J Real Estate Finan Econ
DOI 10.1007/s11146-015-9514-3

Water Contamination, Land Prices, and the Statute of Repose

John F. Chamblee[1] · Carolyn A. Dehring[2] · Craig A. Depken II[3] · Joseph R. Nicholson[4]

Abstract We examine how water contamination risk from an inactive hazardous waste site is capitalized into surrounding vacant land prices. After public knowledge of the first instance of off-site contamination, we find that shallow groundwater contamination potential is negatively capitalized into land prices, as is proximity to a known contaminated well. Public knowledge of off-site contamination and associated land price changes occur after the North Carolina's 10-year statute of repose. Our findings raise questions concerning such statutes when environmental contamination has a long latency period, especially given a recent Supreme Court ruling that Superfund law does not preempt state statutes of repose.

Keywords Superfund · Pollution · Hydrology · Property values

Introduction

A Superfund site is a hazardous waste site that has contamination extensive enough that the U. S. Environmental Protection Agency (EPA) either cleans the site itself or

✉ Craig A. Depken, II
cdepken@uncc.edu

John F. Chamblee
chamblee@uga.edu

Joseph R. Nicholson
nicholsonj@mail.montclair.edu

1 Coweeta LTER, University of Georgia, Athens, GA, USA

2 Department of Insurance, Legal Studies and Real Estate, University of Georgia, Athens, GA, USA

3 Department of Economics, University of North Carolina at Charlotte, Charlotte, NC, USA

4 Department of Economics and Finance, Montclair State University, Montclair, NJ, USA

Published online: 12 July 2015

requires parties responsible for the contamination to do so. The Superfund program was established after the discovery of several toxic waste sites across the United States during the 1970s and was created by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA U.S. 42 § 9601). As of January 2014 there were over one thousand sites on the EPA's National Priorities List (see U.S. Geological Survey 2014).

In this study we examine the effect of off-site groundwater contamination from a former manufacturing site on vacant land prices. Located near Asheville, NC, the site housed a series of firms that, over several decades, engaged in electroplating as part of their manufacturing process. The CTS Corporation operated at the site from 1959 to 1985. The solvent trichloroethylene (TCE) is the main contaminant at the site. TCE is associated with various adverse health consequences, including cardiac and neurological problems and liver damage. The site remained the responsibility of the state of North Carolina until March 2012, when it was designated a Superfund site by the Environmental Protection Agency.[1]

We test for price effects to vacant land values after the discovery of off-site groundwater contamination, where this discovery predates the later Superfund designation date by 12 years. We account for the site's highly fractured underlying geology by distinguishing between shallow groundwater contamination and deep groundwater contamination. In order to account for the fact that the contaminant plume's location is not fully known, this paper utilizes predicted plume trajectories, rather than measured plume locations.

Groundwater refers to any water that, after a precipitation event, seeps into the soil, from whence it either continues flowing in line with local topography through pores in the soil into a stream or continues flowing until it becomes trapped in crevices in the underlying bedrock (USGS 2014). The groundwater flow process, known as advection, is determined by the structure of the soil and rock layers containing the water (Tague and Band 2004, and Fetter 2001). The primary method for predicting the likely direction of groundwater contamination through subsurface flow is with a subsurface model of the contaminant plume that accounts for how the structure of the underlying geology will affect the mechanical dispersion of the contaminant that is dissolved in the groundwater (Fetter 2001). These methods vary widely and depend on the chemicals involved and the nature of the subsurface geology. There are important differences between measuring the location of a contamination plume and forecasting its location. Measuring a plume relies on direct water samples taken from multiple wells and developing an isoline map based on measured concentrations (see McLaughlin 2011, Figs. 4 and 5, for examples). By contrast, predicting a plume's likely direction depends on a variety of methods for studying the underlying geologic structure. In this case, the subsurface geology is highly fractured, meaning that groundwater near the surface can be resident for days or months and groundwater stored in fractured bedrock cracks may stay resident for up to 25 years or more (see Plummer et al. 2001).

We expect groundwater quality to be capitalized into vacant property values. Property owners who rely on wells for water consumption would be most directly impacted by groundwater contamination, but those on municipal water supplies would

[1] Those sites on EPA's NPL are a small percentage of the country's inactive hazardous waste sites. Of the approximately 3000 such sites in the state of North Carolina, only 34 have made the NPL.

also be impacted, especially since contaminated groundwater has the potential to seep into crawlspaces and basements, leading to health problems resulting from diminished indoor air quality (Turczynowicz and Robinson 2001, and Hers et al. 2002). However, we also expect that capitalization occurs only in those areas where there is both knowledge of the potential for contamination and the perception of a potential threat.

We argue that in a mountainous landscape landowners use their knowledge of where local streams flow in order to project groundwater flows and predict contamination locations. Studies in other disciplines have verified that people outside the fields of geology and hydro-geology understand groundwater only incompletely, using an analogy based on their intuitive understanding of surface water movement (for example, the movement of water in a stream).[2] Where such analogies coincide with actual groundwater movement, we would expect to find changes in land prices.

Our empirical analysis indicates that land market participants negatively capitalize the potential for groundwater contamination into vacant land prices. We find a price discount on those properties with potential shallow groundwater contamination from the CTS site. However, while deep groundwater contamination might pose the greatest long-term risk to drinking water supplies, we find no evidence that potential deep groundwater contamination influences property values. We suspect that this is because geologically-based predictions and measurements for shallow groundwater contamination flows are coincident (though not causally related to) the direction of surface water flows, while the predicted and measured directions for deep groundwater contamination plumes are not, and thus are harder for market participants to assess.

Our findings raise questions concerning state statutes of repose when environmental contamination has a long latency period. While commonly confused with a statute of limitation, a statute of repose "is designed to bar actions after a specified period of time has run from the occurrence of some event other than the injury which gave rise to the claim" (Indiana Court of Appeals 1991). The reasoning supporting a statute of repose is that there should be some amount of time beyond which a defendant should no longer be held responsible for their actions. Examples most often apply in product liability cases where damages discovered long after the product was delivered are subject to the statute of repose (see, for example, Indiana General Assembly 2014).

In 2011, homeowners living near the former CTS site sought to bring a nuisance act against the CTS Corporation for property damage and possible health problems stemming from contaminants on the land. CTS had sold the property in 1987, and the state had a statute of repose that was 10 years in length.[3] The case rose to the US Supreme Court, which ruled that CERCLA did not preempt the state's statute of repose. Our findings suggest that the market capitalizes such property damage only after public knowledge of off-site contamination, which in this case exceeds the length of the state's statute of repose. Therefore, the finding that CERCLA did not preempt the state's statute of repose imposed an economic

[2] Dickerson et al. (2007) summarized the literature on American vernacular understandings of groundwater in their study of groundwater education techniques among primary and secondary education science teachers. In doing so, they demonstrated that, not only did many Americans still rely on notions of underground rivers to explain groundwater flow, but also that such concepts are reproduced in by elementary and secondary science texts in spite of the fact they bear no resemblance to the actual mechanisms of groundwater movement.

[3] North Carolina's 1979 product liability law limits civil claims liability ten years after the last contaminating act (North Carolina General Assembly 2014).

taking on property owners who were precluded from pursuing damages against CTS.

Literature

In most studies relating property values to environmental contamination, the hedonic pricing methodology is used to measure the price effect of environmental disamenities such as landfills, the discovery of contamination at a particular site, a site receiving the EPA's NPL designation, or the cleanup at a Superfund site.[4] The first study to measure the effect of the NPL designation is Kohlhase (1991) who examines property values near multiple hazardous waste sites in the Houston, TX area that are eventually placed on the NPL. She finds property values near the sites decline only after the NPL listing. However, the finding that these declines reverse at one site after cleanup suggests that such effects may not be permanent.

Michaels and Smith (1990) examine properties near hazardous waste sites in the Boston area, some of which are on the NPL. They find that house prices increase with distance from a site, although their results vary by submarket. Mendelsohn et al. (1992) use a repeat-sales methodology to examine a site contaminated with PCB in New Bedford, MA and find negative price effects associated with the site before it is proposed to the NPL.

Kiel (1995) is the first to examine the price effects of hazardous waste sites using a sample period that includes discovery of contamination, NPL listing, and clean up. Using data from Woburn, MA, where two NPL sites are located, Kiel finds no adverse price effects associated with the sites until discovery of contamination. After discovery, but before the NPL listing of the sites 3 years later, price effects from contamination are partially capitalized in the housing market. Further capitalization occurs with the listing. Unlike Kohlhase (1991), Kiel finds no effect of EPA clean-up announcements on property values in the area.[5]

Dale et al. (1999) examine property values near a lead smelter in Dallas, TX, which is initially declared to be clean but is then placed on the NPL. They find the market generally capitalizes negative externalities from the site before information about soil contamination and potential health risks are known. Like Kohlhase (1991), Dale, et al. find property values rebound after the initial clean-up (which at the time was thought to have been successful).

Gayer et al. (2002) study Superfund sites in the Grand Rapids, MI area between 1988 and 1993. The sample period begins before any public health risks associated with the sites are publicized and ends after the EPA declares the site to be clean. They find the willingness-to-pay by residents to avoid the risks associated with these sites decreases after the EPA's NPL designation, suggesting the public perceives lower levels of risk following the designation. McLaughlin (2011) tests

[4] Studies that investigate the impact of environmental disamenities include Hite et al. (2001) investigate the impact of landfill proximity on property values and Caroroll, et al. (1996) investigate the impact of a chemical plant explosion in Nevada on surrounding property values. See Boyle and Kiel (2001) for a general review of hedonic studies focusing on environmental contamination.

[5] Kiel and Zabel (2001) use hedonic valuation to estimate the willingness to pay to clean up the same sites examined by Kiel (1995).

for house price effects from a location in a special well construction district that is associated with potential TCE groundwater contamination after the NPL designation of the source site. McLaughlin finds houses sell up to an 8 % discount due to location in a well construction zone.

Boyd et al. (1996) investigate the impact of environmental liability law on property sales that have potential environmental contamination. They find that liability-driven market distortions arise because of asymmetric information and imperfect detection rather than legal uncertainty. Segerson (1997) provides a theoretical model that specifically incorporates the various liability models provided by CERCLA. She shows that various forms of legal liability for environmental contamination lead to ambiguous impacts on market efficiency; in some cases the liability induces too few sales relative to efficiency and in other cases induces too many sales.

Background

The NPL Superfund site that is the basis for this study is located about five miles outside of Asheville, NC. From 1952 to 1985 the site housed various entities that engaged in electroplating at the site, or the use of electricity to coat solid surfaces with metals dissolved in water (see Paunovic and Schlesinger 2006).[6] As part of this process, parts were washed with TCE prior to electroplating with tin, nickel, zinc, and silver. This contaminant was washed off during the electroplating process and released from the building via drains in the facility, a one-story building located in the northeast corner of the site.[7]

The site has a long history of environmental inspections. In 1984, during a Resource Conservation and Recovery Act compliance inspection, the North Carolina Solid and Hazardous Waste Management Branch found noncompliance in several areas, including the accumulation time of hazardous waste at the facility.[8] In 1985, the North Carolina Department of Human Resources (NCDHR) conducted a preliminary assessment of the site, but it was given a low priority recommendation.[9] In 1987, the site owner hired a consultant to provide an assessment of the actual and potential environmental liabilities associated with the property.[10] Between 1989 and 1991, an EPA subcontractor took part in a two-phase screening site inspection (SSI). The substances vinyl chloride, TCE, and 1,2-dichloroethene were detected in soil, sediment, and surface water samples at the site. However no further remedial action was recommended to the owner.[11]

The first recorded instance of offsite water contamination occurred in July of 1999, when the North Carolina Department of Environment and Natural Resources (NCDENR) was contacted concerning oily water in a ditch on a property adjacent to the site. Samples from this site and from those of two springs on neighboring properties

[6] US Environmental Protection Agency (2011, p. 15).
[7] Ibid.
[8] Ibid p.16
[9] Ibid.
[10] Ibid.
[11] Ibid p. 18

showed TCE and other chlorinated solvents. Residents were advised to refrain from using one spring as a water source.[12] Around this time the NCDENR found TCE in one of nine wells within a quarter mile of the site. The residents were advised not to use the well for drinking water. The NCDENR then requested a review of the property by the EPA to see whether it qualified for a removal action under Superfund.[13] In August of 1999, the EPA issued an emergency delivery order to connect four residences to the public water supply and to provide potable water as needed.[14] Additional sampling in subsequent years revealed more instances of well and surface water contamination.[15] In August of 2009, the site eventually scored high enough to be listed on the NPL. In March of 2011, the EPA proposed adding the site to the NPL, and in March of 2012 this action was finalized.

Local citizens from Asheville and Buncombe County were highly involved with matters concerning contamination at the site. In 2008 a citizen monitoring group called for both the EPA and the NCDENR to not let the previous owner go into "voluntary remediation" because taxpayers would likely bear the majority of the cleanup costs. The citizens' board stated that Buncombe County had not put adequate pressure on the federal and state governments to speed up the contamination cleanup process.[16] In May 2009, Ashville residents collected 3100 signatures demanding "full, proper, and time-critical cleanup" of the site.[17] The group is credited with successfully lobbying to raise North Carolina's remediation expense cap for a single responsible party from $3 million to $5 million.

States have fewer resources than the EPA for environmental clean-up. North Carolina state law imposes a $5 million cap on remediation expenses by a single responsible party, yet clean-up costs sometime run in the tens of millions of dollars. The EPA also has greater authority than do states to pursue responsible parties. In particular, CERCLA recognizes the concept of joint and several liability, meaning that any party that contributed to contamination can be held responsible as if they were the sole contributor. The EPA's greater enforcement capability provides local citizens with an incentive to obtain a NPL listing for nearby sites, especially if they perceive clean-up costs will exceed the state's legal capacities or resources for clean-up.[18]

Empirical Approach

We use a hedonic pricing model to test for the effect of actual and potential water contamination on vacant land prices.[19] The dependent variable in the hedonic model

[12] Ibid.
[13] Ibid
[14] Ibid.
[15] Ibid pp. 19–23.
[16] http://mountainx.com/news/040908ctssite/
[17] Ibid.
[18] Telephone conversation with Charlotte Jesneck, Branch Head, Waste Management, Superfund Section, Inactive Hazardous Sites Branch, DENR. August 16, 2013.
[19] We use vacant land sales rather than developed land sales because there are a sufficient number of vacant sales to conduct the analysis, and because available transaction data on developed parcels does not provide information on structure attributes.

is the natural logarithm of the sale price of a vacant land parcel. The model, estimated via OLS, is presented in Eq. 1 below:

$$\begin{aligned} lnPRICE_i = {} & \alpha_1 lnACRES_i + \alpha_2 SLOPE_i + \alpha_3 ELEV_i + \alpha_4 DISTCBD_i + \alpha_5 CITYASHE_i \\ & + DISTSITE_i(\beta_1 + \beta_2 POST99_i) + SHALLOW(\beta_3 + \beta_4 POST99_i) \\ & + DEEP(\beta_5 + \beta_6 POST99_i) + DISTWELL99(\delta_1 + \delta_2 POST99_i) \\ & + DISTWELL08(\delta_3 + \delta_4 POST08_i) + DISTWELL09(\delta_5 + \delta_6 POST09_i) \\ & + \gamma YEAR_i + u_i, \end{aligned} \tag{1}$$

where the α's, β's, δ's, and γ's are parameters to be estimated and u_i is a zero-mean error term.

The explanatory variables can be broadly classified into three groups. The first group of variables describes the physical attributes of the parcel and its location relative to the city of Asheville. Included in this group is the natural log of the lot size (*ACRES*), the slope (*SLOPE*), and the elevation (*ELEV*) at the parcel centroid, respectively.[20] We expect the lot area elasticity of value to be less than one, or that the coefficient α_1 is positive but less than one (Colwell and Sirmans 1993). The steeper the slope the higher will be the expected costs of any development on the parcel and thus we expect the coefficient α_2 to be negative (see Chamblee et al. 2009). Higher elevation is often associated with better views in a mountainous landscape, and we expect better views to be associated with high land prices. On the other hand, a higher elevation can indicate remoteness or more difficult access, and we might expect this to negatively influence land price though higher associated construction costs. Thus the sign of the estimated coefficient α_3 is ambiguous (see Chamblee et al. 2011).

The variable *DISTCBD* is the distance from the parcel to the center of Asheville's historical central business district. We expect α_4 the estimated parameter on this variable, to be negative, indicating that land values are negatively related to distance from the center of the Asheville business district. The variable *CITYASHE* indicates whether a parcel is within the city limits of Asheville. We expect the coefficient α_5 to be positive, since land prices should increase, on net, with the added amenities provided by a City of Asheville location. These physical and location attributes have been shown to influence vacant land prices in the Asheville, North Carolina area (see Chamblee et al. 2009, 2011).

The second group of variables presented in Eq. 1 describes distance from the parcel to the contamination site as well as the potential for groundwater contamination for the parcel. The variable *DISTSITE* measures the distance of the parcel from the contamination site in meters. The coefficient β_1 is the percentage change in price with an additional meter of distance from the contamination site. To test the effect of contamination on land prices after the contamination becomes public, the model includes an interaction between *DISTSITE* and *POST99,* which is a dummy variable that takes a value of one if a sale took place after 1999, when there is public knowledge about offsite contamination. Thus, β_2 is the additional percentage change in price with an additional meter of distance from the contamination site after 1999. If there is a premium associated with linear distance from the site after public knowledge of off-site contamination, we would expect the coefficient β_2 to be positive.

[20] We use the natural logarithm of lot size because the distribution of lot size is skewed. The parameter α_1 is thus an elasticity of lot price with respect to lot size.

To capture effects from potential groundwater contamination, we use two variables, *SHALLOW* and *DEEP*, which distinguish between water flows at different depths below the soil layer. These variables are developed from US Environmental Protection Agency (EPA) surveys of the geologic layers underlying and surrounding the site. The variables are based on two different survey methods, both of which are derived from estimates of the orientation of cracks in the subsurface geology (Chapman and Huffman 2011, and Wischkaemper 2011). For the variable *SHALLOW*, estimates are calculated from a survey of the exposed bedrock in the area around the site, and for the variable *DEEP*, estimates are based on a survey of subsurface boreholes established in the area around the site.[21] Thus, *SHALLOW* is assigned a value of one for those properties that fall within groundwater plume directions predicted using observations from shallow, exposed cracks in the bedrock, and *DEEP* is assigned a value of one for properties that fall within the groundwater plume directions predicted using observations from deeper, well-based samples.

If there is no expectation of groundwater contamination before there is knowledge of off-site contamination, we would expect $\beta_3=0$ and $\beta_5=0$. After off-site contamination, there was no publically available information about differences in predicted groundwater contamination plume directions related to the site prior to the end of the sample period.[22] Thus our expectations on the variables *SHALLOW* and *DEEP* are as follows: we expect the land market assigns a discount to parcels subject to where contamination predictions are based on shallow bedrock crack observations, but not to those predictions based on observations from deeper well-based observations. Accordingly, we expect that $\beta_4<0$ and $\beta_6=0$, respectively.

The final group of variables in Eq. 1 involves distance from contaminated wells in the study area. We measure the distance of each parcel from three private wells that were found to be contaminated during the study period. The variables *DISTWELL99, DISTWELL08* and *DISTWELL09* indicate the distance of the parcel from wells discovered to be contaminated in 1999, 2008, and 2009, respectively. The coefficients δ_1, δ_3, and δ_5 reveal the percentage change in price with an additional meter of distance from the wells contaminated in 1999, 2008 and 2009; we expect $\delta_1=0$, $\delta_3=0$, and $\delta_5=0$. Like the variable *POST99*, the variables *POST08* and *POST09* take a value of one if a sale took place after public knowledge of contamination of the associated well. Each well-distance variable is interacted with an associated post-disclosure dummy variable. If, after each well contamination is made public, land market participants place a premium on properties that are further away from the wells, we would find that $\delta_2>0$, $\delta_4>0$, and $\delta_6>0$.[23]

Data

The sample includes 186 qualified vacant land parcels in Buncombe County, NC which sold between 1996 and 2010, all of which are less than 2 km (1.24 miles) from the

[21] In each case, the calculations for orientation were obtained by counting the number of times a particular degree on the compass rose was noted during the surveys (see Chapman and Huffman 2011:7–9; Wischkaemper 2011:14–16 and especially Figs. 1.9B and 1.9C).

[22] The EPA report used to predict contamination plumes was initially released in 2011.

[23] We also control for date of sale with annual dummy variables.

contamination site. All parcel transaction data are obtained from the Buncombe County, NC Tax Department and the geographic placement data are obtained via ArcGIS. Data on predicted shallow and deep groundwater contamination are from the US EPA (Chapman and Huffman 2011). As in much of the US, house prices in the study area were rising from 1996, the first year of our sample, through the mid-2000s. In Buncombe County the downturn in house prices began in 2007, and continued until the end of the sample period in 2010. [24]

Maps of the study area are provided in Fig. 1a and b. The study area is located in the south of Buncombe County. The contamination site is denoted in the center of the sales map. The shaded triangles extending outward from the site show the predicted directions of groundwater flows based on the EPA studies of sampled bedrock crack orientations.[25] The EPA's studies of shallow subsurface geology cracks predict shallow groundwater flows toward northwest and south-southeast. Similarly, predicted deep groundwater flows in the study area are to the southwest and north-northeast of the contamination site.

Table 1 lists the variables used in the analysis and their descriptions. Table 2 reports the descriptive statistics of the data. Consistent with the mountainous terrain of the area, the average slope of the parcels in the sample is 10.78 %, and the average parcel is located 735 m above sea level. Parcels sizes range from under one acre to 8.84 acres. Average sale price is approximately $182,500. Less than half the sample, 34 % of parcels, is located within the Asheville city limits. Fifteen percent of parcels lie in the path of estimated shallow groundwater contamination plumes, while 17 % of the parcels are in path of estimated deep groundwater plumes. No parcels in the sample have private wells.

Estimation Results

Table 3 reports the estimation results. Four models are reported. Model 1 includes parcel characteristics and distance from the contamination site; Model 2 adds groundwater characteristics; Model 3 features well contamination variables rather than groundwater characteristics; and Model 4 includes both groundwater and well characteristics per Eq. (1). All models include year fixed effects (not reported for brevity) and exhibit non-specific heteroscedasticity; thus White (1980) robust standard errors are used for inference.[26]

[24] Federal Housing Finance Agency (2014).

[25] The predicted contamination paths in the figure are based on rose-compass diagrams showing the frequency at which subsurface cracks observed in rock outcrops and bedrock cores at different angles of declination. Thus, the plume approximations appear like wedges because they correspond to directions, although they are derived from the EPA studies.

[26] At the suggestion of an anonymous referee we undertook a falsification test of the common trends assumption placed on properties before the announcement of off-site contamination. We do so by restricting the sample to be only those parcels that sold before 2000, we create an artificial "post" period as being the years 1998 and 1999, we include the artificial post and its interaction with whether the property is located in the city of Asheville, the distance from the Asheville CBD, the distance from the contamination site, whether the property is in the path of shallow groundwater flow, and whether the property is in the path of deep groundwater flow. The test that the artificial post and the interactions are jointly equal to zero, indicating common trends in these dimensions, cannot be rejected (F=1.76, p=0.12).

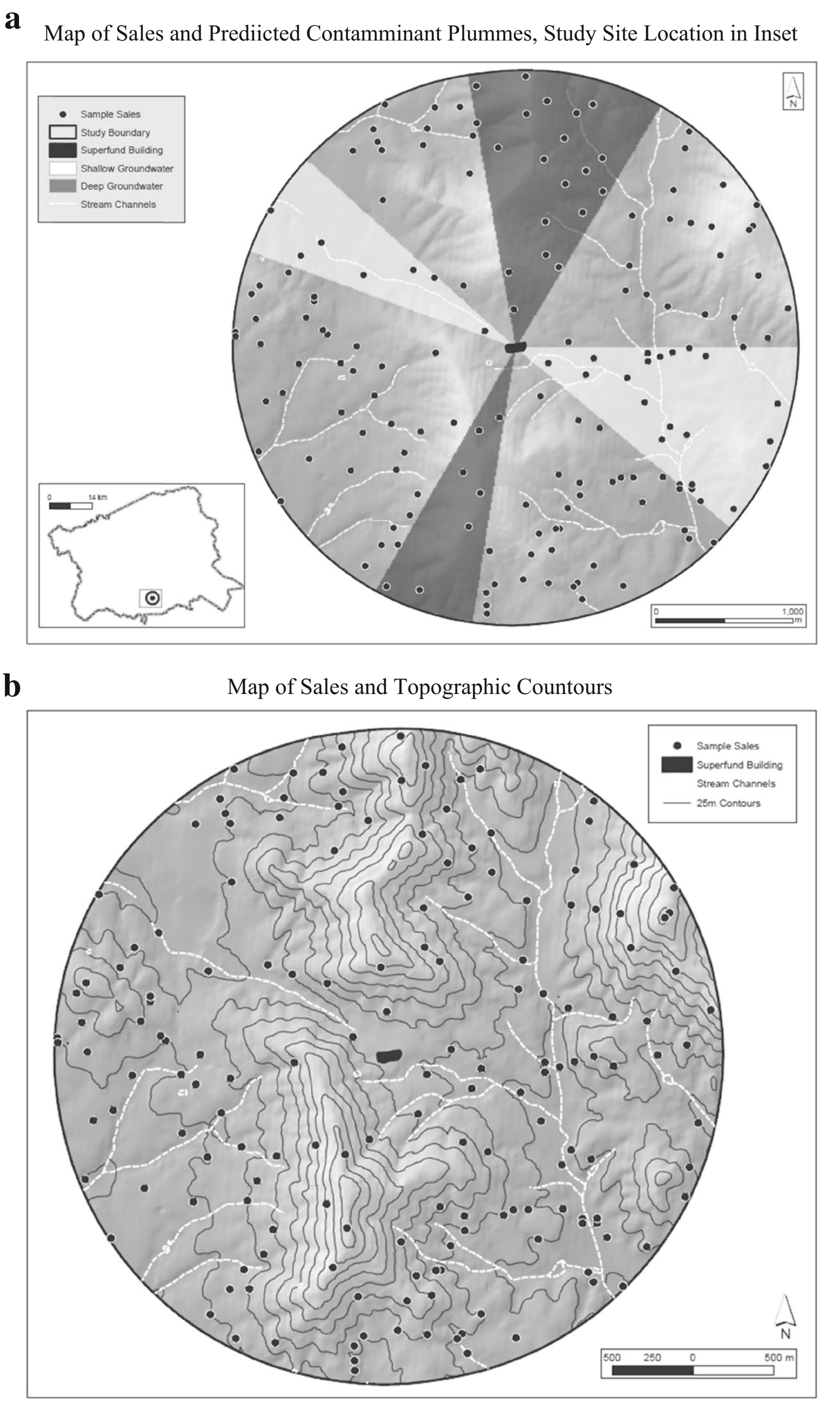

Fig. 1 **a**. Map of sales and predicted contaminant plumes, study site location in inset. **b**. Map of sales and topographic contours

Table 1 Variable descriptions

	Variable	Description
Parcel characteristics	*PRICE*	Transaction price
	ACRES	Parcel size in acres
	SLOPE	Slope of parcel
	ELEV	Elevation of parcel in meters
	DISTCBD	Distance to Asheville CBD in thousands of meters
	CITYASHE	Parcel is within the city of Asheville
	DISTSITE	Distance from parcel to contamination site in thousands of meters
	DISTSITEPOST99	*DISTSITE* x Sale after 1999
Groundwater contamination	*SHALLOW*	Parcel has potential for shallow groundwater contamination
	SHALLOWPOST99	*SHALLOW* x Sale after 1999
	DEEP	Parcel has potential for deep groundwater contamination
	DEEPPOST99	*DEEP* x Sale after 1999
Off-site well contamination	*DISTWELL99*	Distance in thousands of meters to well found contaminated in 1999
	DISTWELL08	Distance in thousands of meters to well found contaminated in 2008
	DISTWELL09	Distance in thousands of meters to well found contaminated in 2009
	DISTWELL99POST99	*DISTWELL99* x Sale after 1999
	DISTWELL08POST08	*DISTWELL08* x Sale after 2008
	DISTWELL09POST09	*DISTWELL09* x Sale after 2009

In all models, the lot-size elasticity of price is positive, statistically different from zero, and statistically less than one, consistent with other studies. On average, a 1 % increase in lot size corresponds with an increase in sale price of approximately 0.75 %. In all models the slope of the parcel is negatively related to transaction price, consistent with Chamblee et al. (2009 and 2011), which reflects increased development costs and lower amenity value of steep parcels. On average, a one percentage point increase in slope corresponds with a decrease in transaction price of approximately 2 %. Elevation, on the other hand, is not a significant contribution to transaction price. The distance from the Asheville central business district is positively related to price in Model 1 and Model 2 but for the other models distance is not statistically meaningful. A City of Asheville location increases price by a factor of 3, reflecting the increased amenities and services that being within the city of Asheville provides.

Turning to the results related to groundwater contamination, in Model 1 we find that land prices decline with each meter of distance from the contamination site before public knowledge of contamination. This result indicates that the contamination site is located in a localized value peak. However, we note that the significance of this

Table 2 Descriptive statistics of the sample

	Mean	Std. Dev.	Min	Max
PRICE	182,486	358,230	1,000	3,600,000
ACRES	1.36	1.60	0.08	8.84
SLOPE	10.78	6.98	0.02	40.67
ELEV	735.43	49.71	672.86	925.59
DISTCBD	11.45	1.10	9.30	13.21
CITYASHE	0.34	0.48	0.00	1.00
DISTSITE	1.40	0.44	0.18	1.99
DISTSITEPOST99	0.89	0.75	0.00	1.99
SHALLOW	0.15	0.35	0.00	1.00
SHALLOWPOST99	0.13	0.33	0.00	1.00
DEEP	0.16	0.37	0.00	1.00
DEEPPOST99	0.07	0.26	0.00	1.00
DISTWELL99	1.57	0.61	0.22	2.78
DISTWELL08	1.68	0.73	0.10	3.06
DISTWELL09	1.36	0.49	0.10	2.21
DISTWELL99POST99	1.03	0.90	0.00	2.67
DISTWELL08POST08	0.04	0.31	0.00	2.76
DISTWELL09POST09	0.03	0.23	0.00	1.88

variable disappears as we start to control for hydrological variables, suggesting that the (weakly) statistically significant result in Model 1 is perhaps the result of an omitted variables bias. After the discovery of off-site contamination, we find no significant price effects related to distance from the site. The mountainous nature of the study area may be the reason that land prices are not explained by linear distance from the contamination source after off-site contamination is discovered.

In Model 2 (Table 3, column 2) properties that are in the path of potentially contaminated shallow groundwater (located to the northwest and the south-southeast of the site) experience price premiums over other similar properties before the off-site contamination is made public. Yet, after the off-site contamination is made public the entire premium is erased. The net price effect for parcels with predicted shallow groundwater contamination is −17.55 %. We find no price effects associated with those properties that sit in the path of potentially contaminated deep groundwater (to the southwest and the north-northeast of the contamination site) either before or after public knowledge of offsite contamination.

In Model 3 (Table 3, column 3), groundwater characteristics are replaced by the distances to the three private wells that were discovered contaminated at various times during the sample period. None of the parameters associated with the three well-related variables are statistically significant pre-contamination. However, after the 2008 discovery of contamination, there is a premium associated with distance from the well. Specifically, land prices fall by approximately 54 % when the property is located 1000 m closer to the contaminated well. That is, a property adjacent to the well contaminated in 2008 would have a 54 % price discount relative to an otherwise

Table 3 Estimation results

VARIABLES	(1) lnprice	(2) lnprice	(3) lnprice	(4) lnprice
LNACRES	0.740*** (0.076)	0.725*** (0.078)	0.743*** (0.076)	0.740*** (0.077)
SLOPE	−0.023** (0.009)	−0.023*** (0.009)	−0.027*** (0.010)	−0.028*** (0.009)
ELEV	0.001 (0.001)	0.001 (0.002)	0.002 (0.002)	0.003* (0.002)
DISTCBD	0.155*** (0.059)	0.148** (0.058)	−0.113 (0.152)	−0.101 (0.167)
CITYASHE	1.498*** (0.148)	1.430*** (0.140)	1.425*** (0.160)	1.374*** (0.152)
DISTSITE	−0.482* (0.277)	−0.305 (0.290)	0.869 (0.753)	0.962 (0.913)
DISTSITEPOST99	0.211 (0.312)	0.006 (0.324)	0.209 (0.363)	0.137 (0.368)
SHALLOW		1.203*** (0.379)		1.065** (0.409)
SHALLOWPOST99		−1.396*** (0.417)		−1.450*** (0.439)
DEEP		−0.029 (0.300)		−0.001 (0.323)
DEEPPOST99		−0.201 (0.363)		−0.343 (0.353)
DISTWELL99			−0.604 (1.517)	−1.094 (1.610)
DISTWELL99POST99			−0.022 (0.267)	−0.182 (0.263)
DISTWELL08			0.891 (0.999)	1.234 (1.045)
DISTWELL08POST08			1.158*** (0.321)	1.410*** (0.362)
DISTWELL09			−1.447 (0.958)	−1.205 (1.274)
DISTWELL09POST09			0.293 (0.499)	0.114 (0.622)
Constant	9.100*** (1.290)	8.354*** (1.311)	10.401*** (1.726)	9.331*** (2.071)
Observations	186	186	186	186
R-squared	0.635	0.655	0.654	0.676

identical one 1000 m away. Finally, in Model 4 (Table 3, column 4), both groundwater characteristics and well characteristics are included. The results on the variables of interest from Models 2 and 3 hold in Model 4.[27]

The results suggest three interesting aspects with respect to the valuation of potential groundwater contamination. First, the land market discounts parcels that could experience contaminated shallow groundwater but not those with the potential for deep groundwater contamination, even though the deep groundwater might have more long-term health impacts than other types of contamination, especially for those homeowners who obtain drinking water from wells. Second, we find some evidence that house prices increase with distance from newly contaminated wells suggesting that

[27] To confirm that the estimation results in Table 3 are not the result of specification error, we undertook a number of different robustness tests, the tabular results of which are available from the authors upon request. One test was to calculate the path distance from the contamination site to the parcel along a stream; there was no impact pre- or post-announcement. We also considered whether the parcel buyer was a so-called "outsider" or not from one of the eleven zip codes in Asheville and the immediate vicinity; our intuition is that perhaps buyers from outside the area would have less information about the contamination than locals. In no specification was the outsider effect a significant contributor to parcel prices either on its own or interacted with surface and groundwater characteristics. In all cases, the deep and shallow groundwater results remain essentially unchanged and inferences do not change. The results from these additional models are available from the authors upon request.

the property market predicts that proximity to already contaminated wells increases the probability of other parcels being affected by the contamination. Third, our findings suggest that linear distance from a contamination source may not be an effective way of detecting price effects from groundwater contamination in a mountainous landscape. It is therefore important to distinguish between commonly investigated contamination sites that are located in flatter terrain and the terrain under study here. Future research might focus on how price impacts are differentiated across various terrains surrounding a contaminated site.

Discussion

We find that land prices decrease near the CTS site after off-site contamination is discovered. This is consistent with claims from nearby homeowners, who in 2011 attempted to sue the CTS Corporation for property damages and possible health problems. A Federal judge dismissed the case due to North Carolina's statute of repose, which prevents a plaintiff from taking action due to personal injury or property damage more than 10 years after the defendant's last action- here the sale of the property by CTS in 1987. The plaintiffs appealed, and the lower courts reinstated the lawsuit, finding that with regard to hazardous waste contamination, the Superfund law (CERCLA) preempts North Carolina's statute of repose. Specifically, state time limitations on claims do not start until a plaintiff could have possibly known about such contamination. CTS Corporation appealed to the US Supreme Court, contending that the Superfund law preempts statutes of limitations, but not statutes of repose. The former sets a time limit within which a plaintiff can sue once there is knowledge of harm, and is expressly exempted by CERCLA. On June 9, 2014, the U.S. Supreme Court ruled that the state's statute of repose supersedes the federal Superfund law, noting the intent of Congress in writing the Superfund law was to distinguish between the two statutes.[28]

The nature of groundwater contamination from the CTS property, and the associated adverse land price effects, point to limitations of state statutes of repose in the case of toxins with long latency periods. Because of the slow rate of groundwater movement and the complexity of the underlying geology, it may take years or even decades to adequately understand the impact of a pollutant's release on even nearby groundwater sources. The high court's interpretation of CERCLA and state statutes effectively leave property owners with no recourse. Interestingly, the State of North Carolina addressed this head on, passing Senate Bill 574 just weeks after the US Supreme Court Ruling.[29] The new legislation clarified that the state's statute of repose law was not meant to apply to groundwater contamination. As of this writing, it remains to be seen whether homeowners may proceed with the case against CTS Corporation. Thus far, it seems that they will not be able to pursue property damage claims, because Senate Bill 574 was deemed by the courts to be substantive change in the legislation, rather than a mere clarification.[30]

[28] See CTS Corporation v. Peter Waldburger, et al. 2014, Percival 2014, and Lueders 2014.
[29] The authors thank Jesse Lueders, UCLA School of Law, for this information.
[30] The authors thank John Korzen, Wake Forest University School of Law, for this information.

Conclusion

We examine the effects of off-site water contamination from a former manufacturing site in Buncombe County, NC. The contamination site was designated an EPA Superfund site in March 2012. Between 1959 and 1985, the CTS Corporation engaged in electroplating as part of their manufacturing process and used the main water contaminant, the chlorinated solvent trichloroethylene (TCE), which is associated with various adverse health consequences, including cardiac problems, liver injury, and neurological problems.

We examine how the risk of water contamination is capitalized into nearby property values following public knowledge of off-site contamination. We use a hedonic model where land prices are regressed on a composite of key parcel characteristics, including hydrological characteristics and distance of parcels from known contaminated sites. The different models allow us to test how land market participants understand the spatial aspects of water contamination. In this market, parcels that face potential shallow groundwater contamination suffered substantial price declines after off-site contamination was found. However, potential deep groundwater contamination, which might pose greater long-term health risks, is not generally incorporated into transaction prices in our mountainous landscape. Our findings suggest that studies of house price effects from water contamination should consider hydrologic variables, including groundwater flow estimates, in cases where the terrain is varied.

The evidence here suggests that land market participants have incomplete information with regard to contamination. In this case, groundwater flows predicted from observations of cracks in the bedrock exposed on the ground surface flows may be roughly “guesstimated” using a basic knowledge of an area’s terrain and understanding of water flows above ground. However, in most situations, the flow of water through bedrock may have little to do with the shape of the surface topography, as was the case in this instance with the predicted groundwater flows based on well data. In all cases, groundwater contamination predictions are dependent on rock composition, the chemical composition of the contaminants themselves, and the structure of the underlying bedrock. In this case, the orientation of subsurface cracks in the bedrock were an important factor and these cracks were sampled using methods that observed cracks both near the surface and deeply below it. The case is exceptional because the orientation of the cracks near the surface happened to coincide with the shape of the terrain. However, this is not always true, since such cracks are always the result of the geologic processes of folding, faulting and uplift that could have happened hundreds of thousands or millions of years ago, before the present ground surface existed.

Whatever the case may be with respect to the differences between risks predicted by EPA technicians and contractors and those predicted by the public, the estimated loss in property value from the perceived risk of groundwater contamination is substantial. Evaluated at the sample mean, our results suggest that affected land prices decline by between $126,580 and $139,680 following the public’s awareness off-site contamination. However, these price effects are consistent with Abdalla et al. (1992) who examine Perkasie, PA household expenditures in response to TCE groundwater contamination. Estimates of expenditures associated with bottled water purchases, home treatment systems, and the hauling and boiling of water between December 1987 and September 1989 ranged from $61,313 to $131,334. Adjusting for inflation, this range becomes $111,620 to $239,091 in 2012 dollars; the estimated shallow groundwater price effects from Models 3 and 4 in Table 3 fall in this range.

Our analysis may underestimate the cost of contamination of properties subject to actual contamination or contamination risk if some of these parcels are no longer marketable. Realtors operating in this market must reveal the nature of the contamination and the regulatory status of the site to potential buyers. In the case of the CTS site, which has received both state and national attention, our estimates of property value declines might represent a lower bound.

Acknowledgments This research was supported by a National Science Foundation award DEB-0823293 from the Long Term Ecological Research Program to the Coweeta LTER Program at the University of Georgia. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the University of Georgia. The authors express their gratitude to Richard Cary, hydro-geologist, and Dr. Elizabeth Cary, geochemist, for helping us with groundwater and groundwater contamination monitoring. We thank Charlotte Jesneck of the North Carolina Department of Environment and Natural Resources, Jesse Lueders of the UCLA School of Law, and John Korzen of the Wake Forest University School of Law for legal insights concerning CTS Corp v Waldburger. We also thank Rhett Jackson and other participants at the Coweeta LTER Brown Bag series for helpful comments.

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