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Something in the Water? Testing for Groundwater Quality Information in the Housing Market

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I test the level of information regarding possible groundwater contamination in the residential real estate market in Washington County, Minnesota. An approximately seven square-mile trichloroethylene plume has affected hundreds of households' water supplies since at least 1988 in the region. I find that homeowners were initially well-informed by market forces, but were later somewhat misinformed by government actions regarding the potential of water contamination from the plume. A disclosure law passed in 2003 may have added new, low-cost, and imperfect information to the market that could explain the change in informational awareness.

Key words: disclosure law, environmental disamenity, groundwater, groundwater contamination, hedonic model, incomplete information, water quality, real estate

Introduction

In 1988, an extensive plume of trichloroethylene (TCE), which the U.S. Environmental Protection Agency lists as a potential carcinogen, was discovered in the groundwater in Baytown Township, Washington County, Minnesota. Many houses and businesses in the area rely on groundwater as the primary source for water consumption. So, the Minnesota Pollution Control Agency (MPCA) and the Minnesota Department of Health (MDH) subsequently took actions to limit human exposure to TCE and to prevent further spread of the contaminant plume. The contaminant plume is an environmental disamenity that may negatively affect real estate prices in the area. Well-water measurements of TCE levels by the MPCA, as well as other actions taken by MPCA and MDH, contain information that may affect real estate values in different ways, and these effects may not be limited to only those houses situated on the plume. If the real estate market is completely informed about the plume's location, then any negative effect on real estate prices should occur only where houses could access contaminated water or where contaminated water may occur in the future. Conversely, if the market is not completely informed about the plume's location, then houses that will likely never be affected by the plume could experience a loss in property value.

In this paper, I test for the presence of complete information, incomplete information, or no information regarding the quality of groundwater in the residential real estate market near the Baytown Township Groundwater Contamination Superfund Site (Baytown Site or the Site). I also test the effects of state regulations regarding the Site on information levels and, correspondingly, prices in the real estate market. The hypotheses that I test are:

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Hypothesis 1: Housing prices reflect no information regarding groundwater quality (this is observationally equivalent to the hypothesis that market participants simply do not value groundwater quality).

Hypothesis 2: Housing prices reflect incomplete information regarding groundwater quality. This hypothesis might hold if market participants rely on imperfect proxies such as distance from the contaminant source or state and local regulations for information about present and future groundwater quality.

Hypothesis 3: Housing prices reflect complete information regarding groundwater quality. This hypothesis might hold if market participants rely on groundwater tests at each house for information about present groundwater quality and are able to reliably predict future groundwater quality.

One focus of this paper is to determine whether governmental regulations regarding the Baytown Site induce market reactions. For example, one regulation resulted from the special well construction area (SWCA) legislation, passed in 1988 and subsequently revised in 2002. The SWCA legislation and a later statute could affect the real estate market in two ways. The first is the geographic delineation of the area that would be included in the SWCA; any work done on wells inside this area required special permits and inspections, increasing the cost of new well construction. The geographic boundaries of the SWCA do not match the edges of the groundwater contamination plume, and, furthermore, the boundaries of the SWCA changed once over the time period I examined in accordance to changes in regulatory policies regarding the relative toxicity of TCE. Market participants may rely on the delineation of the SWCA as a proxy for the probability that a house will have contaminated groundwater, negatively affecting real estate value inside the SWCA. The second way the SWCA may, indirectly, affect the real estate market is through a Minnesota statute passed in 2003 requiring sellers of property in Washington County to disclose to prospective buyers if property is located within the SWCA. It is possible that market participants did not possess information about the SWCA prior to the disclosure law, or that market participants interpreted the creation of a SWCA disclosure law as a signal that all houses in the SWCA might possess contaminated water. If the disclosure law either added information regarding groundwater quality or lowered the cost of information gathering, housing prices in the SWCA might respond accordingly.

The results indicate that during the 1995 - 2002 period, the market was well-informed about the location of the contaminant plume. Houses that are in the SWCA but not at risk of contamination did not suffer any loss in property value, while those that are at risk of contamination did. In the period from 2003 - 2006, after the passage of the disclosure law, houses in the SWCA that were not at risk of contamination lost property value relative to the previous period. Houses that were at risk of contamination suffered no more loss in property value than other homes (assumed not to be at risk) in the SWCA after the passage of the disclosure law. These results imply that market participants used the lowest-cost information available – namely, whether a house was located in the SWCA – regarding groundwater quality, even though that information was an imperfect proxy for the real distribution of risk. Alternatively, these results could indicate that market participants interpreted the disclosure law as a signal that the contaminant plume might expand, even though the plume had been relatively stable for many years.

Background

In the residential real estate market, some information about the valued components of a house is readily observable and quantifiable: a prospective buyer can tour a house, count the number of bedrooms, and test the functionality of bathrooms at a relatively low cost. Conversely, some components of housing are not as easily observable. For example, a prospective buyer would find it difficult to predict whether the neighborhood will offer adequate "peace and quiet" without spending a few weekends in the house listening for raucous neighbors, and prospective buyers regularly rely on professional house inspectors for information regarding structural integrity.

One implicitly-owned component of a house that is costly to observe is the quality of the groundwater beneath the property. Groundwater quality presumably would be an important aspect of houses with private wells used for water consumption. Also, groundwater quality may be important even if the house had a municipal water supply, because of the possibility of exposure to groundwater-borne contaminants through some medium other than consumption. While the present quality of groundwater at a given house can be tested at some expense, it is much more difficult to predict the future quality of groundwater at that house. One way to predict the future quality level of groundwater when there is a known contaminant source is to use a groundwater contaminant transport model. Such a model requires detailed information about the hydrological and geological features in an area, as well significant scientific and mathematical expertise. As an alternative, market participants may rely on proxies and signals to inform them of quality levels. There are many possible sources of information about groundwater quality. Some, such as well sample tests and effective groundwater contaminant transport models, are more accurate sources than others such as taste, smell, newspaper articles, word of mouth, distance from the contamination source, if known, or legislated zones like the special well construction area (SWCA). The less accurate sources might indeed create a misperception of health risk from consumption of groundwater if the information conveyed does not reflect the actual present and probable future groundwater contamination status. Conveyance of incomplete or incorrect information regarding groundwater contamination might induce market reactions where none would have otherwise occurred.

Similarly, economists have used a variety of proxies and measures of quality to estimate environmental disamenities. Several have linked physical measures of water quality to house prices.[1] More typically, however, distance from the contaminant source is the only variable available to researchers. For example, Kiel (1995) looked at sales data around two Superfund sites in Woburn, MA, using minimum distance to the nearest Superfund as a pollution proxy. Her results showed that announcement of Superfund status and initiation of Superfund cleanup did not reduce the estimated negative effect of the contaminated sites on house prices. In fact, Superfund status announcement and cleanup may have increased the magnitude of the disamenity.[2] In contrast, Gayer, Hamilton, and Viscusi (2002) find that site-specific information releases about risk levels led to both a lowering of risk beliefs and an increase in house prices.[3]

In the case of a publicly-known groundwater contamination site such as those in Kiel (1995) and Gayer, Hamilton, and Viscusi (2002), market participants may use some proxy for the probability of groundwater contamination, such as distance from the contaminant source, the aforementioned SWCA, or other government legislation requiring prospective buyers to be informed of a house's proximity to a groundwater contamination source. Two recent studies show that laws requiring disclosure of both obvious disamenities such as airport noise (Pope, 2008a) and more subtle disamenities such as risk of flooding (Pope, 2008b) can affect house prices. In this study, I note that proxies such as distance from a contaminant source and information from disclosures laws are often imperfect in their conveyance of house-specific risk information. In the case of groundwater, contaminants do not normally migrate away from their source at equal speeds in

[1] For example, Steinnes (1992) used Secchi disk readings, which measure turbidity, as did Michael, Boyle, and Bouchard (1996). Epp and Al-Ani (1979) used pH entered linearly or in dummy variables. Leggett and Bockstael (2000) used median coliform concentrations at each house. While these studies address surface water rather than groundwater, they use water quality variables that are not subject to an assumption of spatially uniform distribution.

[2] Other examples of studies that use distance as a proxy include Michaels and Smith (1990), which used distance to nearest hazardous site to measure the impact of hazardous waste sites on house prices in the Boston area and test for estimate stability across geographic markets. Kohlhase (1991) used distance and distance-squared to examine the impact on house prices of toxic sites in the Houston area that had been declared as Superfund sites. Nelson, Genereux, and Genereux (1992) used distance from a landfill in Ramsey, Minnesota, to estimate the effects of possible contamination on house sales.

[3] Other studies that show that market participants rationally process new information about risk include Viscusi and O'Connor (1984), Viscusi, Magat, and Huber (1987), and Smith and Johnson (1988).

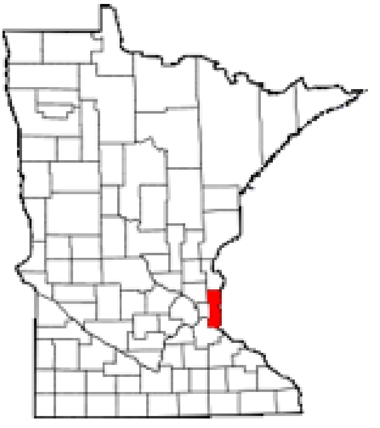

Figure 1. Location of Washington County in Minnesota

Notes: Washington County abuts the St. Croix River on the east, and St. Paul on the west. It is shaded in the figure above.

all directions, nor do they tend to follow county or township borders inside which legally created signals such as the SWCA exist. For instance, a house might be situated a very short distance from a contaminant source yet have almost zero probability of groundwater contamination from that source because contaminants are transported away from the house. In such a case, using distance from the contaminant source as a proxy for the probability of groundwater contamination from that source would result in an overestimation of that probability.

Baytown Site History

This paper focuses on the level of information regarding groundwater quality that is present in the real estate market surrounding the Baytown Site at different points in time and how that information is priced into the housing market. Figure 1 shows the location of Washington County in Minnesota. Table 1 details a chronology of Baytown Site events.

In 1987, a Minnesota Department of Health (MDH) sampling of wells near a landfill at Stillwater Prison showed the presence of trichloroethylene (TCE) and carbon tetrachloride (CCl4) in the groundwater. Subsequent testing showed that CCl4 was not widespread or at high levels, and the primary contaminant of concern became TCE. People who drink water containing TCE in excess of five micrograms per liter (μg/L) over many years could experience liver problems and may have increased cancer risk (U.S. Environmental Protection Agency, 2006). The Minnesota Pollution Control Agency (MPCA) tracked the plume to the Lake Elmo Airport, and in May 1988, MDH designated an area of Washington County including the known plume and its vicinity as a special well construction area (SWCA). One MDH document states, "The SWCA informs well owners and drillers about the potential for contaminated ground water [sic] in the area and serves to prevent further degradation of the aquifer by requiring proper construction of new wells" (Minnesota Department of Health, 2004, p. 10). The Baytown Site was added to Minnesota's State Superfund Permanent List of Priorities, while U.S. EPA added the site to the Superfund National Priorities List in 1995.

Further testing found significant quantities of TCE below the airport in two aquifers, the Prairie du Chien aquifer and the Jordan aquifer, both of which are used for drinking water. In 2000, based on a feasibility study finished in 1999, MPCA decided to install point-of-use granulated activated carbon (GAC) filter systems on certain private wells as the primary remedial action. Tests performed by the MPCA on post-filter samples showed that the GAC filter systems effectively

Table 1. Chronology of Site Events

Date	Event
6/1987	MDH sampling of private water wells surrounding the Baytown Dump detects several volatile organic compounds (VOCs), including TCE and CCl4.
5/1988	MDH establishes the SWCA.
1988	Site listed on the Minnesota Permanent List of Priorities (PLP).
12/16/1994	Site listed on the National Priorities List (NPL).
6/1995	MPCA assumed full responsibility for oversight of Site under the Enforcement Deferral Pilot Project.
1999	Consent Order.
4/1999	Feasibility Study (FS) completed for the site.
5/1999	Proposed Plan published.
5/2000	EPA and MPCA executed a Record of Decision (ROD).
1999 onward	Site wide water sampling and GAC installation initiated.
1988 to 2001	Metropolitan Airports Commission (MAC) conducted investigations at and near Lake Elmo Airport.
2002	MDH changes human risk limit for TCE from 30 micrograms/liter to 5 micrograms/liter.
2002	MPCA expands SWCA in accordance with new human risk limit.
2002 to 2004	MPCA conducts investigations designed to identify TCE source area.
2004	MPCA investigations succeed in locating primary TCE source area.
2004 onward	MPCA conducts investigation designed to further delineate the nature and extent of the TCE source area and to characterize the site.
2/2005	Feasibility study completed for TCE plume containment near source.
2005 onward	MPCA pursuing design, approval, and implementation of remedial actions addressing the groundwater contamination plume and source area.

Notes: Minnesota Pollution Control Agency Five-Year Review Report: First Five-Year Review Report, 2007b, p.2.

reduced TCE to below critical levels, "indicating that [GAC filtered-] well users were not exposed to the contaminants" (Minnesota Pollution Control Agency, 2007a, p. 9). Although the source of contamination was suspected to be underneath the airport, the actual location could not be identified so that it was not possible to remove or treat the source. Minnesota Department of Health's maximum allowable level of TCE was 30 μg/L. Houses that had water with TCE above 30 μg/L received GAC filters. Six filter systems were installed under this policy prior to 2002. A change in the human risk limit in 2002 resulted in many more houses receiving GAC filters at MPCA's expense. As of March 2007, a total of 162 GAC filters had been installed and paid for by MPCA. Houses that were built on parcels platted after April 9, 2002 that had TCE measured above 5 μg/L in private wells were required to install GAC filter systems, but the MPCA did not pay for these.

The TCE plume covered about seven square miles in central Washington County in March 2007. Approximately 650 homes and several businesses rely upon private wells that use the contaminated aquifers. The MPCA monitors public sentry wells (monitoring wells) and many private wells in the area, and offers bottled water to residents whose wells exceed the human risk limit until GAC filter systems can be installed.

Special Well Construction Area

Legislative and institutional controls may be a source of information for real estate market participants. One institutional control was the establishment of the special well construction area (SWCA), the legislation for which was passed in 1988 and revised in 2002. Two factors related to the SWCA could affect the real estate market. The first is the delineation of the area that would be included in the SWCA. The second is a Minnesota statute (Minn. Statute 103I.236) passed in 2003 that required sellers of property in Washington County to disclose to prospective buyers whether the property is located in the SWCA. The disclosure must occur if property is not served by a municipal water system or contains an unsealed well.

The original SWCA legislation identified a geographic area encompassing the known plume as well as an extra buffer area. At that time, the U.S. EPA had determined that the maximum allowable TCE contaminant level in drinking water was 30 μg/L; MDH had adopted the same standard, setting its human risk level at 30 μg/L. Accordingly, the primary goal for MDH was to ensure that residents were not consuming water with TCE above the accepted human risk level, and created the original SWCA with this human risk level in mind. Later, however, regulators expanded the SWCA both as additional testing discovered the full extent of TCE migration and as EPA policy regarding the maximum contaminant level for TCE changed. The SWCA has substantial limitations on the construction, sealing, repair, and location of wells (Minnesota Rule 4725.3650 U.S. Environmental Protection Agency, 2006; Minnesota Pollution Control Agency, 2007a). Conversations with well drillers licensed to drill in and out of the SWCA in Washington County (McCullough, 2007; Sampson Brothers Drilling, 2007) revealed that the costs of drilling a new residential well inside the SWCA range from $5,000 to $20,000 more than drilling a well just outside of the SWCA border.

Importantly, house location in the SWCA does not always imply a significant increased risk of groundwater contamination compared to locations outside the SWCA. The original SWCA is shown in figure 2, and the expanded SWCA is shown in figure 3. Additionally, figures 4 and 5 show the expanded SWCA in relation to the 5 μg/L plume contours in years 1999, 2001, 2002, and 2003. As of 2007, the SWCA was a 12.5 square-mile area surrounding the Baytown Site that did not perfectly match the known contaminant plumes. According to an MDH summary of the Baytown site published in April 2006, "The SWCA includes a generous border area outside the plume. Many wells within the SWCA are too far from the plume to be affected [by TCE contamination]" (Minnesota Department of Health, 2006, p. 1). As figures 4 and 5 show, the SWCA is drawn along county quadrant and half-quadrant borders, while the plume is not nearly so well-behaved.

The second component of the SWCA is the statutory requirement of disclosure to prospective buyers whether the property is located in the SWCA if it is not served by a municipal water supply or has an unsealed well. This statute, which went into effect at the beginning of 2003, may have changed the amount or nature of information present in the market regarding groundwater quality. One goal of this paper is to determine whether there is a difference in the effect of actual groundwater contamination on house prices and the effect of location in the SWCA, because a house could be in the SWCA and not have any TCE contamination problems. If the market reacts to possible water contamination, does it react only where houses have a reasonable possibility of water contamination, or does it react to the larger, legislatively-defined zone in which some houses do not have a reasonable possibility of water contamination? In this paper, a "reasonable possibility of water contamination" is based on MPCA investigations and conclusions. The market could, of course, have a different opinion about which houses have a "reasonable possibility of water contamination."

Changing the Human Risk Limit

Other legislation may have effects as well. In January 2002, Minnesota Department of Health responded to a draft EPA health risk assessment for TCE by changing the human risk limit from 30 μg/L to 5 μg/L. This resulted in an increase in the area of concern and caused a substantial expansion the SWCA. Many more residential wells were suddenly classified as having groundwater with TCE above the newly-adopted human risk limit. Anecdotal evidence gleaned from local newspaper articles and conversations with residents indicates that residents reacted with much concern. Some residents appear to have used bottled water for all domestic (including pet) consumption despite the installation of new GAC filters (Associated Press, p. 1). Other residents worried that the water they consumed while the human risk limit was at 30 μg/L would have long-term negative health consequences (Associated Press, p. 1). The increase in media coverage resulting from the change

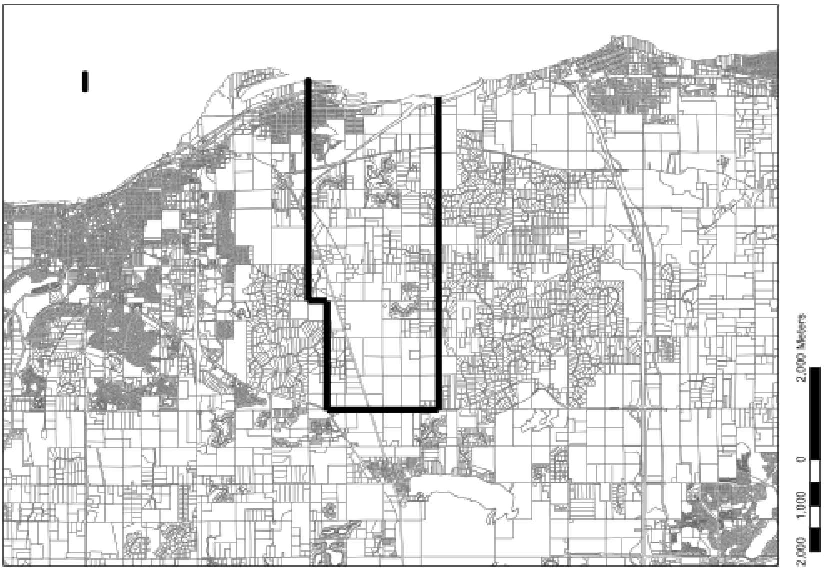

Figure 2. Original SWCA

Note: The solid black line shows the border of the SWCA prior to its expansion in 2002.

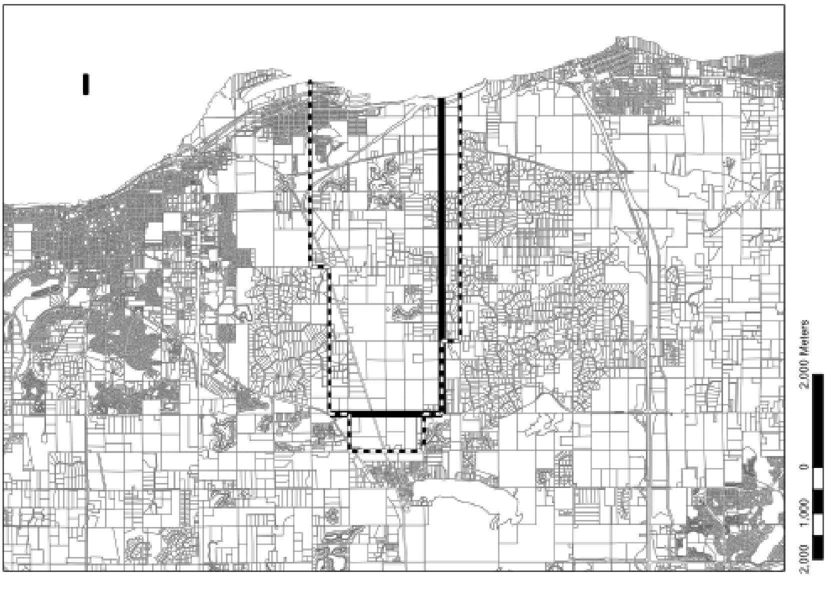

Figure 3. Expanded SWCA

Notes: The dotted line shows the border of the SWCA after its expansion in 2002. The solid black line shows the old border of the SWCA on the west and southern ends, where the expansion took place. The expanded SWCA is 12.5 square miles.

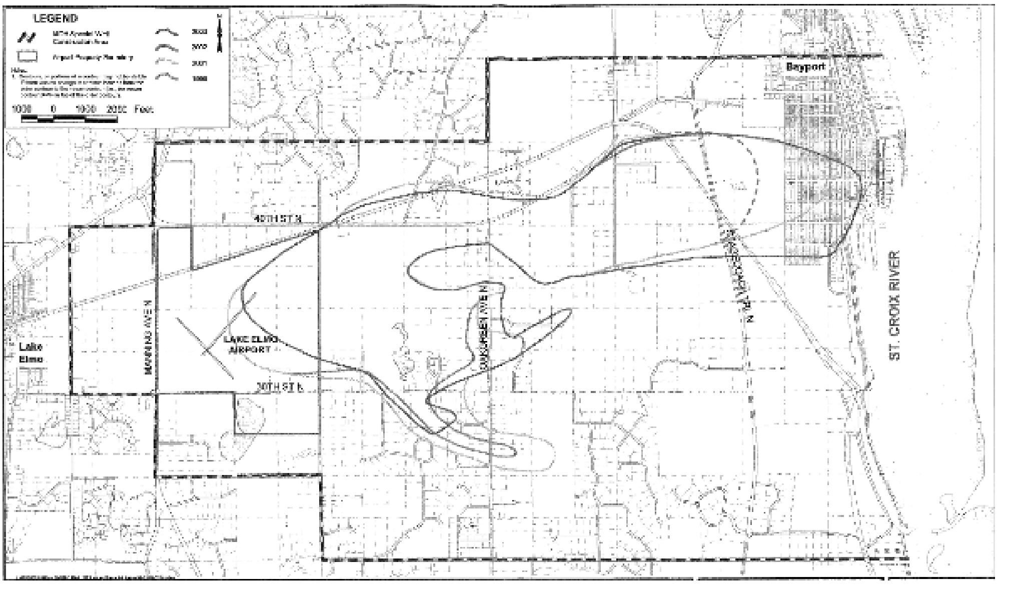

Figure 4. Expanded SWCA and the 5 Microgram per Liter TCE Contour in Jordan Aquifer

Notes: This shows the 5 μg/l TCE contour in the Jordan aquifer in years 1999, 2001, 2002, and 2003. The edges of the contour change somewhat across years, particularly in the east near the St. Croix River and Bayport. The dotted line around the perimeter is the expanded SWCA. Source: Wenck Associates, Inc.

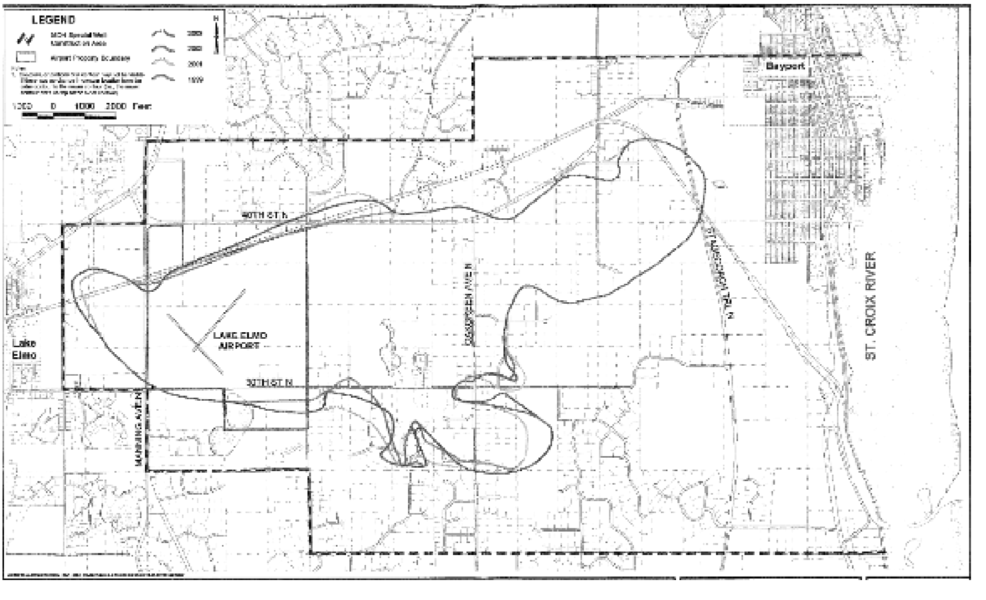

Figure 5. Expanded SWCA and the 5 Microgram per Liter TCE Contour in Prairie Du Chien Aquifer

Notes: This shows the 5 μg/l TCE contour in the Prairie Du Chien contour in years 1999, 2001, 2002, and 2003. The edges of the contour are relatively stable across time. The dotted line around the perimeter is the expanded SWCA. Source: Wenck Associates, Inc.

probably created a greater public awareness of the possibility of groundwater contamination in the area.

Any change in a human risk limit may have consequences for the real estate market. The change might induce people to mistrust human risk limits as determined by governmental agencies. As a result, even if MPCA declares that some houses have no reasonable probability of future contamination, potential buyers might still believe that those houses do face some risk. Indeed, market participants might conclude that no human risk limit set by the MPCA is reliable, that homes that are outside the SWCA might eventually be inside the SWCA, or that the plume will spread in the future.

The lower human risk limit resulted in many more houses qualifying for MPCA-financed GAC filters; houses that existed on property platted before April 9, 2002, and had private wells with TCE levels above the human risk limit received MPCA-financed GAC filters. On average, each filter cost $1,500 to install and $450 every two to six years for replacement and maintenance (Minnesota Pollution Control Agency, 2007b, p. 2, 10). Any wells installed on property platted after April 9, 2002, that accessed groundwater containing TCE levels above the stated limits, however, were required to have GAC systems installed that would not be paid for by MPCA.

Methods and Data

I follow Rosen's (1974) hedonic model, which assumes that consumers maximize utility by choosing the characteristics of the house they buy, given a competitive housing market with a continuous equilibrium price schedule for house characteristics. Consumers can affect the price they pay by choosing which house and bundled characteristics they buy, but they cannot affect the equilibrium price schedule (Palmquist, 2003, p. 3-4).

Empirically, the hedonic model is estimated by using data on the prices of houses and their characteristics, such as numbers of bedrooms and bathrooms, square footage, etc. One innovation of this research is the inclusion of multiple variables which measure information regarding the probability that a particular house has, or will eventually have, contaminated groundwater. The binary variables "measured and not filtered" (m_{it}) and "SWCA" (s_{it}) indicate whether a house had a TCE reading of its well water done (as reported by MPCA) at any time prior to the sale and whether a house is located inside the SWCA, respectively.[4] The hedonic model attempts to predict house prices by quantifying and estimating the marginal prices of all observable house characteristics, while assuming there is an unobserved stochastic element. The most appropriate functional form of estimable hedonic models (e.g., linear, semi-log, log-linear, etc.) is an empirical question. Cropper, Deck, and McConnell (1988) found that linear, semi-log, and linear Box-Cox forms provided the best accuracy for predicting marginal component prices. In this paper, a semi-log functional form was chosen. The estimation equation is:

$$p_{it} = \alpha + \beta x_{it} + \gamma y_i + \mu m_{it} + \sigma s_{it} + \tau T_{it} + \varepsilon_{it}, \tag{1}$$

where:

p_{it} = natural log of adjusted price of house i at time t (nominal price was adjusted by a GDP deflator, base year 2000),
x_{it} = physical characteristics of the house (square footage, bathrooms, age, lot size, etc.),
y_i = locational attributes of the house (school district, proximity to lake or river, etc.),
m_{it} = "measured and no filter" dummy, equal to 1 if house i had its well tested for TCE prior to time t and did not receive a GAC filter prior to time t,
s_{it} = SWCA dummy, equal to 1 if location of house i is in the SWCA at time t, 0 otherwise,

[4] I use "measured and not filtered" as a variable rather than the more obvious variable, "measured TCE level," because of the possibility of measurement error in the latter.

T_{it} = time dummy, equal to 1 if sale of house i at time t occurred in year T, and
ε = iid disturbance term capturing other factors determining housing price. A full listing of components included in the above variable vectors is provided in table 2.

The primary variables of interest in this baseline specification are s_{it} and m_{it}. The coefficients on these variables will provide tests of the three hypotheses presented in table 3. The hypothesis tests rely on two assumptions. The first is that GAC filters effectively render water at houses free of TCE. The second is that m_{it} is an accurate proxy for the probability that a house might eventually have contaminated groundwater.

Two important estimation issues must be addressed in a hedonic model: spatial extent of the housing market and the temporal stability of parameter estimates.

Spatial Extent of the Market

The hedonic model estimates an equilibrium price schedule for house components in a single market. Problems can occur when separate markets are treated as one single market, particularly when the variable of interest is observed only in one of the markets. According to Palmquist, "if there are a reasonable number of consumers who would consider the alternative areas [as substitutes], then those areas can be treated as a single market, even if many people only consider one or the other [area]" (Palmquist, 2003, p. 26). Nevertheless, most researchers consider an urban area to be a single market, and urban areas often encompass multiple counties. I treat all of Washington County as a single market. Alternative specifications were investigated, such as using only the central portion of the county, which centers on the plume. The results do not differ substantially; all coefficient estimates were similar in sign and significance levels. Furthermore, I include township fixed effects (32 townships) in all regressions.

Temporal Stability

More important to this study is whether the values of the various characteristics of houses were relatively stable over the period studied and, if they were not, whether this affects estimates on the variables of interest. I test information levels regarding groundwater quality present in the real estate market by estimating changes in the coefficients on s_{it} and m_{it} after certain events which might alter the content and amount of information present in the market, such as the expansion of the SWCA and the enactment of the SWCA disclosure law. These estimates will be valid only if the contributions of the other house characteristics to the value of the house were stable over time (Palmquist, 2003, p. 26) or if the contributions of other house characteristics are orthogonal to the coefficients of interest. I collected data from January 1, 1980, to December 31, 2006. However, any pooling of data over this entire time period would likely be inappropriate, because the housing market in Washington County changed drastically over the same period. In the 1980's, Washington County was largely agricultural. However, in the late 1980's and early 1990's, large farms were gradually transformed into suburban-type subdivisions because of the proximity of St. Paul, MN.[5]

I pooled data from 1995 through 2006 because it appears that after 1995 the average parcel size in each year had stabilized. Furthermore, I include yearly fixed effects in all regressions.

Data

House sales and house characteristic data were taken from the Washington County Tax Assessor's website. Government legislation variables, such as the delineation of the SWCA, were created using

[5] Despite this suburbanization process, there remained large amounts of unused parcels and agricultural lands in the county as of 2007.

Table 2. Definitions of Variables

Variable	Definition
realprice	GDP deflator-adjusted sale price of the house, in dollars
Lnprice	natural log of realprice
Age	age of house at time of sale = year sold less year built; negative values of age were changed to zero.
Agesq	newage squared
Tla	total living area, in square feet
Lotarea	size of parcel, in square feet
bedroomss	number of bedrooms
Full	number of full bathrooms
Half	number of half bathrooms
threequart	number of 3/4 bathrooms
Deluxe	number of deluxe bathrooms
fireplace	number of fireplaces
add1	area of 1st addition in square feet, if it existed at time of sale
Addn	area of n^{th} addition in square feet, if it existed at time of sale
gar1	area of 1st garage in square feet, if it existed at time of sale
Garn	area of n^{th} garage in square feet, if it existed at time of sale
Ac	dummy indicating presence of central air-conditioning system
porcharea	area of porch(es) in square feet
deckarea	area of deck or patio in square feet
river_dist	convex index between 0 and 1 indicating proximity of a house to a river. $river\_dist = max[1-(d/d_{max})^{1/2}, 0]$, where d is the distance to the nearest river in meters and is d_{max} set to 500 meters. If $d > 500$, $river\_dist = 0$.
lake_dist	convex index between 0 and 1 indicating proximity of a house to a river. $lake\_dist = max[1-(d/d_{max})^{1/2}, 0]$, where d is the distance to the nearest lake in meters and d_{max} is set to 500 meters. If $d > 500$, $lake\_dist = 0$.
read_nofilt	dummy variable equal to one if a house had its TCE level measured by the MPCA prior to sale and had not received a GAC filter system, zero otherwise.
Swca	dummy variable indicating location inside the SWCA at time of sale

Table 3. Null Hypotheses

Hypothesis Tested	Variable(s) of Interest and Their Coefficients (in parentheses)	Reject if:
Hypothesis 1: There is no information about groundwater in the market.	SWCA dummy: $s_{it}(\sigma)$; measured and no filter dummy: $m_{it}(\mu)$	$\sigma \neq 0$ or $\mu \neq 0$
Hypothesis 2: There is incomplete information about groundwater in the market.	$s_{it}(\sigma), m_{it}(\mu)$	$\sigma \neq 0$ and $\mu \neq 0$
Hypothesis 3: There is complete information about groundwater in the market.	$s_{it}(\sigma), m_{it}(\mu)$	$\mu = 0$

various sources including MPCA and MDH documents and their websites. I included all houses sold between Jan. 1, 1995, and Dec. 31, 2006. Townhouses, condominiums, and apartments sales were excluded because these types are typically sold bundled with unobservable (to the econometrician) home owners' association payments. Table 2 lists and defines the house sales and characteristic variables, location variables, and water quality variables. The data are divided into two time periods, 1995 - 2002 (23,270 observations) and 2003 - 2006 (15,341 observations) because of the events that occur in 2002 related to changing the human risk limit and the disclosure law that went into effect at the beginning of 2003. Summary statistics for each period are shown in table 4 and table 5. MPCA provided its well sampling data for houses in and around the SWCA.

Table 4. Summary Statistics, Period 1,[a] Years 1995-2002

Variable	Mean	Median	Std. Dev.	Min	Max
realprice	186980.40	158500.00	113687.30	2096.14	1904311.00
Lnreal	11.99	11.97	0.56	7.65	14.46
Full	1.28	1.00	0.59	0.00	10.00
threequart	0.47	0.00	0.56	0.00	4.00
Half	0.36	0.00	0.49	0.00	3.00
Deluxe	0.22	0.00	0.42	0.00	2.00
bedroomss	3.18	3.00	0.89	1.00	12.00
Tla	1624.91	1401.00	698.31	0.00	9572.00
Lotarea	46499.59	12289.00	121876.40	0.00	2792196.00
Age	19.65	9.00	28.06	0.00	154.00
Agesq	1173.31	81.00	3000.56	0.00	23716.00
fireplace	0.72	1.00	0.71	0.00	9.00
Ac	0.86	1.00	0.34	0.00	1.00
porcharea	60.14	0.00	101.69	0.00	2011.00
deckarea	104.11	0.00	135.29	0.00	1000.00
schooldist2	0.20	0.00	0.40	0.00	1.00
schooldist3	0.05	0.00	0.22	0.00	1.00
schooldist4	0.00	0.00	0.05	0.00	1.00
schooldist5	0.11	0.00	0.32	0.00	1.00
schooldist6	0.07	0.00	0.26	0.00	1.00
schooldist7	0.29	0.00	0.45	0.00	1.00
schooldist8	0.27	0.00	0.44	0.00	1.00
schooldist9	0.00	0.00	0.05	0.00	1.00
watershed2	0.03	0.00	0.16	0.00	1.00
watershed3	0.08	0.00	0.27	0.00	1.00
watershed4	0.09	0.00	0.29	0.00	1.00
watershed5	0.14	0.00	0.34	0.00	1.00
watershed6	0.32	0.00	0.46	0.00	1.00
watershed7	0.21	0.00	0.41	0.00	1.00
river_dist	0.02	0.00	0.12	0.00	0.98
lake_dist	0.02	0.00	0.10	0.00	0.95
add1	139.45	37.00	217.81	0.00	3474.00
add2	26.75	0.00	86.21	0.00	1484.00
add3	4.75	0.00	36.27	0.00	960.00
add4	0.02	0.00	1.33	0.00	128.00
gar1	517.71	528.00	259.02	0.00	2800.00
gar2	21.33	0.00	135.62	0.00	2480.00
gar3	0.11	0.00	6.47	0.00	624.00
read_nofilt	0.01	0.00	0.10	0.00	1.00

Notes: [a] 23,270 observations in Period 1.

Information regarding groundwater quality can enter the market in multiple ways. If there existed complete information in the market and market participants valued uncontaminated water, then the actual measured contaminant level should consistently reflect this with a negative coefficient estimate. Furthermore, assuming that the GAC filter systems perfectly remove all TCE prior to water consumption, then the negative coefficient estimate on the measured contaminant level variable

Table 5. Summary Statistics, Period 2,[a] Years 2003-2006

Variable	Mean	Median	Std. Dev.	Min	Max
realprice	301597.70	260356.60	159097.90	1882.93	2412175.00
Lnreal	12.51	12.47	0.46	7.54	14.70
Full	1.19	1.00	0.52	0.00	6.00
threequart	0.48	0.00	0.58	0.00	3.00
Half	0.49	0.00	0.52	0.00	3.00
Deluxe	0.38	0.00	0.49	0.00	2.00
bedroomss	3.31	3.00	0.91	1.00	12.00
Tla	1793.37	1620.00	760.92	0.00	8886.00
Lotarea	33871.39	10801.00	102164.70	0.00	2586379.00
Age	20.80	11.00	27.43	0.00	158.00
Agesq	1185.28	121.00	3079.81	0.00	24964.00
fireplace	0.81	1.00	0.71	0.00	9.00
Ac	0.90	1.00	0.30	0.00	1.00
porcharea	65.54	0.00	94.70	0.00	1240.00
deckarea	88.86	0.00	129.48	0.00	772.00
schooldist2	0.14	0.00	0.35	0.00	1.00
schooldist3	0.04	0.00	0.20	0.00	1.00
schooldist4	0.00	0.00	0.03	0.00	1.00
schooldist5	0.11	0.00	0.31	0.00	1.00
schooldist6	0.05	0.00	0.22	0.00	1.00
schooldist7	0.41	0.00	0.49	0.00	1.00
schooldist8	0.23	0.00	0.42	0.00	1.00
schooldist9	0.00	0.00	0.04	0.00	1.00
watershed2	0.02	0.00	0.14	0.00	1.00
watershed3	0.06	0.00	0.23	0.00	1.00
watershed4	0.12	0.00	0.33	0.00	1.00
watershed5	0.13	0.00	0.34	0.00	1.00
watershed6	0.42	0.00	0.49	0.00	1.00
watershed7	0.14	0.00	0.35	0.00	1.00
river_dist	0.02	0.00	0.11	0.00	0.98
lake_dist	0.01	0.00	0.08	0.00	0.96
add1	141.86	44.00	213.21	0.00	2551.00
add2	38.32	0.00	105.87	0.00	2970.00
add3	8.47	0.00	44.16	0.00	810.00
add4	0.01	0.00	0.38	0.00	38.00
gar1	562.72	576.00	238.78	0.00	2800.00
gar2	16.76	0.00	116.09	0.00	2925.00
gar3	0.49	0.00	22.52	0.00	1840.00
read_nofilt	0.01	0.00	0.08	0.00	1.00

Notes: [a] 15,341 observations in Period 2.

should decrease after the year 2002 when most of the filter systems were installed on those houses with more than 5 μg/L TCE.[6]

However, it is possible that the contaminant level variable contained measurement errors. Not all houses' wells in the dataset were actually tested for TCE. In fact, not even all houses' wells

[6] There were 162 GAC filter systems installed by the end of 2006. 120 of these were installed in the year 2002.

inside the SWCA were tested for TCE. MPCA tested wells at those houses that are most likely to have TCE contamination. The decision on which houses are most likely to have TCE contamination is presumably based on knowledge of where the plume actually is, which aquifer a residential well uses, and where the plume is most likely to spread. While this cost-minimizing water testing strategy might be effective in terms of preventing residents from consuming water with more than 5 μg/L TCE, it does not provide actual measurements at all houses in the dataset. It is probably the case that all wells with high levels of TCE were tested, but there is still the possibility that some houses' wells with low (less than 1 μg/L) levels of TCE were not. One certainly cannot assume that untested wells had zero TCE levels.

Despite this issue, tests of information levels in the housing market are still possible. Information regarding whether a house has contaminated water or is likely to have contaminated water in the future is revealed if a house had its water tested by the MPCA. The MPCA tests water at houses most likely to have TCE contamination, and the dataset contains records of which houses were tested and when. Thus, m_{it}, a dummy equal to unity if a house had its water tested prior to the sale and did not have a GAC filter installed prior to the sale. This variable provides information regarding MPCA's opinion of the probability of TCE contamination. The information relayed to the market is that those houses that were tested were deemed most likely to have contaminated water by the MPCA. The dataset includes 359 house sales between 1995 and 2006 that occurred after each was tested for TCE. Assuming that GAC filter systems reduce the probability of TCE contamination to zero, observations of house sales for which water was tested and a filter was installed prior to the sale receive a value of zero for m_{it}. Houses that had wells tested for TCE were also likely to be situated near monitoring wells and other visible indicators of possible water contamination. Thus, it is reasonable to assume that potential homebuyers may have been more concerned about possible TCE contamination at those homes that were tested relative to those that were not. Hence, I place all house sales into two categories: those with possible contamination issues and those without. Sales at houses that had their water tested and no filter installed prior to the sale are in the first category. Sales at houses with wells that ere never tested or with wells that were tested and had filters installed prior to the sale are in the second category.

A second source of information regarding possible water contamination is location of a house in the SWCA. This is particularly pertinent after the SWCA disclosure law went into effect at the beginning of 2003. However, location in the SWCA does not necessarily mean that a house has contaminated water. Houses can be inside the SWCA and still have zero TCE in their water. Also, some houses inside the SWCA never had their water tested. A dummy variable, s_{it}, indicates whether a house is inside the SWCA at the time of the sale. I examine the effect of location in the SWCA, s_{it}, and the effect of whether a house's water was measured, m_{it}, before and after the disclosure law went into effect. This procedure is used to determine whether the market discounted houses that the MPCA tested but did not install filters on ($m_{it} = 1$), regardless of the SWCA, or whether the market discounted houses that were located in the SWCA ($s_{it} = 1$), regardless of whether the MPCA decided the house needed its water tested.

Outliers and Erroneous Data

Tax assessors' sales data often include probable non-market transactions. Evidence for such transactions is apparent in that 561 different observations of sales of three-bedroom houses have recorded prices of \$0.00. There are possibly other non-market transactions, such as sales of \$100.00, \$10.00, or even \$1.00, which likely represent intra-family trade, shifting of nominal ownership for tax purposes, or refinancing. Additionally, some sales records reflected other questionable data, such as negative house ages.[7]

[7] A negative house is age is possible if the house is sold before it is built. However, it seems unlikely that such a sale would occur more than a few years prior to construction.

I addressed these data errors in two ways. First, all observations that seemed obviously either erroneous or non-market transactions were deleted. Accordingly, all observations of sales at nominal price of less than $1001 were deleted (1,087 observations). Also, all houses with an age (calculated as year sold less year built) of less than negative three were dropped on suspicion of erroneous entry (667 observations), and the few remaining negative ages were changed to zero. A group of houses that had two sales recorded for the same house on the same day at vastly different prices was deleted (634 observations).

Second, the presence of outliers was somewhat tempered by the use of quantile regressions, which "emphasize the middle of the distribution rather than the tails" (Evans, 2007, p. 18). All quantile regression parameter estimates are reported for the median quantile.

Results

The three hypotheses regarding information levels in the market were tested using quantile regressions at the median of adjusted house prices using a semi-log functional form.[8] Table 6 shows the results of testing whether "measured and not filtered," m_{it}, or SWCA, s_{it}, inform the market about water quality, and whether this changes after the events of 2002 and the implementation of the disclosure law at the beginning of 2003. In 2002, the human risk limit was lowered from 30 μg/L to 5 μg/L, the SWCA was expanded, 120 of 162 GAC filters were installed; more newspaper articles about the Baytown Site were written than any other year; and multiple town meetings occurred because of residents' concerns about health risk and property values. I have divided all sales into two time periods: 1995 - 2002 and 2003 - 2006. Columns 1 and 2 of table 6 show the coefficient estimates from a quantile regression of the log of real price on housing and location variable vectors as well as township, school district, watershed, and yearly fixed effects. Column 1 is for Period 1, 1995 - 2002, and Column 2 is for Period 2, 2003 - 2006. All housing and location variables have the expected signs and most are significant in both periods.

For brevity I focus here on only the variables of interest. The variables *read_nofilt* and *swca* represent m_{it} and s_{it}, the variables of interest. The coefficient estimate of *read_nofilt* in the first period, 1995 - 2002, is -0.030, or -3.0%, while that of *swca* is -0.023, or -2.3%. Neither is significant at the 5% level, but the coefficient estimate of *read_nofilt* is significant at the 10% level. As these are both binary variables, houses could be in one of four categories: measured, unfiltered, and in the SWCA; measured, unfiltered, and not in the SWCA; not measured (or measured and filtered) and in the SWCA; and not measured (or measured and filtered) and not in the SWCA. The net effects for the four groups are obtained by summing the appropriate coefficient estimates from table 6 and reported in table 7. Wald tests of joint significance of *read_nofilt* and *swca* show that the negative, net effect on Group 1 (measured, unfiltered, and in the SWCA) is statistically significant at the 1% level in both periods.

Column 1 of table 6 shows that the housing market seems to have reacted to the information captured by the *read_nofilt* variable in the first period. The negative coefficient of -3.0% on *read_nofilt*, statistically significant at the 10% level, indicates that houses with the possibility of contaminated water sold at a discount of about $4,755 at the median in Period 1. There was no SWCA disclosure law in place in this period, so market participants may have had little information about the legislation. Market participants reacted to the information produced by the selection of houses for measurement: those houses that are tested are also those most likely to have TCE contamination and, therefore, suffer a "tainted water" discount. The less accurate, in terms of indicating which homes have a possibility of contamination, proxy *swca* does not appear to capture the "tainted water" discount in Period 1. This is consistent with the hypothesis that there is complete information in the market in Period 1.

[8] For robustness, ordinary least squares regressions in the semi-log form were also performed. Results of OLS had the same signs and significance levels, but the magnitudes of some coefficient estimates of the variables of interest were greater than in quantile regressions. Quantile regression results are reported because of possible outlier influence.

Table 6. Quantile Regressions at Median

	Township Fixed Effects				Tax Group & Township Fixed Effects			
Dep. Var.: lnreal	(1) Years: 1995 - 2002		(2) Years: 2003 - 2006		(3) Years: 1995 - 2002		(4) Years: 2003 - 2006	
Full	0.047	(15.19)***	0.056	(16.88)***	0.045	(15.77)***	0.055	(17.33)***
threequart	0.045	(15.20)***	0.055	(19.05)***	0.044	(16.22)***	0.055	(19.76)***
Half	−0.021	(6.15)***	−0.032	(9.63)***	−0.018	(5.89)***	−0.029	(8.79)***
Deluxe	0.072	(14.50)***	0.125	(26.35)***	0.072	(15.69)***	0.124	(27.21)***
bedroomss	0.026	(14.42)***	0.026	(13.92)***	0.027	(15.90)***	0.026	(14.78)***
Tla	0.001	(55.97)***	0.001	(64.46)***	0.001	(60.04)***	0.001	(66.12)***
Lotarea	0.001	(26.60)***	0.001	(41.88)***	0.001	(27.98)***	0.001	(43.41)***
Age	−0.003	(18.63)***	−0.003	(17.89)***	−0.003	(20.70)***	−0.003	(19.52)***
Agesq	0.001	(7.19)***	0.001	(8.32)***	0.001	(8.43)***	0.001	(9.33)***
fireplace	0.053	(22.74)***	0.064	(27.69)***	0.051	(23.95)***	0.062	(27.73)***
Ac	0.030	(6.83)***	0.017	(3.26)***	0.030	(7.39)***	0.018	(3.68)***
porcharea	0.001	(15.55)***	0.001	(26.81)***	0.001	(16.72)***	0.001	(27.46)***
deckarea	0.001	(14.59)***	0.001	(14.90)***	0.001	(15.00)***	0.001	(14.40)***
river_dist	0.108	(8.58)***	0.140	(9.79)***	0.111	(9.50)***	0.146	(10.58)***
lake_dist	0.099	(7.35)***	0.076	(4.55)***	0.095	(7.59)***	0.062	(3.78)***
add1	0.000	(6.30)***	−0.001	(5.54)***	0.001	(6.48)***	−0.001	(4.98)***
add2	0.001	(3.90)***	0.000	(0.780)	0.001	(4.26)***	0.000	(1.300)
add3	0.001	(2.90)***	0.001	(6.06)***	0.001	(2.48)**	0.001	(6.59)***
add4	0.001	(1.010)	0.005	(2.53)**	0.000	(1.220)	0.005	(2.57)**
gar1	0.001	(73.95)***	0.001	(47.12)***	0.001	(79.89)***	0.001	(48.22)***
gar2	0.001	(8.47)***	0.001	(7.38)***	0.001	(9.21)***	0.001	(7.94)***
gar3	−0.001	(2.04)**	0.001	(1.87)*	−0.001	(1.85)*	0.000	(0.400)
read_nofilt	−0.030	(1.73)*	0.003	(0.170)	−0.024	(1.480)	0.012	(0.670)
Swca	−0.023	(1.350)	−0.074	(3.67)***	−0.030	(1.90)*	−0.080	(4.10)***
Constant	11.258	(255.50)***	11.887	(252.48)***	10.357	(140.74)***	11.553	(143.06)***
N	23,270		15,341		23,270		15,341	
Pseudo-R^2	0.4385		0.5854		0.4408		0.5880	

Notes: Absolute value of *t* statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. Time dummy variables, watershed variables, and school district variables are all included in all above regressions; their coefficient estimates are suppressed for brevity and are available upon request. Several estimates were smaller than 0.001 in absolute value yet statistically different from zero at least the 10% level. These estimates have been represented as 0.001 for ease of reading.

Table 7. Net effects of *read_nofilt* and *swca*

	Group 1: measured, unfiltered, in the SWCA,	Group 2: measured, unfiltered, outside the SWCA	Group 3: not measured (or measured and filtered), in the SWCA	Group 4: not measured (or measured and filtered), not in the SWCA
Period 1	-3.0% -2.2% = -5.2%	-3.0%	-2.2%	baseline (0)
Observations	223	28	563	22679
P-value	0.0007	0.085	0.179	
Period 2	0.0% -7.4% = -7.4%	0.0%	-7.4%	baseline (0)
Observations	100	8	307	15026
P-value	0.0007	0.8630	0.0000	

Column 2 shows the results of the same regression for houses sold in the second period, 2003 - 2006. During this period, the SWCA disclosure law was in effect. The coefficient estimate on *read_nofilt* in the second period equals -0.024 or -2.4% and is not statistically different from zero. The coefficient estimate on *swca* went from -0.023 and not statistically significant to -0.074 and significant at the 1% level. In other words, location in the SWCA comported little discount in Period 1, but it led to a 7.4% discount in the second period. That translates to a discount of about $19,266 at the median house price in Period 2.

Thus, across the two periods, the effect of *read_nofilt* changed from likely negative to not significantly different from zero. However, the effect of *swca* changed from having no statistically significant effect to causing a substantial "tainted water" discount. The most likely explanation is the SWCA disclosure law. In the second period, the market discounted all homes in the SWCA. It did not matter whether a house's water had been tested by MPCA; the disclosure law indicated to market participants that location in the SWCA meant a house might have "tainted water." These results are consistent with the second hypothesis of incomplete information in Period 2. The "tainted water" discount appears to apply to homes located in the SWCA in both periods.

Columns 3 and 4 show the results of quantile regressions with township, school district, watershed and yearly fixed effects as well as property tax group fixed effects, performed for robustness. Property taxes in Washington County are a function of three location variables: watershed, school district, and township. Therefore, I added a tax group fixed effect for every unique combination of the three variables for a total of 82 different tax groups in the dataset. The results from these regressions are quite similar to those in Columns 1 and 2. However, one noticeable difference is that, unlike the first model, the coefficient estimate on *read_nofilt* is not statistically different from zero in either period in the tax groups fixed effects model. Also, location in the SWCA comported a statistically significant discount in both periods, but that discount was much larger in magnitude in the second period. In Period 1, the coefficient estimate on *swca* equals -0.03 (statistically significant at 10% level), and in Period 2 it equals -0.08 (statistically significant at 1% level). Thus, the second model's results are consistent with the second hypothesis of incomplete information in both periods.

Both models (township fixed effects and township-and-tax-groups fixed effects), point to a rejection of the first hypothesis, that there is no information regarding groundwater quality in the housing market. In both models, market participants react negatively to at least one of the indicators of "tainted water" in both periods.

In both models, the diminution of the cost of learning whether a house is in the SWCA results in the market actually using a less accurate proxy for the probability of contamination in the second period.. The "tainted water" discount is no longer captured by the more accurate "measured and not filtered" variable in the first model, and never was captured by it in the second model. Instead, in the first model, the *swca* discount decreases from a statistically insignificant -2.3% in the first period to a statistically significant -7.4% in the second period. A similar change occurs in the second model: the swca discount decreases from -3% in the first period to -8% in the second period. These results indicate, perhaps unsurprisingly, that the cost of gathering information is important in determining what information is incorporated into market prices. In the second period in both models, the market incorporated incomplete information regarding groundwater quality because it was less costly to do so.

An alternative interpretation of these results is that there is complete information in the market in both periods. Market participants interpreted the decision by legislators to force disclosure of location in the SWCA as a signal that the water contamination might be wider spread than they thought in the first period. If this is the case, the market is forecasting that the plume will spread farther. There has been some minor spreading of the plume to the east, but overall, it has remained relatively stable. Only future mappings of the plume will allow a test of whether the impact of the disclosure law was a result of a change from complete information to incomplete information or a result of the addition of new, correct information to the market. That is, if the plume does expand in the future, then the market was indeed forecasting correctly when those homes assumed here to be "at no risk of contamination" but still located in the SWCA lost some value.

Net Cost of Regulation

In this section, I evaluate how the regulatory changes wrought in 2002 (i.e., at the end of Period 1) affected house values in and around the contaminated area. The affected houses fall into three different categories: in the SWCA and tested; outside the SWCA and tested; and in the SWCA and not tested. Of the three categories, the largest group is the "in the SWCA and not tested" group (table 7 shows the number of observations in each group in each time period). To determine the net effect of regulation, I calculated the realized net effect of the SWCA and water testing in each period for all the groups. The realized net effect is the actual number of house sales in each group multiplied by the premium or discount for each group in each time period evaluated at the mean price for the period. A calculation of realized costs from the net effect of the SWCA and water testing before and after the disclosure law passed at the beginning of 2003 yields a net effect of -$4,780,541 prior to the disclosure law's passage. After the disclosure law was passed, the net effect was -$9,022,566. This is likely an underestimation because Period 1 includes eight years of sale observations (1995 - 2002) while Period 2 includes only four years (2003 - 2006).

Thus, even a conservative estimate of the effect of regulation in the area shows that homeowners lost over $4.2 million in equity. A significant portion of these houses that lost equity had no realistic probability of experiencing water contamination from this TCE plume.

Conclusions

In this paper, I have tested information levels regarding groundwater quality and their effects on house prices. Tax assessor real estate, GIS, and Minnesota Pollution Control Agency (MPCA) testing data were used to evaluate the impacts of a disclosure law mandating that homesellers inform homebuyers about a house's location in a special well construction area (SWCA). Prior to the passage of the law, it appears that the real estate market incorporated relatively complete information about where trichloroethylene (TCE) contamination was likely to occur. In the preferred model, only those houses that the MPCA tested because they are the most likely to have contaminated water suffered a "tainted water" discount during this time period. After the disclosure law passed, the market incorporates incomplete information about where TCE is likely to occur. This might have occurred because the disclosure law offered a very low-cost way of gathering information about groundwater quality, and as a result, all houses in the legislatively-created SWCA suffered a "tainted water" discount despite many of those houses having uncontaminated water and little to no possibility of future contamination.

An alternative interpretation of the shift of the "tainted water" discount from those houses that were tested by the MPCA to all houses in the SWCA is that the disclosure law informed the market that the plume might spread to other houses in the SWCA. Thus, if the plume spreads to those houses in the SWCA that presently have no contamination and are viewed by the MPCA as having no risk of contamination, then the market would have predicted this. To date, however, the plume has spread little, while the disclosure law was passed in 2003.

These results emphasize the importance of information in markets. Many researchers have studied market reactions to potentially harmful environmental disamenities. Often, these market reactions are cited as evidence of non-economic behavior on the part of market participants. Few studies, however, have questioned the assumption that market participants possess complete information about the environmental disamenity (Pope (2008a,b) are notable exceptions). Information acquisition can be costly. When markets react in ways that researchers find odd or "irrational," it could simply be the case that markets react to incomplete information because gathering complete information is too costly. When government regulations add more information to a market, even if it is imperfect information such as in this case, some market participants will still rely on it. This may occur even if the information is imperfect because it is often relatively inexpensive relative to acquiring better information. In its role as information provider, therefore, governmental agencies possess the potential to distort markets with imperfect information.

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