Public Health Report

PRIVATE WELL IMPACTS

FROM

WISCONSIN'S OLD LANDFILLS

FEBRUARY 13, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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PUBLIC HEALTH REPORT

PRIVATE WELL IMPACTS FROM

WISCONSIN'S OLD LANDFILLS

Prepared by:

Wisconsin Department of Health and Family Services
Division of Public Health
Bureau of Environmental Health
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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1. Executive Summary

Some of Wisconsin's old landfills are impacting groundwater and residential wells at levels that pose a public health hazard. Although most of Wisconsin's old landfills are not believed to pose this hazard, sampling residential wells near them is an appropriate and important means of finding problem sites. This investigation examined old landfills that contaminate groundwater and impact residential wells, and then looked at methods for finding these old landfills that pose the greatest threat to nearby residential wells.

There are over 4,000 old landfill sites in Wisconsin. These sites predate modern landfill regulation and, as a result, do not have the engineered features used at modern landfills to protect groundwater. The results and conclusions in this report are not relevant to modern landfills because groundwater near these facilities is monitored closely, and experience has not shown them to pose similar concerns. As rural residential development increases, an increasing number of Wisconsin residents are relying upon private residential water supply wells near these old landfills. Because the groundwater at most of these sites is not routinely monitored, we do not always know when residential wells are contaminated.

This investigation was a collaborative effort between the Wisconsin Department of Natural Resources (DNR) and the Wisconsin Department of Health and Family Services (DHFS). DNR and DHFS agreed upon a method for selecting old, unlined landfills that warranted further investigation. DNR contacted private well owners and collected well water samples. DHFS, using funding provided by the federal Agency for Toxic Substances and Disease Registry (ATSDR) and existing state resources, arranged for sample analysis and assisted DNR with interpretation of the data and related health activities. During the first phase of the project, many of the landfills in a specific Wisconsin county (Ozaukee County) were chosen for residential well testing. One site was found to be impacting eight private wells at contaminant levels exceeding health-based drinking water standards. The impacted water supplies were replaced by extending a municipal water supply line from a nearby community. Work is currently ongoing to address the contamination problem.

The second phase of the project took a broader look at old landfills across the state. DNR staff selected seventeen sites across the state based on several historically important risk factors and the professional judgement of staff familiar with local geology. Groundwater impacts were found at twelve of these landfills. In total, twenty-four wells contained chemical contaminants above health-based drinking water standards. Alternative water supplies have been established to prevent unhealthy exposures, and work to address the contamination is currently at varying stages at each site. This work began in late 1997 and some investigation and cleanup work is ongoing at this time.

DHFS recommends residents, landfill owners, and state agencies each play a role in continued testing of wells around old landfills. When problems are found, steps should be taken to prevent unnecessary chemical exposures and reduce the stress on affected residents. Experience with this project indicates that owners of old landfills and nearby residential well owners are often not aware of the potential implications of these sites.

This report summarizes the results of each of the two project phases. It also contains discussion on many of the most common questions and concerns raised by residents and others affected by contaminated groundwater near old landfill sites.

2. Purpose and Statement of Health Issues

The purpose of this investigation was to identify whether old landfills were impacting private wells and presenting a public health hazard. A secondary purpose was to identify methods for finding the old landfills that pose the greatest threat. The project focussed on human exposure to contaminants in groundwater near these sites, and does not address issues related to landfill gas or direct contact with wastes in the landfill. The primary public health issues included chronic health effects from long-term exposure and the psychological stress that residents faced once contamination was found.

This report was written to summarize the findings of the project and to serve as background information for state and local officials who are dealing with a similar contamination problem for the first time. The report also identifies areas where additional work is needed.

3. Background

In the mid to late 1990s, the DNR and DHFS had been responding to growing concerns about landfills and private well contamination. There appeared to be similarities between old, unmonitored landfills that operated during similar time periods, and experienced similar problems. After talking with DNR staff in the waste and drinking water programs, DHFS initiated this project to sample selected private wells near old, unmonitored landfills. This project was intended to identify drinking water contamination problems, address community health concerns about these sites, and evaluate the effectiveness of the pilot project.

Table 1: Landfill Regulation Timeline

1969	DNR established, begins licensing landfills
1975	1,200 feet landfill setback added to Wisconsin’s Well Code
1980	Solid Waste Code established (NR180 – now NR500). DNR begins to require site specific construction features and monitoring at new landfills.
1984	Wisconsin legislature passes Groundwater Law
1985	DNR begins requiring monitoring at 123 non-approved solid waste landfills suspected of impacting groundwater. Sites were recommended by regional DNR offices. Some regions allowed the landfills to close instead of installing monitoring wells.
1988	EPA publishes draft RCRA Subtitle D regulations. DNR informs landfill owners of proposed changes. Many operating landfills without groundwater monitoring close.
1992	Remaining active landfills required to install monitoring wells.
1996	EPA RCRA Subtitle D regulations take effect.

There are more than 4,000 old landfills scattered around Wisconsin.[1] These *dumps* are different from today’s engineered landfills in that most do not have liners or effective caps. Very few of them have monitoring wells, and of those that do, few are routinely sampled. For the remainder of this document, these older unengineered landfills are referred to as "old landfills" to distinguish them from today's engineered and closely monitored sanitary landfills. One lesson learned from our former waste disposal practices was that without a proper cap and liner, groundwater contamination is a common problem.[2][3]

Table 1 contains a summary of major regulatory changes related to Wisconsin's landfills. Today's engineered landfills are now designed to prevent chemical leaks into the groundwater.[4] They are also constructed with groundwater monitoring well networks to detect any leaks in the event that they occur. Nationwide, our landfills have evolved from small township dumps serving small areas, to very large sanitary landfills that can serve large areas for many years. For this reason, there are relatively few active landfills in the state now, compared to nearly one active dump in each of Wisconsin's 1,265 townships during previous decades (1950s–1970s). The number of active landfills in Wisconsin decreased from 1,120 in 1980 to 125 in 1993. As of 2002, there are just over 80 active sites currently accepting wastes, about 40 of which are municipal solid waste landfills.

Of Wisconsin's 39 Superfund Sites, 25 are old landfills.[5] In 1984, DNR created a list of all of the waste disposal sites they could identify across the state. This list has been updated and revised several times and currently contains 4,299 sites.[1] These sites are not necessarily sources of contamination. Many of them did not receive chemical wastes or wastes that break down to create chemical contamination.

While the number of old landfills is not increasing, the number of private drinking water wells in rural areas is increasing rapidly. Approximately 35% of the state's population, or nearly two

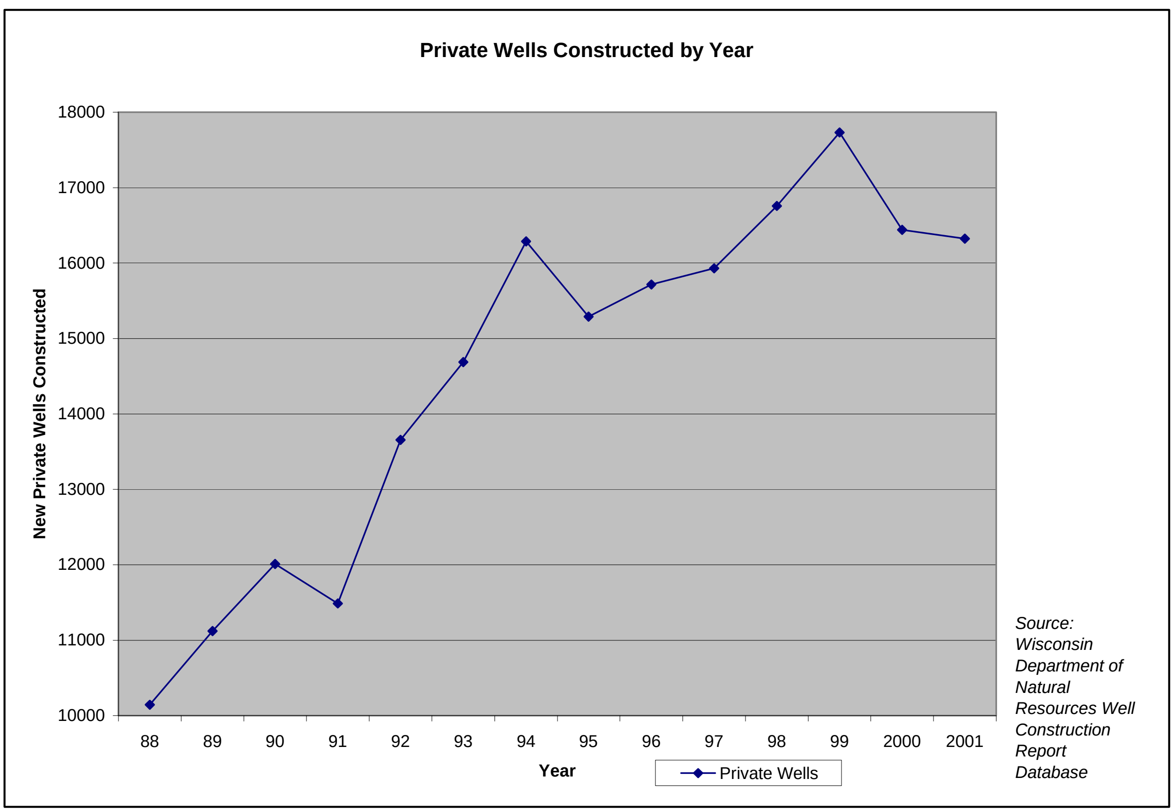

Figure 1: General increase in private well construction in Wisconsin, 1988-2001.

million Wisconsin residents live in rural areas as defined by the US Census Bureau.[6] Each year, more than 15,000 new private drinking water wells are installed in Wisconsin (refer to Figure 1).[7] That number has been growing steadily since 1988. Many of these are private drinking water wells serving newly constructed homes in rural areas. The rapid rural residential development Wisconsin has been experiencing has not spared many parts of the state. As a result, more wells are being constructed near old landfills, placing them at greater risk of chemical contamination.

Municipalities with public water supplies are required to conduct regular water quality testing to ensure that the water they provide to customers meets state and federal drinking water standards.[8][9] There is no similar testing program for the nearly two million residents relying upon private wells in Wisconsin. Each well owner is responsible for testing his or her own drinking water. DNR has a variety of educational fact sheets and brochures that help well owners understand how to test their well to ensure their well water quality is safe. The most common groundwater contaminants that can migrate significant distances from a landfill are volatile organic compounds (VOCs). Because laboratory analysis for VOCs can be relatively expensive, few private well owners test their wells even once for VOCs.

Wisconsin's existing groundwater law (Chapter 160, Groundwater Protection Standards) provides the authority that allows Wisconsin to protect groundwater from contamination and to restore groundwater quality when contamination is identified. However, the old landfill sites of most concern were constructed prior to promulgation of Wisconsin's groundwater law.[10]

Wisconsin's well construction code restricts the installation of drinking water supply wells within 1,200 feet of an "existing, proposed, or abandoned landfill."[11] This restriction was created to recognize the potential threat that old landfills can have on nearby groundwater. When abiding by the restriction is not feasible, the code contains a variance procedure whereby a well driller may construct the well closer.[11] In return, the driller may have to add additional construction or installation features to safeguard the groundwater and well. Because this setback requirement was added to the code in 1975, wells serving older homes were not similarly restricted. Over 1,800 landfill-related variances, allowing wells to be placed within 1,200 feet of landfills, have been issued as of the end of calendar year 2001. Since this project was initiated, DNR has required a VOC sample from each well receiving a landfill setback-related variance when the well appears to be potentially in the direction of groundwater flow from the site.

4. Pilot Tests Ozaukee County (Phase 1)

In December 1997, DHFS and DNR began a pilot sampling project to prioritize and sample private wells near old landfills in Ozaukee County. This project focused on Ozaukee County because recent findings of private well contamination raised public concern in this area.

<u>Site Selection</u>

Old landfills were selected based on the lack of groundwater monitoring and the potential for groundwater contamination. When nearby private wells were present, and plausibly downgradient, representative wells were selected for monitoring. If the homeowner was not interested in having his or her well sampled, another well was selected. If contamination was found, the homeowner was notified and was provided appropriate public health advice. Some of the advice provided to homeowners for reducing exposure is discussed later in this document.

A team was formed that included personnel from DHFS, DNR, the Ozaukee County Health Department, and a retired DNR solid waste investigator. The group met to review file information and to discuss historic knowledge about the 43 individual sites on the Registry of Waste Disposal Sites for the county. In doing so, the group eliminated sites that would not be expected to cause groundwater contamination. Those landfills contained only yard and wood waste. Seventeen of the original 43 sites were selected for sampling. Of the twenty-six sites not selected, seven had already been identified as sources of groundwater contamination and were being addressed separately; ten had received only yard waste or demolition debris and were not believed to be likely sources of groundwater contamination; four sites were within municipalities with monitored public water supply systems; three had some level of groundwater monitoring that did not indicate a problem; one site had been excavated and relocated to a sanitary landfill; and one site had been previously evaluated as part of a separate testing program within DNR. This phase of the project began in the fall of 1997.

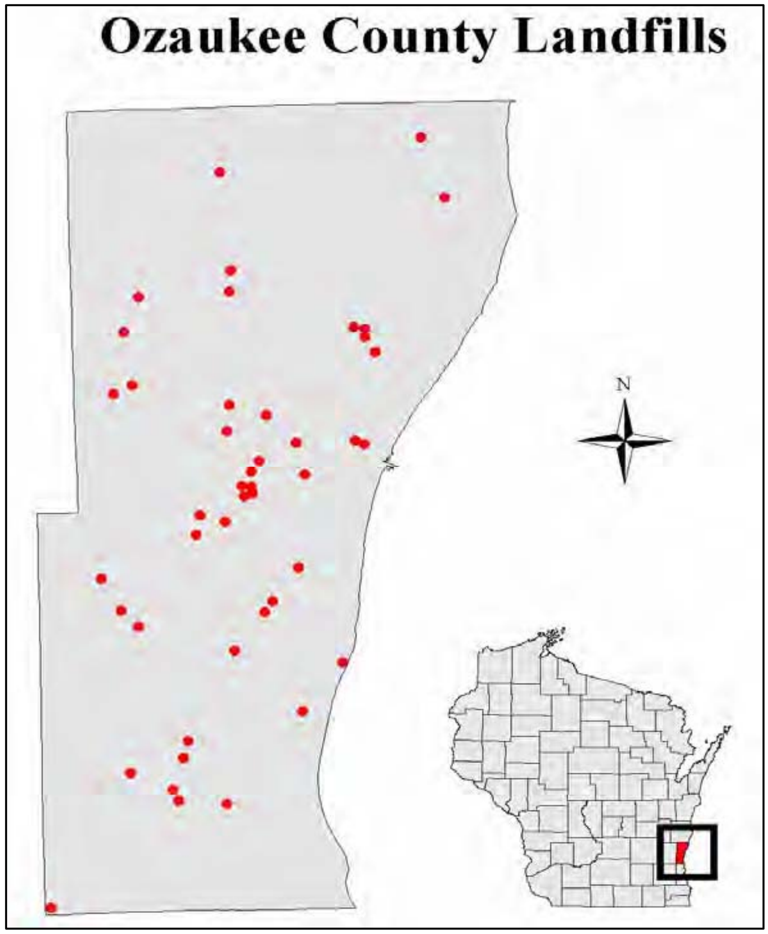

Figure 2: Old Landfills in Ozaukee County

While in the office, staff reviewed aerial photographs and topographic maps to identify private wells that might be at risk of contamination. Once in the field, staff were able to identify new homes not represented on the older aerial photographs that might have been better candidates for sampling based on location. Wells were selected because of their proximity to the site and because they were in the likely direction of groundwater flow. Because local groundwater flow maps were not available, the orientation of the surface watershed was used as a surrogate for groundwater flow.

Because some sites had few homes nearby and because some of the sites were close to one another, the initial sampling for the seventeen sites only involved twenty samples. Each sample was analyzed for VOCs. A follow-up sample was taken at one site to address contamination from a laboratory artifact. In addition, testing was expanded to twenty-seven additional wells around the one site where VOCs were detected. Only one of the seventeen sites selected for Ozaukee County was found to be impacting nearby drinking water wells. This site was the Town of Grafton Landfill.

Town of Grafton Landfill

While discussing the sites in Ozaukee County, a number of individuals in the workgroup expressed concerns about the Town of Grafton Landfill that was later found to be impacting private wells. In a discussion with the Board of Health for Ozaukee County, one board member also expressed concern about what may be found at this site.

The former Town of Grafton Landfill, also called the Denow Landfill, operated from 1970 until it was closed in 1989. Limited information available in DNR files indicated that the ten-acre site accepted municipal solid waste, though some reports of illegal, unsupervised dumping were noted. When faced with having to install monitoring wells and conduct long term groundwater monitoring to stay in operation, the township chose instead to close the landfill without providing for groundwater monitoring.

Three samples were initially collected near the Town of Grafton Landfill. Two of the three samples contained no VOCs. However, the third sample contained three VOCs, including vinyl chloride at 33 parts per billion (ppb). Follow-up sampling found a total of eight private wells containing vinyl chloride between 0.2 and 60 ppb. Wisconsin's drinking water standard for vinyl chloride is 0.2 ppb. At levels above 2.0 parts per billion (ppb) for vinyl chloride, residents are advised not to use their water for household uses other than flushing toilets. Six of the eight wells contained vinyl chloride above the DHFS "flush only" advisory level.

DNR provided bottled water service for those residents within a few days. Shortly after, the town of Grafton took responsibility for the bottled water program for the residents. The Emergency Response Branch of the Superfund Program from the Environmental Protection Agency (EPA) Region V office in Chicago was contacted for assistance because the vinyl chloride levels were above their removal action level of 1.8 ppb.[12] EPA had whole-house water treatment systems installed in six of the eight affected homes. Later in 1998, DNR and EPA worked with the nearby Village of Grafton to extend a municipal water supply line to approximately 30 homes in the area of concern.[13]

In order to fully characterize the extent of private well impacts, DNR, EPA, and DHFS sampled more than 40 wells. In total, DHFS funding was used for 27 VOC samples.[14][15]

DHFS, DNR, and EPA participated in three public meetings held in the Grafton Town Hall to provide information about the problem and to address the community's questions and concerns. The agencies also developed and distributed an informational fact sheet that included an announcement about the first of the public meetings. Prior to the first meeting, DHFS conducted a community involvement needs assessment, which was used to organize the meeting content. Following the first meeting, an evaluation form was mailed to the residents attending the meeting. The responses from that evaluation were used to focus the content of follow-up meetings.

5. Methods Developed for Statewide Sampling (Phase 2)

Following the private well sampling conducted in Ozaukee County, additional sampling was conducted near an additional seventeen landfills across the state (Figure 3). Staff in the DNR programs dealing with private wells and those dealing with landfill issues were asked to select locations for sampling. They were asked to use their professional judgement in assessing various criteria used to identify old landfills that might pose a threat to nearby private wells. Seventeen locations statewide were chosen for follow-up with private well sampling.

Site Selection

There were a number of reasons for selecting each of the sites. Involved staff members were asked to describe the factors that led to their selection. The six most common factors/criteria are ranked (a)–(f). The specific sites selected because of characteristics coinciding with the reason are numbered in parentheses. The numbers correspond to the sites mapped in Figure 3.

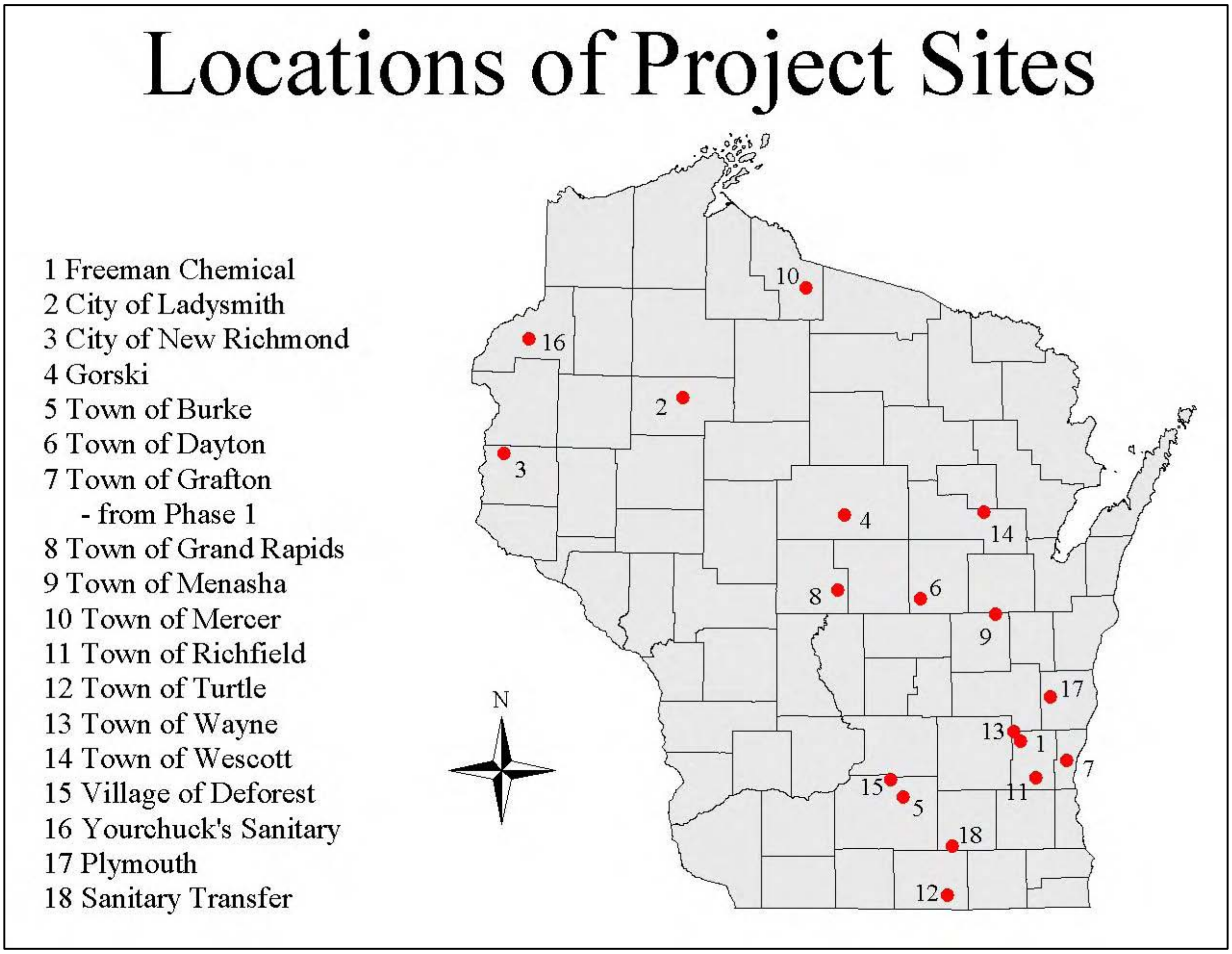

Figure 3: Old Landfills Evaluated in Phase 2

<u>(a). Private wells near/downgradient</u> – Twelve of the seventeen sites were of concern because private wells appeared to be close to the areas of waste disposal and likely to be downgradient based on limited information about groundwater flow direction. (#1,2,3,4,6,7,8,9,10,11,12,13)

<u>(b). Landfill monitoring issues</u> – Concerns were raised at seven sites related to an existing monitoring program issue. At four sites, there was some existing evidence of impact to groundwater in either monitoring wells or other nearby wells (nearby municipal well). When the party currently responsible for the site requested reduced monitoring requirements, DNR staff found concerns about the adequacy of the existing monitoring program while reviewing the request. (#4,5,6,10,12,15,17)

(c). Geologic and landfill construction factors – Seven sites were identified as having geologic conditions and poor construction features, indicating high potential for groundwater impacts. The geologic conditions tended to involve shallow groundwater, sand and gravel, or karst geology. The landfill construction feature mentioned most frequently was the lack of an engineered liner. (#3,6,9,10,11,13,18)

(d). Operation practices – Operation practices noted in the file or observed by existing staff who were knowledgeable about site operations caused concerns to be raised about six sites. Concerns were raised about the use of the sites for disposal of commercial wastes and drum disposal. Whether the wastes were burned raised additional concerns. Staff believed that operations that burned wastes were less likely to contaminate groundwater. Two of the sites were licensed to accept toxic and hazardous wastes. Operation issues were also a significant concern at the Ozaukee County site found to be impacting private wells. (#1,7,11,13,14,16)

(e). Increased residential development – Concerns were raised about recent development near four of the sites. One site had no prior nearby residential development, so concern was raised after initial development was begun. New construction drew attention to existing homes at other sites, where the existing homes predated landfill construction or setback requirements for residential wells. (#3,6,14,16)

(f). Problem landfill nearby – Two of the sites were selected largely because they were near other landfills already shown to be impacting groundwater and private wells. Nearby sites tend to be in similar geologic settings and often had wastes brought from the same sources. (#3,5)

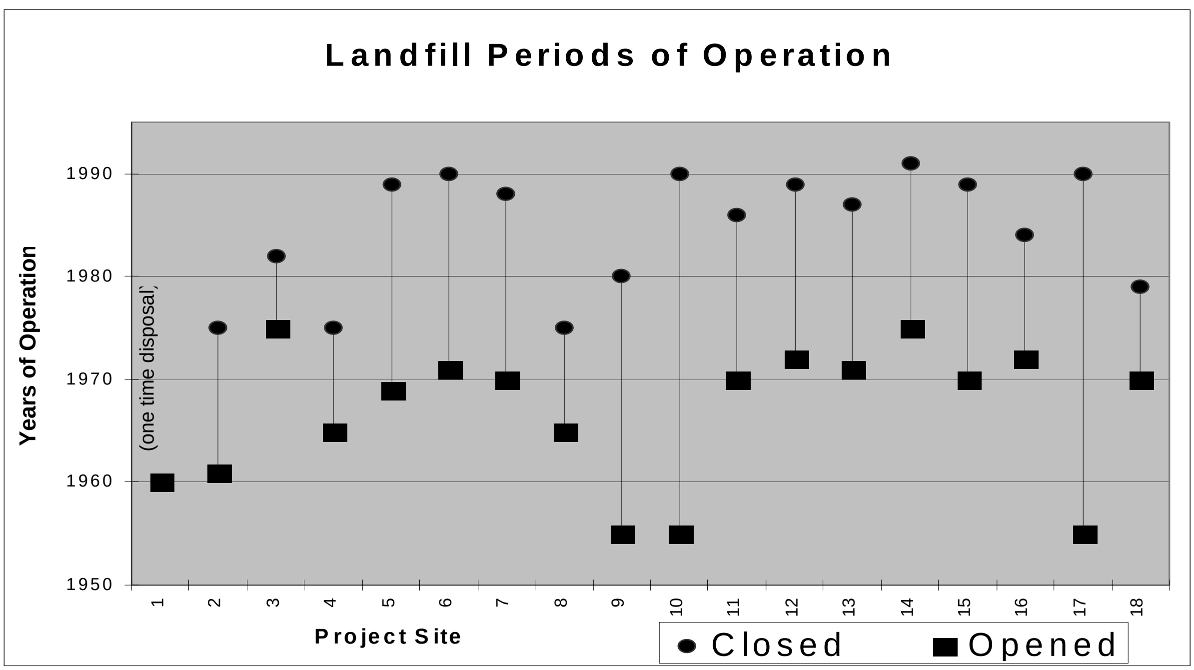

Figure 4: Years of Landfill Operation. Project Site corresponds with numbered list in Figure 3.

Period of Operation

The period that the landfill operated is a key factor influencing the threat it poses to area groundwater. Sites that opened prior to the creation of landfill construction requirements rarely had any form of engineered liner. Similarly, landfills that closed before such requirements were in place would not have an engineered cap or groundwater monitoring.

The period of operation of the sites selected for this project was not always clear. Prior to 1969, DNR did not exist, and file records from before that time are scarce. The sites in this project operated between 1955 and 1992. All of them were opened by 1975 (Figure 4).

Contamination
Samples from private wells next to twelve of the seventeen sites contained VOCs (#2,3,4,6,7,8,9,11,12,13,14,17,18). Between one and five wells were initially sampled from each of the sites. Follow-up sampling was conducted at the locations where contaminants were found. More than 120 individual private wells were sampled for this project. More than 50 of the wells contained VOC detects. Table 2 contains a summary of the VOCs detected in the private wells during this project.

Contaminants Found
The typical groundwater contaminants at Wisconsin's unlined landfills include VOCs, semi-volatile organic compounds, pesticides, and metals. However, of that list, VOCs are generally the most likely to migrate longer distances from the waste at levels that could pose a health concern to residents using private wells. Some exceptions include sites where sulfates and metals such as boron and selenium at fly ash landfills are more common contaminants of concern.

The VOCs themselves do not all migrate at the same rates from landfill sites. The petroleum-related VOCs (such as benzene, ethyl benzene, toluene, and xylenes), while common components of landfill leachate, are more readily degraded by microorganisms in the soil and groundwater. On the other hand, the chlorinated solvents (such as trichloroethylene and vinyl chloride) and freons, also common to landfill leachate do not attenuate nearly as well and have migrated as far as a few miles from some Wisconsin waste sites.

At the 34 landfills tested in both project phases, there were twenty-five different VOCs detected. Table 2 contains a summary of the sample results. Although twenty-five different VOCs were detected, only six of them (all chlorinated solvents) were detected at levels of health concern in private wells. Table 2 shows the highest level of each contaminant detected compared to Wisconsin's health-based groundwater standards and the ATSDR comparison values. The frequency of detection shown in the table is based on the number of sites at which each chemical was found, rather than the number of wells where it was detected.

Table 2
Summary of Residential Well VOC Test Results

Compound	# Sites With Wells > Standard	# Sites With Chemical Detects	Highest Detected Level Units ppb	Health Based Groundwater Standard[a] Units ppb	ATSDR Comparison Value[b] Units ppb
Benzene	0	3	0.71	5.0	0.6 CREG
Bromoform	0	1	0.56	4.4	4.0 CREG
Butylbenzene(sec)	0	1	0.2	NA	NA
Chloroform	0	2	1.7	6.0	6.0 CREG
Chloromethane	0	1	1.8	3.0	3.0 LTHA
Dichlorobenzene(1,3)	0	1	0.19	1,250	600 LTHA
Dichlorobenzene(1,4)	0	2	1.1	75	75 LTHA
Dichlorodifluoromethane	0	8	34	1,000	1000 LTHA
Dichloroethane(1,1)	0	6	73	850	NA
Dichloroethane(1,2)	0	1	0.46	5.0	0.4 CREG
Dichloroethylene (1,1)	**1**	**2**	**53**	**7.0**	**7.0 LTHA**
Dichloroethylene (cis-1,2)	**1**	**7**	**190**	**70**	**70 LTHA**
Dichloroethylene (trans-1,2)	0	2	2	100	100 LTHA
Dichloropropane(1,2)	0	3	0.2	5.0	NA
Methylene chloride	0	1	0.67	5.0	5.0 CREG
Methyl-tert-butyl ether	0	1	0.6	60	200 LTHA
Naphthalene	0	2	0.18	40	100 LTHA
Styrene	0	1	0.75	100	100 LTHA
Tetrachloroethylene	**2**	**2**	**42**	**5.0**	NA
Trichlorobenzene(1,2,4)	0	1	0.89	70	10 LTHA
Trichloroethane(1,1,1)	**1**	**3**	**450**	**200**	**200 LTHA**
Trichloroethane(1,1,2)	0	2	1.5	5.0	0.6 CREG
Trichloroethylene	**2**	**4**	**390**	**5.0**	NA
Trichlorofluoromethane	0	4	3.5	1,000*	2000 LTHA
Vinyl chloride	**4**	**4**	**62**	**0.2**	**0.03 CREG**

a – Wisconsin's public health based Groundwater Enforcement Standards are set to be protective of public health and are consistent with regulatory standards for public drinking water supplies.
b- ATSDR Comparison Values are used for screening environmental sample results. Environmental concentrations below these levels are not expected to pose a health hazard to people. Concentrations above this level do not necessarily pose a hazard to people but warrant closer consideration.
ppb – Parts per billion
CREG – The Cancer Risk Evaluation Guide is a level below which exposure would result in an increased cancer risk less than one in one million.
LTHA – The Life Time Health Advisory is a level below which exposure is not expected to cause adverse health effects for non-carcinogenic chemicals.
Bolded font indicates results above comparison value.

Distance to Wells with Contaminants

The private wells containing contaminants ranged in distance from about 200 to 4,000 feet from their respective sites. The graph in Figure 5 plots the distances to the wells containing contamination for each of the twelve sites.

Variances

Although there were many private wells within 1,200 feet of these landfills, variances had been issued for only one site (#17). Two wells at this site had received variances for construction within 1,200 feet and were later found to be contaminated with trichloroethylene and other VOCs. In another three landfills (#2,4,16) variances should have been requested prior to well installation (the wells were within 1,200 feet of the landfill), but had not been. In most cases, the variance requirements did not apply to the wells in question because they were greater than 1,200 feet away or they were installed before the requirement came into effect in 1975. Since this project was initiated, the DNR is now asking for a VOC sample from each well receiving a landfill setback related variance when the well appears to be potentially in the direction of groundwater flow from the site.

Responses Taken

The follow-up response at each of these facilities varied depending upon what was found and other issues specific to each site. The three general categories of follow-up activity included: (1) informing affected/interested residents: (2) conducting additional investigation; and (3) providing alternative/replacement water supplies.

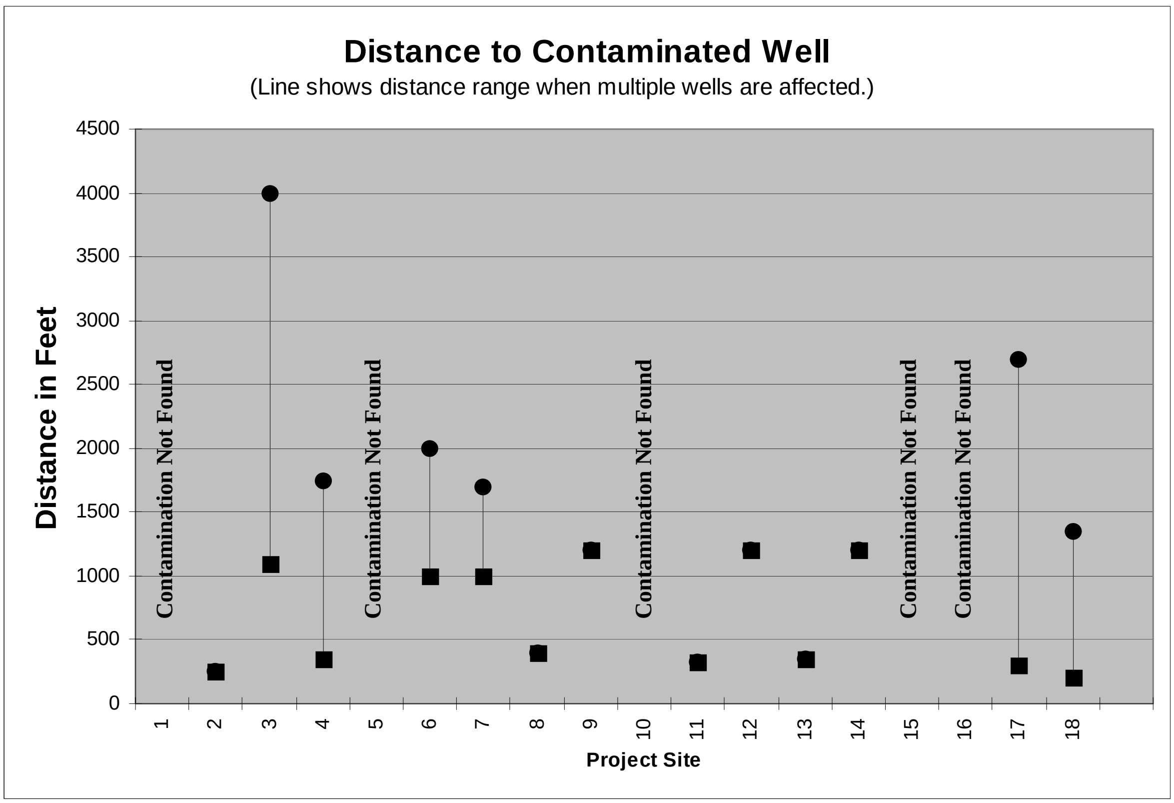

Figure 5: Distance Between Landfills and Contaminated Wells. Project Site corresponds with numbered list in Figure 3.

<u>Sites Without Contamination</u>

There were five landfill sites in the statewide portion of the project for which no VOCs were found in nearby private wells (#1,5,10,15,16). Each well owner received a copy of their results and a letter explaining how to interpret the results. Although the sampling did not identify a concern, in some cases merely visiting the sites and opening the files prompted additional activities. At one site, wells had been installed within 1,200 feet of the landfill without the required variances. DNR staff involved are working with the property owners to obtain the variances and ensure that additional wells are not installed without going through the variance review process. At another landfill site, staff were concerned that the most at risk wells were not sampled, so additional sampling is recommended.

Sites with VOCs at Levels Below Standards
At seven sites, contaminants were detected in private wells, but all contaminant concentrations were below levels of health concern (#6,8,11,12,13,14,18). In most cases, only one or two wells were impacted. Future re-sampling is recommended by DHFS for these wells. Most of the impacted wells, and additional nearby wells, were sampled to confirm results and better define the extent of contamination. At one site (#6), several private wells contained low level VOCs. Although none of the wells contained VOCs at levels of health concern, several wells were impacted, and there was new residential development in the area. At this site significant additional work has been done to better characterize the extent of contamination. The monitoring plan for this site has been modified to reflect the discovery of contaminated wells. Many residents near the site have expressed serious concerns about the contamination and several public meetings were held to discuss the problem.

Sites with VOCs Above Standards
At five sites, contamination was found in private wells at levels exceeding health based groundwater and drinking water standards (#2,3,4,9,17). DHFS staff contacted each of these residents by phone and gave them general health advice when their test results were received. After confirmation samples were analyzed, letters were sent to each resident with an explanation of their sample results. In each case where the landfill owner did not already provide bottled water, the residents were provided bottled water through the Environmental Fund administered by DNR. This program authorizes bottled water for six months with a possibility of an additional six-month extension. At two of these sites the homeowners with impacted wells have been provided whole-house water treatment systems by the responsible party while additional investigation is ongoing into more permanent water supply replacement options. At two other sites bulk water to serve household water needs is being provided to the affected homes while permanent replacement options are considered. At one site (#9) the single home with the contaminated well was provided alternate water after being connected to the nearby public water supply within several months of discovering the problem.

In total, 177 wells were sampled at least once as part of testing at the 34 old landfills in this project (phases 1 and 2). Of those wells, 32 wells at 6 sites contained chemical contaminants above health based drinking water standards. For this project, Wisconsin's human health based Groundwater Enforcement Standards were used as the primary reference. These standards are consistent with Wisconsin's public water supply maximum contaminant limits or MCLs. Each of those exposures has been stopped by the provision of water treatment, provision of bulk water, or connection to a nearby public water supply system.

Communications

The risk communication process for this project began when DNR staff contacted the homeowner to request permission to collect a sample. DNR staff provided residents with a letter explaining the reason for sampling and providing the resident with some understanding of what they could expect, or they called them to convey the same information. This initial contact was particularly beneficial for cases in which contamination was found.

When the results were received from the lab, DHFS staff contacted residents whose wells contained contamination directly by telephone. DNR staff followed that contact with a copy of the lab results and a letter explaining what they meant. This letter was also sent to those whose wells did not contain contamination. For cases in which multiple wells were affected, additional fact sheets were developed, and public informational meetings were held periodically to keep people informed and to respond to additional questions.

6. Community Health Concerns

As a result of the contamination found through this project there were many opportunities to talk with the residents whose wells were contaminated. Many of the questions and concerns raised were common among the residents near each site. The following is a summary of the most common questions raised:

What are the specific health implications of the site-specific chemical exposures on children? *This is discussed in the* Child Health Considerations *Section of the document.*

What are the effects on the child from maternal exposure to contaminants during pregnancy? *This is also discussed in the* Child Health Considerations *Section of the document.*

What are the combined effects of multiple chemicals present in well water? *A* Chemical Mixtures *section was added to the document within the Contaminant Toxicity section.*

Are there concerns about exposure through uses of the water other than drinking? *A discussion of* Water Use/Route of Exposure *has been added to the section on Exposure Variability and Uncertainty.*

What are the effects of exposure to these chemicals on house hold pets (e.g. dogs, cats, birds, fish, etc.)? *This topic has not been directly addressed in this document as our emphasis is on human health. Our response during the meetings and other discussions have been to refer residents to their veterinarian. We also add that since much of our toxicity information comes from animal studies, residents may assume potentially similar health risks based on similar exposures. A discussion has been added to the* Water Use/Route of Exposure *Section.*

What are the effects of exposure on livestock (particularly dairy)? *Similar to the previous question, this document doesn't directly address this topic. Some of the residents were referred to the Wisconsin Department of Agriculture Trade and Consumer Protection, particularly with questions about how contamination may affect Grade A Dairy Certification. A discussion has been added to the* Water Use/Route of Exposure *Section.*

Is it safe to water gardens with contaminated well water (both for exposure and vegetable uptake of contaminants)? *A discussion of this Water Use has been added to the* Water Use/Route of Exposure *Section.*

Is it safe to use well water for filling pools or hot tubs? *A discussion of this Water Use has been added to the* Water Use/Route of Exposure *Section.*

Could exposure to these contaminants explain the incidence of cancer in the area of the landfill? *This topic is discussed in the section on* Reported Health Effects.

Can exposure to these contaminants explain other unexplained health symptoms among area residents? *This topic is discussed in the section on* Reported Health Effects *also.*

Is it possible to conduct a health study of area residents to find out if they have been affected by past or continuing exposure? *This topic is discussed in the* Health Study/Exposure Registry *section.*

How often will area private wells be sampled? *This topic is discussed in the* Monitoring Private Wells *section.*

Several common questions not directly related to public health involved effects on property values, cost of new water systems, local taxes to pay for cleanup, and potential for annexation to nearby municipalities. Although not directly health related, these concerns do offer additional insight into additional sources of stress that can be of public health significance. These concerns were referred to and addressed by the appropriate authorities. *A discussion of issues involving emotional stress has been included in a section on* Stress *in the document.*

7. Public Health Implications

Contaminated drinking water supplies near old landfills come with a range of public health implications. The health risks posed by exposure to the contaminants can be complex. In addition to drinking water, people are exposed to contaminants through many household water uses. It is common for well water impacts to involve more than one chemical, and the individual chemicals themselves are often linked to several different health effects. The exposed populations often include particularly sensitive groups including children, senior citizens, and people with pre-existing health problems. The chemical and exposure concerns are joined by a list of additional concerns faced by private well owners. Each of these concerns combines to create a level of emotional stress, representing what is often the most significant health issue.

Contaminant Toxicity

In general, scientists have very little information about the health significance of very low level, but long-term, chemical exposures. Most of what we know of chemical toxicity comes from either occupational exposures where people are exposed to potentially very high chemical levels, or animal studies where again, very high exposure doses must be used in order to show measurable effects using relatively small numbers of animals. State and federal groundwater and drinking water standards are developed to prevent exposure to chemicals that could pose a health risk based on the most sensitive of possible health effects. These standards usually begin with information from the occupational or animal studies and factor in the difference in exposure through drinking contaminated water over a lifetime. In this way, the levels of exposure allowed are much lower than the lowest level of exposure documented in toxicological studies to cause a health effect. This process gives regulators confidence that public health is being protected.

Many residents do their own research on the chemicals found in their wells and tend to learn about health effects only relevant to occupational exposures. The public perception can be that exposures to chemicals above a standard is likely to result in each of the health effects related to that chemical. The following is a discussion of possible health effects associated with the six chemicals found above their health based groundwater standards.

Chlorinated Solvents

Chlorinated solvents are a family of organic chemical compounds that contain chlorine. They are used for a wide variety of commercial and industrial applications: degreasers, cleaning solutions, paint thinners, pesticides, resins, and adhesives. They dissolve organic fats and greases efficiently. They also play a key role as base or intermediate chemicals in the production of other chemicals. The following chemicals identified in Table 1 are chlorinated solvents: 1,1 dichloroethane (1,1-DCA), 1,1-dichloroethylene (1,1-DCE), cis 1,2-dichloroethylene (cis 1,2-DCE), trans 1,2-dichloroethylene (trans 1,2 DCE), methylene chloride, tetrachloroethylene (PCE), 1,1,1-trichloroethylene (1,1,1-TCA), 1,1,2-trichloroethylene (1,1,2-TCA), trichloroethylene (TCE), and vinyl chloride. Other chlorinated solvents that can be found in private wells near a leaking site (but were not found in this project) include carbon tetrachloride and 1,1,2,2-tetrachloroethylene.

Because of their common historical industrial, commercial, and residential use, most old landfills contain a variety of these solvents. As these chemicals degrade, they often create other chemicals in the chlorinated solvent family. The degradation process typically involves the loss of chlorine from the compounds (commonly referred to as reductive dechlorination) (e.g., PCE to TCE to cis 1,2-DCE to vinyl chloride).

Health concerns are generally driven by the chemicals classified as known or potential carcinogens (vinyl chloride, PCE, TCE, 1,1-DCE, 1,2-DCA, 1,1,2-TCA). The primary non-cancer health concerns related to low-level chlorinated solvent exposures vary but usually include effects to the liver and kidneys.

1,1-Dichloroethylene (1,1 DCE) is considered to be a possible human carcinogen and has a relatively low drinking water and groundwater standard of 7.0 ppb. The highest level of 1,1 DCE detected in this project was 53 ppb. This level of exposure over many years could result in a low increased theoretical risk of developing cancer. Its carcinogenicity is based on animal studies, while investigation of exposed humans has not found evidence of carcinogenicity. The carcinogen classification of 1,1 DCE is currently under review by the USEPA and may no longer be regulated as a carcinogen in the future. Nine of the wells sampled in this project contained 1,1 DCE above its health based standard.

ATSDR develops minimal risk levels (MRLs) for chemicals to indicate levels of exposure below which no non-cancer health effects would be expected. The MRL for long-term drinking water exposures to 1,1 DCE is 0.009 mg/Kg/day. Assuming a drinking water exposure for a child (1 liter per day for a 10 Kg child - most sensitive individual for DHFS estimates), this would relate to a groundwater concentration of 90 ppb. While on its own, exposure to 1,1 DCE at levels below 90 ppb would not be expected to result in non-cancer health effects, this chemical was always found with other chlorinated solvents who have a similar potential for causing damage to the liver and kidneys.[16]

Cis-1,2-Dichloroethylene (cis 1,2 DCE) is not classified as a human carcinogen. The EPA reference dose (RfD) is similar to ATSDR's MRL in that it is intended to represent levels of exposure below which no non-cancer health effects would be expected. The RfD for cis 1,2

DCE is 0.01 mg/Kg/day, which, to be protective of children, would relate to a groundwater concentration of 100 ppb. The highest level detected in this project was 190 ppb. The health effects potentially relevant to this level of exposure would be reduced red blood cell count and damage to the liver. Cis-1,2 DCE is a common product of the breakdown of TCE, it is frequently found in Wisconsin groundwater. This chemical was found in two wells at levels exceeding its health based standard of 70 ppb. Similar to 1,1 DCE it is not often found at levels that pose a non-cancer health hazard on its own, but can contribute to an overall exposure of chemicals that can cause liver damage.[17][18]

Tetrachloroethylene (PCE) has been found to cause some forms of cancer in laboratory animals (kidney, liver, and leukemia), and its classification as a carcinogen is currently under review by EPA. The highest level detected in wells tested for this project was 42 ppb. Based on the most recent cancer slope factor for PCE, a long-term exposure (many years) at levels in the range of the highest level detected, could result in an increased risk of developing some forms of cancer. Liver and kidney damage has been noticed among highly exposed workers and could also be a concern related to long-term exposures among people with PCE contaminated drinking water. PCE was found in ten wells above its groundwater standard of 5.0 ppb. The MRL for PCE for long-term exposures is 0.01 mg/Kg/day which corresponds with a drinking water concentration of 100 ppb, exposures below which should be protective of children for non-cancer health effects.[19]

1,1,1-Tichloroethane (1,1,1 TCA) is not classified as a carcinogen. Studies of animals exposed to high levels of 1,1,1 TCA have resulted in affects on the nervous system, and damage to the liver. These effects were only seen at high levels of exposure. The EPA has developed an RfD of 0.035 mg/Kg/day for 1,1,1 TCA which would correspond to a level protective of childhood exposures through drinking water of 350 ppb. The highest level of 1,1,1 TCA detected in wells sampled as part of this project was above this level at 450 ppb. Five wells contained 1,1,1 TCA at levels above its groundwater standard of 200. Long-term exposures to concentrations in this range could result in an increase in liver problems, particularly in sensitive individuals.[20][18]

Trichloroethylene (TCE) is one of the most commonly found VOCs in Wisconsin Groundwater. TCE is considered to be a carcinogen and the National Toxicology Program has recently concluded that its cancer potency may be greater than previously thought. The highest level detected in private wells for this project was 390 ppb. Eleven wells contained TCE above its drinking water standard of 5.0 ppb. Long-term exposure to TCE at this level could result in an increase in the risk of developing cancer. Animals exposed to high levels of the compound have developed liver, kidney, lung, testicular tumors, and leukemia.[21]

Long term exposures to TCE in drinking water may also cause damage to the liver and kidney. Animal studies indicate there may be an association between maternal exposure to TCE and specific heart defects in the offspring. Preliminary evidence in humans exposed to the chemical in their drinking water indicates similar effects.[18]

Vinyl Chloride is classified as a known human carcinogen by EPA and other organizations that classify carcinogens (IARC, WHO, etc.). Workers exposed to high concentrations of vinyl chloride have higher rates of a form of liver cancer called angiosarcoma. Other occupational studies and some animal studies have found that long-term exposures to vinyl chloride can cause a variety of liver problems. The highest level of vinyl chloride found in drinking water wells for this project was 42 ppb. Vinyl chloride was found in fifteen wells above its groundwater standard of 0.2 ppb. EPA has developed an RfD of 0.003 mg/kg/day for vinyl chloride, which would correspond to a concentration in drinking water of 30 ppb, below which childhood exposure would not be expected to result in adverse non-cancer health effects.[18][22]

Because vinyl chloride is a potent carcinogen, its Wisconsin groundwater standard and its public water supply Maximum Contaminant Limit (MCL) are quite low (0.2 ppb)[a]. Most common laboratory detection limits are only slightly lower (0.1 to 0.15 ppb). For this reason, whenever vinyl chloride is detected it is already in a range considered to be of health concern. A large number of occupational studies reported an association between VC and liver angiosarcoma or hepatocellular carcinoma.[23]

In summary, 1,1 DCE, TCE, PCE, and vinyl chloride were found in drinking water wells at levels that would pose a low increased cancer risk from long-term exposures. While, TCE, cis 1,2 DCE, 1,1,1 TCA, and vinyl chloride were found at levels that could result in an increase in non-cancer health effects. Liver and kidney damage were each noted as non-cancer health effects for a number of the chemicals listed. For this reason it is important to consider the additive effect of exposure to multiple chemicals in well water when they are found together.

Freons and Chloromethane.

The two freons most commonly detected in private wells near old landfills are dichlorodifluoromethane (Freon 12) and trichlorofluoromethane (Freon 11). When these chemicals enter the groundwater beneath a site, they tend to be very mobile, and are often among the chemicals on the outer edges of the plume. These chemicals have not been found in private wells near Wisconsin landfills at levels of possible health concern Chloromethane (Freon 40) was also a very popular refrigerant and aerosol propellant. However, unlike the Freons, it is considered to be harmful to people at much lower levels of exposure.

Disinfection By-Products.

Disinfection by-products (also called trihalomethanes) are commonly found in private wells as the result of recent well chlorination for disinfection purposes. Many of these chemicals can also be found in contamination from a landfill. The related chemicals detected in wells reviewed for this report are bromoform and chloroform. Other common disinfection by-products that can be found in landfill contamination include bromodichloromethane and dibromochloromethane.

Unless these contaminants are known to occur in the VOC plume from a particular site, the well owner should be asked about disinfection history prior to assuming a connection to the landfill. Under some circumstances the disinfection (also called *shock chlorination*) of a well can also result in the by-products affecting other nearby wells. It is important to know the true source of these chemicals in a private well because if a landfill is the source, it would indicate a significant problem, but if the source is a recent chlorination, it would be of little concern. By-products of well disinfection remain only temporarily and as such, are not a source of chronic exposure. In contrast, landfill contamination can be a source of long-term ongoing exposure once it reaches a residential well.

[a] The federal MCL is 2.0 ppb due to technical feasibility to detect the compound at lower levels at the time that the federal MCL was established.

Petroleum Related Contaminants

Benzene, ethylbenzene, toluene, xylenes, methyl-t-butyl ether (MTBE) and other petroleum related contaminants are commonly found in landfill leachate and groundwater close to the landfill. However, because most petroleum contaminants attenuate much better than chlorinated solvents, they are found less frequently in private wells. MTBE is an exception because it attenuates more slowly, but its production and use began later than the period of operation for most old landfills. Therefore, its detection is more likely an indication of an unrelated and more recent gasoline release. The source may still be in the area of the landfill, because it is not uncommon for these properties to continue to have multiple uses after closure of the waste disposal areas. Because exposure to benzene has been shown to cause cancer (leukemia) in people, it is usually the petroleum contaminant of greatest concern when found in well water.

Other VOCs

A long list of other VOCs can be found in groundwater near old unlined landfills. Different commercial and industrial activities in different parts of the state result in different wastes entering the local landfills. This in turn often results in a different chemical “fingerprint” contaminating the groundwater beneath.

Estimating Health Risk

Overall health risk from a contaminated water supply is a function of: (1) the toxicity of the contaminant; (2) the level of contamination (concentration); (3) the presence of multiple chemicals in the water; (4) the way people use their water; (5) other sources of chemical exposure; and (6) individual health circumstance and sensitivity to chemical exposure. There is a large degree of variability and uncertainty involved in each of these factors.

Toxicity

Much of what we know about a chemical’s toxicity has been derived from studies generally unlike the environmental exposures we see in communities. Many assumptions and mathematical estimations are made to translate from animal studies or occupational studies to long-term, low-level chemical exposures. There is uncertainty involved in the process of predicting human toxicity. Where uncertainty exists, the assumptions are selected to err on the conservative side to protect sensitive members of impacted communities. As a result, health officials tend to overestimate the health risk posed by a substance when the toxicity information is limited.

Concentration

As seen from the results of the well samples, the concentrations change over time. We can also expect some amount of variability in the sample results based on variability in sample collection and laboratory analysis. This makes it difficult to predict the level of future exposure with much accuracy. Unless either the contaminant source or water supply well is new, it is generally impossible to estimate historic contaminant concentrations. The most common method for estimating exposure concentration is to assume the current concentration has always been the same and will not change over time. In projects involving chlorinated solvents from an old landfill, this can be a fair assumption. It is not uncommon to find that a plume has reached a “steady state” from an old source.

Chemical Mixtures

Due to the wide variety of wastes that are disposed in a landfill, there is also a wide variety of chemicals in landfill leachate. Some of these chemicals degrade relatively quickly, others stick to soil and organic matter and do not move into groundwater. The chemicals that do reach the groundwater and move with it still make up a relatively long list. As a result, contaminated wells usually contain several chemicals at a time. The health-based groundwater standards (established in Wisconsin Administrative Code NR140) are based on the health effects of each individual chemical by itself. However, the health risk of a mixture of chemicals may be unacceptable even though none of the individual chemicals are found above a standard.

The combined effects of two or more chemicals may result in no change in the way we evaluate them, if they are associated with completely different and unrelated health effects. For chemicals that affect similar organs or systems, predicting the cumulative effects can be complicated. The combined effect may be the same as adding the effect of each chemical if they act in a similar way. The effect may be greater than the additive effect, if the presence of one chemical amplifies the effects of another (synergistic effect). It is even possible the effect will be decreased if the presence of a particular chemical interferes with the effect of another (antagonistic effect).

In order to address this issue, DHFS uses an additive total risk for carcinogens, and a total combined hazard index for non-carcinogens. Exceptions can be made, if the chemicals involved have very different modes of action and are considered unlikely to act in an additive fashion.[24] This procedure is also recommended by ATSDR in their Draft Guidance Manual for the Assessment of Joint Toxic Action of Chemical Mixtures when more rigorous toxicity information isn't available for the actual mixture of concern.[25] ATSDR has begun development of a number of interaction profiles, in which research on the combined effects of common mixtures are reviewed. One such profile is currently under development for four common chlorinated solvents (1,1,1-trichloroethane, 1,1-dichloroethane, trichloroethylene, and tetrachloroethylene). The current draft of this document supports the use of additive toxicity as the limited studies of joint toxic action do not suggest a greater-than-additive effect.[26]

Water Use/Route of Exposure

Often more variable than the level of contamination is the way in which people use their water. Many people already do not drink their water because of aesthetic problems, while others drink a lot of water as a matter of daily routine. The Environmental Protection Agency's National Center for Environmental Assessment publishes estimates of water use by people in its Exposure Factors Handbook.[27]

Most of our health-based drinking water and groundwater standards are developed to prevent drinking water or ingestion related exposures. However, for many VOCs, ingestion is not the only significant route of exposure. It is the nature of VOCs to evaporate from the water and into the air. The rate of volatility varies among VOCs, and the type of household water use can also influence how much of the VOC leaves the water and enters the air. The rate at which VOCs enter air is influenced by the temperature of the water, the surface area exposed to the air, and the period and rate of water use.

Vinyl chloride, for example, has a very high Henry's Law Constant, indicating that it volatilizes relatively quickly from water. Because most kitchen faucets are equipped with an aerator, much of the vinyl chloride in tap water enters the air rather than the water glass when drawn for drinking. The exposure we predict through ingestion actually takes place to a greater extent through inhalation. A long hot shower can result in some of the greatest releases to indoor air from household water uses. The water temperature is generally higher, and the stripping efficiency of the shower spray is very high. Other large volume uses such as washing clothes or dishes can add to the VOCs released to indoor air, though generally there is more dilution in larger rooms (compared to a shower), which can lower exposure concentrations.

Small amounts of VOCs may be absorbed into the skin of people who have skin contact with the water (e.g., bathing, washing hands, dishes). The proportion of VOC exposure through skin absorption is generally relatively low compared to that of either inhalation or ingestion, because of the relatively low expected rate of absorption for VOCs and typical household water uses.

Total exposure is cumulative across each of these exposure routes. However, due to the variability in water use over time, total exposure is very difficult to generalize. We already accept a high degree of variability within the drinking water exposure without the added dimensions from other exposure routes.

Residents with contaminated wells commonly raise questions about other exposure-related issues, including the exposure from watering gardens, filling pools and hot tubs. Most outdoor uses of water contaminated with VOCs would provide very little opportunity for exposure. The constant dilution with circulation of fresh air prevents buildup of VOC concentrations even with large volume uses. Much of the VOCs in the source water volatilizes into the air while watering gardens and would not be expected to accumulate in garden vegetables as a result. Filling pools and hot tubs can provide some potential for exposures through skin absorption of the VOCs remaining in the water after filling for the relatively short period before they volatilize into the air. DHFS has recommended to residents concerned about this exposure that they encourage volatilization by spraying the water into the pool or hot tub when initially filling.

Concerns about the health effects on pets and livestock are also raised routinely by residents with contaminated wells. While DHFS does not have specific expertise in the health implications to these animals, some of the same exposure advice can be useful. House pets are primarily exposed to contaminants in water through drinking from bowls. Filling the water bowl and setting it outside for an hour or two would reduce any potential VOC exposure.

Livestock questions can be more complicated to address. Outdoors or with the large volume air exchange of a typical dairy barn, there is little concern about inhalation exposures. Similarly, there are few large volume water uses that would result in a skin absorption concern for livestock. Watering horses and other large animals using large water troughs can provide the same opportunity to enhance volatilization by spraying the water to fill them. However, the individual self-watering devices used for dairy cows don't significantly reduce VOC levels during use. The Wisconsin Department of Agriculture Trade and Consumer Protection should be contacted for information on the water quality implications for dairy and meat production.

Variability and Uncertainty

Uncertainty represents a lack of knowledge about the exposure or risk, whereas variability is the true difference in how people are exposed and affected by exposure. The uncertainty can lead to inaccurate estimates, whereas variability can affect the degree to which the estimates can be generalized to the general population.

Perhaps the greatest area of variability is in how different people respond to chemical exposures. Current scientific understanding and medical technology does not provide many tools for identifying, characterizing, or predicting these differences. Some population-wide generalizations have been made for groups considered sensitive sub-populations (children, elderly, etc.), and those with existing medical conditions.

Estimating each of the exposure variables includes a high degree of uncertainty. This makes it unrealistic to attempt accurate quantification of exposure. However, because of individual variability, and acknowledged quantitative uncertainty behind the toxicity values themselves, it is usually of questionable scientific benefit to establish an accurate estimate of past exposure.

Health Advisories

When residential well samples contain contaminants above levels of health concern, DNR and/or DHFS staff issue a drinking water advisory and offer health advice on how the residents may reduce the related exposure. The level and type of health concern involved determines the level of the advisory and the agency from which it is issued. For contaminant concentrations exceeding a drinking water or groundwater standard, staff from the DNR Private Water Supply Program issue a *drinking water* advisory. This advisory recommends that residents find an alternative source of water for drinking and food preparation. When no standard is exceeded but the cumulative risk from the presence of multiple contaminants exceeds safe levels, a similar advisory is issued by a DHFS toxicologist.

A *flush only* advisory is issued by DHFS when the level in the water exceeds the one in ten thousand cancer risk for carcinogenic VOCs. In this advisory, DHFS advises that residents not use the water for household uses other than flushing toilets. Although inhalation is the route of exposure of concern, the risk estimate is based on drinking water assumptions. This type of advisory is only issued when routes of exposure other than drinking are also a concern. If acute or sub-chronic, non-cancer health effects are possible for uses other than drinking water, this advisory may also be issued.

The difference in the thresholds for these advisories does not indicate that inhalation is a concern only at much higher levels. Rather it is intended to balance the level of risk and the level of effort needed to follow the advisory. It is relatively easy to switch to bottled water to avoid drinking water exposures to contaminants, so the drinking water advisories and standards are set to prevent low unnecessary risks. Conversely, it is extremely difficult to provide an alternative whole-house water supply to accommodate other household water uses, so the threshold for the flush only advisory is considerably higher. If residents wish to continue use of their water, DHFS staff will provide suggestions for reducing exposure until a clean water supply can be obtained. Some of these suggestions include taking shorter and cooler showers, use of bathroom ventilation fans while showering, properly venting clothes dryers outside, and opening windows while washing dishes.

Reported Health Effects

At four of the sites, from both phases of the project, residents expressed concerns that symptoms such as skin irritation (rashes), headaches, and chronic fatigue were related to contamination in their wells. Because a survey was not conducted, it was not possible to compare the rates of reported symptoms with those experienced by the general public at large. The contaminant concentrations in their wells were not near levels expected to cause acute symptoms. Many of the wells were sampled for additional organic compounds, metals, and microbial contaminants. No contaminants were found that would represent a likely source of these symptoms.

Many of these residents reported relief from the symptoms when they changed the source of their water. Several explanations are possible. Some people may have an unusual sensitivity to these exposures, which is not described in existing toxicity information for these chemicals. There may be a power of suggestion for those who had personally associated exposure with their symptoms; or simply coincidence, because these are not uncommon health symptoms.

Concerns about clusters of disease (particularly cancers) are often raised by residents when contamination is identified. Residents near three of the sites raised concerns about suspected cancer clusters. However, the cancers were generally not similar, were relatively small in number, and the residents didn't share similar chemical exposures. During this project, DHFS created a fact sheet on cancer clusters for use at one of the project sites and other sites around the state. A copy of this fact sheet can be found on the DHFS web site.
www.dhfs.state.wi.us/eh/HlthHaz/fs/CancerClus.htm

In light of the studies available, the health effects would be very subtle (if even noticeable) for exposures in the ranges listed in Table 1. The non-cancer health effects implicated for the chemicals are common and also have other more common causes. Likewise, for these chemicals considered to be known or potential human carcinogens, the forms of cancer that have been associated with those chemicals are not uncommon and again have a variety of much more common risk factors.

For this reason, we expect to find individuals among those with the contaminated wells exhibiting at least some of the health effects or symptoms. In such cases, we cannot generally implicate the particular chemical exposure as they arise, but we are also unable to rule out some possible relationships.

Stress

Although no health questionnaires were distributed, stress was clearly evident at each site where contamination was found. The presence of stress seemed to be correlated with the presence of contamination at the site. However, the level of stress did not seem to mirror the level of contamination.

Stress itself is not a direct physiological product of chemical exposure. Rather, it is caused by the fear of illness, uncertainty, and lack of control over chemical exposure and the future. Many studies have shown that stress can cause a wide variety of measurable health effects. Some of these effects can include elevated blood pressure and heart rate, hypertension, cardiovascular disease, headache, impaired immune and endocrine function, gastrointestinal disorders, skin effects (including rashes), anxiety, depression, concentration problems, and difficulty sleeping. Some of these effects have also been associated with high level (occupational) exposures to some of the VOCs reviewed in this project. This makes it difficult to sort out causal relationships and could actually have some combined effect.

The Agency for Toxic Substances and Disease Registry (ATSDR) convened an expert panel on the topic of Psychological Responses to Hazardous Substances which documented the effects of stress related to hazardous waste sites.[28] The panel identified uncertainty and loss of control as significant sources of stress. Some of the recommended responses to address stress include early intervention to address exposure and information gaps, validation of stress as a normal reaction to an abnormal situation, and involving the community in developing the solution.

According to this panel, stress is often stated as the central concern of communities affected by contamination; however, a health concern is also often the only issue that some community members feel they can cite to legitimize their concerns. Quality of life, social stigma, and loss of property value are concerns that sometimes go unstated because residents believe those concerns will not generate support.

Several actions were taken in this project in an attempt to reduce uncertainty and to give residents control over their exposures and the selection of solutions. Letters explaining individual sample results were provided to each resident. However, residents were also contacted directly when possible to discuss contamination found in their wells. In this way, we did not have to anticipate what each of their concerns would be, and we were able to answer follow-up questions without the delay involved with additional correspondence. In order to return control to residents, DHFS provided suggestions for how residents could reduce their families' exposures while work on replacement water supplies was ongoing. DHFS and DNR staff also worked with residents where appropriate to get them in touch with their local government officials so that they would be more directly involved in the process of identifying solutions to the contamination problem.

Some of the uncertainty related to actual health risk cannot be eliminated. The degree and extent of exposure cannot be accurately quantified for each exposed individual, and the health effects are often unmeasurable due to individual variability or the latency period that can accompany exposure to carcinogens.[29] However, we can usually provide some perspective to help characterize the related risks. An accurate measure of exposure is generally not needed in order to know that acute effects would or would not be likely.

Health Study/Exposure Registry

It is quite common for communities that have experienced contamination in their water supply wells to request a health study. These requests generally arise because the residents want to know if they have been affected, or they believe they have been affected and want something to confirm that belief. Generally, however, there are too few chemically exposed people to make a health study useful. Without a large exposed population and a relatively rare health effect of concern, study results would be inconclusive.

ATSDR has set up some exposure registries for people who have been exposed to a few of the more common groundwater contaminants. These registries seek to take statistical advantage of large populations of exposed individuals by compiling health information from similarly exposed people in several areas around the country. There are currently four active subregistries: trichloroethylene (TCE), trichloroethane (TCA), benzene, and dioxin. The health status of people was and continues to be followed over time. There are a number of limitations with this type of registry, such as the level and duration of past chemical exposures cannot be fully known, and the inability to control for other factors. Periodically the health status of the registry population is compared to control populations of unexposed individuals.

In 1988, ATSDR established the National Exposure Registry for the health tracking of persons exposed to TCE in their drinking water. This longitudinal survey, of self-reported adverse health conditions, is conducted for 14 TCE sites nationwide. The ‘trends’ seen in the registries do not suggest correlation with exposure, rather the registries are hypothesis generating. Statistically significant rates of health conditions were reported for the following conditions: hearing impairment (after age 25 years); asthma, emphysema, or chronic bronchitis; arthritis, rheumatism, or other joint disorders: and other respiratory allergies or problems, such as hay fever.

A baseline survey of all TCE registry participants found that speech and hearing problems in children less than 10 years old were reported at significantly higher rates compared to the national health interview survey. Based on this finding, ATSDR funded a study of TCE exposure and oral motor, speech, and hearing functions in a subset of children belonging to this registry. A series of standardized tests were used for this clinical assessment. Although anatomical and physiological differences between the TCE-exposed and comparison groups were found, they appear to have no impact on speech and hearing function. When gestation-exposed children (exposed prior to birth) were compared with children exposed in later life, no differences in the test results were observed.[30]

In the TCA subregistry the following health conditions were reported more frequently than the general public for some age groups: anemia and other blood disorders, arthritis and urinary tract disorders.[31] However, several health conditions were reported less frequently than the general population for some age groups, including: arthritis for some age groups, asthma and emphysema, diabetes, hearing and speech impairments, hypertension, kidney disease, allergies, ulcers and other stomach problems, and mental retardation.

Although a causal relationship cannot be ruled out, it does not seem toxicologically plausible that such health conditions would be caused by low level exposures that were stopped a decade or more prior. The excess reporting of some health conditions might be explained by methodological differences in data collection. The results reinforce the need to continue the triennial follow-up of registrants.

Child Health Considerations

Because of differences in physiology and behaviors, exposures among children are expected to be different than among adults. Children may be more highly exposed to environmental toxicants than adults because they consume more food and water, have higher inhalation rates per unit of body weight, and have higher skin surface area to volume than adults. [32] Exposure to chemicals in breast milk affects specifically infants and young children. Some studies have found that TCE can be found in the breast milk of exposed mothers and in the blood stream of newborns of exposed mothers.[33] The studies are limited, so it is not clear how the level of exposure of the mother relates to that of the child. In terms of risk, children may also be more vulnerable to environmental pollutants because of differences in absorption, excretion, and metabolism.

Concerns about the specific health effects on children are the most common concerns raised by residents with contaminated wells. These concerns are also a source of considerable stress as previously mentioned. However, DHFS has limited educational and informational materials to address these common concerns. Other than differences in exposure factors, there is little information from any source specific to the health effects of chemical exposure on children at the levels found in private well samples collected and analyzed for this project. Fact sheets that address water quality concerns specific to parents of small children and expectant parents would have been very useful during this project.

In cases where elevated lead levels were found, DHFS provided residents with advice on how to reduce exposure for their families. Because lead is of particular concern for exposed children, DHFS also took this opportunity to provide parents with information about lead from multiple sources and to encourage participation in child blood lead screening programs.

Other Water Quality Issues

At several sites, residents mentioned aesthetic problems (taste, odor, color, etc.) with their water and were concerned that those problems were an indication of contamination from the nearby landfill. At each of these sites, the aesthetic quality problems were traced to more common problems such as iron bacteria, high naturally occurring levels of iron, or sulfates. The VOCs identified during this project were not found at levels that would have an aesthetic impact on the water.

Changes in the taste, odor, and clarity of well water can be an indication of a water quality change that can also include substances of health concern. However, the most common causes of taste and odor problems (e.g., iron, sulfate, nuisance bacteria, and common mineral and hardness elements) are not generally of health concern. More information about private well water quality problems, as well as on how to address them can be found on the following web sites:

- DNR web page covering common water quality problems and solutions: http://www.dnr.state.wi.us/org/water/dwg/priweltp.htm
- USEPA web page addressing common questions about drinking water quality: http://www.epa.gov/safewater/dwhealth.html
- Water Quality Association web page for diagnosing common water problems: http://www.wqa.org/

At two sites where VOC impacts were found, follow-up testing for metals found elevated lead in a number of water supply samples. The elevated lead results did not match the pattern of wells impacted by VOCs. In each case, DHFS and DNR staff informed the residents early on that the lead was most likely related to plumbing sources within each home. However, in each case multiple follow-up samples were needed to demonstrate this to the residents. In each case the contractors conducting the initial sampling were not aware of sampling procedures needed to avoid impacts from plumbing sources. These results allowed DHFS to inform residents how they could reduce unsafe lead exposures from plumbing sources.

Although there is a clear need to consider health implications of exposure to chemicals regardless of the source, these two cases demonstrate the importance in keeping the site-related well water impacts separate from those that are not site-related. The mischaracterization of the problem can easily lead to a solution that would not match true site problems. Although DHFS and DNR staff work to keep these issues separate, the non site-related concerns are also addressed when talking with residents.

8. Broader Implications and Lessons Learned

The investigation has several key implications and impacts. The following section contains a summary of the key findings related to site selection, the use of private wells for monitoring, the available response options, and the responsibilities of different parties:

Site Selection
Statewide Implications – The first site selection method (Phase 1) included a review of each known disposal site in a county and sampling of a large portion of them. Based on the results of this method, there are more old landfills with private well impacts across the state than we are currently aware. The proportion of old landfill sites with impacts is likely to be low. A small portion of the 4,299 sites could still include more than 100 sites.

DNR Staff Judgement - Using the professional judgement of DNR staff provided an effective means of focusing and prioritizing sampling resources for identifying problem sites.

Proximity to Another Problem Site – Landfills that operated in the same general area as sites known to be impacting groundwater are of particular concern. They would tend to be constructed in areas with similar geology, and their waste streams may also have been similar.

File Information – Some site files contain notations indicating that “barrels” or “drums” were observed during past inspections. Some sites had received specific approval to accept “hazardous wastes” prior to the creation of the federal hazardous waste programs.

Period of Use – With few exceptions, the sites in use prior to 1980 did not have engineered clay liners. The absence of a liner dramatically increases the potential for groundwater contamination. At landfills operating prior to 1976 chemical wastes were more likely to be disposed as that corresponds to the creation of the Resource Conservation and Recovery Act (RCRA). Additional specific restrictions were placed on chemical disposal in landfills in 1984.

Nearby Residential Development – Some landfills may present a threat to groundwater, but there are no residential wells nearby in the direction of groundwater flow (downgradient). As new home construction encroaches on landfills, the potential for well impacts increase.

Existing Monitoring Indicating Problems – While most older landfills did not have monitoring wells, some that closed in the 1980s or after may have them. Many of these wells are tested only for indicator parameters such as iron, chlorides, and conductivity. Trends in these parameters can indicate a contamination problem at the site. This data has not always been routinely evaluated. Upon review of these data, DNR waste program staff have occasionally identified sites that were contaminating groundwater.

Large Capacity Landfills (>50,000 cubic yards) – The larger landfills often served areas with more industrial customers and as a result may have accepted greater volumes of chemical wastes over time. The same is true for sites near communities with a large industry base.

Monitoring Private Wells
Benefits - Groundwater quality surveillance near landfills by collecting samples from residential private wells does not require the installation of individual monitoring wells which can be costly. Because monitoring wells collect water from relatively discrete depth intervals (5 feet), they may miss contamination that threatens residential wells drawing water from a greater vertical cross section. Homeowners can chose to do the testing themselves if they are concerned. The well owner does not have to rely upon another party to investigate the landfill. The results are directly relevant to public health because they provide information about exposure.

Limitations - Many residents are unaware their wells were constructed near a landfill site. VOC samples are relatively expensive when compared to the well water samples typically performed by homeowners (bacteria and nitrate). A sample from a private well may provide a false sense of security because long-term monitoring is not likely to occur. Samples of residential wells find contamination only after it has reached a point of exposure, giving no opportunity to prevent exposure. Monitoring wells show the actual groundwater flow direction, which is not always accurately inferred from surface features. The well selected may not be located downgradient of the site, and impacts may be missed that travel towards wells further from the site.

Response Options
When a residential well becomes contaminated, there are several options available for preventing chemical exposure and protecting public health. Although none of the options is as ideal as if the original well were not contaminated, there will usually be an acceptable solution for each case. Some solutions involve treating the existing water, drawing water from another part of the aquifer, or bring water to the home from another source completely. The point of each solution is to prevent exposure to the contaminants of concern. The following list includes the most common water supply solutions and the situations and conditions for which they are used:

Bottled Water – Obtaining bottled water is the most common first step taken by or for residents. This step effectively prevents exposures through drinking water and food preparation. For VOC-contaminated drinking water, bottled water is only considered a short-term solution because it does not address exposures through inhalation or skin absorption. Unless remediation is expected to remove contaminants within a year, DHFS recommends that work begin to identify a whole-house solution once bottled water is established. The use of bottled water requires a significant behavioral change for residents so it may not be consistently implement or sustained.

Water Treatment – Most VOC contaminants are effectively removed by use of activated carbon treatment systems. These systems are used to treat the water before it is distributed throughout the home. The water serving outside faucets is not usually treated to extend the life of the carbon treatment units. Because the carbon loses its capacity to remove additional chemicals after extended periods, these systems need to be sampled, and filters replaced periodically. Vinyl chloride is not easily removed with traditional activated carbon. When vinyl chloride is present, a system based on stripping the VOCs from the water with air is recommended. This system is often followed by carbon treatment to remove the VOCs that are less volatile than vinyl chloride. The Wisconsin Department of Commerce has a program for evaluating and approving treatment systems based on their ability to remove contaminants from drinking water. In combination with a DNR review of the specific conditions of each site, an approved system is generally available for the common range of VOC contaminants in Wisconsin groundwater. Because DNR prefers solutions that provide safe water at the source, water treatment is considered an effective interim solution while a permanent replacement is sought.

Bulk Water – In rare cases when other alternatives are not readily available, a bulk water tank can be brought to a home and filled regularly by tanker truck. These systems are usually placed in an attached garage, if available, because they take up considerable space. They can be problematic during winter months because they must be in a heated area to prevent the water from freezing. The use of bulk water systems was more common before advances in water treatment systems reduced the need.

Deeper Well – This option is only viable after more is known about the vertical extent of contamination. Installing a deeper well with the casing sealed through the contaminated portion of the aquifer can be an effective permanent solution. Due to the time it can take to investigate the extent of contamination, an interim solution (bottled water, treatment, etc.) is often necessary. Deeper wells often draw water higher in iron and other minerals that require additional treatment. If the home is not already equipped with a water softener or iron removal system, these components may be needed in addition to the new well.

Shared Wells or Small Community Systems – If multiple homes are affected and the costs for constructing satisfactory replacement wells are high, residents can group together and share the cost to use a single well. Depending on the number of homes and people served, these systems may be regulated as public water supplies, and regular testing and maintenance is required. Because these systems would then have distribution piping to carry the water from the well to the affected homes, the homes served must be close to one another. In some rare or temporary situations, a resident may connect to a neighbor's well when that well is not contaminated and the additional pumping from that well would not draw contaminated water over to it.

Municipal Connection – When a public water system is located near contaminated wells, it may be possible to extend the service from that system to the impacted homes if the public system is large enough to provide the additional capacity. Extension of a public system can bring up other issues including annexation, cost to homeowners, public sewer extension, fire protection, long-term development planning, and property taxes. These are important issues that must be discussed and worked out between residents and the involved local governments. Public systems are monitored regularly to ensure that they provide a safe water source. However, they also often include chlorine for disinfection, which some residents find unpleasant when used to untreated well water.

Each of the permanent solutions available can take several months or years to establish. For this reason, DHFS recommends that work begin to identify and establish alternative water supplies as soon as significant exposures are identified, rather than after the investigation and cleanup are complete. Although some parts of the initial investigation of an individual site support both efforts, much of the work can and should be conducted concurrently. Once residents have acceptable water supplies, investigators can be more deliberate in identifying the appropriate remedy for the site.

Responsibility for Sampling and Mitigation
Landfill Owners – Most of the 4,299 landfills on the DNR Registry of Waste Disposal Sites were closed under the presumption that they would not impact the environment, so no long term monitoring or maintenance was required. Until impacts are found, many landfill owners do not have any related responsibilities for these sites. Once an impact is found, current property owners are responsible for impacts to the environment. Landfill owners, who are often township or village governments, have a considerable stake in knowing if their site is impacting groundwater. Once contamination is identified, the responsibilities that follow can easily overwhelm existing budgets and expertise needed to address the problem. No matter when a problem is found, the immediate demands on resources can be very high. These peak demands can be moderated if the owners are able to plan for such a contingency. However, local officials are generally unaware of the magnitude of the responsibility before dealing with their first site. The current landfill owners may not have been contacted about these issues since their sites were closed. In many cases, due to staff turnover and changes in elected officials, there may be little memory left that the site exists.

Agencies - This project has been a one-time sampling effort and does not represent an ongoing program. In the absence of a known source of contamination, residential well owners are responsible for ensuring the safety of their own water supplies by arranging their own sampling and conducting routine maintenance. In the past, DNR staff have sampled private wells on a site-specific basis when they believed there was a substantial risk of contamination and exposure. In fact, many of the problems we currently know about were found as a result of those efforts.

Residents – In Wisconsin each residential well owner is responsible for conducting the water quality testing of their wells. There is no requirement that this testing be done unless the well serves the public or multiple families, exceeding 25 people. Once contamination is found, residents are not responsible for continued testing, water treatment, or cleaning up the problem unless they are also the landfill property owners.

9. Conclusions
While most old landfills in Wisconsin are not impacting nearby residential wells, a small percentage may be. Long-term exposure to chlorinated solvents in impacted water supplies can pose a public health hazard to residents from both increased cancer risk and non-cancer health effects. In this project 177 private wells were tested near 34 old landfills. Of these, 32 private wells near 6 landfills contained contaminants above health based drinking water standards posing a public health hazard to those families.

Sampling nearby residential wells can be an effective method for finding the problem sites and halting exposures. In addition to the public health implications of the chemical exposure, problem sites can be a source of significant stress for residents.

10. Recommendations
- DHFS recommended actions to reduce or stop exposures for each of the water supplies with impacts above health based groundwater standards.

- DNR and DHFS should promote increased testing of residential wells near old unmonitored landfills. Residents who are aware they live near an old landfill site should test their wells for VOCs. The Wisconsin Groundwater Coordinating Council, which includes members from both DNR and DHFS has updated its recommendations and related brochure for residential well sampling to include VOC testing for wells near old landfill sites.

- As resources permit, DNR and DHFS should continue to sample the residential wells appearing to be at greatest risk of contamination. The factors identified by DNR staff in this report should be used for prioritizing sampling resources. Additional monitoring of private wells has been done at multiple additional landfills since the completion of this project.

- Information should be made available to landfill owners and nearby residents explaining the implications and responsibilities related to these sites. This information should also include suggestions as to how to plan for and address these problems proactively. Landfill owners who do not already do so, may wish to periodically sample nearby residential wells. DHFS has completed and distributed a fact sheet on old landfills and dumpsites for this purpose.

- Where possible, steps should be taken to reduce the stress on residents with affected wells,. Refer to the Public Health Action Plan for more specific actions.

11. Public Health Action Plan

- When DNR identifies a private well they believe to be at high risk of contamination by a nearby landfill, DHFS will attempt to identify funding to have the well sampled. DHFS recognizes that the number of wells at risk, the responsiveness of the landfill owner, and current budgets will determine our ability to do so. DNR is aware of this option and has contacted DHFS and received support for testing of private wells.

- In 2004, DHFS will provide information on the implications of old landfill sites to local municipalities who are the owners of the majority of these sites. Municipalities can also make use of this information in comprehensive land use planning, to avoid inappropriate development near these sites.

- Residents who would like to sample their own wells for VOCs may do so by contacting a private water-testing laboratory. A list of laboratories certified to analyze drinking water samples can be found on the DNR web site at: http://dnr.wi.gov/org/es/science/lc/INFO/Lablists.htm

- Residents and landfill owners who identify well contamination should inform their local DNR office immediately so that the problem can be properly addressed as soon as possible.

- DHFS and DNR will continue to work with landfill owners and nearby residents to address unsafe drinking water exposures as they are identified. For each of the 32 families involved, unhealthy exposures were reduced or eliminated completely within a year of identifying the problem.

Based on the concerns raised at several sites, DHFS will develop fact sheets in 2005 on "Chlorinated Solvents in Residential Well Water," and "Drinking Water Information for Pregnant Women and Families with Young Children." As a result of work on this project DHFS has developed a fact sheet on "Old Dumps and Landfills," (http://www.dhfs.state.wi.us/eh/HlthHaz/fs/Dumps.htm) and updated a fact sheet on "Cancer Facts and Cancer Clusters," (http://www.dhfs.state.wi.us/eh/HlthHaz/fs/CancerClus.htm).

- In order to reduce the emotional stress on residents with affected wells DHFS will:
  - Ensure that residents receive a balanced explanation of the health implications relevant to their chemical exposure.
  - Provide information and answers to questions as quickly as possible.
  - Involve residents directly in early discussions and the decision making process.
  - Continually work to minimize delays in investigation and water supply replacement activities.

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14. Certification

This Public Health Report on Private Well Impacts from Wisconsin's Old was prepared by the Wisconsin Department of Health and Family Services under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved methodologies and procedures existing at the time the document was written. Editorial review was completed by the Cooperative Agreement partner.

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15. ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together.

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports;

determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

EPA
United States Environmental Protection Agency.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing followup of people who have had documented environmental exposures.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

ppb
Parts per billion.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public meeting
A public forum with community members for communication about a site.

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Risk
The probability that something will cause injury or harm.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)

National Center for Environmental Health (CDC) (http://www.cdc.gov/nceh/dls/report/glossary.htm)

National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

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