Table 2.2: Estimated numbers of private wells with MTBE detections above particular concentration thresholds and the estimated population served by those wells.

MTBE Concentration Range*	Number of PWTA Wells with Detections **	MTBE Detection Frequency	Estimated # of Private Wells with Detections***	Estimated Population Served****
>=70	46	0.05%	217	537
>=10 ppb	384	0.45%	1,809	4,480
>=5 ppb	838	0.99%	3,948	9,776
>=1 ppb	4,108	4.84%	19,355	47,924
>=0.5 ppb	6,590	7.76%	31,049	76,880
At Any Concentration	11,442	13.48%	53,909	133,484
Total Wells Sampled	84,898			

* MTBE concentrations detected range from 0.01 to 1,500 ppb.
**2011 PWTA database.
***Estimates based on an estimated 400,000 private water wells (Judy Louis, NJDEP Office of Science, 2009).
**** Based on an estimated 2.48 people per household.

2.1.2 MTBE in the United States

Widespread use of MTBE at high volumes in gasoline began in 1992 with the federally mandated seasonal use of oxygenates in other parts of the country. Within a few years, MTBE was detected in water resources across the country (*Squillace et al., 1996; NESCAUM, 1999; Squillace et al., 1999*). An early study by the United States Geological Survey (USGS) National Water Quality Assessment Program (NAWQA) found that by 1995, MTBE was the second most frequently detected volatile organic compound (VOC) in shallow urban groundwater wells in the U.S. (USGS, 1995). At about the same time, MTBE was detected in two of the five operating Charnock Sub-basin public water supply (PWS) wells owned by the City of Santa Monica, California. These five wells supplied approximately 45% of the City's drinking water at the time (*Happel, 2003*). By June 1996, all five PWS wells were shut down due to persistent and increasing MTBE concentrations [*California Department of Health Services water quality database (CDHS database), September, 2003*]. Meanwhile, in 1996 MTBE was also detected in PWS wells located in the South Tahoe Basin. Eventually, 12 out of the South Tahoe Public Utilities District's then 33 producing wells would be shut down due to MTBE impacts (*South Tahoe Public Utilities District, personal communication, 2006*).

All the while, MTBE use and production was on the rise (Figure 2.4). Its use increased further when the year-round use of oxygenates was federally mandated in 1995. By 1998, MTBE ranked fourth in production volume among organic chemicals (*Clawges et al., 2001; Johnson et al., 2000*).
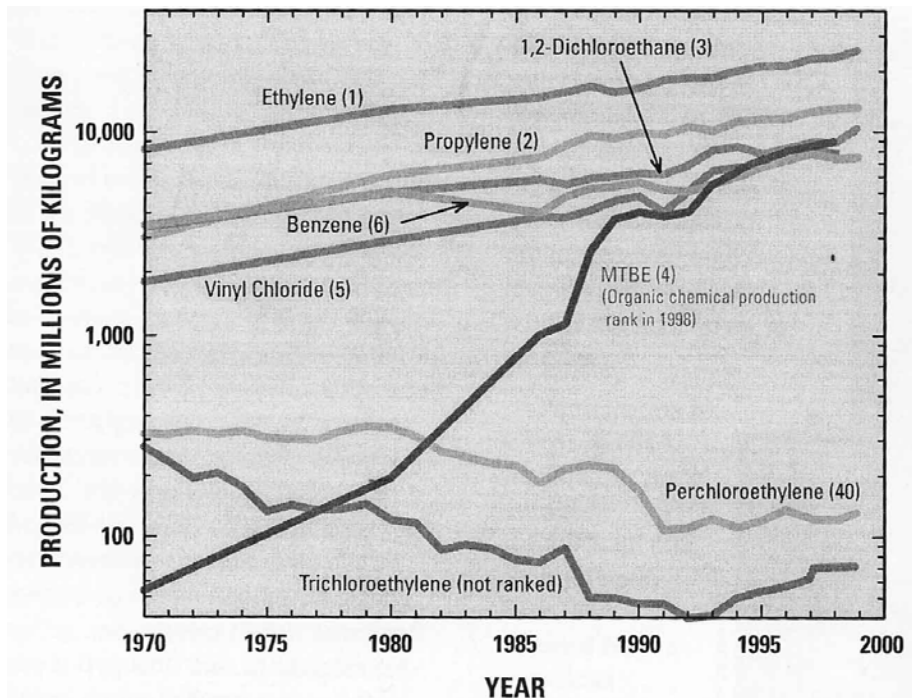
Figure 2.4. Production for MTBE and other organic chemicals in the U.S. Note that MTBE production has increased approximately 500 times since the 1970s. In 1998 MTBE ranked fourth in production volume among organic chemicals (from U.*S.G.S. Fact Sheet FS-064-01*; *Clawges*, 2001).

In California, within a few years, MTBE had been detected at more than 4,000 leaking underground fuel tank (LUFT) sites more than 50% of which were located within 0.5 mile (800 meters) of a public drinking water well. Further, data from nearly 10,000 additional LUFT sites were still unavailable, leading to an estimate of 6,700 MTBE plumes within 0.5 mile of a public drinking water well (*Happel et al., 1999*). For example, Figure 2.5 shows the collocation of public drinking water wells and LUFT sites in the Los Angeles Basin, California in early 1999. This collocation is typical for urban areas that rely on local groundwater as a source of drinking water.

Other states were experiencing similar MTBE impacts. In New York, a few years after its introduction into gasoline at high volumes and on a wide scale, a focused study conducted by the New York Department of Environmental Conservation (NY. DEC) found that MTBE had been detected in groundwater at 32% of 5,262 gasoline remediation sites surveyed (*NY. DEC, 2000*). The survey results also indicated that 47 public wells and 866 private wells had been impacted by MTBE.

The fast spread of MTBE into groundwater was cause for alarm, leading scientific panels, communities, states, and federal agencies to recommend limiting or phasing out its use in gasoline:

- In the 1998 University of California (U.C.) Report to the Governor of California, U.C. scientists including myself recommended the phase out of MTBE over an interval of several years (*Fogg et al., 1998b*).

- In 1999, The U.S. Environmental Protection Agency (USEPA) Blue Ribbon panel on Oxygenates in Gasoline "agreed broadly that, in order to minimize current and future threats to drinking water, the use of MTBE should be reduced substantially. Several members believed that the use of MTBE should be phased out completely" (*Report of the Blue Ribbon Panel on oxygenates in gasoline, Executive Summary and Recommendations, July 1999*).

- The Northeast States for Coordinated Air Use Management (*NESCAUM, 1999*) recommended a "Three year phase down and cap on MTBE in all gasoline" citing several reasons, including: "MTBE is now one of the most commonly detected VOCs in Northeast drinking water supplies."

- By June of 1999, Maine, New Hampshire and Connecticut had taken action to either opt out of the Federal Reformulated Gasoline (RFG) Program, or to seek ways to reduce the use of MTBE in gasoline (*NESCAUM, 1999*).

- In May of 2000, New York Governor George Pataki signed a bill to ban MTBE use in the state of New York[5].

- In March 2001, the Private Well Testing Act was signed into law, making New Jersey the only state in the Nation to require "mandatory statewide private well testing upon the sale of a house" (*NJDEP, 2004*).

- In 2005, the New Jersey State Legislature issued a ban on the sale of gasoline containing more than 0.5% MTBE, effective January 2009[6]. As of August 2007, a total of 22 States had passed legislation that would ban MTBE[7].

- Similar actions were being taken around the world. For example, in April 2000, the Danish Environmental Protection Agency added MTBE to its list of undesirable substances (*Report to the European Commission, 2001*). In Australia, legislation was passed to limit the concentration of MTBE in gasoline to 1% by volume starting January 1, 2004 (*Bellamy et al., 2003*). In Canada, the decision to stop adding MTBE to gasoline was taken by the refining companies: "The Canadian Petroleum Products Institute (CPPI) representing most Canadian refiners has indicated

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[5] New York passes MTBE ban, National Petroleum News, July, 2000.

[6] http://www.state.nj.us/dep/dsr/mtbe/mtbe-report.htm last accessed October 30, 2012.

[7] Data available at *www.epa.gov/mtbe/420b07013.pdf*; accessed 6/24/10.

that its member companies ceased adding MTBE to gasoline by the end of 2001 and that none have the intention of using MTBE in the future" (*Bellamy et al., 2003*).

In 2000, a group of scientists and engineers including some from the Oregon Graduate Institute and the United States Geological Survey (USGS) summarized well the reason MTBE stands out among the many contaminants in gasoline (*Johnson et al., 2000*):

> "If MTBE behaved like the gasoline hydrocarbons in all respects, the scale of its use would not by itself be a reason for concern. After all, the current numbers for gasoline production in the United Sates are about 40 times larger than those for MTBE, and 385,000 known releases of gasoline have already occurred at LUFT [leaking underground fuel tank] sites. Unfortunately, MTBE is very soluble in water and is therefore very mobile in groundwater systems. And, the absence of any carbon branches more than one carbon long on the MTBE molecule make MTBE very resistant to biodegradation. Thus, like the chlorinated solvent compounds [trichloroethylene] TCE and [perchloroethylene] PCE, MTBE has been found to persist in groundwater, and cases of MTBE plumes extending kilometer-scale distances in the subsurface have now been documented (e.g., Port Hueneme, CA; East Patchogue, NY; Spring Creek, WI; and Vandenberg AFB, CA)" (see Figure 2.6).

By 2001, the spread of MTBE in the environment was characterized as: "a water resources disaster of national magnitude" (*Jacobs et al., 2001*).
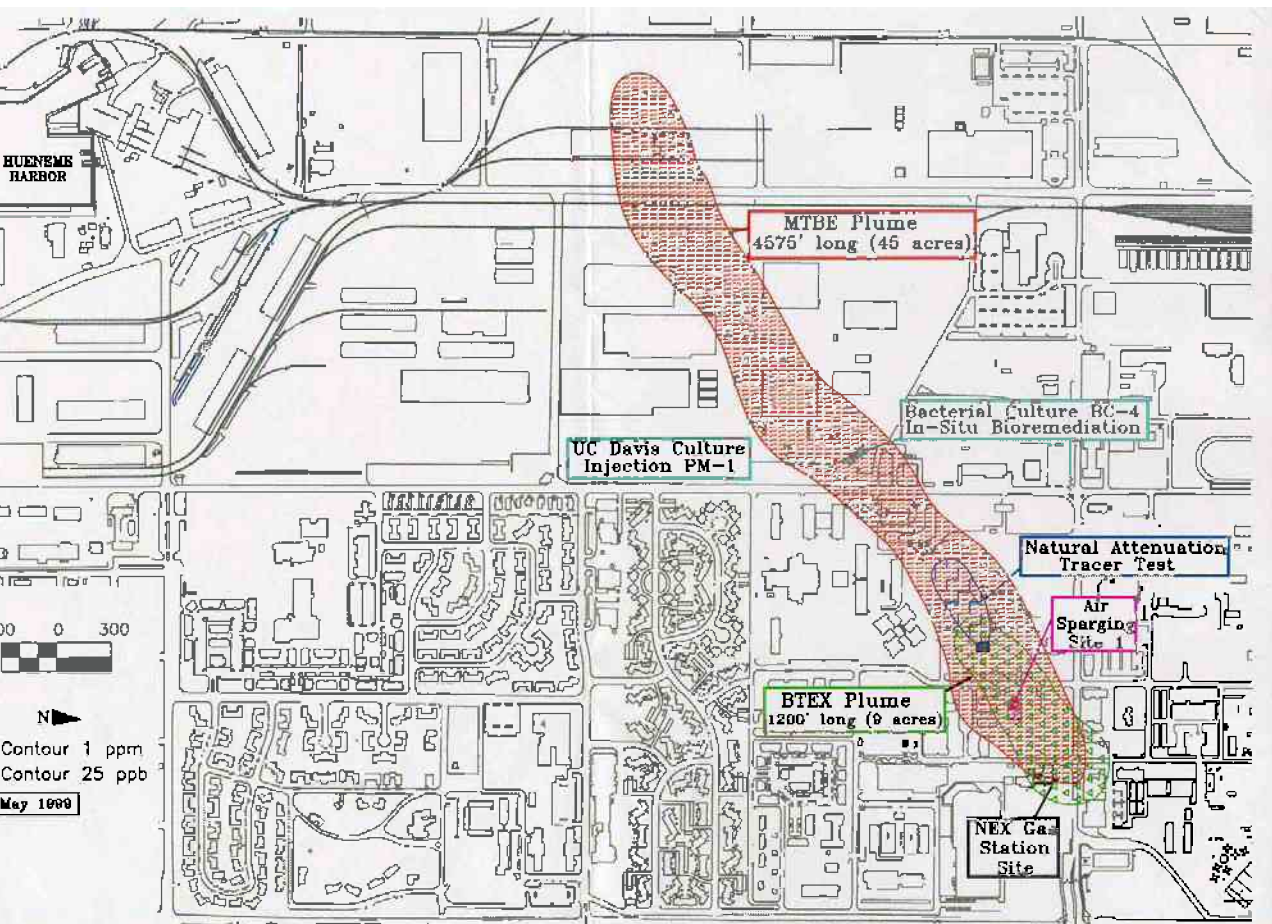
Figure 2.6. The MTBE Plume at Port Hueneme, California, resulting from a leaking underground fuel tank is plotted against the corresponding Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX components of gasoline) plume demonstrating that the unique transport properties of MTBE lead to large, high concentration plumes (*MTBE2000 Team*, 1999).

In what follows, I review the scope of and the science behind the MTBE problem. Specifically, the nation's, and New Jersey's, reliance on groundwater; the processes governing the transport of MTBE in groundwater; remediation and natural attenuation of MTBE in groundwater; the occurrence of MTBE in groundwater in the U.S. in general and in New Jersey in particular; and the potential impacts to groundwater from ethanol addition to gasoline. I also summarize details on the ten Trial Sites at issue in this case, specifically with regards to the hydrogeology, the contamination history, and the impacts to groundwater.

3　Groundwater

"Ground water is one of the Nation's most important natural resources. It provides about 40 percent of the Nation's public water supply. In addition, more than 40 million people, including most of the rural population, supply their own drinking water from domestic wells. As a result, ground water is an important source of drinking water in every State" (*Alley et al., 1999*). The population of the U.S. is expected to grow over the coming years, increasing the demand for groundwater.

Groundwater quality is particularly vulnerable to contaminants that persist, or fail to degrade at appreciable rates, such as MTBE. Because groundwater moves slowly, once persistent contamination is allowed to enter groundwater, it can render the water unusable for decades to centuries unless costly and time-consuming remediation, or expensive treatment is undertaken. Research shows that "Subsurface contamination has the potential to threaten local CWS [community water supply] wells for tens to hundreds of years" (*Johnson et al., 2000; Weissmann et al., 2002*).

3.1　Groundwater and Aquifers

Water in the subsurface fills the voids between unconsolidated soil and sediment particles, or in rock fractures. Water can reside in the unsaturated zone (above the water table where both water and air fill the voids) or in the saturated zone (below the water table where only water fills the voids); water in the saturated zone is referred to as groundwater.

The nation's major aquifers are generally composed of either unconsolidated sands and gravels (such as the aquifers of the Coastal Plain of New Jersey), in which groundwater flows relatively easily, inter-bedded with clays and silts that are less permeable to water, or consolidated rocks (e.g., sandstone, mudstone, shale, and crystalline rock, typical of the aquifers in northern New Jersey). In unconsolidated and consolidated sedimentary groundwater systems, the typically complex geometry of sedimentary deposits, and their ability to transmit water, leads to vastly different rates of flow in sands and gravels as compared to adjacent clays and silts. Similarly, in consolidated hard rock groundwater systems, fractures of various geometries and varying degrees of connection form pathways for water that flows at differential rates. At the same time, the rock itself is porous, but does not transmit water easily.

3.1.1　Groundwater Use

The distribution and use of groundwater varies widely both among and within States (Figure 3.1). Its use not only varies in space, but also in time. In dry years, groundwater consumption can increase. In New Jersey, it is estimated that on average, groundwater accounts for 31% of the State's total water supply (*NGWA, 2012*). The rest is supplied by surface water systems. The number of different water systems (public and private), using groundwater, and the communities served by those systems, are summarized in Table 3.1 below.

Table 3.1: Groundwater use in the State of New Jersey by system and population served. Data for public supply wells obtained from NGWA (2012), and data for domestic supply wells obtained from Louis (2012).

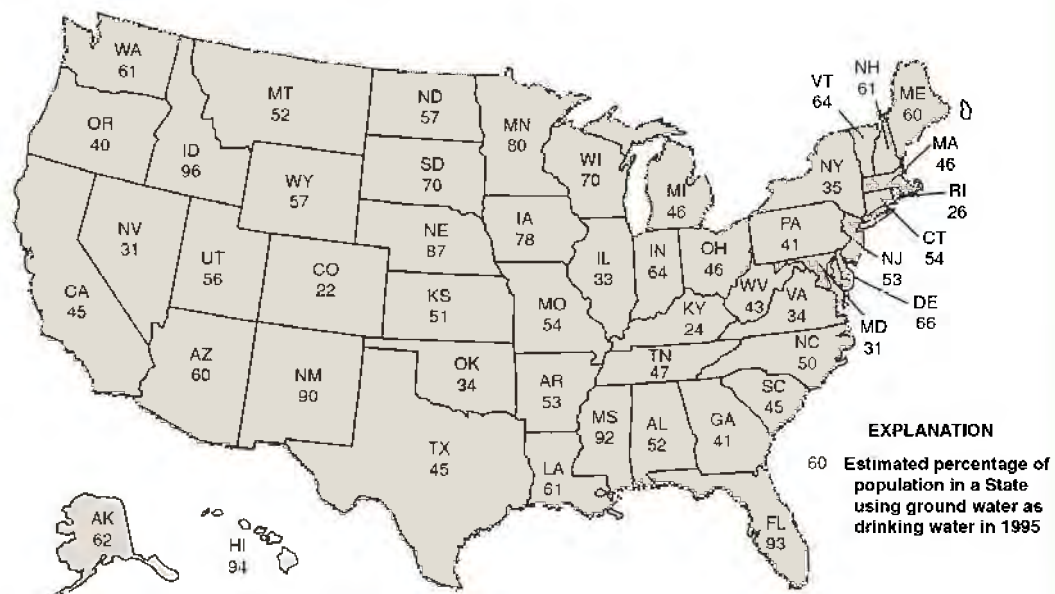| Type of System	Number of systems	Population served
Community Water System (CWS)	473	2,643,847
Non-community, non-transient system	772	350,281
Non-community, transient	2,503	428,677
Domestic wells	400,000	1,130,000

Figure 3.1. Estimated percentage of population in each State using groundwater as a source of drinking water in 1995 (from *Alley et al., 1999*).

3.1.2   Groundwater Recharge and Discharge

Groundwater moves through the subsurface from areas where water enters or recharges, the aquifer system, to areas where it exits, or discharges from, the aquifer system (Figure 3.2). Groundwater is recharged by percolation of water through the land surface and by inflow from surface water such as streams and lakes. Groundwater can also discharge naturally to surface water and springs. Pumping wells are also discharge locations. In many aquifers that are heavily pumped, wells may be the only discharge locations.

3.2 The Physiographic Regions of New Jersey

The geologic processes that formed the landscape of New Jersey have resulted in distinctive landforms that can be divided into four regions, commonly referred to as Physiographic Provinces[8] (*Dalton, 2003*). The regions within each Province share similar geologic features and climate that are different from those in the neighboring provinces. The main physiographic provinces in New Jersey are (see Figure 3.3):

- Valley and Ridge

- Highlands

- Piedmont

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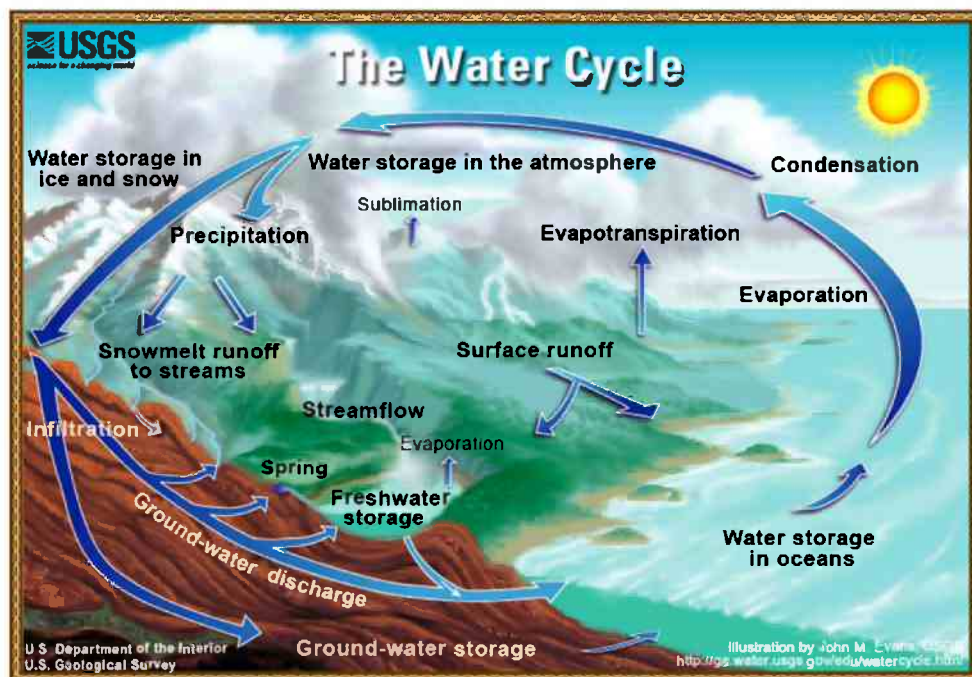
The Valley and Ridge, Highlands, and Piedmont, together, are known as the Appalachian Highland, while the Coastal Plain is known as the Atlantic Slope. Aquifers in the Appalachian highlands tend to be more commonly fractured bedrock with overburden on
top, whereas the Coastal Plain is characterized by aquifers composed of unconsolidated materials (sands, gravels and silts) for the most part. A more detailed description of the geologic formations that formed those distinct Provinces is given below:

The Valley and Ridge Province

This is the smallest of the provinces in the northern most part of the State and includes major portions of Sussex and Warren counties. The Province "is characterized by steep-sided, linear ridges and broad valleys. It is underlain by folded and faulted Paleozoic sedimentary rocks of Cambrian to Middle Devonian age (540 to 374 million years old) and minor amount of earliest Silurian-aged igneous rocks" (*Dalton, 2003*).

The Highlands Province

Slightly larger in size than the Valley and Ridge Province, this mountainous region is characterized by "rugged topography", with "discontinuous rounded ridges separated by deep narrow valleys" (*Dalton, 2003*). This province is "mainly underlain by highly metamorphosed igneous and sedimentary rocks of Middle Proterozoic age (1.2 billion to about 900 million years old)" (*Dalton, 2003*). At the southern side, the "boundary with the Piedmont Province is placed at the base of the Highlands where the crystalline rocks are in contact with significantly younger sedimentary and igneous rocks. Starting at the New York border the boundary follows the Ramapo Fault southwest to just south of Peapack. It then alternately follows the contact between the Precambrian crystalline rocks and the Cambrian sediments and various segments of the border fault to the Delaware River" (*Dalton, 2003*).

The Piedmont Province

This region accounts for approximately one-fifth of area of the state. The area is characterized by "low rolling plain divided by a series of higher ridges" (*Dalton, 2003*). The Province is "mainly underlain by slightly folded and faulted sedimentary rocks of Triassic and Jurassic age (240 to 140 million years old) and igneous rocks of Jurassic age. Highly folded and faulted lower Paleozoic sedimentary rocks along the northwestern margin in the Clinton and Peapack areas, as well as at several smaller areas are included as part of the Piedmont. In the Trenton and Jersey City areas, along the southern margin of the province, there are small bands of highly metamorphosed rocks ranging in age from Middle Proterozoic to Cambrian that are also included" (*Dalton, 2003*).

The Coastal Plain

The largest of the provinces, accounting for three fifths of the area of the State. The province is characterized by unconsolidated deposits that "dip gently to the southeast and range in age from the upper Lower Cretaceous to the Miocene (90 to 10 million years old)" (*Dalton, 2003*). The boundary between the Piedmont and the Coastal Plain Provinces (where the rock units of the Piedmont meet the unconsolidated sediments of the Coastal Plain) is known as the Fall Line, because it is "marked by a series of falls and rapids all along the East Coast" (*Dalton, 2003*).

The MTBE contamination sites at issue in this case (the Trial Sites) are located across the State and cover all, but the Valley and Ridges Province.
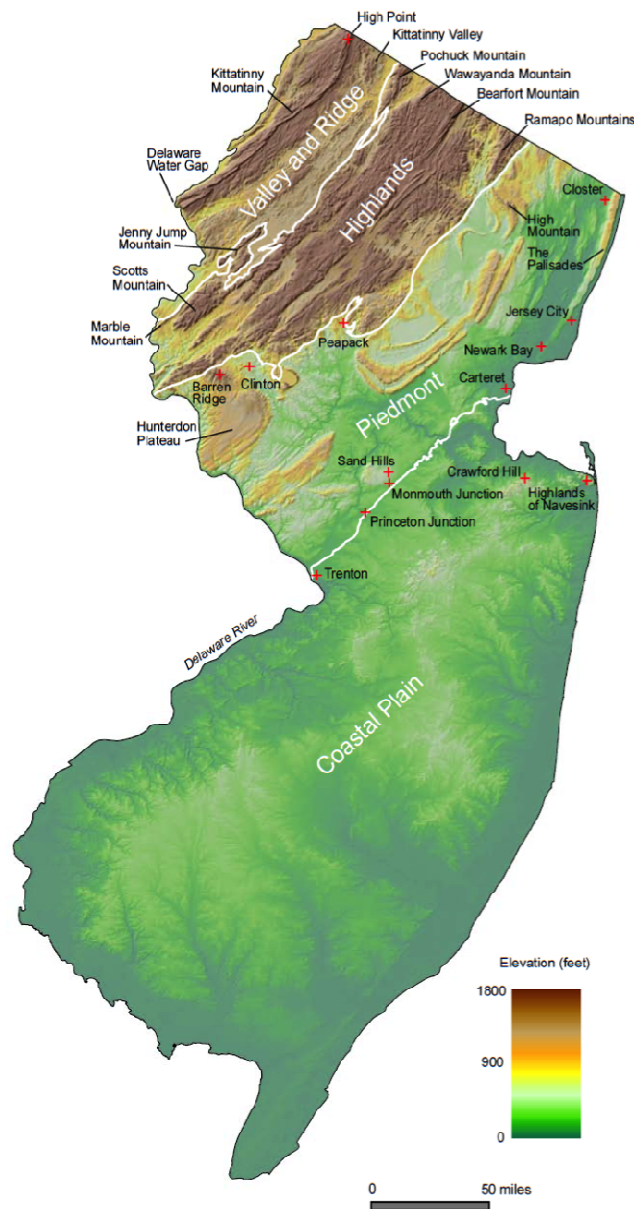

Figure 3.2. The Physiographic Provinces of the State of New Jersey from *Dalton*, *2003*.

3.3   Water Supply Wells

Water supply wells are commonly constructed with a long pipe (casing) that penetrates sediments or fractured rocks below the water table (see *Harter, 2003* for further information). Slots in the casing, referred to as a well screen, allow groundwater to move through the aquifer(s) and into the well. Typically the well screen is surrounded by a sand or gravel pack during installation. Precautions in well construction are commonly taken to prevent the downward flow of water into the aquifer from locations above the screened interval. Supply well screens are typically long, intersecting a range of sediments that derive water from various recharge locations. Pumping water from a well will continually move water from recharge locations, through sediments, and to the well.

In New Jersey, wells can be quite shallow, or very deep. In 2002, the reported range of depth of groundwater wells ranged from 15 feet to 1,984[9]. Shallower wells are more vulnerable to contamination because of shorter flow paths.

3.3.1   Groundwater Age

"[Groundwater] velocities under typical hydraulic gradients can range from a few millimeters per year to a meter per day" (*Squillace et al., 1998*). As such, travel times from recharge locations to discharge locations, such as an individual supply well, commonly range from years to centuries (e.g., *Fogg et al., 1998a; Johnson et al., 2000*). The time a 'packet' of water spends in the groundwater is referred to as its age. Although groundwater ages are commonly expressed as average values, water pumped from a well is derived from a mix of different recharge locations resulting in a mix of different ages (times of travel to the well) in any given sample (e.g., *Busenberg and Plummer, 1992; Fogg et al., 1998a; Weissmann et al., 2002; Bethke and Johnson, 2002*). Additionally, supply wells will commonly draw a significant fraction of older water (*Fogg et al., 1998a; Weissmann et al., 2002*). Therefore, it would not be surprising, for example, to find groundwater with an average age of 50 years resulting from a mix of waters that range from tens to hundreds of years in age.

3.3.2   Vulnerability to Contamination

The vulnerability of a water supply well to contamination depends upon the travel time from contaminant source areas to the well screen, which in turn, depends in part upon hydrologic conditions, well placement, well construction, and pumping rate. As a general rule, shallow groundwater is more vulnerable to contamination than deep groundwater, due to its proximity to the land surface, and therefore contaminant source areas. Poor well construction can result in rapid pathways for flow of shallow groundwater down a high-permeability gravel pack, increasing the vulnerability of both the aquifer and the well to contamination. Private wells are generally more susceptible to contamination than public wells, as they tend to be shallower and of poorer construction with regards to minimizing contamination (*Happel et al.,*

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[9] From Source Water Assessment Program (SWAP) http://www.nj.gov/dep/swap/faq.htm last accessed

1998).

The aquifer systems of New Jersey are generally vulnerable to contamination. A study by the Northeast States for Coordinated Air Use Management (*NESCAUM, 1999*) on the occurrence of MTBE in the NESCAUM region noted that:

> "Aquifers in the coastal plain of southern New Jersey are composed of unconsolidated sand and gravel aquifers. The surficial aquifers are highly vulnerable to contamination due to their permeability and direct hydraulic connection with the surface. There are also deeper lying confined aquifers beneath the surficial aquifers. The deeper aquifers are generally less susceptible to contamination but there may be locations where the aquifer outcrops at the surface, forming recharge areas that provide potential points of contamination. In northern New Jersey, fractured bedrock aquifers are more common. The aquifer types differ in geology (sandstones, mudstones, shales, crystalline bedrock), which will result in differences in geochemistry, degree of fracturing, and other physical characteristics. In general, however, the different types of fractured bedrock aquifers are all vulnerable to contamination, especially at shallower depths near the surface. Another type of aquifer in northern New Jersey was formed by the retreat of glaciers. These "valley-filled" aquifers are generally comprised of unconsolidated gravel, sand, or silt deposits that are highly permeable and susceptible to contamination from the surface"

The vulnerability of the Trial Sites is addressed below in section 4 of this report.

4. The New Jersey Trial Sites

In this section I review information obtained from the ten Trial Sites in New Jersey. Based on information gathered so far, the patterns observed at these sites, especially with regards to MTBE and TBA, are consistent with many others observed across the nation. At several of the sites, as I discuss herein, contamination is only discovered after a receptor has been impacted, or during tank closure operations. Often, the sites have multiple releases and unknown volumes of fuel released. Because site characterization, monitoring, and remediation most often do not start immediately after the release occurs, the plumes tend to migrate offsite and are difficult to delineate. Furthermore, the monitoring network tends to be shallow or limited to the site, and as such, vertical and horizontal delineation of plume extent may not be complete. MTBE, being more mobile and persistent than other gasoline components, tends to travel farther than the other contaminants at these sites, impacting larger volumes of water.

The SDWIS and PWTA data discussed previously can be used to assess the relative vulnerability of the regions occupied by sites. Figures 4.1 and 4.2 plot detections of MTBE at or above 1.0 ppb in the states public water supply systems and private wells tested for MTBE, respectively, against the physiographic provinces of the state. The data are summarized in Tables 4.1 and 4.2 showing the relative detection frequencies (percent of wells tested with detections) by province. The detections frequencies are a function of the collocation of MTBE sites and wells and the hydrogeologic characterics of the region. These data can be referred to in assessing the relative vulnerability of the regions in which the trial sites are located.

Below is a summary of some of the details of contamination at each of the ten sites. The locations of these sites, in relation to the counties of New Jersey, can be seen in Figure 4.3. This summary is based on information available to me at this time. Based on this information, it is clear that MTBE has impacted the underlying aquifers at each of the ten sites, and has impacted drinking water supplies at several of them. Remediation (primarily groundwater extraction and or soil vapor extraction employed at some of the sites) can remove some of the contaminant mass near the release source. However, contamination mass not captured by remediation is free to travel with groundwater and is likely to impact other nearby receptors as it travels away from the source.
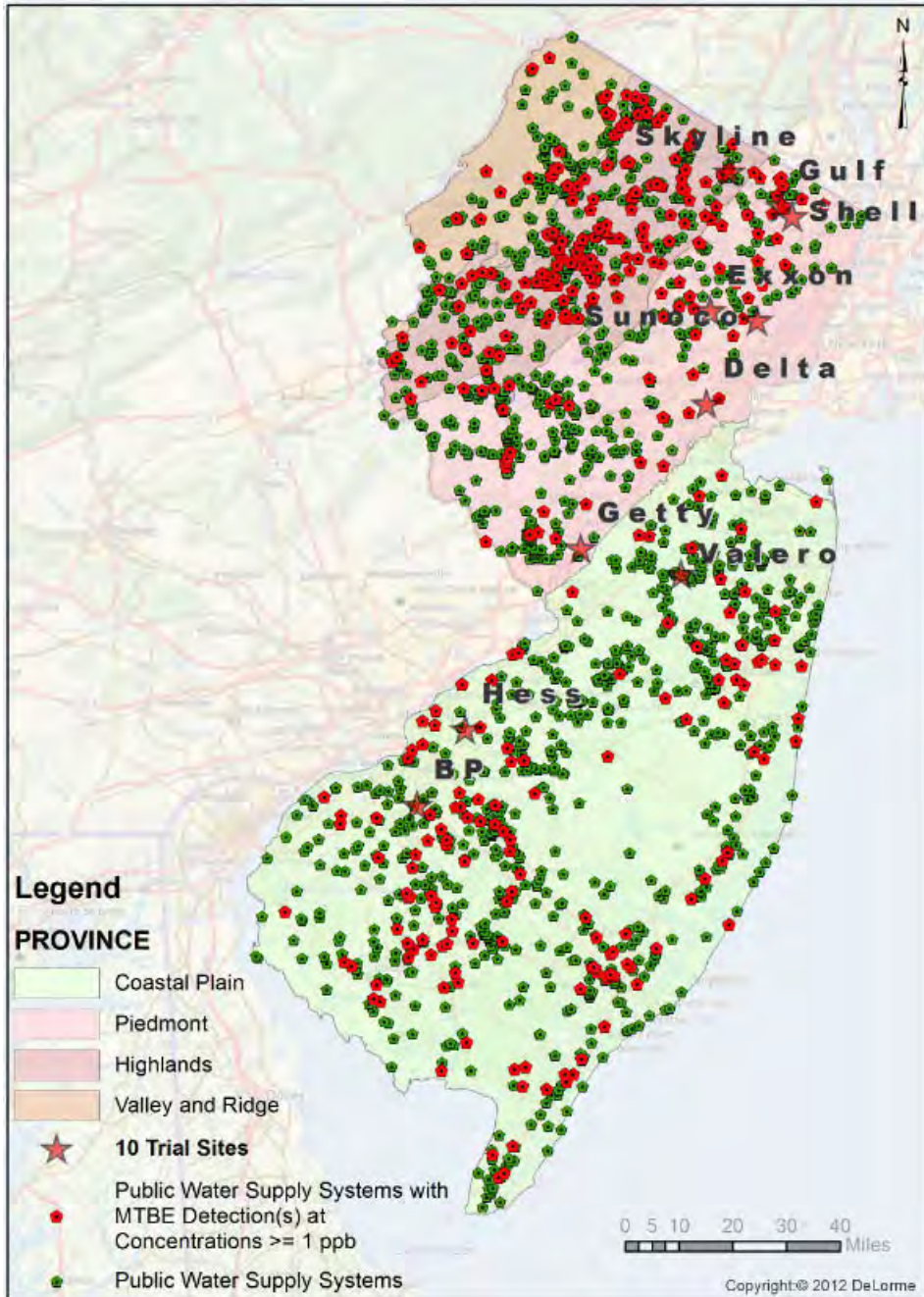
Figure 4.1. Public water supply systems with detections at or above 1.0 ppb plotted against provinces in New Jersey. Data are from the state's SDWIS database.
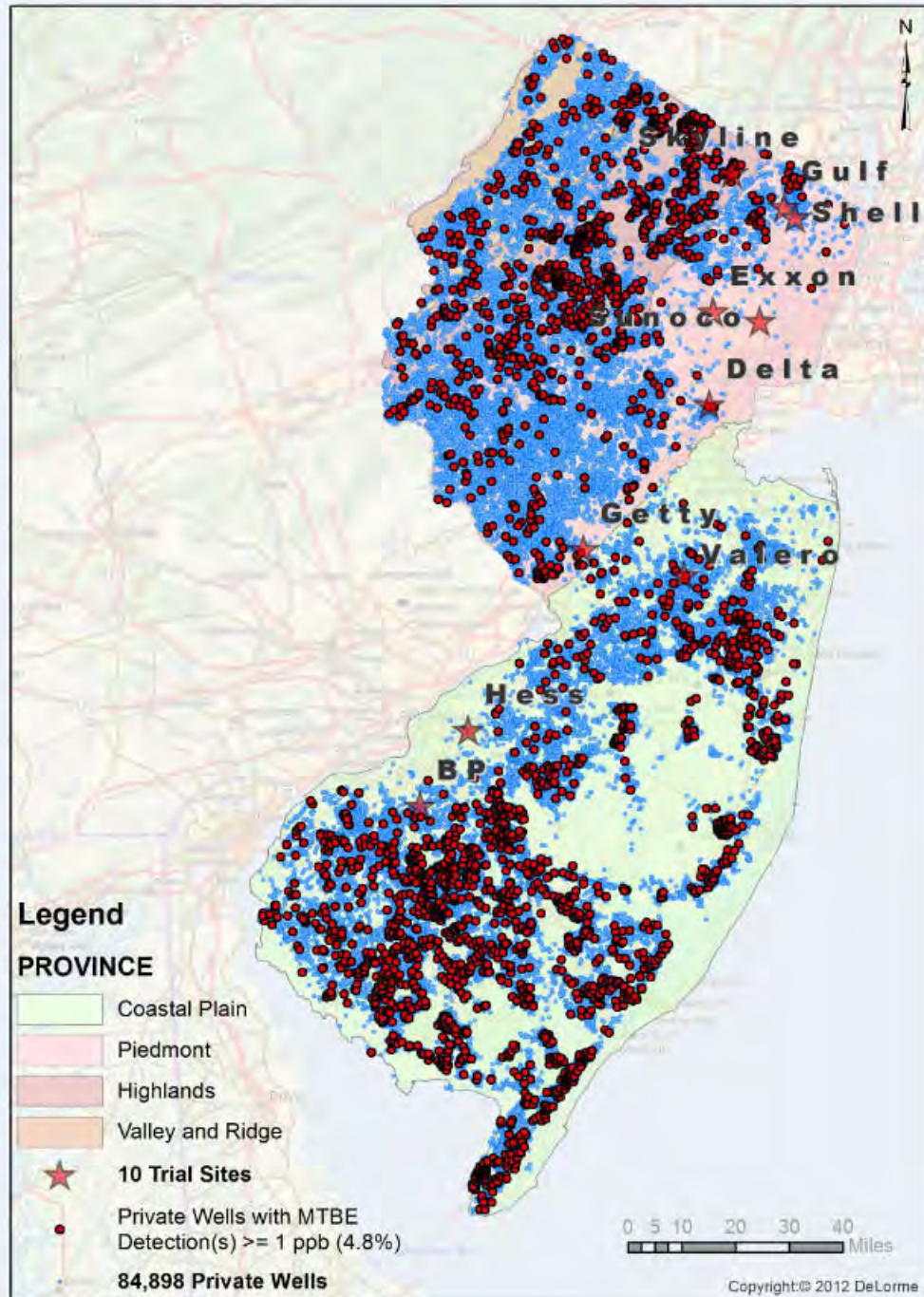
Figure 4.2. Private wells with detections at or above 1.0 ppb plotted against provinces in New Jersey. Data are from the state's June, 2011 PWTA database.

Table 4.1: Detection frequencies of MTBE in public water supply systems by province.

PROVINCE	# of Systems Sampled	# of Systems with detection	# of Systems with detection >= 1 ppb
Coastal Plain	889	210 (23.6%)	145 (16.3%)
Piedmont	387	114 (29.5%)	63 (16.3%)
Highlands	460	199 (43.3%)	139 (30.2%)
Valley and Ridge	165	47 (28.5%)	30 (18.2%)
Total	1901	570 (30.0%)	377 (19.8%)

Table 4.2: Detection frequencies of MTBE in private wells by province.

PROVINCE	# of Wells Sampled	# of Wells with detection	# of Wells with detection >= 1 ppb
Coastal Plain	42,964	7,520 (17.5%)	2,654 (6.2%)
Piedmont	16,205	826 (5.1%)	260 (1.6%)
Highlands	19,131	2,677 (14.0%)	1,044 (5.5%)
Valley and Ridge	6,226	383 (6.2%)	130 (2.1%)
Total	84,526	11,406 (13.5%)	4,088 (4.8%)

As will be explained in detail in the following chapter, without significant biodegradation, MTBE attenuation in groundwater is generally poor (see Chapter 6 for details). To my knowledge, there was no documented evidence of biodegradation of MTBE or TBA at any of the ten Trial Sites in New Jersey. Without biodegradation, MTBE (and TBA) mass will persist and continue to move with the groundwater to impact large volumes of water for many years to come.

4.1 TS#1 Skyline

The site is located at 236 Skyline Drive Ringwood, in Passaic County. The surrounding topography is "characterized by gently rolling terrain." The site is located along a steep slope, with residential property down gradient from the site, and Skyline Lakes located approximately 0.3 miles to the west of it.

Geology and Hydrology: The geology of the site is characterized by stratified glacial drift overlying fractured metamorphic rock. The overburden is estimated at 10 to 20 feet in thickness and contains sands and gravels with varying amounts of silts. Groundwater is shallow, somewhere between 7 and 12 feet below ground surface (bgs) based on monitoring well records dating back to 1998[10]. Groundwater in the shallow overburden flows in a southerly direction towards High Mountain Brook, which discharges into Upper Skyline Lake. In the bedrock, the water level in monitoring wells offsite ranges from 1 to 34 feet bgs (*Louis Berger Group, 2011*).

Groundwater flow in the bedrock appears to follow a similar direction to that in the overburden, south

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[10] The Louis Berger Group (2009b) report.

towards High Mountain Brook and Upper Skyline Lake (*Louis Berger Group, 2011*). However, because of the nature of fracture structure, groundwater flow in the bedrock aquifer is not well mapped:

> "Groundwater flow is influenced by fractures sub-parallel to the unnamed fault and by intersecting joint sets, therefore it is interpreted that groundwater flow is most likely in the south and west direction. The near vertical fractures and faults may also influence groundwater flow onsite and offsite. In addition, the pumping (and the termination of pumping) of potable wells is likely to have had an effect on groundwater flow" (*Louis Berger Group, 2009b*).

Site history: The site has operated as a car repair center and a gasoline vendor since 1984. According to the consultant's report (*Louis Berger Group, 2009a*) the underground gasoline storage tanks were placed in the bedrock at the time of installation: "During construction, local bedrock was blasted and carved out to allow for the installation of the Underground Storage Tanks (UST) used to store gasoline." As a result, contamination from the USTs very likely entered the bedrock fractures.
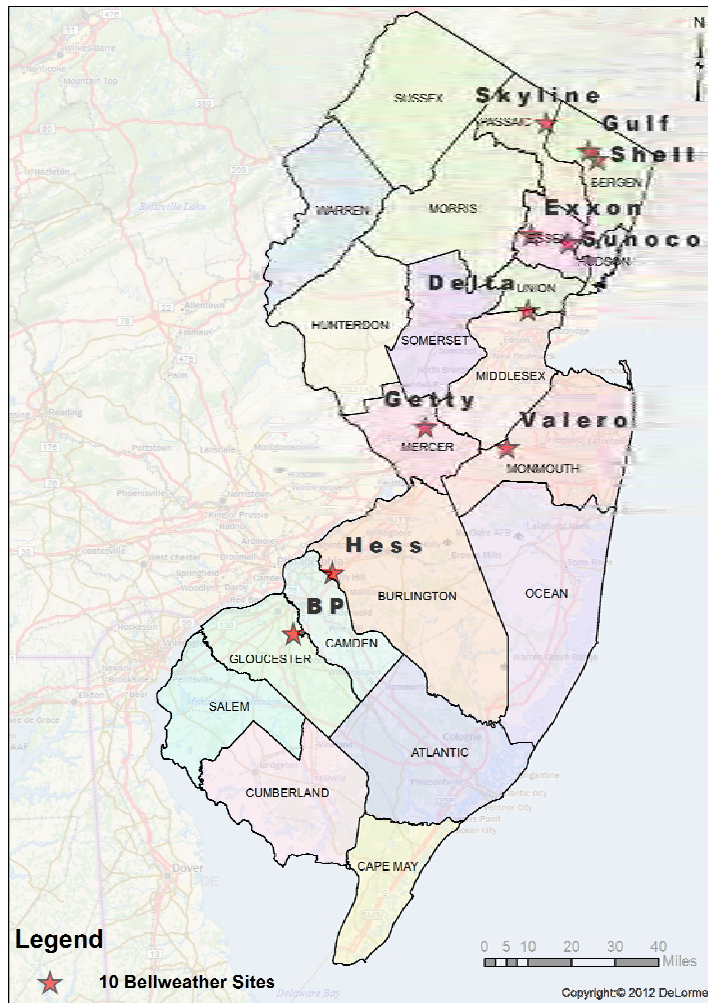

Figure 4.3: Location of the ten Trial Sites at issue in this case relative to the Counties map of the State of New Jersey.

Nearby Receptors: In 1998, the Passaic County department of Health (DOH) conducted limited sampling of residential wells nearby. MTBE and TBA contamination was discovered in 16 out of 18 domestic wells sampled at the time. Another round of sampling conducted in the summer of 2004 by NJDEP, in conjunction with the Ringwood Health Department, showed MTBE and TBA contamination in 29 out of 44 domestic wells in the area south and southwest of the site (*Louis Berger Group, 2009b*). As a result, "all associated residents on potable wells moved to public water by spring 2005" (*Louis Berger Group, 2009b*).

Sampling of three monitoring bedrock wells conducted in 2009 shows MTBE contamination in one of the wells (SCC01D) above the groundwater quality standard (GWQS) at all depth intervals (ranging from 45 to 195 feet bgs). Benzene was not detected in any of the intervals, in any of the three wells.

4.2 TS#2 Valero

The site, a Valero service station, is located at 436 Route 33 West, Manalapan, in the county of Monmouth. The site has operated as a gasoline station since the 1950's. Nearby topography is generally flat, with the nearest surface water body (a tributary to Millstone River) is approximately 2,160 feet southwest of the site.

Geology and Hydrology: Consultants' report (*Sovereign Consulting 2011*) describes the local geology as consisting primarily of unconsolidated deposits "consisting mostly of sand, quartz, and mica, fine gravel, silty and clayey, massive to thick-bedded dark gray to medium gray clay."

Groundwater at the site occurs at 10 to 12 feet bgs, and flows to the southeast. The depth to bedrock in the area is unknown. The consultants' report indicates a hydraulic conductivity of 5.75 – 9.59 ft/day (0.002 – 0.0034 cm/sec) was used in modeling the MTBE plumes. A seepage velocity of 26.2 – 44.6 ft/yr was assumed, and the hydraulic gradient was estimated at 0.0038 ft/ft.

Site History: Based on a letter from the NJDEP, underground storage tanks were removed from the property in 1995, but no closure report was submitted. The letter from the NJDEP ("Notice of Deficiency") dated June 2007, notes that a closure report was not submitted when fuel tanks were removed from the site in 1995 (*Sovereign Consulting 2011*). The letter also notes:

> "failure to delineate the horizontal and vertical extent of contamination to the applicable remediation standard, including the extent to which contamination has migrated off the property…
>
> failure to delineate the vertical and horizontal extent of ground water contamination and the sources of ground water contamination, including free and residual product…
>
> failure to properly sample potable and supply wells which are suspected to be contaminated…"[11]

In 2005, piping connecting the dispensers to the underground storage tanks was upgraded. Soil samples collected during the upgrade operation showed MTBE contamination. Further sampling indicated the presence of other contaminants including TBA and BTEX. Groundwater monitoring was started in 2006 and was limited to 4 wells on site. In 2011 two additional monitoring wells were installed at the edge of the

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[11] Bates stamp # SOVCON015069 and SOVCON015070