBE concentration increases beyond the limit (40 μg/L) set by the RI Department of Health when pumping the production well at 240 gpm, but remains below that limit when pumping at a lower rate (150 gpm). It may therefore be possible by carefully adjusting the pumping regime and continuously monitoring the hydraulic and chemical conditions at the site to produce at least some amount of water from the aquifer. Because the pump test was comparably short (approximately 6 weeks), it is recommended to follow up with a step-up pumping rate test and, more importantly, longer (e.g., 6 months) pump test to ensure that the MTBE concentration remain at low levels over extended periods of time.

Introduction

The Pascoag Water District serves about 5,000 people in the Town of Pascoag, RI. Their drinking water was pumped from *one* 16” well, drawing 350 GPM from both the bedrock and overburden aquifers. On August 30, 2001, a resident of Pascoag noticed an odor in his water. A chemical analysis confirmed that the drinking water was contaminated with MTBE.

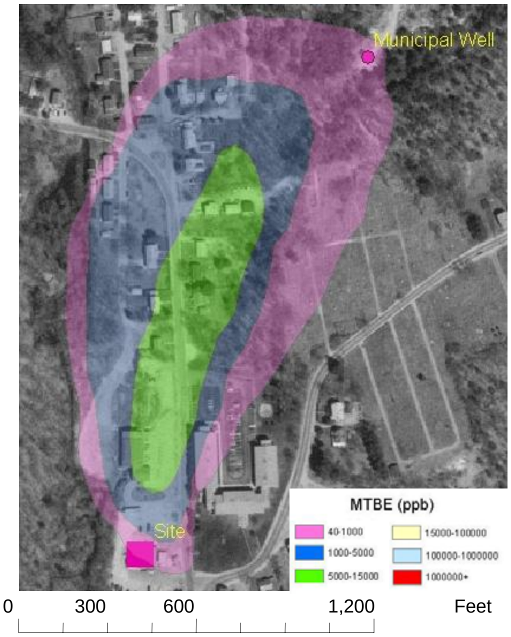

Figure 1: Currently known extend of the Pascoag MTBE plume in the bedrock aquifer.

The acronym MTBE is short for a synthetic organic compound chemically known as methyl tertiary-butyl ether. MTBE is a volatile, flammable, colorless liquid at room temperature and has a terpentine-like odor. MTBE is informally known as a fuel oxygenate because it provides extra oxygen for the internal combustion process (“anti-knocking agent”). MTBE has been used in U.S. gasoline at low levels since 1979, replacing lead-organic compounds as octane enhancer. Since 1992, MTBE has been used at higher concentrations (approx. 10%) in some gasoline to fulfill the oxygenate requirements set by Congress in the 1990 Clean Air Act Amendments. MTBE is now recognized as a very serious threat to groundwater. MTBE contamination is very difficult and expensive to cleanup and is becoming the most common drinking water problem faced by state agencies today.

Following the detection of MTBE in the drinking water, Pascoag residents were immediately notified that they should not drink the town water and minimize skin contact. Nonetheless, residents complained about massive headaches, vomiting, wheezing, and blisters on their lips. Ever since 2001, when the drinking water well was shut down, the people of Pascoag have been without a drinking water source of their own.

Responding to Pascoag’s drinking water emergency, the Burrillville School District opened up the hockey rink for residents to take showers and fill water jugs. In the following months, the RI Department of Environmental Management (RI-DEM) supplied the Pascoag residents with about a quarter million dollars worth of bottled water. Currently, Pascoag is receiving water from village/district of Harrisville (both within the Town of Burrillville) at a cost of more than $1,000,000/year. Pascoag cannot sustain this financial burden and may soon become insolvent. Because no other drinking water resources are available, there is strong political pressure building to reactivate the Pascoag well.

RI-DEM identified a nearby gas station as the source of the MTBE. After the owner of the gas station declared bankruptcy, RI-DEM took over all assessment and remediation activities (Project Manager Mike Cote (401) 222-2797, ext. 7118). During the emergency site investigation over 6” of free gasoline was found in some wells. Intrusion of toxic vapors demanded the temporary evacuation of 200 senior citizens from a nearby home for the elderly. By now the MTBE contamination plume is approximately 20 acres in size and up to 100 feet deep. This makes the MTBE problem at Pascoag one of the largest in the country and probably the largest in New England.

The contamination resides in both the overburden and fractured bedrock aquifers and has been consistently detected in a nearby river, too. Bedrock contamination is very complex and expensive to cleanup. It is a common problem in New England as its bedrock aquifers are susceptible to this contamination, due to their being relatively shallow. Currently MTBE in the bedrock aquifer reaches to a maximum of 15,000 μg/L. For comparison, the RI drinking water limit for MTBE is 40 μg/L.

To date, over 50 shallow and deep overburden wells and 16 bedrock wells were installed by RI-DEM. Over 3 million gallons of contaminated water and over 3,000 gallons of gasoline were pumped so far. Funding for the site investigation and water treatment has been provided by the U.S. EPA. EPA's assistance prevented the Rhode Island Leaking Underground Storage Tank (LUST) program from immediate collapse. RI-DEM has now reached a critical decision point – either focusing the remaining funds on constructing a water treatment plant and reactivation of the public well to allow some degree of normalcy to return to the area. Or, concentrate on remediation of the bedrock contamination problem, which – if remained untreated – may again jeopardize the water quality in the future - even after a treatment system has been installed.

The main objective of this pilot-scale field project was to development a conceptual model of MTBE fate and transport within the drinking water aquifer at the Pascoag site. The principle means of generating these data were a tracer test and water quality analysis. Also, the study of this MTBE site served students as an experiential learning opportunity as they were working next to environmental professionals and regulators. Ultimately, the results of this study are expected to produce hydraulic and chemical data in support of RI-DEM and the Town of Pascoag in attempt to reopen the well field.

Methods, Procedures, and Facilities

In cooperation with RI-DEM, more than 60 wells were installed at the site, including many nested wells (i.e. closely spaced wells penetrating different depths of the aquifer). The depth of the wells ranges from 10 ft (overburden) to over one hundred feet into the fractured bedrock. The actual production well (PW3A) is 64 ft deep and penetrates the fractured bedrock aquifer approximately 10 ft.

Starting March 14, 2005, a pump test was conducted at PW3A. The flow rate was recorded at the well head and water level elevations were measured using a vented InSitu data logger. Additional wells were monitored manually and by loggers installed in wells MW18D, MW20S, MW20D, MW28BR, where S and D stand for shallow and deep overburden wells, respectively, while BR is a bedrock well. Precipitation data was recorded at a NOAA weather station located 13 miles south in South Foster, Rhode Island.. Bedrock well LE2 and overburden well MW14D were used as tracer injection wells.

From March 14 through April 19, 2005, the pump rate was 240 gpm. For the last day of the test, April 20, 2005, the pump rate was decreased to 150 gpm. Water samples for MTBE and tertiary amyl methyl ether (TAME), another gasoline oxygenate, were collected on a daily basis starting the day before the beginning of the pump test. All samples were collected in 40 mL VOA vials and preserved with 6N hydrochloric acid with zero headspace. All these samples were analyzed by EPA method 8260B (Low QL) for volatile organic compounds (VOC) and oxygenates by Premier Laboratory (Dayville CT). Samples collected between 04/03/05 and 04/08/05 were collected but not analyzed.

A conservative tracer (fluorescein) was released in well LE2 A total of 50 g fluorescein was pre-dissolved in 1000 ml of deionized (DI)and injected into LE2 at once. The tracer was released one day after the pumping rate was decreased from 240 to 150 gpm. About 100 ml tracer samples were collected on hourly basis. Fluorescein was analyzed by UV-Vis spectrometry (Shimadzu) at a wavelength of 491 nm.

A fracture analysis at bedrock outcrops on and near the site was carried out and statistically evaluated for dominant fracture orientation. Measurements of lineation, foliation, and fracture orientations were collected using a *Silva Compass*. Fracture strikes were plotted on rose diagrams using the *Rockworks* software for plotting individual locations and groups of measurements.

Results

The locations of those wells utilized in this study are shown in Figure 2. Figure 3 shows the water table elevation under non-pumping conditions, while Figure 4 shows the water table under pumping conditions (240 gpm).

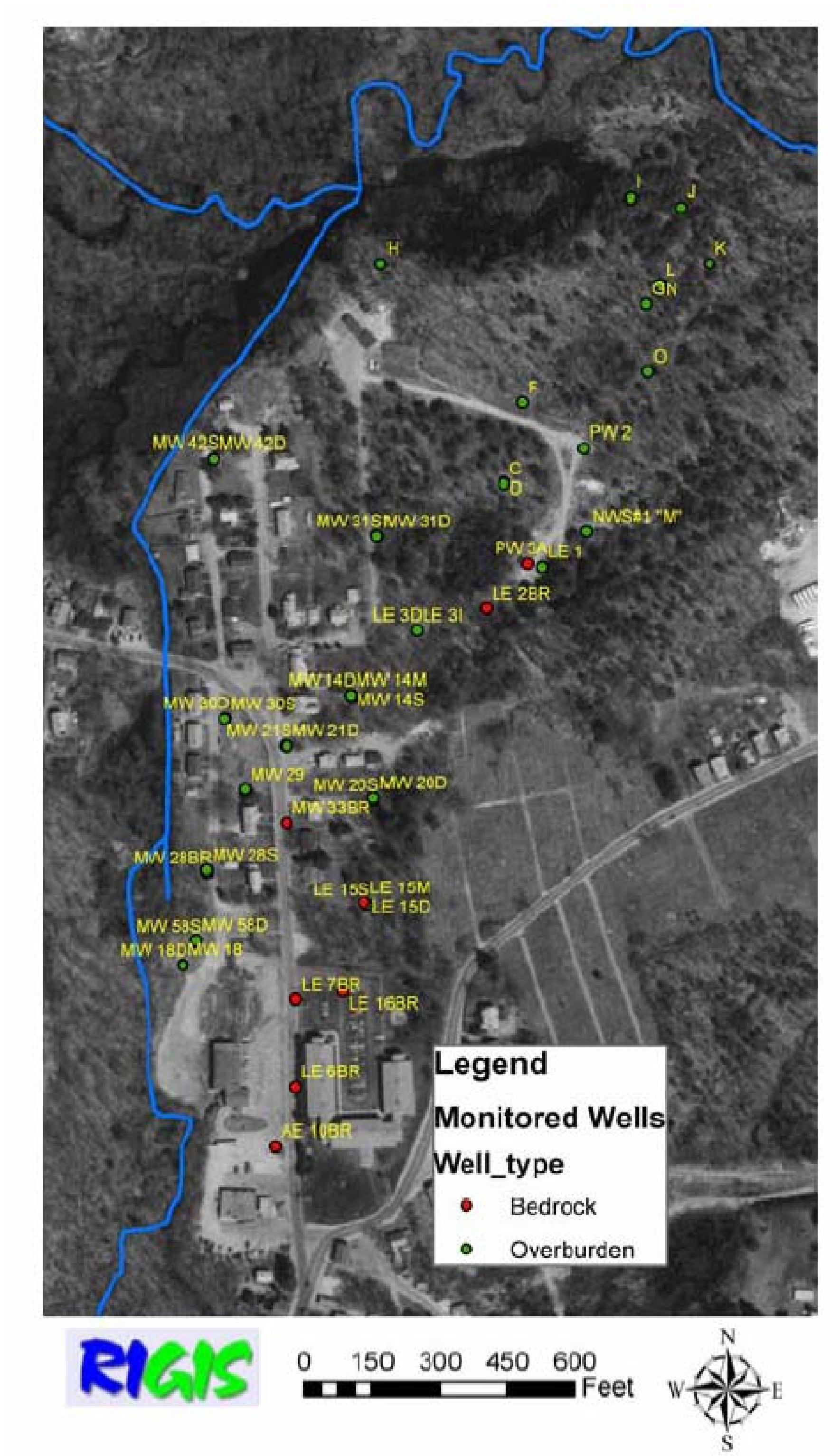

Figure 2: Location of monitoring well utilized in this study.

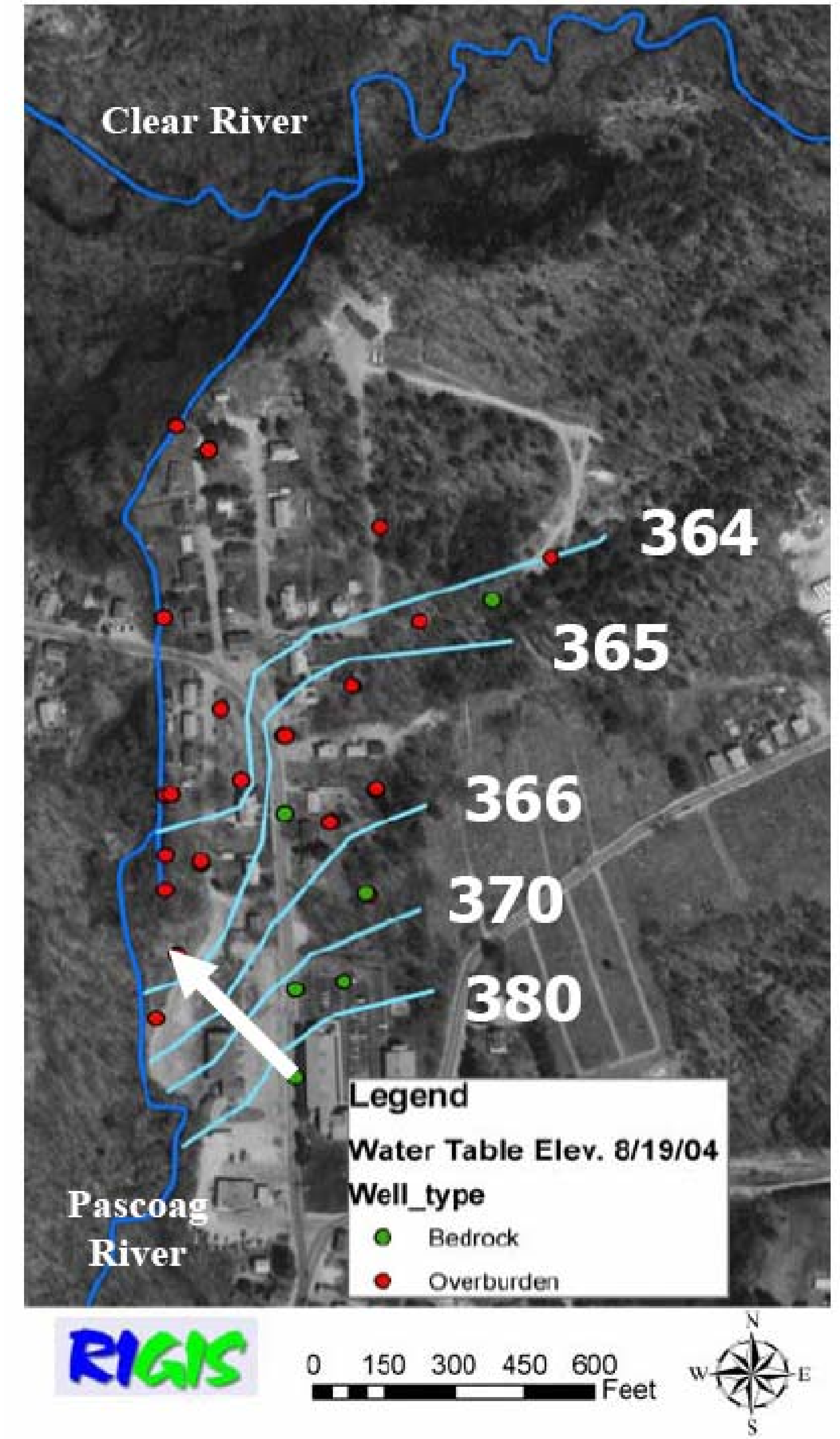

Figure 3. Water table of site under non-pumping conditions. Table drawn using combined bedrock and overburden wells. Uneven contour interval

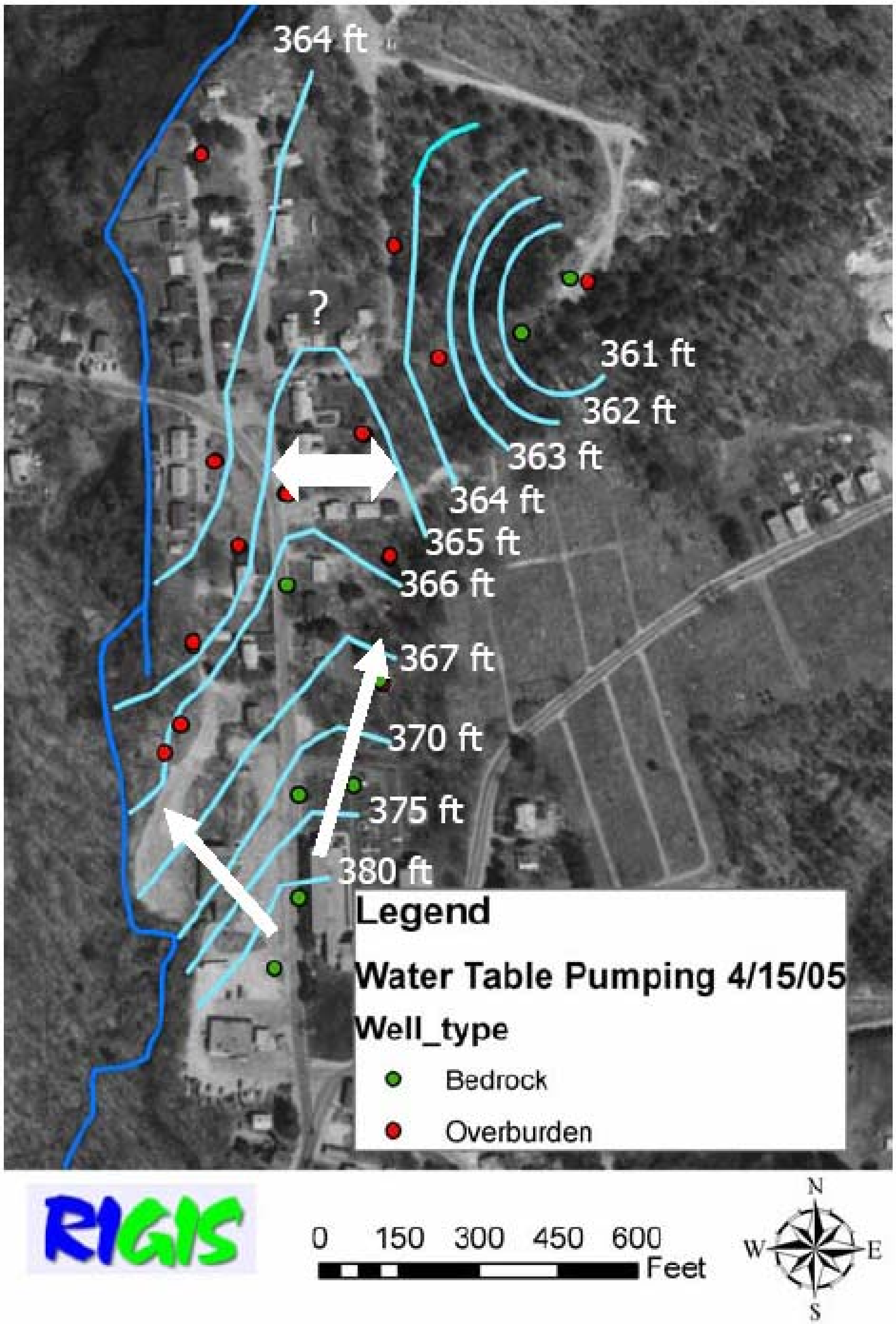

Figure 4. Water table gradient under pumping conditions of 240 GPM. Notice plume separation and the flow divide in middle of the site. Uneven contours

The water table elevations in the pumping and observation wells are summarized in Figure 5. Also shown are the precipitation measurements. There were two significant precipitation events during the aquifer test. These events occurred on March 28 and April 2, with amounts of 2.8 and 2.5 inches respectively.

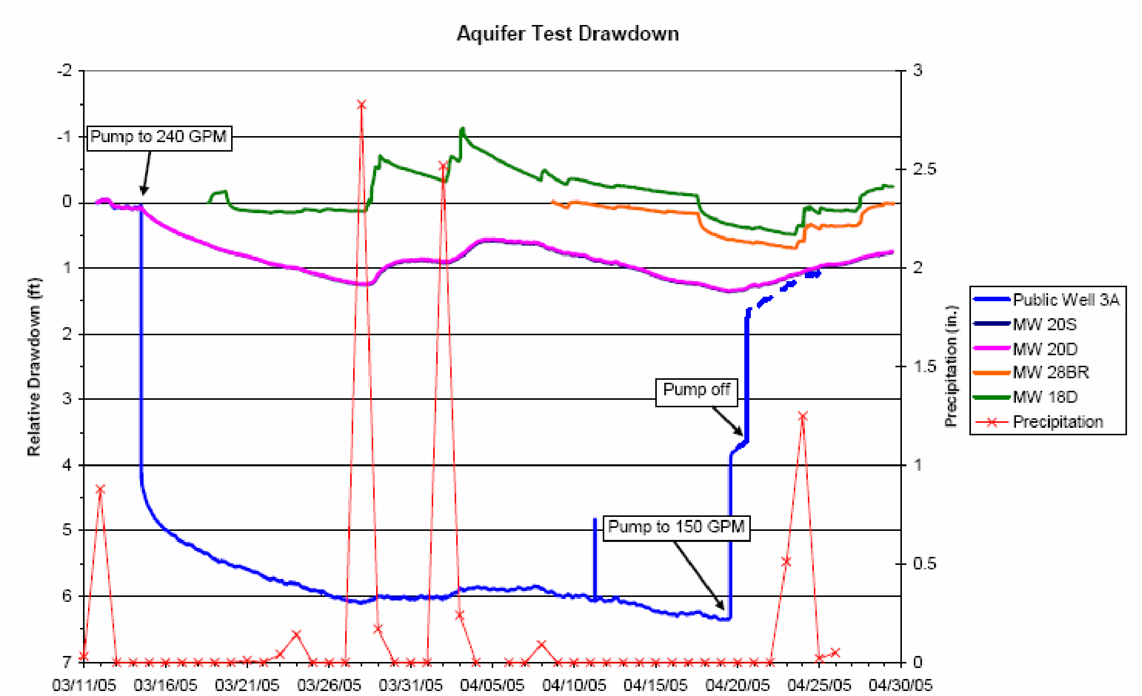

Figure 5: Drawdown curves obtained from pressure transducers. Precipitation is also plotted. The origin of the anomalous point in Public Well #3A on 4/10/05 is unknown. It may have been related to a very short pump disruption.

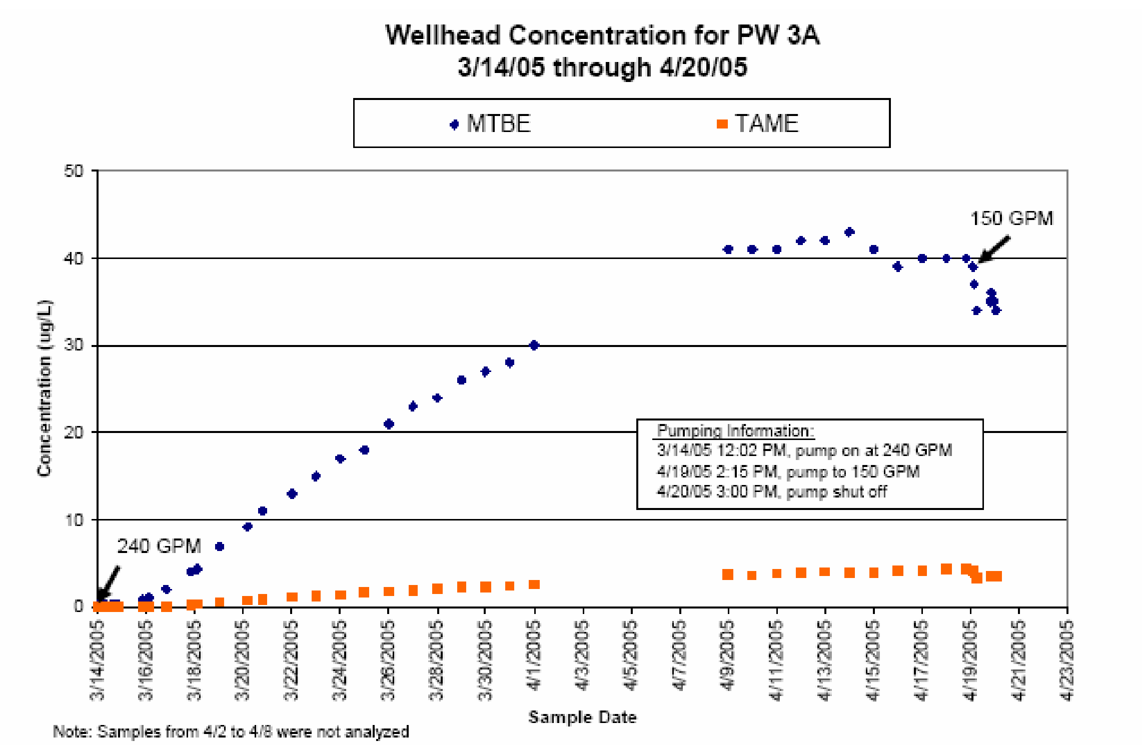

Figure 6: Concentrations of MTBE and TAME at the wellhead from the start of the aquifer test through the end. Notice the apparent steady state at 43 µg/L for MTBE and the drop when pump rate changed.

Water Quality Data

The results of the water analysis at the production well head are summarized in Figure 6. MTBE and TAME were detected in every sample after the first few days. MTBE levels increased asymptotically and peaked at 44 μg/L on 04/14/2005. TAME levels never exceeded 5 μg/L.

After injection of the fluorescein tracers (04/20/2005), samples were collected for only 4 hours. The reason for this short sampling period was that the pump test was shut down on 04/20/2005 by the Pascoag Utility District because MTBE levels had exceeded the 40 μg/L limit. This was unfortunate because at the time of the shut-down, MTBE levels had dropped to less than 40 μg/L , presumably in response to lowering the pump rate to 150 gpm. Because there was a 14-day lag time between sampling and availability of laboratory results, the shut down was ordered without knowing that a drop in MTBE concentration had occurred. Once the pump test was shut down, it was not possible to restart the pump test again.

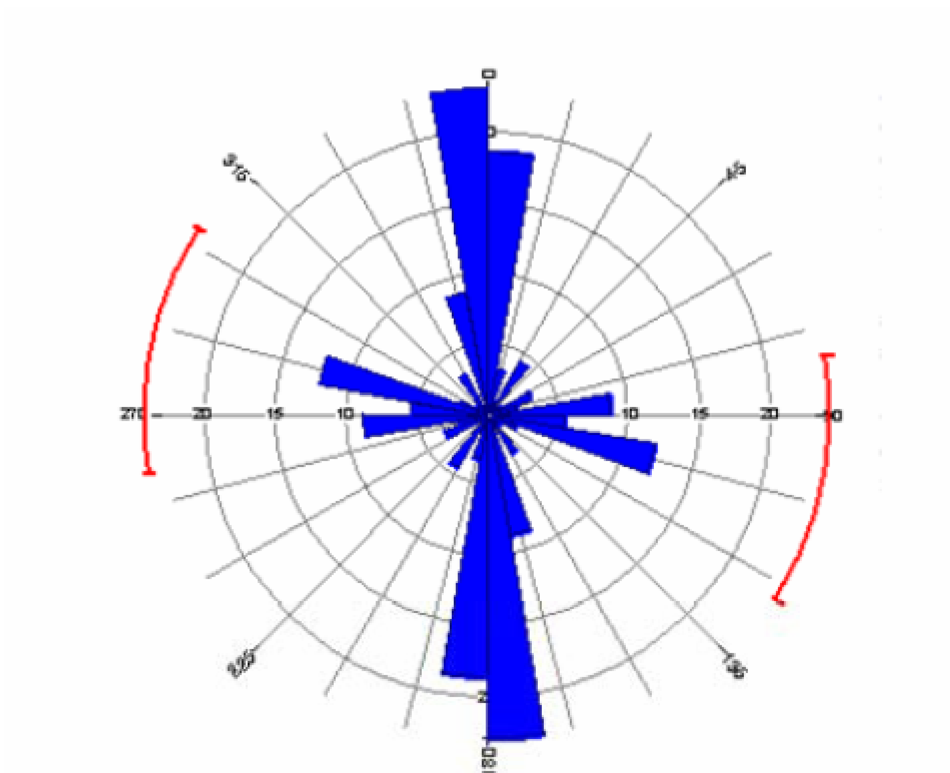

Figure 7: Average fracture strike for all field measurements

Fracture Analysis

The results of the fracture study (91 total observations) indicate that there are two dominant fracture orientations in this area. The trend of mineral lineation is approximately N2E and plunges at 10° to the north. The dominant fracture orientation is nearly parallel to the mineral lineation and has an average dip of 65E. The other less dominant fracture orientation is N75W and dips 75S. Figure 7 shows the average strike of all fractures measured. Slight variation and other orientations do occur, however the frequency and transmissivity of these fractures is less significant. Orthogonal fractures that trend along the same dominant strike but dip much more shallowly also occur. The frequency of the N75W trending fractures appear to be concentrated in localized fracture zones. Between these zones the rock units are massive. The N2E fractures are more regular and their frequency is more consistent.

Discussion

The results of the water table elevation measurements before and during the pump test clearly indicate that the production well – even when pumped at a lower rate than during pre-contamination production (300 gpm) – strongly influences the groundwater gradient and pulls MTBE from the source zone towards the well head. Under no-pumping conditions the MTBE appears to migrate away from the well field and towards the river in an approximately north-north-easterly direction. The natural direction of the groundwater movement seems to be controlled by fractures running in approximately south-to-north direction and by the presence of the river. Also, the response of the water table elevation to precipitation is almost instantaneous suggesting that there is a good hydraulic connection between the surface and the aquifer.

The shape of the MTBE concentrations graph indicates that a quasi-equilibrium concentration level between 40 and 50 μg/L MTBE is being approached when the pumping rate is at 240 gpm for about 4 weeks. Once the pumping rate was lowered to 150 gpm, MTBE concentrations dropped below the regulatory threshold limit of 40 μg/L. This suggests that by carefully controlling the pumping rate, water of drinking water quality can be pumped from the aquifer. Because the aquifer test ended prematurely, the injected conservative tracers had not arrived at the pumping well.

The analysis of the test data has led to a better understanding of the ground water flow, contaminant transport, and ground water/surface water interactions. The goal was to determine how and where contaminants are moving and if it is possible to eventually reactivate the well. Major new advancements regarding water table gradients, plume stabilities, contaminant transport pathways, and the aquifer/surface water interactions have now been made. Based on these findings it is suggested to design a stepped pumping test and monitor the water quality in the production well as well as in up-gradient wells for at least 6 months duration. Ideally, this stepped pumping test should give evidence for, potentially, a threshold pumping rate at which the MTBE concentrations will remain below the drinking water limit.

Acknowledgements

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