ATSDR
AGENCY FOR TOXIC SUBSTANCES
AND DISEASE REGISTRY

# Public Health Assessment for

Perfluorochemical Contamination in Lake Elmo and
Oakdale, Washington County, Minnesota

EPA Facility IDs: MND980704738
MND980609515

MARCH 21, 2008

**MAY 21, 2008**

# THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.



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# PUBLIC HEALTH ASSESSMENT

Perfluorochemical Contamination in Lake Elmo
and Oakdale, Washington County, Minnesota

EPA Facility IDs: MND980704738
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Prepared by:

Minnesota Department of Health
Under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry
U.S. Department of Health and Human Services

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## FOREWORD

This document summarizes public health concerns related to two waste disposal sites in Minnesota, and is a formal site evaluation prepared by the Minnesota Department of Health (MDH). For a formal site evaluation, a number of steps are necessary:

- *Evaluating exposure:* MDH scientists begin by reviewing available information about environmental conditions at the site. The first task is to find out how much contamination is present, where it is found on the site, and how people might be exposed to it. Usually, MDH does not collect its own environmental sampling data (although this case is an exception). Rather, MDH relies on information provided by the Minnesota Pollution Control Agency (MPCA), the Minnesota Department of Agriculture (MDA), the US Environmental Protection Agency (EPA), private businesses, and the general public.

- *Evaluating health effects:* If there is evidence that people are being exposed—or could be exposed—to environmental contaminants, MDH scientists will take steps to determine whether that exposure could be harmful to human health. MDH's report focuses on public health— that is, the health impact on the community as a whole. The report is based on existing scientific information.

- *Developing recommendations:* In this report, MDH outlines conclusions regarding any potential health threat posed by a site and offers recommendations for reducing or eliminating human exposure to pollutants. The role of MDH is primarily advisory. For that reason, the evaluation report will typically recommend actions to be taken by other agencies—including EPA and MPCA. If, however, an immediate health threat exists, MDH will issue a public health advisory to warn people of the danger and will work to resolve the problem.

- *Soliciting community input*: The evaluation process is interactive. MDH starts by soliciting and evaluating information from various government agencies, the individuals or organizations responsible for the site, and community members living near the site. Any conclusions about the site are shared with the individuals, groups, and organizations that provided the information. Once an evaluation report has been prepared, MDH seeks feedback from the public. *If you have questions or comments about this report, we encourage you to contact us.*

*Please write to:* Community Relations Coordinator
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http://www.health.state.mn.us/divs/eh/hazardous/index.html

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## Summary

Perfluorochemical (PFC)-containing wastes were disposed of by the 3M Company (3M) in two land disposal sites, the 3M-Oakdale Disposal Site in Oakdale and the former Washington County Landfill in Lake Elmo, Minnesota. PFCs were released from the two facilities resulting in contamination of groundwater and nearby drinking water wells. Past exposure through: drinking water, possible air emissions during the handling, disposal, or burning of wastes, or direct contact with the wastes could have been significant for some people.

PFCs have been detected in public and private wells across a wide area of Oakdale and Lake Elmo. Eleveated levels of PFCs have also been detected in the blood of selected residents of Oakdale and Lake Elmo. While current studies suggest that the levels found may not represent a significant health risk, the human data are limited to occupational studies that do not include potentially vulnerable sub-populations. Exposure to PFCs in drinking water at levels above health concern is currently largely being addressed in Oakdale by the operation of a carbon filtration plant and by careful management of the city wells and distribution system. In Lake Elmo, exposure through drinking water in private wells to levels of PFCs above health concern is being prevented by the connection of approximately 200 homes to municipal water, and by offering bottled water and whole-house activated carbon filters to 55 other homes that have been issued a drinking water well advisory by MDH. Local residents have expressed concern over perceived elevated rates of cancer and other diseases in the affected area; cancer rates in the two affected communities are similar to cancer rates in the Twin Cities metropolitan area according to MDH data. Because of the uncertainty over a Health-Based Value for perfluorobutanoic acid (PFBA) and other factors, current exposures to PFCs in the area represent an uncertain or indeterminate public health hazard. Remedial actions to address the PFCs at the two disposal sites are being evaluated by 3M and the MPCA.

### Introduction

The 3M Company (3M; formerly Minnesota Mining and Manufacturing Company) used or produced perfluorochemicals (PFCs) at its Cottage Grove, Minnesota facility in southern Washington County, Minnesota from the late 1940s until 2002. During production, which occurred via an electrofluorochemical process, air emissions of PFCs occurred, and may have extended off the site property. MDH has prepared a Health Consultation focusing on PFC releases at the Cottage Grove facility (MDH 2005). Wastes from the PFC production process, including production wastes and wastewater treatment plant sludge, were disposed of at the Cottage Grove facility and several known disposal sites identified by 3M in Washington County (Weston 2005). The names of these facilities, the types of wastes disposed of, and the estimated time of the disposal were formally provided to the Minnesota Pollution Control Agency (MPCA) in June of 2005 and are listed below:

**Table 1: Waste Disposal Facilities that Received 3M PFC Wastes**

| Disposal Facility | Waste Disposed | Estimated Dates |
|---|---|---|
| 3M-Oakdale Disposal Site | Liquid and solid industrial waste | 1956 - 1960 |
| 3M-Woodbury Disposal Site | Liquid and solid industrial waste | 1960 - 1966 |
| Washington County Landfill, Lake Elmo | Wastewater treatment plant sludge, incinerator scrubber sludge and ash, iron oxide sludge | 1971 - 1974 |

The general locations of these three disposal sites, along with the 3M Cottage Grove facility are shown in Figure 1 (see Appendix 1 for figures).

Perfluorochemicals are a class of organic chemicals in which fluorine atoms completely replace the hydrogen atoms that are typically attached to the carbon 'backbone' of organic hydrocarbon molecules. Because of the very high strength of the carbon-fluorine bond, PFCs are inherently stable, nonreactive, and resistant to degradation (3M 1999a). PFCs made by 3M at its Cottage Grove facility were used in the manufacture of a variety of commercial and industrial products by 3M and other companies, including fabric coatings (such as Scotchgard™), surfactants, non-stick products (including Teflon™), fire-fighting foams, film coatings, and other products.

Because of their unique physical and chemical properties, PFCs appear to move easily through the environment, and have been found globally at low levels. Some PFCs are bio-accumulative, i.e., build up in living organisms, and have been detected in the blood and tissues of humans and animals from virtually all parts of the world.

Toxicological research on PFCs is ongoing in government, industry and academia. Published studies show that animal exposure to PFCs at high concentrations adversely affects the liver and other organs. The mechanisms of toxicity are not entirely clear; one likely major mechanism involves effects on certain enzymes regulating metabolic pathways in the liver. Exposure to high concentrations of one PFC, perfluorooctanoic acid (PFOA) over long durations has been shown to cause cancer in some test animals, although the specific mechanisms and relevance to humans are not clear. Developmental effects have also been observed in the offspring of pregnant rats and mice exposed to PFCs.

PFCs disposed of at the sites identified above have impacted soil, groundwater, surface water, sediments, and nearby drinking water wells, both public and private. MDH has prepared this report to summarize current conditions in Lake Elmo and Oakdale relative to the PFC contamination, to evaluate the potential health risks associated with the use of drinking water impacted by PFCs, and to make recommendations to protect public health. MDH has consulted with staff from EPA, MPCA, Washington County, the cities of Lake Elmo and Oakdale, community members, and 3M to gather information for this report. A separate report will be prepared to evaluate PFC waste disposal at the 3M-Woodbury Disposal Site and its potential impact on groundwater in southern Washington County. An updated report on the 3M-Cottage Grove facility and PFC impacts to the Mississippi River is also planned.

**Background**

Washington County Landfill Site Description and History

In 2004, the MPCA learned that PFC containing wastes may have been disposed of at the former Washington County Landfill, located on the east side of Jamaca Avenue in Lake Elmo, near Lake Jane. The former Washington County Landfill is a 40-acre site that operated as a sanitary landfill from 1969 to 1975, accepting residential, commercial, and industrial wastes (see Figure 2). It closed in 1975, and at that time a clean soil cap was placed on the landfill. In 1981, groundwater monitoring indicated the presence of elevated concentrations of volatile organic compounds (VOCs) and some heavy metals in on-site monitoring wells and off-site residential drinking water wells. A Special Well Construction Area (SWCA; then called a Well Advisory Area) was established around the site on July 19, 1982, requiring MDH review of any proposed well construction within the area. Its boundaries were modified in 1982 based on new investigation findings. In 1983 and 1984, alternate drinking water supplies were provided to the affected residences, in the form of a municipal water system extension from the adjacent city of Oakdale. In 1983, Ramsey and Washington counties installed a remediation system to reduce or eliminate VOCs in groundwater migrating away from the landfill. The system involved groundwater extraction wells to pump the contaminated groundwater from beneath the landfill and spray it back over the ground surface, allowing the VOCs to evaporate (where they would degrade in the atmosphere) and the water to infiltrate back into the aquifer. This type of treatment effectively removes and treats VOCs in groundwater.

In 1984, the site was added to the federal Superfund list, the National Priority List (NPL) and the state Superfund list, the Permanent List of Priorities (PLP). After entry into the MPCA's newly created Closed Landfill Program (CLP) in 1996, the site was removed from both the state and federal Superfund lists. Since 1996, additional steps were taken by the MPCA to address ground-water contamination by improving the landfill cover and ground-water recovery and treatment systems.

MDH has evaluated conditions and potential public health concerns at the former Washington County Sanitary Landfill in a Public Health Assessment (ATSDR 1989a), and two reports known as a "Site Review and Update" (MDH 1993a; MDH 1995). These reports focused on VOC contamination in groundwater, and on landfill gas issues at the site itself. At the time of these reports, PFCs had not been identified as environmental contaminants at these or any other sites.

3M-Oakdale Disposal Site Description and History

In 2004, the MPCA and MDH also learned that PFC containing wastes may have been disposed of at the 3M-Oakdale Disposal Site. This site is in the city of Oakdale, just west of the intersection of Minnesota Highway 5 and Hadley Avenue (see Figure 3). This site is currently on both the state and federal Superfund lists. It consists of three former waste disposal areas called Abresch (approximately 55 acres), Brockman (approximately 5 acres) and Eberle (approximately 2 acres), named after the former owners. Minnesota Highway 5 bisects the Abresch site, and wastes were reportedly encountered during the construction of the highway through the site.

From the late 1940's through 1960, private contractors disposed of liquid and solid industrial wastes (solvents, tapes, plastics, and resins) and household wastes (such as roofing shingles, rubbish and paper) at the site (MDH 1993b). The wastes were buried in trenches, dumped on the ground surface, and burned on the ground surface or in pits. The following is a brief outline of past disposal activities at the site:

- Abresch Area: This area appears to have received the most waste. Burial of wastes (contained in 55-gallon drums, metal pails, and fiber barrels) in trenches occurred primarily in the northern portion of this area (north of the present-day location of Highway 5). A typical trench averaged approximately 10 feet in width, 150 feet in length and no more than 15 feet in depth. The majority of wastes disposed of in the remainder of the Abresch area were placed on the ground surface and partially covered with soil. This area of surface disposal covered approximately 27 acres. Waste disposal locations at the Abresch site are shown in Figure 4.

- Brockman Area: The method(s) of waste disposal in this area are not known. Aerial photographs taken between 1947 and 1964 do not show any visible trenches.

- Eberle Area: This area was used for open burning of both solid and solvent wastes. Aerial photographs taken between 1947 and 1964 show no evidence of burial (in trenches) or surface disposal of wastes.

Groundwater contamination at the site was first detected in the fall of 1980 when MDH sampled 46 shallow, private wells in the area surrounding the site. Nine of the 46 wells showed detectable levels of VOC contamination. These wells were subsequently sealed and the homes connected to the Oakdale municipal water supply.

In December 1980, 3M began an extensive hydrogeological investigation of the site area. In July 1983, 3M entered into a legal agreement, called a Response Order by Consent, with the EPA and the MPCA to carry out and pay for cleanup activities at the site. These cleanup activities, outlined in the Remedial Action Plan (as described in MDH 1993b), included:

- The excavation and disposal of all materials (including highly contaminated soils) in trench disposal areas where: 1) massive concentrations of buried steel drums and other metal containers were located (primarily in the northern portion of the Abresch area) and 2) numerous steel drums and other containers were located but seemed to be more dispersed among other waste scrap (Brockman and southern Abresch areas).
- The proper disposal of all excavated materials.
- The location and abandonment of multi-aquifer wells in the vicinity of the site. The purpose of abandoning these wells was to eliminate pathways through which

contaminated groundwater in the Platteville-Limestone could move down to the St. Peter Sandstone aquifer.

- The design and subsequent operation of a shallow groundwater pumpout system to remove and contain highly contaminated groundwater beneath the site. The objective of this system is to remove highly contaminated groundwater and to prevent contaminants from moving to deeper aquifers.
- The development of a groundwater monitoring well network (with wells in the glacial drift, Platteville limestone and the St. Peter Sandstone aquifers). The operation of this monitoring system will continue until it can be demonstrated that the site no longer impacts the area groundwater.

MDH evaluated conditions and potential public health concerns at the 3M-Oakdale Disposal Site in a Public Health Assessment (ATSDR 1989b), and a "Site Review and Update" report (MDH 1993b). These reports focused on waste disposal and VOC contamination in groundwater and wells. As with the Washington County Landfill, at the time of these reports PFCs had not been identified as environmental contaminants.

Geology / Hydrogeology

The geology of the region in which the 3M-Oakdale Disposal Site and Washington County Landfill sites are located consists of glacial drift and alluvial sediments (stratified sand, silt, and clay deposited by glaciers and rivers, respectively) overlying a thick sequence of Paleozoic sedimentary rock formations made up of sandstone, limestone, dolomite, and shale. These, in turn, overlay pre-Cambrian volcanic rock formations composed primarily of basalt. The bedrock formations tilt and thicken slightly to the south and west, forming the eastern rim of a large geologic structure known as the Twin Cities Basin. Figure 5 shows the sequence of bedrock units.

The uppermost bedrock layer beneath the two disposal sites differs because of this tilting of the bedrock. The upper bedrock formations beneath the Washington County Landfill are the St. Peter Sandstone on the west side of the site and Prairie du Chien dolomite on the east side. The Decorah shale is the first bedrock unit beneath the northwestern part of the 3M-Oakdale Disposal Site while the Platteville Limestone is the first bedrock unit beneath the southeastern part of the site (see Figure 6).

Before the glacial drift and alluvial sediments were deposited, streams eroded the surface of the bedrock to create stream valleys. In some places the valleys cut all the way down to the Jordan Sandstone. The valleys were later filled with glacial and alluvial sediments. Figure 7 shows the location of a major bedrock valley in the Lake Elmo area. This bedrock valley extends all the way to the Mississippi River valley.

Regional groundwater flow in this area is generally from northeast to southwest, towards the Mississippi River, where it discharges. However, on the local level, the flow direction may deviate significantly from the regional groundwater flow direction as a result of influence from pumping wells, infiltration of large volumes of water, and large-scale structures in the bedrock, such as faults and buried valleys.

The type of bedrock beneath the disposal sites also affects how groundwater and contaminants move. The St. Peter and Prairie du Chien formations beneath the Washington County Landfill are highly permeable, allowing groundwater to easily move downward through pore spaces between sand grains and fractures. In contrast, the Decorah Shale beneath part of the 3M-Oakdale Disposal Site is relatively impermeable and groundwater tends to flow along the surface to the margins of the shale, rather than through it. As a result, groundwater infiltrating at the 3M-Oakdale Disposal Site flows in a radial pattern off the surface of the Decorah Shale until it reaches the edge of the formation and migrates downward into the Platteville Limestone (Barr 2005). This complicates the pattern of contaminant migration at this site, as shown in Figure 8.

The major drinking water aquifers in the Oakdale-Lake Elmo area are the St. Peter Sandstone, the Prairie du Chien dolomite, and the Jordan Sandstone. The St. Peter and Prairie du Chien are used for private water supplies, while the Jordan is used only by municipal and non-community public water systems (such as businesses, parks, etc.).

The St. Peter Sandstone is used for drinking water primarily in the northern and western parts of Lake Elmo. To the east, the unit thins or is absent where bedrock valleys cut through the formation, and other aquifers such as the Prairie du Chien are used for drinking water purposes. Groundwater in the St. Peter migrates through the pore spaces between the sand grains, although fractures and solution cavities are not uncommon in the St. Peter (Alexander 2007; Runkel et al. 2007). Such solution cavities may create pathways through which groundwater and contaminants migrate more quickly than is typically observed in the St. Peter, and may result in the development of "fingers" of higher contaminant concentrations in areas near the cavities.

Groundwater flow in the Prairie du Chien dolomite is heavily influenced by fractures (cracks and voids) in the formation. The Prairie du Chien is actually considered a "group" composed of two separate dolomite formations, the Shakopee and Oneota. For general purposes, this report will consider the Prairie du Chien Group as a single unit. However, it is useful to note that although the lower Oneota formation tends to be more massive than the sandier Shakopee formation, the Oneota tends to have more solution cavities. As a result, the Oneota provides the higher yield of water to wells, according to the hydrologic atlas for this area (Lindholm et al. 1974). The hydraulic conductivity of similar fractured bedrock groundwater systems in southeast Minnesota has been shown to sometimes exceed several thousand feet per day (Runkel et al. 2007).

Below the Prairie du Chien is the Jordan sandstone. Groundwater can readily move downward (rather than horizontally) from the Prairie du Chien into the Jordan where the Oneota formation at the base of the Prairie du Chien Group has solution cavities and/or fractures. Preliminary modeling of groundwater flow by MDH suggests that groundwater flow from the Prairie du Chien to the Jordan may be occurring primarily in the areas immediately around municipal wells as a result of the high pumping rates of those wells (A. Djerrari, personal communication, 2007).

Underlying the Jordan sandstone is the St. Lawrence formation, composed of dolomite and siltstone. This formation is not considered an aquifer but rather a confining unit because it has low vertical permeability to groundwater. This lower permeability means that in most areas, the St. Lawrence "protects" the aquifers beneath it from downward migration of contaminants. Below the St. Lawrence formation, in descending order, are the Franconia, Ironton, and Galesville sandstone aquifers (which are often considered to be one single aquifer), the Eau Claire confining unit, and the Mount Simon sandstone aquifer. There are no private or public wells in the study area known to draw water from any of these units.

The water table over most of the study area is shallow (the water table is the surface below which all pore space in the sediment or rock is completely saturated with water.) As a result, the groundwater is often in direct connection with local surface water features such as lakes and streams. These groundwater-surface water interactions, which have been studied extensively by Washington County (Barr 2005), are critical to understanding the movement of PFCs at and near the sites.

The water table at the 3M-Oakdale Disposal Site is located between 0 – 20 feet below the ground surface. In the northern and eastern portions of the site, where the groundwater is shallowest, wetlands and surface waters are present and are directly connected to the groundwater. The wetlands are drained by Raleigh Creek, which flows east-southeast into the Tablyn Park neighborhood of Lake Elmo and then into the north end of Eagle Point Lake (Figure 9). Along its course, Raleigh Creek also receives storm water drainage from residential developments in both Oakdale and Lake Elmo.

The water table beneath the Washington County Landfill is deeper, approximately 20 - 50 feet below the ground surface. A small infiltration pond was present in the southeast corner of the property where the groundwater spray irrigation system historically operated, but there are no natural surface water features that provide a pathway for off-site contaminant migration. However, in 1988, a permit was issued by the Valley Branch Watershed District to allow untreated groundwater from gradient control well #1 (GC-1) at the landfill to be discharged to a storm sewer manhole. The storm sewer ultimately discharges to Raleigh Creek at Tablyn Park, approximately ¾ of a mile north of where Raleigh Creek enters Eagle Point Lake (Figure 9). This discharge occurred between 1988 and 1995 and records indicate the annual volume discharged ranged from 50 to 80 million gallons.

Eagle Point Lake is considered to be a "flow-through" lake, meaning that groundwater enters the lake at the north (upgradient) end of the lake, flows through the lake as surface water, and discharges at the south (downgradient) end of the lake returning to the groundwater. The lake also has a natural overflow to the east into Lake Elmo that has been altered by storm water management activities. To prevent flooding in both lakes, a pipeline was constructed in 1986 to divert overflow water from Eagle Point Lake. The pipeline runs across the bottom of Lake Elmo and discharges to Horseshoe Lake further to the east. Water from that lake then flows through a series of natural and manmade drainage features (culverts, ditches, ponds, streams, etc.) to ultimately discharge to the St.

Croix River. At periods of particularly high water levels, a second overflow pipe discharges water directly from Eagle Point Lake to Lake Elmo.

In addition to moving horizontally, contaminants may move vertically in areas where the groundwater is moving either upward or downward between aquifers. This appears to be the case in the Lake Elmo-Oakdale area, as PFCs have been detected as deep as the Jordan aquifer. Preliminary groundwater modeling by MDH suggests that contaminant migration into the Jordan in the study area may have been induced by pumping of the Oakdale city wells (A. Djerrari, personal communication, 2007). However, information on distribution of PFCs in the Jordan is limited by the absence of private wells in this aquifer. Similarly, the PFCs appear to move downward from the St. Peter to the Prairie du Chien, as concentrations in the St. Peter decrease significantly with distance from the Washington County Landfill, and are nearly absent south of 27$^{th}$ Street, except in wells completed at the base of the St. Peter. Uncased private wells in the area may have played a role in the vertical movement of PFCs (Runkel et al. 2007). Figure 10 illustrates the vertical distribution of PFOS, PFOA, and PFBA in the Lake Elmo area.

PFC Analysis

In late 2003, the MDH Public Health Laboratory developed a method to analyze water samples for two PFCs, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). These two PFCs have been the focus of the majority of the scientific research on perfluorochemicals, are bioaccumulative, and have been found to be widespread in the environment and in people. One of them, PFOA, was produced at the 3M Cottage Grove plant on a large scale; some PFOS production also reportedly occurred.

In the spring of 2006, the MDH Public Health Laboratory expanded their PFC method to include a total of seven PFCs. This was done in response to a request from the MPCA in late 2005 following the detection of other PFCs in soil and water samples collected by the MPCA at the former Washington County Sanitary Landfill and analyzed by a laboratory in British Columbia, Canada (Axys Analytical Services). The seven PFCs currently being analyzed are:

- PFBA : Perfluorobutanoic acid
- PFPeA : Perfluoropentanoic acid
- PFHxA : Perfluorohexanoic acid
- PFOA : Perfluorooctanoic acid
- PFBS : Perfluorobutane sulfonate
- PFHxS : Perfluorohexane sulfonate
- PFOS : Perfluorooctane sulfonate

Water samples are collected in clean 250 milliliter polyethylene bottles. Care is taken to avoid use of or the presence of products that could contain PFCs before or during sampling. The analysis is conducted using a combined high-pressure liquid chromatography tandem mass spectrometry (LC/MS/MS) method, using radio-labeled PFOA and PFOS standards. Each sample is spiked in the lab with a known quantity of labeled standard. The sample recovery must be within ± 30% of the standard concentration to meet quality control standards. In September 2007, the MDH Public Health Laboratory issued new formal reporting levels for the seven PFCs of 0.3 micrograms per liter (µg/L), or 300 parts per trillion (ppt) in water (P. Swedenborg, personal communication, 2007). PFCs detected at concentrations between 50 and 300 ppt are reported as estimated, or "J" flagged values.

Evaluation of PFCs in Drinking Water

In late 2002 the MPCA requested MDH to develop Health Based Values (HBVs) for PFOA and PFOS because 3M had detected them both during initial investigations at the 3M Cottage Grove facility. An HBV is an unpromulgated advisory value that represents the amount of a chemical in groundwater or drinking water that is considered to be safe by MDH for people to drink daily for a lifetime. The 2002 HBV for PFOA was 7 µg/L and the HBV for PFOS was 1 µg/L. The 2002 HBVs were the applicable evaluation criteria until March 2006, when MDH began using well advisory guidelines of 1 µg/L for PFOA and 0.6 µg/L for PFOS. This was an interim measure while MDH reviewed the growing amount of toxicological information available on these chemicals. These guidelines were also applied (as surrogates) to the additional PFCs that the MDH Public Health Laboratory began analyzing for in water samples at about the same time.

In early March 2007, MDH issued revised HBVs for PFOA and PFOS of 0.5 µg/L and 0.3 µg/L, respectively (MDH 2007a, MDH 2007b, see also Appendix 2). A law passed during the 2007 legislative session required MDH to promulgate through the rule making process the HBVs for PFOS and PFOA as Health Risk Limits (HRLs) through good cause exemption by August 1, 2007 (Minnesota Session Laws 2007 – Chapter 37). The HRLS for PFOA and PFOS went into effect on August 27, 2007, when they were published in the State Register (Volume 32, Number 9, page 373). The same law also required MDH to provide a report to the legislature on MDH's progress in evaluating health effects and establishing HRLs for PFCs, including PFBA. The report is due January 15, 2008; a status report was submitted September 30, 2007.

There is not enough scientific information to develop separate HBVs or HRLs for the five remaining PFCs that MDH currently analyzes for due to limited toxicological research. However, based on their chemical characteristics, it is anticipated that research will show that these five PFCs are generally less toxic than PFOA and PFOS. Until enough information is available to develop HBVs or HRLs for these chemicals, MDH is continuing to use well advisory guidelines of 1 µg/L for PFBA, PFPeA, and PFHxA, and 0.6 µg/L for PFBS and PFHxS to provide guidance to individual well owners who wish to reduce their exposure through drinking water.

HRLs are used by MDH to determine if a drinking water well advisory is warranted for an individual well. The MPCA uses MDH advisories to take actions to protect public health from long-term exposure to PFCs, such as providing bottled water or individual water treatment. In cases where a combination of PFOS and PFOA are present, but do not exceed their individual HRLs, MDH calculates a Hazard Index to account for possible effects of exposure to more than one PFC. The Hazard Index is the sum of the ratios of the concentrations of PFOS and PFOA over their individual HRL. If the Hazard Index exceeds one, a drinking water well advisory is issued.

Private Well Sampling in Lake Elmo

In 2004, as a result of being informed by 3M that PFC containing wastes may have been disposed of at the former Washington County Sanitary Landfill, the MPCA collected groundwater samples at the site. PFOA was detected at low levels in monitoring wells on the landfill property in both the shallow and deeper groundwater aquifers.

In the summer of 2004, the MPCA and MDH collected water samples from 32 private wells near the landfill; some wells were sampled twice. Low levels of PFOA (less 1 µg/L) were detected in seven private wells. The other 25 wells did not show any detection of PFOA or PFOS, and the area affected appeared to have been defined by the lack of detections on the perimeter of the sampling area.

In early 2005, PFOS and PFOA were detected in four municipal wells in the adjacent city of Oakdale. One of the municipal wells (Oakdale #8) is located very near the Oakdale-Lake Elmo border. As a result, MDH and MPCA staff initiated additional private well sampling on the western edge of Lake Elmo because of the possible presence of PFCs in area groundwater.

The additional private well sampling began in March 2005 with the collection of 37 samples in the Tablyn Park and the Lake Elmo Heights neighborhoods. Eight private wells were found to contain PFOS at levels in excess of the 2002 HBV. An emergency declaration was signed by the MPCA Commissioner on March 30, 2005, and bottled water delivery to the eight residences commenced the next day. One hundred twenty one samples were collected in April 2005 to determine if additional residences were impacted and to identify the edges of the PFC plume. Four residences from this group of samples either exceeded the 2002 HBV for PFOS or the Hazard Index for combined concentrations of PFOS and PFOA; bottled water was provided to these residents as well. Seventy-four additional samples were collected over the next two months. Additional sampling later that year showed seven more residences that either exceeded the 2002 HBV for PFOS or the Hazard Index for PFOS and PFOA combined.

By the end of 2005, a total of 306 water samples had been collected from private wells in Lake Elmo. One hundred seventy six samples showed no detections of PFCs. A regular monitoring program was established by MDH and MPCA for private wells with detections of PFCs below the 2002 HBVs or Hazard Index. The frequency of sampling was based on the concentration of PFCs detected in each well. Bottled water was provided by the MPCA as a temporary response for the nineteen residences whose drinking water exceeded the 2002 HBVs or Hazard Index as of the end of 2005. A local water treatment company under contract to the MPCA installed granular activated carbon (GAC) filter units at each of these residences between May and October 2005. Analysis of the treated water by MDH from a number of the systems showed they were effectively removing the PFOS and PFOA from the water.

In 2006, routine monitoring of private wells continued. In late February 2006, the MDH Public Health Laboratory began analyzing private well samples for seven PFCs using its newly expanded analytical method as described previously. Those samples indicated that PFBA was present in nearly every sample analyzed, including wells in which no PFOA or PFOS was present. As a result, beginning in April 2006, MPCA and MDH began to resample all wells in the affected area to determine the extent of the PFBA contamination. The area of PFBA contamination extended beyond the areas where PFOS and PFOA were detected, greatly increasing the size of the investigation area.

As of July 2007, 455 private and non-community public wells have been sampled for the expanded list of seven PFCs. PFBA has been detected in 363 wells; it is the most commonly detected and widely distributed PFC in the Oakdale-Lake Elmo area, followed by PFOA and then PFOS (Figures 11, 12, and 13). PFBS has not been detected in any well in the Oakdale-Lake Elmo area. PFHxA was detected in 31 wells, PFPeA in six, and PFHxS in two. The last three PFCs were detected only in wells that exceeded the HRL for PFOA or PFOS, or had elevated levels of PFBA. In 2006 129 well advisories were issued, and another 12 in 2007, for a total of 160 well advisories issued total in the Lake Elmo and Oakdale areas. The PFC distribution in Lake Elmo has been complicated by surface water movement of the contaminants, and the manipulation of the surface water drainage systems over time for flood control purposes. As a result, the extent of the PFBA plume has not been fully defined.

Seventy-seven of the properties for which well advisories were issued were provided with bottled water until late 2006 or early 2007, when the wells were sealed and the residences connected to city water (see below). As of July 2007, 54 private wells and one non-community public well (serving a local business) in Lake Elmo had concentrations of PFCs that exceeded the HRLs for PFOS and/or PFOA, the well advisory guideline for PFBA, or a Hazard Index of one based on multiple PFCs. The owners of the wells have been offered or provided with whole-house GAC filters by the MPCA; two have elected to install their own filter systems.

Using adsorption factors developed by 3M for a similar GAC system installed at their Cottage Grove plant, the predicted breakthrough time for each filter can be calculated based on the influent concentration and an assumed water use rate of 300 gallons per day. MDH and MPCA staff use a tracking system to monitor water use at each home, and have collected multiple samples from selected systems over the last few years to monitor system performance. To date, the adsorption factors have proven very useful for predicting filter breakthrough, and filter maintenance can be scheduled accordingly. At average water use, the filters are predicted to last for years in some cases before maintenance is needed.

In September 2005, 3M provided the city of Lake Elmo with a grant in the amount of $3.3 million for the purpose of extending the municipal water supply to the Tablyn Park and Lake Elmo Heights neighborhoods. The Lake Elmo municipal water supply wells are located in the eastern part of the city, and the wells have either shown no PFCs or trace amounts of PFBA (see below). This grant provided for the extension of municipal water supply lines, the connection of homes in the two neighborhoods to the supply lines, the sealing of private wells, and two years of municipal water bills to be paid by 3M. 3M also donated land at the intersection of Minnesota Highway 5 and Ideal Avenue North for the construction of a new city public works facility and an elevated water storage tank to serve the expanded supply area. As of fall 2007, the connection of homes in the two neighborhoods to the Lake Elmo city water supply was basically complete, and the private wells sealed. The main reasons for sealing the private wells were to:

- Eliminate the need to monitor multiple private wells whose uses are unclear;
- Prevent further spread of PFCs in the environment;
- Prevent the possibility of future cross-connection and contamination of the public water supply;
- Eliminate the cost to the homeowner of maintaining, operating, and ultimately sealing their well; and
- Eliminate liability concerns at the time of future property transfer.

This has removed contaminated drinking water as a source of exposure to PFCs for the residents of these two neighborhoods of Lake Elmo.

In mid-2006, 121 Lake Elmo residences south and west of the former Washington County Landfill that were connected to the Oakdale municipal water system in the mid-1980s as a response to contamination found in some private wells were switched to the expanded Lake Elmo municipal water system. This action removed these residents from exposure to PFCs through the Oakdale municipal water supply, as described in the next section.

On March 8, 2007, MDH designated the expanded Lake Elmo – Oakdale Special Well Construction Area (SWCA), covering approximately 20 square miles of Lake Elmo and Oakdale. This expands the area originally designated in 1982. The March 8, 2007 memorandum establishing the expanded SWCA is attached as Appendix 3. The SWCA prohibits new potable water supply wells in areas served by community water supplies, and allows new or replacement wells outside of the community service area to be completed only in the Franconia sandstone aquifer (or deeper). MDH plan review and approval are required prior to construction, modification, or sealing of a well or boring. New wells must be tested for PFCs prior to going into service.

Repeated sampling of the two municipal wells serving the Lake Elmo municipal water system has historically shown no detections of PFOS or PFOA. In September 2007, routine monitoring by MDH detected PFBA at a concentration of 0.050 μg/L in well #1, and 0.070 μg/L in well #2. PFBA was likely present in the wells for some time, and the lower detection limits implemented by the MDH Public Health Laboratory were responsible for the detections. Both results are well below the well advisory guideline of 1 μg/L. An inactive city well in the southwestern corner of the city, drilled for possible future use but never put into service, was sampled in 2006 and showed low levels of PFCs. Other community water supplies in Lake Elmo, including those serving the

Cimarron Mobile Home Park and Oak-Land Junior High School, have also been sampled by MDH and no PFCs were detected.

Oakdale Municipal Water System
The Oakdale municipal water system is served by a network of eight large municipal wells located across the city. The individual wells directly feed the distribution system and holding towers in three separate pressure zones; there is no centralized water treatment plant. Detailed information on the construction of the wells is provided in the following table:

**Table 2: Oakdale Municipal Well Construction**

| Municipal Well # | Unique Well Number | Year Completed | Depth (feet) | Pumping Capacity (gpm†) | Well Diameter (inches)* |
|---|---|---|---|---|---|
| 1 | 208462 | 1958 | 581 | 750 | 20/12 |
| 2 | 208463 | 1964 | 542 | 1150 | 24/16 |
| 3 | 208454 | 1969 | 510 | 1000 | 24/20 |
| 5 | 127287 | 1978 | 520 | 1000 | 24/20 |
| 6 | 151575 | 1984 | 471 | 1200 | 30/18 |
| 7 | 463534 | 1990 | 563 | 1000 | 30/18 |
| 8 | 572608 | 1996 | 463 | 960 | 30/18 |
| 9 | 611059 | 2001 | 517 | 1950 | 30/18 |

†gpm = Gallons of water per minute.
*Diameter changes at depth.

Former city well #4 was located just to the southwest of the 3M-Oakdale Disposal Site, and while it did not show evidence of contamination, it was taken out of service and sealed as a precaution in the 1980s.

MDH first analyzed samples from the Oakdale municipal wells for PFCs in early 2005, after 3M initially disclosed that PFC-containing wastes had been disposed of in nearby waste disposal sites. Low levels of PFCs have subsequently been detected in all Oakdale municipal wells except well #6 at the far northern end of the city; well #3 has shown only very low-level detections of PFCs on three occasions. PFC concentrations in the six primarily affected municipal wells (wells #1, 2, 5, 7, 8, and 9) have not varied widely since monitoring began by MDH in early 2005. The mean and range of concentrations of PFCs consistently detected in each well (minimum of five detections) through September, 2007 are shown in the table below. With the lowering of the MDH laboratory detection limits in the summer of 2007, trace levels (less than 100 ppt) of PFPeA, PFBS, and PFHxS have been variously observed in wells 5, 7, 8, and 9 in recent samples. Additional data are needed to determine if they are consistently detected.

**Table 3: Oakdale Municipal Well PFC Data Summary**

| PFC | Well #1 Mean, µg/L (Range) | Well #2 Mean, µg/L (Range) | Well #5 Mean, µg/L (Range) | Well #7 Mean, µg/L (Range) | Well #8 Mean, µg/L (Range) | Well #9 Mean, µg/L (Range) |
|---|---|---|---|---|---|---|
| PFBA | 0.27 (0.14 – 0.35) | 0.38 (0.18 – 0.45) | 1.75 (1.52 – 1.96) | 0.87 (0.65 – 1.08) | 1.34 (1.08 - 1.55) | 1.96 (1.68 – 2.15) |
| PFPeA | nd | nd | 0.12 (0.07 – 0.18) | nd | nd | nd |
| PFHxA | nd | nd | 0.22 (0.13 – 0.36) | 0.16 (0.06 – 0.26) | 0.19 (0.08 – 0.33) | 0.25 (0.11 – 0.47) |
| PFOA | nd | nd | 0.75 (0.53 - 1.02) | 0.29 (0.21 – 0.39) | 0.55 (0.42 – 0.70) | 0.70 (0.2 – 0.92) |
| PFOS | nd | nd | 1.1 (0.90 – 1.41) | 0.29 (0.15 – 0.45) | 0.78 (0.51 - 1.09) | 0.62 (0.17 – 0.79) |

nd = not detected, or detected less than five times.

3M has collected split samples from some of the municipal wells at the same time MDH staff collect samples, for analysis at the 3M Environmental Laboratory in St. Paul, Minnesota. Results from the 3M Environmental Laboratory have generally been consistent with data generated by the MDH Public Health Laboratory. A formal comparison of the data sets, including the requisite quality control data, is planned.

When the PFOS/PFOA contamination was confirmed in the Oakdale municipal wells in early 2005, the City of Oakdale limited the use of the two most impacted wells, #5 and #9, to the extent possible. During the summer months when water demand increased considerably, the city was forced to use the two wells when necessary to meet demand. Nonetheless, the amount of water pumped from well #5 declined from over 307 million gallons per year (MGY) in 2001 to only 81 MGY in 2005 (DNR 2006). To compensate, the city increased pumping from the least impacted wells. For example, the amount of water pumped from well #3 increased from 27 MGY in 2001 to 183 MGY in 2005. Because the wells are located in three separate pressure zones, some contaminated wells had to be occasionally used year-round to meet demand.

In August of 2005, the city of Oakdale announced that it had reached an agreement with 3M for the construction of a water treatment plant to remove PFCs from the two most affected wells, #5 and #9 (City of Oakdale 2005). The plant would use large GAC filters to remove the PFCs prior to the water entering the distribution system. Construction of the plant began in late 2005, and the plant went into operation in October 2006. The plant is operated by the city of Oakdale; 3M agreed to pay for the operation and maintenance for a period of five years, after which the city would assume those costs. The goal of the treatment plant is to treat the city drinking water so that the levels of PFCs would be "consistently below state and federal guidelines."

Several photos of the treatment plant are presented in Figure 14. The water pumped from wells #5 and #9 enters the plant and is divided into five equal streams, which each enter a series of two GAC filters; each filter contains 20,000 pounds of GAC. The treated water is then combined back into one stream, treated with chlorine and fluoride to meet state and federal requirements, and piped to the distribution system. MDH staff have collected samples from between the two GAC filters in each set and from the combined treated water approximately every two weeks since the plant went into operation.

PFBA was first detected between the GAC filters after only six weeks of plant operation, and more recently has also been detected in samples collected after each set of two GAC filters. PFOS and PFOA continue to be effectively removed from the finished water entering the distribution system. As of October 2007, the level of PFBA in the treated water entering the distribution system was approaching 2 µg/L. The City of Oakdale, MDH, and 3M will determine the appropriate maintenance schedule for the GAC filters based on the performance of the GAC filters up until this point.

The Oakdale water treatment plant has the capacity to provide enough treated water to fulfill much if not all of Oakdale's water needs through the fall, winter, and spring. In the summer, other PFC contaminated wells must be used to help meet the higher demand for water. The city has enacted conservation measures where possible to limit the need for the use of the additional wells. The city is also considering a replacement well for well #8, to be constructed outside of the PFC plume if possible (B. Bachmeier, City of Oakdale, personal communication, 2007).

A community water supply well serving the Whispering Oaks mobile home park, in the northern part of the city, showed no detections of PFCs. MDH also sampled a number of private wells within the city of Oakdale. PFCs were detected in two wells located near the 3M-Oakdale Disposal Site, including PFBA at a concentration of 12 µg/L in one well. That well owner was advised to no longer use the water for drinking or cooking purposes; the house is reportedly vacant.

PFC-Related Investigations and Response Actions at the Washington County Landfill

As described previously, in 2004 the MPCA learned that PFC containing wastes may have been disposed by 3M at the former Washington County Sanitary Landfill in Lake Elmo. The landfill groundwater monitoring system consists of 43 monitoring wells and a surface water monitoring point (MPCA 2006). Nine wells are located upgradient of the waste deposit at the landfill and the remainder are either side gradient or downgradient of the waste. The wells are completed at various depths to provide information on several aquifers. Figure 2 shows the locations of the monitoring wells.

In late 2004, MPCA staff conducted a limited investigation at the site to look for the presence of PFCs in groundwater, surface water, sediment and soil (Oliaei 2006). Groundwater samples were collected from two monitoring wells (one upgradient (J) and one down gradient (V2) of the waste); surface water and sediment samples were collected from the spray treatment area, and soil samples were collected from a soil boring near the treatment area and from a background location a short distance away. A full report of this investigation was not available until 2005. Multiple PFCs were detected in the downgradient monitoring well, including PFBA, PFOS, and PFOA at concentrations of 1,170 µg/L, 2.69 µg/L, and 42 µg/L, respectively. Lower levels of PFCs were detected in two surface water samples, including PFBA, PFOS, and PFOA at average concentrations of 362 µg/L, 1.5 µg/L, and 13 µg/L, respectively. Interestingly, the sediment below the surface water contained relatively lower levels of PFBA (18 micrograms per kilogram, µg/kg) but higher levels of PFOS and PFOA (12 µg/kg and 17 µg/kg, respectively). This indicates that PFBA does not appreciably bind to sediments in this location, while PFOS and to a lesser extent PFOA in a relative sense do.

Results from soil samples collected from a boring near the treatment area show the presence of low levels of PFCs (less than 10 µg/kg) down to the water table, approximately 26 feet below ground. Only PFBA and PFOA were detected below 20 feet, indicating that they may be more mobile in the soil column than PFOS or other PFCs. Lower levels of PFBA, PFOS, and PFOA were found at a background soil location approximately 100 feet away, although only PFOA was detected below four feet. Wind-blown spray from the groundwater remediation system likely contributed to the PFC detections at this location. This limited soil contamination is not likely to extend very far from the location of the groundwater remediation system.

Continued monitoring has shown that PFCs are present in multiple monitoring wells at the site, primarily downgradient of the waste. The highest levels have consistently been found in monitoring well V2; results for a sample collected in August 2007 were as follows:

- PFBA: 365 µg/L
- PFPeA: 7.9 µg/L
- PFHxA: 8.7 µg/L
- PFOA: 44 µg/L
- PFBS: 0.3 µg/L
- PFHxS: 0.9 µg/L
- PFOS: 1 µg/L

Monitoring well V2 is located just south of the waste deposit. PFC levels drop significantly with distance from the waste.

A ground water remediation system is in operation at the Washington County Landfill. The system was originally installed to control migration of VOCs. The groundwater remediation system includes three gradient control wells (MPCA 2006). In 2005, a total of 32,618,680 gallons of water were extracted from the recovery wells. Until 2006, the water from gradient control wells was discharged through a spray irrigator to a treatment area just to the southeast of the waste deposit. This treatment was designed to remove the VOCs and some inorganic contaminants from the extracted groundwater. The pumpout water infiltrated down to the groundwater table, creating a "mound" in the groundwater surface around the treatment area.

Increasing levels of PFCs were found in monitoring wells downgradient of the treatment area in 2005 and 2006, suggesting that improvements to the groundwater remediation system were needed. Options under active consideration by the MPCA include pretreatment of the groundwater before infiltration or piping the extracted ground water for disposal offsite in a sanitary sewer. As an interim measure, in 2006 the MPCA stopped using the spray irrigator and previous treatment area, and moved the groundwater extraction system discharge further south to an area of more permeable soils to reduce the mounding effect in groundwater. This mounding effect at the previous treatment area may have influenced the movement of PFCs in the shallow aquifers at and near the site, perhaps even causing PFCs to migrate in directions that they would not go under normal groundwater flow conditions.

<u>PFC –Related Investigations at the 3M-Oakdale Disposal Site</u>

A table in a 1982 report on groundwater and surface water sampling at the 3M-Oakdale Disposal Site listed a detection of "Fluorocarbon (C-6?)" of approximately 300 μg/L in a surface water sample collected from a pond at the Abresch site in April 1981 (Barr 1982). This was the earliest record in the files reviewed by MDH of a detection of a fluorocarbon-based compound at the site. There was little discussion of the fluorocarbon detection in the text of the report. The same 1982 report described a total surface water discharge from the east side of the site of 1.8 cubic feet per second (cfs). This discharge enters an intermittent stream (Raleigh Creek; see Figure 9) that flows east into the city of Lake Elmo, ultimately discharging to Eagle Point Lake in the Lake Elmo Park Reserve.

In 1985, a groundwater remediation system consisting of twelve pump-out wells was installed at the site to contain VOC contamination in shallow groundwater at the Abresch source area. The system was also designed to prevent migration of VOCs off-site. Over the years adjustments were made to the system (with approval from the MPCA) and currently seven wells remain in operation. The combined pumping rate of the seven wells is approximately 40 gallons per minute, and the extracted groundwater is discharged to the sanitary sewer system operated by the Metropolitan Council (Weston 2007a).

In 2004 the MPCA learned that PFC containing wastes (described as liquid and solid industrial wastes) may have been disposed of by 3M at the former Oakdale Disposal Site, primarily in the Abresch area. To verify if PFCs were present at the site, the MPCA requested that 3M collect samples of the discharge water from the groundwater remediation system (described below) to analyze for the presence of PFOS, PFOA, PFHxS, and PFBS (Weston 2006). The samples were collected in August and again in September 2004. PFCs were detected at the following maximum levels:

- PFOS: 30.1 μg/L
- PFOA: 66.1 μg/L
- PFHxS: 8.1 μg/L
- PFBS: 8.1 μg/L

The results confirmed the presence of PFC containing wastes at the site. This finding led to a broader effort to characterize the PFC contamination. This work was implemented in several phases that began in early 2005, and continued into 2006.

Investigations at the site to date have included the collection of numerous soil samples from several areas of the site (Weston 2006; Weston 2007b). Samples were collected from the surface (0-6 inches), and at regular depth intervals from soil borings and monitoring well installations. Soil samples were mainly collected in the former Abresch area; a small number of soil samples were collected from the Brockman area as well. The initial samples were intended to determine if soil had been impacted by PFCs, and not necessarily to determine the extent of any PFC contamination identified. Samples collected in 2005 were analyzed for four PFCs: PFOS, PFOA, PFHxS, and PFBS only. Samples collected during a second phase of the investigation, in late 2006, were analyzed for twelve PFCs. The twelve PFCs were the C4-C12 perfluorocarboxylic acids, and the C4, C6, and C8 perfluorosulfonic acids.

Results from the soil testing north of Minnesota Highway 5 are shown in Figures 15 and 16 (Weston 2006, Weston 2007b). In surface soils north of Highway 5, PFOS was detected at a maximum concentration of 1,460 µg/kg, and PFOA at a maximum concentration of 74.9 µg/kg. Much higher levels were found deeper in the soil, where PFOS was detected at a concentration of 108,000 µg/kg and PFOA at a concentration of 18,050 µg/kg. Weston concludes that lower levels were found in surface soils because clean fill was brought in and graded during site remediation activities in 1983-84 (Weston 2007b). For all soil depths, the highest level of the individual PFCs found in the 2006 investigation were as follows:

**Table 4: Maximum PFC Levels in Soil, 3M-Oakdale Disposal Site**

| PFC | Maximum Result, µg/kg | Boring, Depth (feet) |
|---|---|---|
| Perfluorobutanoic acid (C4, PFBA) | 1,600 | ASB34, 8.5-9.0 |
| Perfluoropentanoic acid (C5, PFPeA) | 178 | ASB32, 5.5-6.0 |
| Perfluorohexanoic acid (C6, PFHxA) | 1,175 | ASB35, 8.5-9.0 |
| Perfluoroheptanoic acid (C7, PFHpA) | 1,275 | ASB35, 8.5-9.0 |
| Perfluorooctanoic acid (C8, PFOA) | 18,050 | ASB34, 8.5-9.0 |
| Perfluorononanoic acid (C9, PFNA) | 27.2 | ASB35, 5.5-6.0 |
| Perfluorodecanoic acid (C10, PFDA) | 1,230 | ASB36, 3.5-4.0 |
| Perfluoroundecanoic acid (C11, PFUnA) | 92.4 | ASB36, 3.5-4.0 |
| Perfluorododecanoic acid (C12, PFDoA) | 112 | ASB36, 3.5-4.0 |
| Perfluorobutane sulfonate (C4, PFBS) | 224 | ASB34, 8.5-9.0 |
| Perfluorohexane sulfonate (C6, PFHxS) | 5,585 | ASB34, 8.5-9.0 |
| Perfluorooctane sulfonate (C8, PFOS) | 108,000 | ASB32, 3.5-4.0 |

The MPCA recently issued revised Soil Reference Values (SRVs) of 2,000 µg/kg for PFOS and 4,000 µg/kg for PFOA based on a residential exposure scenario (MPCA 2007a). The SRVs represent the concentration of a contaminant in soil at or below which normal dermal contact, inhalation, and/or ingestion are unlikely to result in an adverse human health effect. They are typically used to evaluate if contaminant levels in surficial or shallow soil could pose a long-term human health risk. The MPCA has derived recreational SRVs for other contaminants, but has not done so for PFCs. While a recreational scenario may be more applicable to the type of exposure that could occur at the 3M-Oakdale Disposal Site, the use of residential SRVs for comparison is an appropriate, public health protective approach.

The finding that the highest concentrations of PFCs were at depth is consistent with the fact that the area north of Highway 5 was graded with clean fill during past cleanup efforts. Neither PFOS nor PFOA exceeded their SRV in surface soil, although the level of PFOS at one location was approximately 75% of its SRV. Overall, the highest concentrations of individual PFCs detected were PFOS, PFOA, PFHxS, and PFBA. 3M produced PFOS, PFOA, and PFBA at its Cottage Grove plant, where the waste deposited at the 3M-Oakdale site originated. It is not known if PFHxS was produced as a discreet product. The electrofluorochemical process used by 3M to produce PFCs at its Cottage Grove plant was not 100% efficient in terms of the purity of the final product. In addition to the desired product, PFCs of differing chain lengths were also produced, and may have been more concentrated in the waste products deposited at the site. In most soil samples, the concentrations of the higher chain (C9-C12) PFCs were low.

South of Highway 5, PFOS was found in surface soil at levels above the SRV in two locations (GP14 and GP15, see Figure 17; Weston 2007b). PFOA levels were typically much lower. Only very low levels of PFOS and PFOA were found at the former Brockman area (Figure 18; Weston 2007b). Overall, lower levels of PFBS and PFHxS were also found in soil, with the maximum being 28.5 μg/kg of PFBS and 252 μg/kg of PFHxS in two separate soil boring samples collected at depth north of Highway 5. Typically only very low levels were found in shallow soil.

In the area north of Highway 5, PFCs were detected in sediment at levels of up to 1,447 μg/kg for PFOS, and 235 μg/kg for PFOA (Weston 2006). As with soil, lower levels of PFBS and PFHxS were found, with the maximum level being 1.26 and 40.6 μg/kg, respectively. In surface water, PFOS was found at a maximum level of 11 μg/L, and PFOA at a maximum level of 20.4 μg/L. Small amounts of PFBA (maximum of 1.08 μg/L) and PFHxS (maximum of 0.71 μg/L) were also found. In August 2007, the MPCA established surface water standards of 6.03 nanograms per liter (ng/L, or parts per trillion) for PFOS and 721 ng/L for PFOA (MPCA 2007b). No surface water standards have been developed for PFBA or the other PFCs detected at the site. The results of the sediment and surface water sampling north of Highway 5 are shown in Figure 19.

To evaluate the potential for PFCs to be released from the 3M-Oakdale Disposal Site through surface water discharge, a series of four surface water, sediment, and groundwater samples were collected beginning at the point where Raleigh Creek exits the site on its eastern edge, and extending over one-half mile east into the city of Lake Elmo, along the path of drainage (Weston 2006). The results are shown in Figure 20. The samples were analyzed for PFOS, PFOA, PFBS, and PFHxS, but not PFBA. PFOS and PFOA were present in surface water discharge from the site, at levels of 7.5 μg/L for PFOS, and 9.5 μg/L for PFOA. Downstream, PFOS and PFOA were consistently detected in the 2-3 μg/L range. PFCs were also detected in sediment samples, with a maximum PFOS level of 209 μg/kg found approximately 800 feet downstream of the site. Groundwater samples collected adjacent to the surface water and sediment sample locations had higher PFC levels near the site, lower concentrations in the middle two samples, and essentially identical concentrations in the easternmost sample. This is consistent with the hydrology of Raleigh Creek, which "gains" water from the groundwater at the site and in westernmost Lake Elmo, but becomes a "losing stream" (i.e. the creek water infiltrates down into the groundwater) further east along its course (Figure 9).

The 2006 3M-Oakdale Disposal Site investigation also included laboratory analysis of soil and sediment samples for physical and chemical parameters such as total organic carbon content, grain size, and percent clay/sand/silt (Weston 2006). In their report on the investigation, Weston did not discuss the relationship between these characteristics and PFC concentrations. A thorough examination of the relationship between sediment physical and chemical parameters at the site and PFC concentrations is needed.

3M has prepared a workplan for a feasibility study to look at remediation alternatives for the 3M-Oakdale Disposal Site (Weston 2007c). The feasibility study will be prepared and submitted to the MPCA for review and approval in early 2008.

MPCA – 3M Consent Order for PFC Disposal Sites

At the MPCA April 24, 2007 Citizens' Board meeting, the Board was asked to approve a series of enforcement actions under the state Superfund law to compel 3M to take certain actions to respond to PFC contamination from three known PFC disposal sites: the 3M-Cottage Grove facility, the 3M-Woodbury Disposal Site, and the 3M-Oakdale Disposal Site. The former Washington County Landfill was not included because under the MPCA Closed Landfill Program, the MPCA has assumed responsibility for the site.

Instead of approving the enforcement actions, the Citizens' Board directed MPCA staff to negotiate a Consent Order with 3M on PFC contamination in Minnesota (MPCA 2007c). The Board directed staff to address seven concerns with regards to the disposal sites and proposed actions in the Order, as follows:

1. A rigorous, robust cleanup plan for the disposal sites.
2. Recognition of the MPCA's jurisdiction.
3. Municipal and private drinking water supplies addressed.
4. Address future actions on PFBA.
5. Address additional studies on health and environmental effects.
6. Address cooperation from 3M on sharing research and information.
7. Preserve the MPCA's right to take action in the future.

The MPCA and 3M negotiated the Order, and presented it to the MPCA Citizens' Board for approval at its May 22, 2007 meeting. The Citizens' Board unanimously approved the Consent Order with 3M. The consent order can be accessed on the MPCA web site at: http://www.pca.state.mn.us/cleanup/pfc/index.html (MPCA 2007d):

In the Consent Order, 3M has agreed to contribute up to $8 million to remediate the former Washington County Landfill. 3M will pay $5 million initially to the MPCA for this work, and, subsequently, up to half of the remaining cost of remediation (or $3 million), whichever is smaller. Also included in the Consent Order is an agreement that the MPCA does not waive its right to pursue any natural-resource damage claims related to releases of PFCs from the sites. Such claims are allowed under state and federal law.

Site Visits

MDH staff has conducted several visits to the Washington County Landfill, 3M-Oakdale Disposal Site and their vicinities during the past three years to observe MPCA field sampling, conduct private well searches, collect well and surface water samples, and attend local government and public meetings.

The former Washington County Landfill is completely fenced, and access is limited by several locked gates. The site is inspected regularly by the MPCA to ensure that it remains secure. During a site visit in 2005, no evidence of trespassing was observed, other than by deer or other small animals. Deer tracks were observed around the ponded water from the groundwater treatment system, indicating that deer and other animals may be exposed to PFCs (and other contaminants) by drinking the extracted groundwater.

During a site visit to the 3M-Oakdale Disposal Site, MDH staff observed evidence of walking trails and other usage of the site, mainly in the unfenced area north of Highway 5. Reportedly, nearby residents walk their dogs there and allow them to swim in the ponds. Evidence has also been observed of nearby residents, particularly children, using the Raleigh Creek drainage for hiking, biking, and other recreational activities, including possible fishing in Tablyn Park.

Demographics, Land Use, and Natural Resources

The estimated population for the city of Oakdale in 2006 was 27,249 people, living in 10,803 households (Minnesota Department of Administration 2007). The city is a typical suburban mix of compact residential areas, light commercial districts, and retail areas. It has experienced significant population growth in the last decade (approximately 13% from 1995–2005). This contributed to the need for additional municipal wells in 1996 and 2001 to meet the increased demand for water. Only a handful of private wells used as a primary source of drinking water remain in the city.

The estimated population for the city of Lake Elmo in 2006 was 7,695 people, living in 2,738 households (Minnesota Department of Administration 2007). This city is more rural in character, with most residential developments consisting of larger lots with substantial open space, private wells and septic systems. It has also experienced significant population growth in the last decade (approximately 23% from 1995–2005). The city has expanded its municipal water system to include some of the area affected by PFCs; additional expansions are planned in the future but the timeline is uncertain. At this time, less than 30% of the households in the city are served by the municipal water system. The city has directed that any new residential developments must be served by a public water supply, either by connecting to the existing city distribution system or by constructing one community well and a distribution system to serve the development.

Both cities are home to numerous parks and recreational areas. A large regional park, the Lake Elmo Park Reserve, is located in the affected area of Lake Elmo. Drinking water wells within the park, and the wells serving an artificial swimming pond, have shown low levels (0.2 to 0.6 μg/L) of PFBA and occasional traces of other PFCs. In September 2007, one well, located at the primitive campground, was removed from service due to levels of PFOS and PFOA in excess of the HRLs. Eagle Point Lake within the Park Reserve is also the ultimate discharge point for Raleigh Creek, which carries surface water impacted by PFCs from the 3M-Oakdale Disposal Site. Further assessment of potential PFC impacts to surface water, sediments, and biota in Eagle Point Lake from the historical discharge of Raleigh Creek has not been done.

A second large park, Sunfish Lake Park, is located on the eastern edge of the former Washington County Landfill. This park is undeveloped, and is used primarily for hiking and horseback riding in the summer and cross-country skiing in the winter. Opportunities for exposure to PFCs by users of the park are limited, with the possible exception that wind-blown spray from the previous groundwater treatment system could have reached a trail on the western edge of the park, possibly resulting in minor soil contamination.

In August 2007 MDH and MPCA issued a joint press release announcing revised fish consumption advice for several lakes in the Twin Cities metro area, including Lake Elmo and Lakes Demontreville and Olson, which together with Lake Jane make up the tri-lakes area in the northwest corner of the city of Lake Elmo. The press release was issued due to the detection of PFOS in fish tissue samples collected by the MPCA from the lakes at levels high enough to warrant revised fish consumption advice for certain fish species. In the case of Lake Elmo, fish consumption advice was issued recommending no more than one meal per month of bluegill sunfish, black crappie, and largemouth bass. A later data set included fish sample results from Lake Jane. In Lakes Olson, Jane and Demontreville, consumption advice for largemouth bass only (no more than one meal per week) would appear to be warranted. Of the ten lakes tested and described in the August 2007 press release, PFOS levels were highest in fish from Lake Elmo.

While the source(s) of the PFOS is not entirely clear, in the past Lake Elmo received overflow runoff from Eagle Point Lake, and may continue to during extreme rainfall or flooding events. In September 2007, a sample from a shallow drinking water well at the primitive campground in the Lake Elmo Park Reserve, near the historic surface water drainage path from Eagle Point Lake to Lake Elmo, had a PFOS concentration of 1.1 μg/L, as well as PFOA and PFBA. This appears to confirm that surface water transport from Eagle Point Lake may have played a role in the detection of PFOS in fish in Lake Elmo. The source(s) of the PFOS in Lakes Olson, Jane, and Demontreville is less clear. No surface water or sediment samples were collected from the lakes at the time the fish tissue samples were collected, but are planned by the MPCA.

General Regional Issues

This region of the eastern Twin Cities metropolitan area will likely continue to experience substantial population growth in the coming years. Because this continued growth may present a strain on area resources such as water supplies, the potential need for expansion of water supply systems will have to be evaluated by the cities. The widespread PFC contamination in the aquifers typically used for municipal water supplies complicates this process.

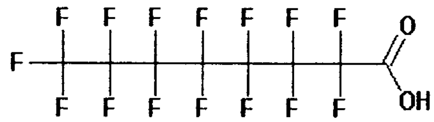
Community Concerns
MDH staff have had numerous contacts with citizens living in the cities of Lake Elmo and Oakdale who have expressed concern about PFCs in their private well or the Oakdale water supply. Community meetings were held in Lake Elmo by MDH in May and October of 2005, and in September 2006. A total of approximately 800 people attended these meetings. MDH has also attended many other local meetings in the two cites, and responded to hundreds of phone calls and e-mails.

Some residents have expressed concern about the following: that cancer or other disease rates in the area seem higher than normal, the health implications for children who may have been exposed to contaminated water (both before and after birth), and the health of domestic animals that may be drinking contaminated water. Residents also had questions about multiple exposure pathways to PFCs, and the lack of regulatory criteria for some PFCs in water. MDH has made every effort to address these health issues where possible. MDH has produced multiple information sheets for area residents, regularly updated its web site on PFCs (www.health.state.mn.us/divs/eh/hazardous/topics/pfcs/index.html), and created an e-mail distribution list (715 recipients as of October 2007) to notify interested residents and local officials of new information. The cities have also provided multiple updates for local residents in their city newsletters, water quality reports, and web sites. There have also been numerous stories in state, Twin Cities, and local media.

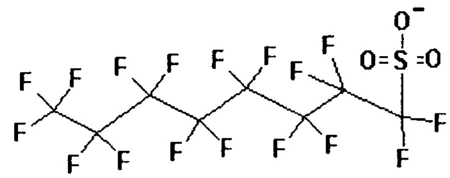
## Evaluation of Environmental Fate and Exposure Pathways

Introduction
Perfluorochemicals (PFCs) have been the subject of considerable attention in the popular press and scientific literature since 3M announced they would cease production of PFOS and PFOA at the end of 2002. The focus of the attention has evolved from the initial reports of detections of PFCs in wildlife around the world to more recent concern over the detection of PFCs in drinking water supplies in Ohio, West Virginia, North Carolina, New Jersey and Minnesota and the implications for human health. The concerns about human exposure to PFCs were described in a cover story that appeared in the May 2007 issue of *Environmental Health Perspectives* entitled "Perfluoroalkyl Acids: What is the Evidence Telling Us?" (Betts 2007). The paper summarizes the relatively brief history of PFCs as known environmental contaminants, and the current understanding of their toxicity based on animal research and epidemiological studies in humans. Various research needs are also outlined. No firm conclusions are drawn in answer to the critical question raised by the title.

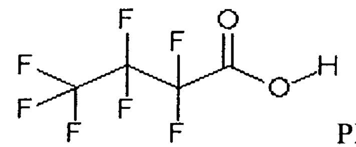
PFCs, primarily perfluorooctanoic acid (PFOA; $C_8F_{15}O_2H$) and one of its salts, ammonium perfluorooctanoate (APFO; $C_8F_{15}O_2NH_4$), as well as lesser amounts of other PFCs such as perfluorooctanesulfonyl fluoride (POSF; $C_8F_{17}SO_2F$) and perfluorobutanoic acid (PFBA, $C_4F_7O_2H$) were manufactured by 3M at their Cottage Grove facility (formerly known as Chemolite) from the early 1950s until 2002 (PFBA production ceased in 1998). One of the byproducts of the production of POSF is perfluorooctane sulfonate (PFOS; $C_8F_{17}SO_3^-$), which can also be produced by the subsequent chemical or enzymatic hydrolysis of POSF. The chemical structures of PFOA, PFOS, and PFBA are shown below:



PFOA



PFOS



PFBA

PFCs were produced at the 3M Cottage Grove facility using an electrochemical fluorination process, a batch process where hydrogen fluoride was added to organic molecules and electricity was applied to facilitate the complete replacement of hydrogen atoms with fluorine. A unique aspect of this process was the production of both straight-chain and branched isomers (Prevedouros et al. 2006). The other main PFC production process (and the one currently in use) uses fluorotelomers and produces only straight-chain molecules. This fact could help distinguish PFCs found in the environment or in living things as having originated from historical PFC manufacture and waste disposal (such as from the various disposal sites historically used by 3M) as opposed to the modern use of PFCs in commercial products (De Silva and Mabury 2006).

In January 2006, the administrator of the EPA initiated the PFOA Stewardship Program, in which the eight major companies who remained in the PFOA industry (including 3M) committed voluntarily to reduce facility emissions and product content of PFOA and related chemicals on a global basis by 95 percent no later than 2010, and to work toward eliminating emissions and product content of these chemicals by 2015 (EPA 2006). There are still some commercial uses of PFOS in specialty products (primarily in the semi-conductor, metal plating, and aviation industries), but to the knowledge of MDH there is currently no commercial production of PFBA. In its reformulated stain repellent and other commercial products such as Scotchgard™, 3M used a chemistry based on the four carbon sulfonic acid PFBS, instead of the eight carbon PFOS (Brezinski 2003).

Environmental Fate

The carbon-fluorine bond is a high-energy bond, one of the strongest known among organic molecules. As a result, the chemical structures of PFCs make them extremely resistant to natural breakdown, and they are persistent once released to the environment. Their structure also makes them excellent surfactants. The word surfactant is an acronym for 'surface active agent' - a molecule that lowers surface tension in a liquid. Surfactant molecules contain both a hydrophobic ('water-hating') and hydrophilic ('water-loving') component, making them semi-soluble in both organic and aqueous solvents. Surfactants are the active ingredients in soaps and detergents, where the hydrophobic component sticks to grease and dirt while the hydrophilic section sticks to water, helping to remove dirt from skin and hair and stains from fabric. These same properties can also be used to essentially help make materials resistant to water and stains, one of the primary markets for these chemicals. Information on the physical properties of PFCs that would make them potentially useful in industrial applications was published by 3M scientists in technical journals as far back as the early 1950s (Kauck and Diesslin 1951; Reid et al. 1955).

On the basis of its physical properties, PFOS is essentially non-volatile, and would not be expected to evaporate from water (OECD 2002). In soil-water mixtures, PFOS has a strong tendency to remain in water due to its solubility (typically 80% remains in water and 20% in soil). PFOS does not easily adsorb to sediments, and is expected to be mobile in water at equilibrium (3M 2003a).

PFOA is slightly more volatile than PFOS, although it also has a very low volatility and vapor pressure (EPA 2002). PFOA salts are very soluble and completely disassociate in water; in aqueous solution it may loosely collect at the air/water interface and partition between them (3M 2003b). In limited studies, PFOA has shown a high mobility in some soil types (EPA 2002). In a study of the sorption potential for various PFCs in sediments, Higgins and Luthy (2006) found that the carbon chain length had a major effect on sorption potential – the longer the chain the more likely adsorption would occur, and that perfluorosulfonates (i.e. PFOS) tended to bind more readily to sediment than perfluorocarboxylates (i.e. PFOA). Other environmental conditions that could affect adsorption include organic carbon content of the sediment, pH, and dissolved calcium. Other studies have shown generally similar results, and adsorption behavior in soils is likely to be very similar to that observed in sediments (Prevedouros et al. 2006).

The vapor pressure and water solubility of PFBA are similar to PFOA (Kwan 2001). PFBA is very soluble in water, and appears to travel easily with groundwater. A number of fluorinated compounds are in fact used as tracers in groundwater flow studies due to their negligible adsorption to soil and aquifer materials (Flury and Wai 2003). The study of sediment adsorption of selected PFCs by Higgins and Luthy (2006), which unfortunately did not include PFBA, nonetheless supports the notion that PFBA may be even more mobile than PFOA or PFOS in the environment because it is a perfluorocarboxylate with a short carbon chain length.

In a study of PFCs in groundwater at a former military fire-training site in Michigan, Moody et al. (2003) found PFOS concentrations up to 120 μg/L and PFOA as high as 105 μg/L near the original concrete pad used for training with fire-fighting foams that contained PFCs. Both PFOS and PFOA were found in groundwater as far away as 500 meters from the pad. The facility was used for fire-training from 1952 until the early 1990s. The results of the study demonstrate that PFCs can travel extended distances with little or no retardation of the contaminants through adsorption to the aquifer substrate, and can persist for years after they were used at the ground surface.

Evaluation of Impacts on Groundwater

The information obtained from investigation and remedial activities at the disposal sites, surface water sampling, and sampling of private, municipal, and non-community wells has been used to evaluate the magnitude, extent, and possible migration history of the PFC contamination in Lake Elmo and Oakdale. The limited number of Jordan aquifer wells and the absence of wells in much of the Lake Elmo Park Reserve limit the overall understanding of the contaminant distribution and migration. However, several patterns have emerged.

PFCs are distributed much more broadly in Lake Elmo than would have been predicted, if regional groundwater flow was the sole means of contaminant migration. In 2005, the MPCA hired Barr Engineering, a local environmental consulting firm, to model the groundwater in the Lake Elmo-Oakdale area. Figure 8 illustrates the area in which groundwater that was beneath the disposal sites at the time disposal was occurring would be expected to have moved over time (Barr 2005). The actual extent of the contaminant plumes (Figures 11, 12, and 13) is much larger than predicted by the model. Barr noted that groundwater mounding at both of the sites may have accounted for some of the wider distribution of the contamination, but this is insufficient to account for how far to the southeast PFCs have migrated in Lake Elmo. Fracture flow in the St. Peter and Prairie du Chien, which the model cannot quantify, as well as movement of PFCs through natural and manmade surface water systems, has likely significantly expanded the area of contamination.

PFBA is the most widely distributed contaminant in the Oakdale – Lake Elmo area. The highest concentrations of PFBA in groundwater have been found at the Washington County Landfill, 1,170 µg/L. The highest concentration detected in groundwater at the Oakdale Disposal Site was 608 µg/L, although sampling for PFBA has been limited at that site to date. Despite the differences between the concentration levels at the two disposal sites, private wells nearest the two sites have similar concentrations of 11-12 µg/L of PFBA. Concentrations of PFBA generally decrease with distance from the disposal sites (see Figure 11), but the pattern is more complex in Lake Elmo and the absence of wells within the Lake Elmo Park Reserve makes it difficult to interpret why some higher concentrations of PFBA have been detected as far south as 10th Street North.

PFOS and PFOA are less widely distributed, with PFOS being detected in the fewest number of wells (see Figures 12 and 13). Their concentrations also generally decrease with distance from the disposal sites, but a very unusual distribution pattern emerges in Lake Elmo south of Raleigh Creek, where both PFOA and PFOS show higher levels downgradient (i.e. south and west) of the creek than are present upgradient (i.e. north and east) of the creek. In fact, PFOS was detected in only one well on the north side of Raleigh Creek, in a private well located very near the creek and within the valley fill associated with it. In addition, the maximum PFOS concentration detected at the Washington County Landfill was only 1 µg/L, but south of the creek private wells had up to 3.3 µg/L of PFOS. Although PFOA was detected at higher concentrations in the landfill, it too is present at higher concentrations downgradient of the creek.

Observation of this distribution pattern led to sampling of Raleigh Creek by MDH and MPCA to determine PFC concentrations in the surface water. Concentrations in the creek were very similar to those found in the private wells immediately downgradient of the creek. The sample location and results are shown in Figure 21. Raleigh Creek is a "losing stream" (i.e., a majority of the stream flow discharges to the groundwater system) for its entire distance through the Lake Elmo Heights and Tablyn Park neighborhoods (Figure 9). The presence of PFOS in the private wells downgradient, but not in the groundwater upgradient of the creek, the increased concentration of PFOA downgradient relative to the groundwater upgradient of the creek, and the similarity of the PFC concentrations in the creek water and the groundwater all point to Raleigh Creek as having acted as a transport mechanism for PFCs discharging from the Oakdale Disposal Site. The PFCs have been transported into Lake Elmo and re-entered the groundwater where Raleigh Creek becomes a "losing stream." This may, in part, help explain the more complex contaminant distribution pattern in Lake Elmo compared to Oakdale.

As noted above, in the late 1980s to mid-1990s, groundwater being extracted by gradient control well #1 (GC-1) at the Washington County Landfill was discharged to a storm sewer that ultimately discharged to Raleigh Creek in the northeast corner of Tablyn Park (Figure 9). This water would have carried PFCs directly to the last ½ mile section of Raleigh Creek, where it discharges into Eagle Point Lake. As discussed earlier, the annual volume discharged ranged from 50 to 80 million gallons, and the discharge continued for a period of 7 years (1988-1995). The ranges of PFC concentrations that have been detected in GC-1 are listed below (ND = not detected):

- PFBA : 68 - 235 μg/L
- PFPeA : 1.5 - 4.1 μg/L
- PFHxA : 2.2 – 5.5 μg/L
- PFOA : 7.9 – 16 μg/L
- PFBS : ND
- PFHxS : ND – 0.3 μg/L
- PFOS : ND – 0.3 μg/L

Based on the concentrations and discharge volumes, the maximum mass of each PFC that may have been discharged to Raleigh Creek may be estimated:

| | Annual Discharge | Total from 1988-1995 |
|---|---|---|
| • PFBA : | 71 kg (or 156 lb) | 497 kg (or 1,095 lb) |
| • PFPeA : | 1.2 kg (or 2.6 lb) | 8.4 kg (or 18.5 lb) |
| • PFHxA : | 1.7 kg (or 3.7 lb) | 12 kg (or 26 lb) |
| • PFOA : | 4.8 kg (or 10 lb) | 33.6 kg (or 74 lb) |
| • PFBS : | not detected – cannot estimate | |
| • PFHxS : | 0.09 kg (or 0.2 lb) | 0.63 kg (or 1.4 lb) |
| • PFOS : | 0.09 kg (or 0.2 lb) | 0.63 kg (or 1.4 lb) |

This would be in addition to the load of PFCs, including PFOS, already present in Raleigh Creek as a result of discharge of contaminated groundwater from the 3M-

Oakdale Disposal Site into the creek. What those concentrations may have been prior to or during this time period is impossible to estimate.

Under non-flooding conditions, water that enters Eagle Point Lake largely passes through the lake, re-entering the groundwater near its southern end. The detections of PFOA, PFOS, and PFBA in the neighborhoods south and west of the lake (Parkview and Whistling Valley) may possibly be related to transport of PFCs through the lake. The current PFC concentrations in Raleigh Creek are not high enough to explain the concentrations found in those neighborhoods, but in the past when direct discharge of wastewater from the landfill and likely higher concentrations of PFCs were exiting the 3M-Oakdale Disposal Site, it is conceivable that Eagle Point Lake was acting as a conduit for contaminant migration. This too may account for the more widespread distribution of PFCs in Lake Elmo than expected based on the regional groundwater flow. However, the absence of wells within the Lake Elmo Park Reserve makes it difficult to test this theory.

The many changes to the groundwater and surface water systems over the period of time since the PFC wastes were disposed make it difficult to determine with any certainty what the PFC concentrations may have been in the past, and when PFCs may have first entered the affected private wells in Lake Elmo and city wells in Oakdale. Private well sampling since 2005 indicates that the PFC concentrations currently are stable, and the contaminant plumes do not appear to be expanding. However, continued monitoring will be needed to confirm this.

Exposure through Private Wells

PFCs can affect humans only if the chemicals move from the environment and come into contact with or accumulate in a person's body. The movement of PFCs (or other contaminants) from the environment into a person's body is called an exposure pathway.

An exposure pathway contains five parts: (1) a source of contamination, (2) contaminant transport through an environmental material (i.e., soil, air, water, food), (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population. An exposure pathway is considered *complete* if evidence exists that all five of these elements are, have been, or will be present in a community or a given situation. More simply stated, an exposure pathway is considered complete when people are highly likely to be exposed to the chemical of concern. A pathway is considered a *potential* exposure pathway if at least one of the elements is missing but could be found at some point. An *incomplete* pathway is when at least one element is missing and will never be present.

A completed exposure pathway to PFCs from the disposal of PFC-containing wastes in Lake Elmo and Oakdale exists primarily from swallowing PFC contaminated drinking water, and from the consumption of fish from local lakes where PFOS has been detected in fish populations. Potential pathways include exposure to contaminated sediments in Raleigh Creek, direct contact with PFC contaminated soils at the 3M Oakdale Dump, or possible exposure through gardening with PFC contaminated water.

As a part of the investigation of PFC releases from the former Washington County Sanitary Landfill and the 3M-Oakdale Disposal Site, samples have been collected from 455 private wells in Lake Elmo and nine private wells in Oakdale. PFCs have been detected in numerous private wells in Lake Elmo, and in several private wells in Oakdale. Levels of PFCs in many wells exceeded current MDH health-based advisory values. The length of time local residents were exposed to PFCs through drinking water is unknown; exposures could have started soon after PFCs wastes were placed in the disposal sites. Citizens in the Tablyn Park and Lake Elmo Heights neighborhoods in Lake Elmo who were exposed to PFCs through their private wells have now been placed on the Lake Elmo municipal water supply, and the wells have been sealed.

At this time, drinking water well advisories have been issued and remain in effect for 55 private well owners in Lake Elmo. None of the residents are being exposed to PFOS or PFOA above MDH HRLs, or to PFBA above the well advisory guideline due to the provision of bottled water and/or GAC filters by the MPCA, or the use of owner-installed filter systems. These actions by the MPCA are triggered by a MDH drinking water well advisory. When an HBV for PFBA is available, MDH will reevaluate each well to determine if a drinking water well advisory remains warranted. Continued routine monitoring of private wells with levels of PFCs below HRLs or HBVs will ensure that if levels of PFCs rise, exposure to levels above health protective values will be brief.

<u>Exposure through Public Water Supplies</u>
Levels of PFOS and/or PFOA have met or exceeded current MDH health-based advisory values in four Oakdale municipal wells. The length of time local residents were exposed to PFCs through the municipal water supply system at these levels is also unknown; exposures could have started soon after PFCs wastes were placed in the disposal sites. Recently, because of careful management of the water distribution system and the installation of the activated carbon treatment plant in late 2006, the levels of most PFCs in the Oakdale water supply system have declined. The city generally relies on wells #5 and #9 to supply the majority of its water needs during the fall, winter, and spring. The remaining wells are used during that time only to meet peak demands or to allow for maintenance on the two main wells. This means that during those months, water entering the distribution system is free of PFOS and PFOA as the treatment plant is effectively removing them. Recent testing has shown that PFBA is no longer being effectively removed by the carbon treatment plant. During the summer months, the use of other city wells is increasingly needed to meet the higher demand for water. This can lead to short term exposure to PFOS and PFOA while those wells, especially #7 and #8, are in use. Until the carbon filters in the plant are changed, there is likely to be a low level of PFBA present in the Oakdale water supply on a year-round basis.

The Oakdale city wells and the treatment plant typically are monitored on a monthly and bi-weekly basis, respectively, and the results of monitoring are reported to the city staff. MDH will continue to monitor the wells and treatment plant regularly, but to date very little change has been observed in PFCs levels.

PFBA contamination from the former Washington County Landfill and 3M-Oakdale Disposal Site have likely contributed to low levels of PFBA contamination (0.2 to 0.5 µg/L) detected in municipal wells in the city of Woodbury, Minnesota. Woodbury is located just south of Oakdale and Lake Elmo. MDH staff continue to work with the City of Woodbury to monitor PFBA levels in the city wells.

Exposure through other Pathways

The use of water contaminated with low levels of PFCs for bathing, showering, or other incidental uses is unlikely to contribute appreciably to overall exposure. Ingestion of the contaminated water is by far the predominant exposure pathway. Use of PFC contaminated water for canning or cooking purposes may contribute to exposure, as suggested by the study conducted by Emmett et al. (2006a). Irrigation of plants with PFC contaminated water may possibly lead to some uptake of PFCs by the plants, also contributing to overall exposure. So-called "market basket" studies of food products occasionally show low levels of PFCs. In a study conducted in the United Kingdom, PFOS was found at low concentrations in potatoes, some canned vegetables, eggs, and in the sugars and preserves food groups, while PFOA was detected only in potatoes (UK Food Standards Agency 2006).

Some additional exposure to PFOS in Lake Elmo and Oakdale could come as a result of the consumption of fish from local lakes that have been found to be impacted, as described above.

## Public Health Implications of PFC Exposure

This section will summarize the current information on the toxicity of PFCs to animals and humans, and summarize the public implications of exposure to PFCs through drinking water in Lake Elmo and Oakdale, Minnesota.

Summary of Toxicological Information from Animal Studies

MDH described the available toxicological information on PFOS and PFOA in its Health Consultation on the 3M-Cottage Grove Facility (MDH 2005). This section will briefly summarize that information. For further information on studies of the toxicology of PFOS and PFOA that were reviewed during the process of revising the MDH HBVs/HRLs, please refer to Appendix 2. This section will also describe the available information on the toxicity of PFBA. An excellent overview of the current state of knowledge on the toxicity of perfluorinated acids was also recently published online (Lau et al. 2007).

PFOS is well absorbed orally, but is not absorbed well through inhalation or dermal contact (OECD 2002). Half-lives of PFOS have been estimated at over 100 days in rats in a single-dose study, and 200 days in a sub-chronic dosing study in cynomolgus monkeys (OECD 2002). Animal studies have shown that PFOA and APFO (its ammonium salt) are easily absorbed through ingestion, inhalation, and dermal contact (EPA 2002; Kennedy 1985; Kennedy et al. 1986; Kudo and Kawashima 2003). The estimated half-life of PFOA in animals ranges from four hours in female rats and nine days in male rats to 20 days in male cynomolgus monkeys (Kudo and Kawashima 2003; Butenhoff et al. 2004). PFCs are not metabolized, and are excreted in the urine and feces at different rates in various test animal species and humans.

Limited evidence suggests that the carbon chain length of perfluorocarboxylic acids is related to the half-life in animals, with a longer carbon chain length associated with a longer half-life (Ohmori et al. 2003). Exceptions to this have been found in humans, however, as described below.

Exposure to high levels of PFOA, PFOS, and PFBA is acutely toxic in test animals (Kudo and Kawashima 2003; OECD 2002; Takagi et al. 1991). Chronic or sub-chronic exposure to lower doses of PFOA in rats typically results in reductions in body weight and weight gain, and in liver effects such as an increase in liver weight and alterations in lipid metabolism (Kudo and Kawashima 2003). The liver appears to be the primary target organ of PFOA toxicity in rats, although effects on the kidneys, pancreas, testes, and ovaries have also been observed (EPA 2002). Exposure to PFOA in rats results in a phenomenon in the liver known as peroxisome proliferation. This phenomenon is considered to be limited to rats and similar test animals, and is not observed in primates. Some of the adverse liver effects observed in rats such as an increase in liver weight are in part attributed to peroxisome proliferation. Adverse liver effects in higher animals are likely the result of a different mode of action. Current research involving rodents who have been genetically altered to eliminate the peroxisome proliferation mechanism may help answer mechanistic questions.

Chronic exposure to PFOS at high doses results in liver toxicity and mortality, with a steep dose-response curve for mortality in rats and primates (OECD 2002). Indications of toxicity observed in 90-day rat studies include increases in liver enzymes and other adverse liver effects, gastrointestinal effects, blood abnormalities, weight loss, convulsions, and death.

Some long-term animal studies suggest that exposure to PFOA (and possibly PFOS) could increase the risk of cancer of the liver, pancreas, and testes (Kudo and Kawashima 2003, EPA 2002, OECD 2002). The mechanism of potential carcinogenesis is unclear, but evidence suggests that the cancers are the result of tumor promotion (via oxidative stress, cell death, or hormone-mediated mechanisms) and not from direct damage to the genetic material within cells (genotoxicity). The tumors observed in rats may be a result of peroxisome proliferation, and may not be of relevance in humans (Kennedy et al. 2004).

Various reproductive studies of rats followed for two generations showed postnatal deaths and other developmental effects in offspring of female rats exposed to relatively low doses of PFOS and APFO (EPA 2002, OECD 2002). These studies demonstrate that exposure to APFO/PFOA and PFOS can result in adverse effects on the offspring of rats exposed while pregnant.

PFBA has not been studied as extensively as PFOA or PFOS. PFBA has been demonstrated to cause peroxisome proliferation in the livers of rats exposed through their diet or by intraperitoneal injection (Ikeda et al. 1985; Takagi et al. 1991). The effects of treatment with PFBA were less severe than was observed with PFOA in these two studies. Similar effects have been seen in mouse studies (Permadi et al. 1992). In a similar study comparing the effects of PFOA and PFBA on rat livers, Just et al. (1989) found that the effects of treatment with PFBA were similar to that of PFOA for some parameters measured in the study.

Data from several ongoing studies of PFBA were presented in several posters at the Society of Toxicology (SOT) annual meeting, held in Charlotte, North Carolina in March 2007. One poster, by Chang at al (2007), summarized data from a study of the pharmacokinetics of PFBA in several animal species. The study showed that PFBA was eliminated quickly through urine in male and female rats, with a half-life of approximately 8 hours in male rats and less than two hours in female rats. The half-life in monkeys was less than two days. A recent preliminary report from 3M states that the half-life of PFBA in four male employees at their Cottage Grove plant was measured as between two and four days (3M 2007b).

A 28-day oral toxicity study of PFBA in rats (Lieder et al. 2007) was also presented at SOT. In this study, some rats were also exposed separately to PFOA as a positive control. Male rats exposed to PFBA were shown to have increased liver weights and decreased cholesterol, and other minor effects that went away once the exposure was stopped. The main differences between male rats given PFBA and PFOA were that PFBA treated rats did not have lower body weights, but did have lower cholesterol. PFOA exposed rats did have a reduction in body weight, exhibited less physical activity and overall health, and had slight reductions in parameters related to red blood cells.

A poster on a developmental study of PFBA in mice underway at the EPA laboratory in North Carolina was also presented at the 2007 SOT meeting (Das et al. 2007). In the study, exposure to PFBA by pregnant mice did not appear to significantly affect maternal weight gain or fertility. Some developmental delays were observed in the offspring of the mice. Final results are expected by the fall of 2007.

No animal studies regarding exposure to multiple PFCs at the same time have been located in the scientific literature.

The current MDH HRLs for PFOS and PFOA (which are identical to the HBVs described in Appendix 2) are based on toxicological studies conducted on Cynomolgus monkeys. In the case of PFOS, the key study was used to derive a toxicity value (known as a reference dose, or RfD) of 0.000075 milligrams per kilogram-day (mg/kg-d). The RfD included a 'dose metric adjustment' of 20 to account for the large difference in half-life between Cynomolgus monkeys (110-132 days) and humans (5.4 years; see below), as well as a total uncertainty factor (used to account for various uncertainties in applying animal studies to humans, among other factors) of 100. The critical effects used to determine the RfD were a decrease in serum high-density lipoprotein (i.e. "good" cholesterol) and thyroid hormones. For PFOA, the key study was used to derive an RfD of 0.00014 mg/kg-d. The RfD for PFOA included a 'dose metric adjustment' of 70 to account for the even larger relative difference in half-life between Cynomolgus monkeys (20 days) and humans (3.8 years), as well as a total uncertainty factor of 300. The critical effect used to determine the RfD was an increase in relative liver weight.

Summary of Human Exposure and Epidemiological Information

The 3M Company has conducted medical monitoring of employees engaged in the manufacture of perfluorochemicals since the 1970s. The company initially measured total serum organic fluorine. In the mid-1990s, the company began measuring serum PFOA and PFOS (Olsen et al. 1998; Olsen et al. 2003a; Olsen et al. 2003b). In a recently published study of 26 retired 3M workers, the mean serum half-life of PFOA was estimated to be 3.8 years, and the mean serum half-life of PFOS was estimated at 5.4 years (Olsen et al. 2007a). The mean serum half-life of PFHxS was longer: 8.5 years. This indicates that some PFCs are retained in the human body for a much longer period than in mice, rats, or monkeys, and that carbon chain length is not necessarily directly related to half-life in humans. The half-life of PFBA in humans has been estimated as between two and four days based on a limited study in 11 male and two female 3M workers (3M 2007b; G. Olsen, personal communication, 2007).

In addition to perfluorochemical workers, PFOS, PFOA, and other perfluorochemicals have been detected in human blood serum from the general population (Calafat et al. 2007a and 2007b, Olsen et al. 2003c, Olsen et al. 2004a, Olsen et al. 2004b). The following table summarizes those data as well as male worker blood serum data for PFOS and PFOA from the 3M-Cottage Grove plant for the year 2000, and statistics from two populations exposed through drinking water. The first such population is a study of Little Hocking, Ohio residents exposed to PFOA through their drinking water, and possibly through air emissions (Emmett et al. 2006a). These residents live directly across the Ohio River from a large DuPont plant that released PFOA into the air and water for many years. Tests of the public water supply serving that community showed an average PFOA level of 3.55 μg/L.

Data for the second population exposed through drinking water are unpublished data collected for a lawsuit filed against 3M in the Tenth Judicial District Court in Washington County, Minnesota (Bilott 2007). Attorneys for the plaintiffs in that case arranged for blood samples to be collected from Oakdale (n=81) and Lake Elmo (n=26) residents interested in participating in the lawsuit for analysis for PFCs at the Axys Analytical Services laboratory in British Columbia, Canada. The data may not be representative of the population of Oakdale or private wells users in the affected area of Lake Elmo as a whole, as the participants were not selected randomly, individual PFC exposure through drinking water is unknown, and no information on possible exposure to PFCs other than through drinking water was provided. Nonetheless, they are the only known data for people in Minnesota known to have been exposed to PFCs through drinking water. The weighted average of PFOA entering the Oakdale public water supply for the years 2003-2005 (calculated from well pumping records (DNR 2006) and the monitoring data described above) was estimated at 0.57 μg/L. Individual or household exposures could have varied widely based on location, well pumping patterns, and the time of year. Data for private wells in Lake Elmo vary widely, so no estimates of the average PFC exposure to that population are possible.

**Table 5: Reported Levels of PFOS/PFOA in Human Serum**

| Population | No. | PFOS (ppb)* | PFOA (ppb)* | Source |
|---|---|---|---|---|
| PFC Production Workers, 3M-Cottage Grove, 2000 | 131 (Male) | 440 (20 – 4,790) | 850 (7 – 92,030) | 3M 2003c |
| Little Hocking, Ohio Residents, age 2 – 60+; 2004-2005 | 291 | NA | 374# (7 – 1950) | Emmett et al. 2006a |
| Oakdale, MN Residents 2005-2006 Adults | 75 | 54.4 (8.3-167) | 36.9 (5.5-121) | Bilott 2007 (Unpublished) |
| Children | 10 | 51.0 (20.1-180) | 32.3 (13.4-155) | |
| Lake Elmo, MN Residents 2005-2006 | 26 | 30.4 (8.9 – 155) | 15.8 (2.4 – 133) | Bilott 2007 (Unpublished) |
| US Population, age 12+ 1999-2000 | 1562 | 30.4 | 5.2 | Calafat et al. 2007a |
| US Population, age 12+ 2003-2004 | 2094 | 20.7 | 3.9 | Calafat et al. 2007b |
| Adults, Red Cross Blood Banks, 2001 | 645 | 34.9 (<4.2 – 1656) | 4.6 (<1.9 – 52.3) | Olsen et al. 2003c |
| Children, 2-12 yrs, 1994-1995 | 598 | 37.5 (6.7 – 515) | 4.9 (<1.9 – 56.1) | Olsen at al 2004a |
| Older Adults, age 65-96, 2001 | 238 | 31.0 (<3.4 – 175) | 4.2 (<1.4 – 16.7) | Olsen at al 2004b |

* Geometric Mean & Range #Median value
NA: not analyzed

The specific source(s) of exposure to PFOS, PFOA, and other perfluorochemicals in the general population is unclear, but could include consumer products, environmental exposures, or other occupational exposures (Butenhoff et al. 2006). Both PFOS and PFOA have been detected in samples of dust collected from household vacuum cleaner bags in Japan (Moriwaki et al. 2003) and Canada (Kubwabo et al. 2005), indicating the indoor environment is one potential source of exposure. Low ppt levels of PFOS have also been detected in rainwater collected in Winnipeg, Canada (Loewen et al. 2005). A recent study of food items in Canada found low levels of PFOS and PFOA in some food products, including beef, fish, and microwave popcorn (Tittlemier et al. 2007). Small amounts of unbound fluorotelomer alcohols that can break down to PFOS or PFOA (or other PFCs depending on their specific composition) have also been found in consumer and industrial products (Joyce et al. 2006). Release of telomer alcohols, and subsequent degradation in the environment or by organisms, could also be a source of human exposure to PFCs.

Recently, Olsen et al. (2007b) reported that concentrations of PFOS and PFOA in the blood of 40 American Red Cross donors in the Twin Cities metro area were lower than levels measured in the Twin Cities in 2000, perhaps due to the phase-out of production of the two chemicals by 3M at the end of 2002. They compared blood serum from 100 donors collected in 2000 with 40 samples (unpaired) collected in 2005. The geometric mean for PFOS for the samples collected in 2000 was 33.1 ppb; in 2005 it was 15.1 ppb. For PFOA, the geometric mean in 2000 was 4.5 ppb, and in 2005 it was 2.2 ppb. This may indicate that the elimination of PFC production at the 3M-Cottage Grove plant has resulted in less exposure to the general Twin Cities population, or more likely is a result of the overall reduction in the use of these two chemicals in consumer products. The fact that the Twin Cities population sampled in 2000 was part of the larger American Red Cross study cited in the table above, and the data for the Twin Cities subset was not substantially different than populations elsewhere in the U.S. suggests that local manufacture of PFCs was not a significant source of exposure to the general Twin Cities population. There could well be local variations in an urban area the size of the Twin Cities, and this issue has not been studied in Minnesota or elsewhere. The much broader U.S. population data from Calafat et al. (2007a and 2007b) support the idea that PFOS and PFOA levels in the blood serum of the general population are indeed declining.

PFCs have been shown to cross the placenta. In a study of fifteen pairs of maternal and cord blood samples in Japan, Inoue et al. (2004) detected PFOS in the cord blood samples at approximately one-third the concentration in maternal blood. PFOA was detected in maternal blood, but not in cord blood. A similar study of 11 paired maternal and cord blood samples collected in Germany showed PFOS in cord blood at approximately 60% of the maternal blood concentration (Midasch et al. 2007). This study did detect low levels of PFOA (median of 3.4 μg/L) in cord blood samples, slightly above that found in the maternal blood samples. A larger study conducted in the city of Baltimore measured ten PFCs in the cord serum of 299 newborns (Apelberg et al. 2007). PFOS and PFOA were detected in nearly all of the samples, at a geometric mean level of 4.9 and 1.6 ppb, respectively. Other PFCs were detected much less frequently, and at lower levels.

PFCs have also been detected in human breast milk at low ppt levels in China (So et al. 2006) and Sweden (Kärrman et al. 2007). The Swedish study found that levels of PFOS in human breast milk were approximately 1% of the level found in blood serum. This indicates that breastfeeding may also be a source of PFC exposure during early life, and the magnitude of the exposure may be dependent on the body burden in the mother. However, the exposure is relatively short-term, given that most U.S. infants are exclusively fed breast milk only during the first six months of life (Otten et al. 2006). The benefits of breastfeeding (as described in a policy statement by the American Academy of Pediatrics; AAP 2005) would far outweigh any potential minimal long-term health risks from this low level exposure to PFCs.

The Drinking Water Inspectorate of the United Kingdom has proposed a drinking water guideline for PFOS of 67 μg/L for bottle-fed babies, based on presumed acute effects in animals (DWI 2007). If human breast milk concentrations of PFOS are approximately 1% of the blood serum PFOS level, then the serum level in the mother would need to reach 6,700 μg/L before PFOS in breast milk would reach the proposed United Kingdom value for an infant consuming the milk as its only source of nutrition. That high a level of PFOS in human blood serum has not been reported in the general population.

There are two separate investigations of community exposure to PFOA in a population living near what was a major environmental source of PFOA – the DuPont Washington Works facility located near Parkersburg, West Virginia. The first is being led by researchers from the University of Pennsylvania under a grant from the National Institute for Environmental Health Sciences (NIEHS). The first paper (Emmett et al. 2006a) evaluated exposure to PFOA through drinking water, ambient air, and occupational exposure in 353 people living in several communities in Ohio, just across the Ohio River from the DuPont plant. Exposure to PFOA was quantified by analysis of blood serum for PFOA. As described above, the median blood serum PFOA value for the largest exposure group, consumers of public water in Little Hocking, Ohio, was 374 ppb.

Ambient air and casual occupational exposure were not found to be a significant contributor to blood PFOA. Increased consumption of contaminated city water, or use of contaminated water for cooking, canning, or reconstituting soup or juice were positively correlated with increased blood PFOA levels, while the use of a carbon filter was negatively correlated with PFOA levels in blood. The study found a positive correlation between blood PFOA levels and consumption of home-grown fruits and vegetables. Whether this finding is a result of the use of contaminated water for cooking, canning, or washing the produce, the produce itself containing PFOA, or is otherwise related to the habits of those who consume home-grown produce is unclear.

The second paper (Emmett et al. 2006b) also looked at the relationship between serum PFOA levels and specific medical indicators such as liver function, cholesterol, thyroid hormones, or blood parameters. A questionnaire was used to inquire about any history of liver or thyroid disease in the participants. No significant correlation was found between serum PFOA level and liver function, thyroid hormone levels or blood parameters, and serum PFOA levels were not elevated in people who reported a history of liver or thyroid diseases. While this study was limited and did not examine other potential health effects (such as cancer or developmental effects) it does provide some assurance that highly elevated PFOA levels in blood serum do not appear to correlate with obvious clinical effects. With regards to cancer, PFOA induced cancer in animal studies is always associated with obvious liver toxicity. The lack of any measurable liver effects in this population would imply that the likelihood of cancer is also very low.

The second major investigation of PFOA exposure in the Ohio-West Virginia area grew out of a court settlement in a class action lawsuit against DuPont in 2005. This investigation is known as the C8 Health Project, and information on it can be found on the project's web site, http://www.c8healthproject.org/health.htm. The project has enrolled approximately 70,000 people who were exposed to PFOA through drinking water. The participants will be tested for PFOA exposure through analysis of blood samples. The project will also involve ten separate studies to help determine whether PFOA is associated with human health effects. Eight of the studies will focus on diseases such as cancer, heart disease, stroke, diabetes, immune function, liver and hormone disorders, and birth outcomes. Two studies will look at exposure to PFOA and its half-life in the general population. The studies are estimated to be complete in 4-5 years, although some results will be available sooner. Details of the studies can be found on the C8 Science Panel web site at http://www.c8sciencepanel.org/index.html.

Discussion of the Public Health Implications of PFC Exposure

Based on limited data collected in 2005 and 2006 for a lawsuit filed against 3M in Washington County Court, exposure to PFOA and PFOS through drinking water appears to have resulted in elevated levels of these two chemicals in the blood serum of participating Oakdale and Lake Elmo residents compared to national averages. Mean PFOA levels in the blood serum of Oakdale and Lake Elmo residents were approximately five to ten times national averages (compared to 2003-2004 NHANES data), whereas PFOS levels were approximately 2.5 times the national average in Oakdale, and 1.5 times the national average in Lake Elmo. Based even on the maximum levels of PFOS and PFOA detected in area water supplies, calculated daily intake rates are well below the "point of departure" doses used to derive MDH RfDs and HRLs. However, epidemiological studies in Ohio and West Virginia will ultimately provide a clearer interpretation of the potential public health implications of elevated serum levels of PFCs in Minnesota.

Of the other PFCs analyzed for, PFHxS and PFBA were the most commonly detected (29 of 85 samples). The geometric mean concentration of PFHxS in Oakdale residents was 11.7 ppb, or 21% of the geometric mean PFOS concentration. PFHxS has only been detected by the MDH Public Health Laboratory in a few samples from Oakdale city wells #5, #8 and #9, at levels of approximately 0.1 µg/L. Similar levels of PFHxS were detected in samples collected in March 2007 from wells #5 and #9 for analysis by the 3M Environmental Laboratory, 0.076 µg/L and 0.090 µg/L, respectively (3M 2007a). Very low levels of PFHxS in drinking water, coupled with its long estimated half-life in humans (8.5 years) may be at least partly responsible for its detection in blood serum in Oakdale residents. Whether PFHxS is present in consumer products, or what other sources of exposure exist is unknown. PFBA was only detected in the blood serum of three Oakdale residents, at a maximum level of 2.73 ppb. PFBA was included in the analysis of only a portion of the Oakdale resident's blood serum, as the extraction of PFBA in blood serum for analysis is reportedly difficult.

Past exposure to PFCs through water supplies in Oakdale and Lake Elmo are highly uncertain. PFCs appear to move swiftly through soil and groundwater systems, so it is conceivable that some wells near the disposal sites became contaminated soon after the wastes were deposited, in the late 1950s in the case of the 3M-Oakdale Disposal Site, and the early 1970s to 1980s in the case of the former Washington County Landfill in Lake Elmo. Levels of PFOS and PFOA in blood serum samples collected by attorneys engaged in a lawsuit against 3M do not appear to correlate well with the estimated time each resident reported using the water. In other words, those who reported using contaminated water for a longer period of time (in excess of 30 years in some cases) did not appear to have higher levels of PFCs in their blood than those who reported being exposed for shorter time periods.

Removing or reducing exposure to levels of PFCs in drinking water that exceed MDH HRLs or well advisory guidelines should result in a reduction of PFCs in blood serum in the population of Oakdale and the affected area of Lake Elmo over time. MDH's health-based criteria are protective for all segments of the population, including vulnerable sub-populations. Nevertheless, those who may be especially concerned with their continued exposure to low levels of PFCs through drinking water (even at levels below the MDH HRLs or well advisory guidelines), such as pregnant women or parents with infants, can take additional steps to reduce exposure by using bottled water for drinking, cooking, or making formula, or by using point of use filters to treat water used for these purposes.

In summary, while current studies suggest that serum levels and daily intakes in the ranges reported in this document may not represent a significant public health risk, the human data are limited to occupational studies that do not include potentially vulnerable sub-populations, and studies of the effect of exposure to multiple PFCs at the same time are lacking. At this time MDH therefore considers the exposure to PFCs through drinking water in Lake Elmo and Oakdale to be an indeterminate or uncertain public health concern.

Health Outcome Data Review

On June 7, 2007 the Minnesota Cancer Surveillance System (MCSS), located within the Chronic Disease and Environmental Epidemiology Section of MDH issued a report presenting detailed profiles of cancer rates among residents of Dakota and Washington Counties (MDH 2007c). Using MCSS data for the 15-year period 1988-2002, county-wide cancer rates for all cancers combined and for each of about 25 of the most frequent types of cancer, including liver and thyroid cancer were examined. In addition, analyses were also conducted to examine incidence rates for 16 selected cancers for specific communities, by zip code, within each county. The communities included Oakdale and Lake Elmo. For that analysis, data from the years 1996-2004 were used, largely due to population growth in the two communities and limitations on community census data.

The report (which can be accessed at the MDH web site, www.health.state.mn.us/) found that overall cancer rates in Washington and Dakota counties are very similar to the rest of the state, or slightly lower. In addition, the rates and types of cancers that occurred within specific communities in the two counties were generally similar with other communities in the Twin Cities metropolitan area. This was also true for the cities of Oakdale and Lake Elmo.

Analyses of community cancer rates are rarely useful for evaluating potential cancer risks from low levels of environmental pollutants. Nevertheless, such data can be helpful in addressing public concerns over cancer rates in a county or a community. The reader is referred to the full report for a more detailed description of the benefits and limitations of the analysis.

## Child Health Considerations

MDH recognizes that the unique vulnerabilities of infants and children are of special concern to communities faced with contamination of their water, soil, air, or food. Children are at a greater risk than adults are from certain kinds of exposures to environmental contaminants at waste disposal sites. They are more likely to be exposed because they often play outdoors and bring food into contaminated areas. Children are smaller than adults, which means children breathe dust and heavy vapors that are close to the ground; and children receive higher doses of chemical exposure per body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Most importantly, children depend completely on adults for risk-identification and risk-management decisions, housing decisions, and for access to medical care.

Children have been exposed to PFCs through contaminated drinking water in Oakdale and Lake Elmo. MDH HRLs are calculated with protection of children's health in mind.

## Conclusions

PFC-containing wastes were disposed of by 3M in two land disposal sites in Oakdale and Lake Elmo, Minnesota. PFCs were released to groundwater from the two sites, possibly shortly after the disposal occurred, resulting in contamination of nearby drinking water wells. The levels of PFCs in drinking water in the past are unknown and past exposure through drinking water, possible air emissions during the handling, disposal, or burning of waste, or direct contact with the wastes could have been significant. Local residents have expressed concern over perceived elevated rates of cancer and other diseases in the affected area; MDH has examined available cancer data and reported that cancer rates in the two affected communities are similar to cancer rates in the Twin Cities metropolitan area.

Currently, PFCs have been detected in public and private wells across a wide area of Oakdale and Lake Elmo. Exposure to PFCs at levels above health concern is currently being partly addressed by the operation of a carbon filtration plant in Oakdale and by careful management of the city wells and distribution system. In Lake Elmo, exposure through drinking water to levels of PFCs above health concern is being prevented by the conversion of approximately 200 homes from private wells to municipal water, by the use of bottled water or whole-house activated carbon filters at 55 other homes that have been issued a drinking water well advisory by MDH, and by the designation of an expanded Special Well Construction Area. Because of the lack of a Health-Based Value for PFBA and data regarding the possible effects of exposure to multiple PFCs at the same time, current exposures to PFCs in the area represent an uncertain or indeterminate public health hazard. Remediation actions to address PFCs at the two waste disposal sites are being evaluated by 3M and the MPCA.

## Recommendations

1. 3M should continue to follow the requirements of the Consent Order agreement with the MPCA with regards to their assessment of PFC impacts to ground water from historical discharge(s) at the 3M-Oakdale Disposal Site. 3M should also conduct further assessment of potential impacts to surface water, sediments, and biota in Raleigh Creek and Eagle Point Lake and, if warranted, additional downstream surface water features, including a thorough analysis of the relationship between sediment physical and chemical parameters and PFC concentrations in Raleigh Creek.
2. 3M should follow the applicable Consent Order requirements to reduce any current discharge(s) of PFCs from the Oakdale Disposal Site into Raleigh Creek, so that the site complies with MPCA surface water standards (MN Rules Ch. 7050). Compliance with these standards will also be protective of human health.
3. 3M should continue to comply with the Consent Order and work with MDH and MPCA staff to establish a network of monitoring wells to determine the extent and magnitude of PFCs in the St. Peter, Prairie du Chien, Jordan and Franconia aquifers in the vicinity of the two sites.
4. 3M should continue to follow the requirements of the Consent Order to evaluate remediation options for soil, sediments, surface water and ground water at the 3M-Oakdale Disposal Site.
5. Local citizens should avoid recreational activities within Raleigh Creek, including fishing.
6. Until remedial actions can be implemented, public access to the PFC impacted areas of the 3M-Oakdale Disposal Site north of Highway 5 should be restricted by signs and/or fencing to limit direct contact with contaminated soil, sediment, and surface water by people and pets.
7. People should avoid trespassing on the former Washington County Landfill and the 3M-Oakdale Disposal Site.
8. A maintenance schedule for the Oakdale water treatment plant should be finalized by the city, MDH, and 3M.
9. The City of Oakdale and its residents should conserve water where possible, especially in the summer months, to limit the need for pumping of wells contaminated with PFOS and PFOA.
10. MDH should proceed with the development of an HBV for PFBA at the earliest possible time.
11. Following the establishment of a HBV for PFBA, all affected wells should be reevaluated to determine an appropriate advisory.
12. Further extensions of the Lake Elmo municipal water supply to serve areas where private wells contain levels of PFCs in excess of MDH HRLs or HBVs should be considered.
13. The MPCA should continue to explore modifications to the groundwater remediation system (or other remedial actions) at the former Washington County Landfill to limit or prevent the migration of PFCs off the site.

14. Monitoring of selected private wells in the affected area should continue under agreed upon sampling plans to track changes in the plume and monitor for changes in concentration in individual wells.

## Public Health Action Plan

The MDH Public Health Action Plan for the site includes the following: 1) distribution of this public health assessment (and/or an information sheet summarizing the information contained in this public health assessment) to area residents; 2) continued consultation with the MPCA, 3M, Washington County, and the cities of Oakdale and Lake Elmo on implementing investigation and response-action activities and the recommendations provided in the *Recommendations* section of this document; 3) development of an HBV for PFBA; 4) continued outreach to private-well owners and well contractors within the SWCA; 5) continued monitoring of public water supplies; and 6) organization and participation in public meetings and meetings with local government officials as needed.

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# CERTIFICATION

This Public Health Assessment was prepared by the Minnesota Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the Public Health Assessment was begun. Editorial review was completed by the Cooperative Agreement partner.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this Public Health Assessment and concurs with the findings.

for AY

Alan Yarbrough
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# Glossary

**Absorption**
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

**Acute**
Occurring over a short time [compare with chronic].

**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 [compare with antagonistic effect and synergistic effect].

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

**Ambient**
Surrounding (for example, ambient air).

**Analyte**
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

**Analytic epidemiologic study**
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

**Antagonistic effect**
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

**Aquifer**
A geologic unit (sediments, rock) in which the pore spaces are fully saturated with groundwater and that can yield water in usable quantities for springs or wells.

**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).

**Biologic indicators of exposure study**
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a chemical substance [also see exposure investigation].

**Biologic monitoring**
Measuring chemical substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

**Biologic uptake**
The transfer of substances from the environment to plants, animals, and humans.

**Biomedical testing**
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a chemical substance.

**Biota**
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

**Body burden**
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

**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.

**Case study**
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

**Case-control study**
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

**CAS registry number**
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

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

**CERCLA** [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980].

**Chronic**
Occurring over a long time [compare with acute].

**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.

**Community Assistance Panel (CAP)**
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

**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.

**Completed exposure pathway** [see exposure pathway].

**Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)**
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

**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.

**Delayed health effect**
A disease or an injury that happens as a result of exposures that might have occurred in the past.

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

**Dermal contact**
Contact with (touching) the skin [see route of exposure].

**Descriptive epidemiology**
The study of the amount and distribution of a disease in a specified population by person, place, and time.

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

**Disease prevention**
Measures used to prevent a disease or reduce its severity.

**Disease registry**
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

**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** (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

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

**Downgradient**
A location "downstream" relative to groundwater flow directions, or the direction to which groundwater is flowing.

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

**Environmental media and transport mechanism**
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

**EPA**
United States Environmental Protection Agency.

**Epidemiologic surveillance** [see Public health surveillance].

**Epidemiology**
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

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

**Exposure assessment**
The process of finding out how people come into contact with a chemical substance or environmental contaminant, 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 environmental contaminants. 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 chemical substances.

**Exposure pathway**
The route a substance takes from its source (where it began) to its endpoint (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.

**Feasibility study**
A study to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

**Gaining stream**
A stream into which groundwater enters through the stream banks and streambed. Compare to "losing stream".

**Geographic information system (GIS)**
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

**Grand rounds**
Training sessions for physicians and other health care providers about health topics.

**Groundwater**
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

**Half-life ($t_{1/2}$)**
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance

to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half-life is the amount of time necessary for one-half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half-lives, 25% of the original number of radioactive atoms remain.

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

**Hazardous Substance Release and Health Effects Database (HazDat)**
The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

**Health consultation**
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

**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 chemical substances.

**Health promotion**
The process of enabling people to increase control over, and to improve, their health.

**Health Base Value (HBV)**
An MDH criteria, a HBV is the concentration of a contaminant in water that is considered safe for people if they drink water daily for a lifetime. HBVs have not undergone the state's rule-making process.

**Health Risk Limit (HRL)**
An MDH standard, a HRL is the concentration of a contaminant in water that is considered safe for people if they drink water daily for a lifetime.

**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.

**Indeterminate public health hazard**
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

**Incidence**
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

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

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

**Intermediate duration exposure**
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

**In vitro**
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

**In vivo**
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

**Losing stream**
A stream in which the surface water infiltrates through the stream banks and streambed, down into the groundwater. Such streams are often intermittent and may appear to be dry for much of the summer, although water is still migrating within the streambed sediments. Compare to "gaining stream".

**Lowest-observed-adverse-effect level (LOAEL)**
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

**MDH**
The Minnesota Department of Health.

**Medical monitoring**
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

**Metabolism**
The conversion or breakdown of a substance from one form to another by a living organism.

**Metabolite**
Any product of metabolism.

**mg/kg**
Milligram per kilogram.

**mg/cm2**
Milligram per square centimeter (of a surface).

**mg/m3**
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

**Migration**
Moving from one location to another.

**Minimal risk level (MRL)**
An ATSDR estimate of daily human exposure to a environmental contaminant 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].

**Morbidity**
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

**Mortality**
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

**MPCA**
The Minnesota Pollution Control Agency.

**Mutagen**
A substance that causes mutations (genetic damage).

**Mutation**
A change (damage) to the DNA, genes, or chromosomes of living organisms.

**National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)**
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

**National Toxicology Program (NTP)**
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

**No apparent public health hazard**
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

**No-observed-adverse-effect level (NOAEL)**
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

**No public health hazard**
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

**NPL** [see National Priorities List for Uncontrolled Hazardous Waste Sites]

**Physiologically based pharmacokinetic model (PBPK model)**
A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

**Pica**
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

**PFC**
Perfluorochemical, a family of fully fluorinated hydrocarbons.
**PLP**

8. Permanent List of Priorities, the Minnesota state Superfund list

**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.

**Point of exposure**
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

**Population**
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

**Potentially responsible party (PRP)**
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

**ppb**
Parts per billion.

**ppm**
Parts per million.

**ppt**
Parts per trillion.

**Prevalence**
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

**Prevalence survey**
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

**Prevention**
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

**Public availability session**
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

**Public comment period**
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

**Public health action**
A list of steps to protect public health.

**Public health advisory**
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

**Public health assessment (PHA)**
An ATSDR document that examines environmental contaminants, health outcomes, and community concerns at a waste site to determine whether people could be harmed from coming into contact with those contaminants. 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 health hazard categories**
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

**Public health statement**
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

**Public health surveillance**
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

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

**RCRA** [see Resource Conservation and Recovery Act (1976, 1984)]

**Receptor population**
People who could come into contact with environmental contaminants [see exposure pathway].

**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.

**Registry**
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

**Remedial investigation**
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

**Resource Conservation and Recovery Act (1976, 1984) (RCRA)**
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

**RfD** [see reference dose]

**Risk**
The probability that something will cause injury or harm.

**Risk reduction**
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

**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 or environmental contaminant. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

**Safety factor** [see uncertainty factor]

**SARA** [see Superfund Amendments and Reauthorization Act]

**Sample**
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

**Sample size**
The number of units chosen from a population or an environment.

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

**Source of contamination**
The place where an environmental contaminant comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

**Special populations**
People who might be more sensitive or susceptible to exposure to environmental contaminants because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

**Special Well Construction Area (SWCA)**
Minnesota Statutes, section 103I, subdivision 5, clause 7, grants the commissioner of health the authority to establish standards for the construction, maintenance, sealing, and water quality monitoring of wells in areas of known or suspected contamination. Minnesota Rules, part 4725.3650, detail the requirements for construction, repair, or sealing within a designated SWCA, including plan review and approval, water quality monitoring, and other measures to protect public health and prevent degradation of ground water.

**Stakeholder**
A person, group, or community who has an interest in activities at a waste site.

**Statistics**
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

**Substance**
A chemical.

**Substance-specific applied research**
A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

**Superfund** [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)

**Superfund Amendments and Reauthorization Act (SARA)**
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

**Surface water**
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

**Survey**
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

**Synergistic effect**
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

**Teratogen**
A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

**Toxic agent**
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

**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.

**Tumor**
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

**Uncertainty factor**

Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

**Upgradient**
A location "upstream" relative to groundwater flow directions, or the direction from which groundwater is flowing.

**Urgent public health hazard**
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

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

**Water table**
The subsurface layer below which all available pore space is completely saturated with groundwater.

Other glossaries and dictionaries:

U.S. Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)

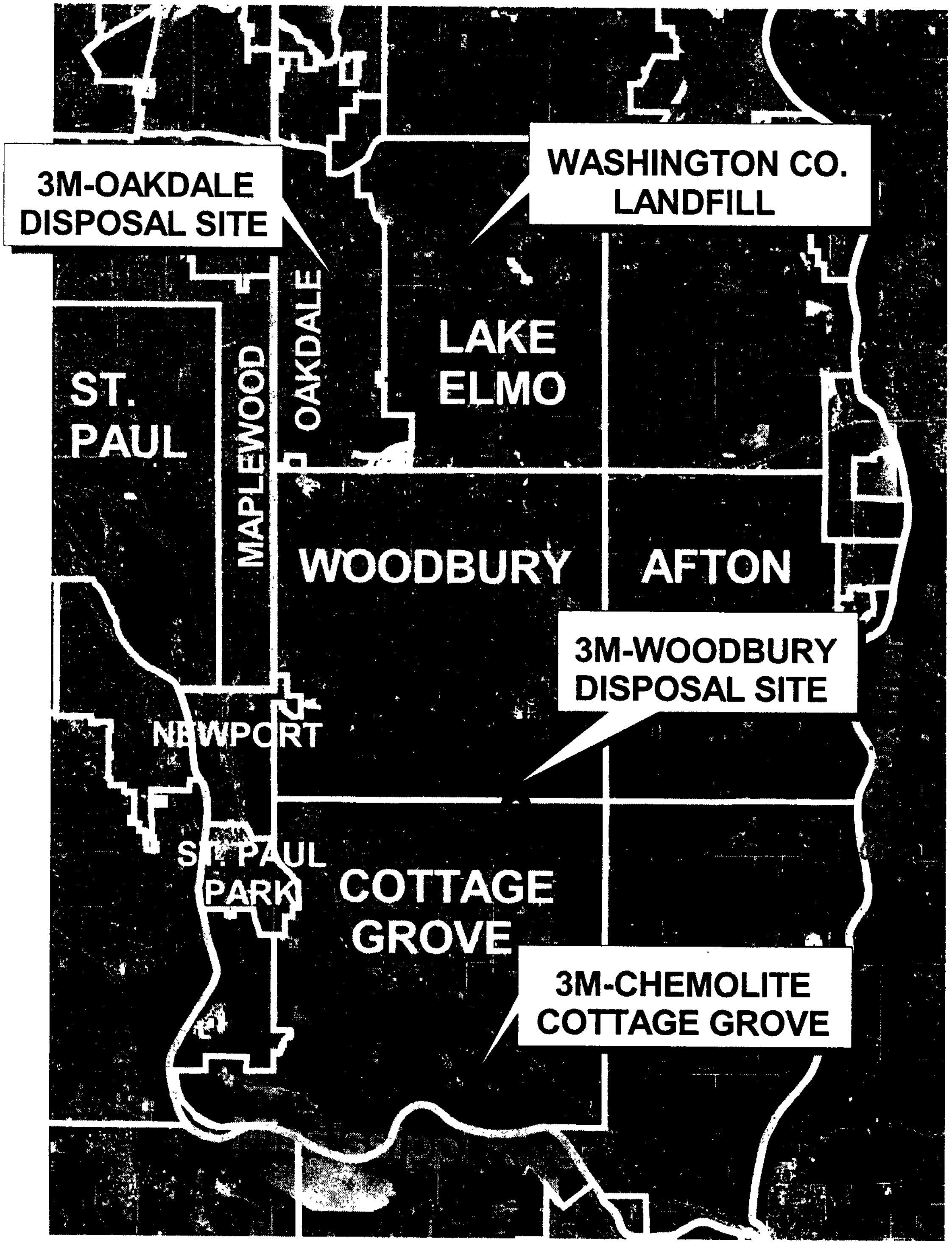
National Center for Environmental Health/Agency for Toxic Substances and Disease Registry (CDC) (http://www.cdc.gov/nceh/dls/report/glossary.htm)
http://www.cdc.gov/exposurereport/

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

For more information on the work of ATSDR, please contact:

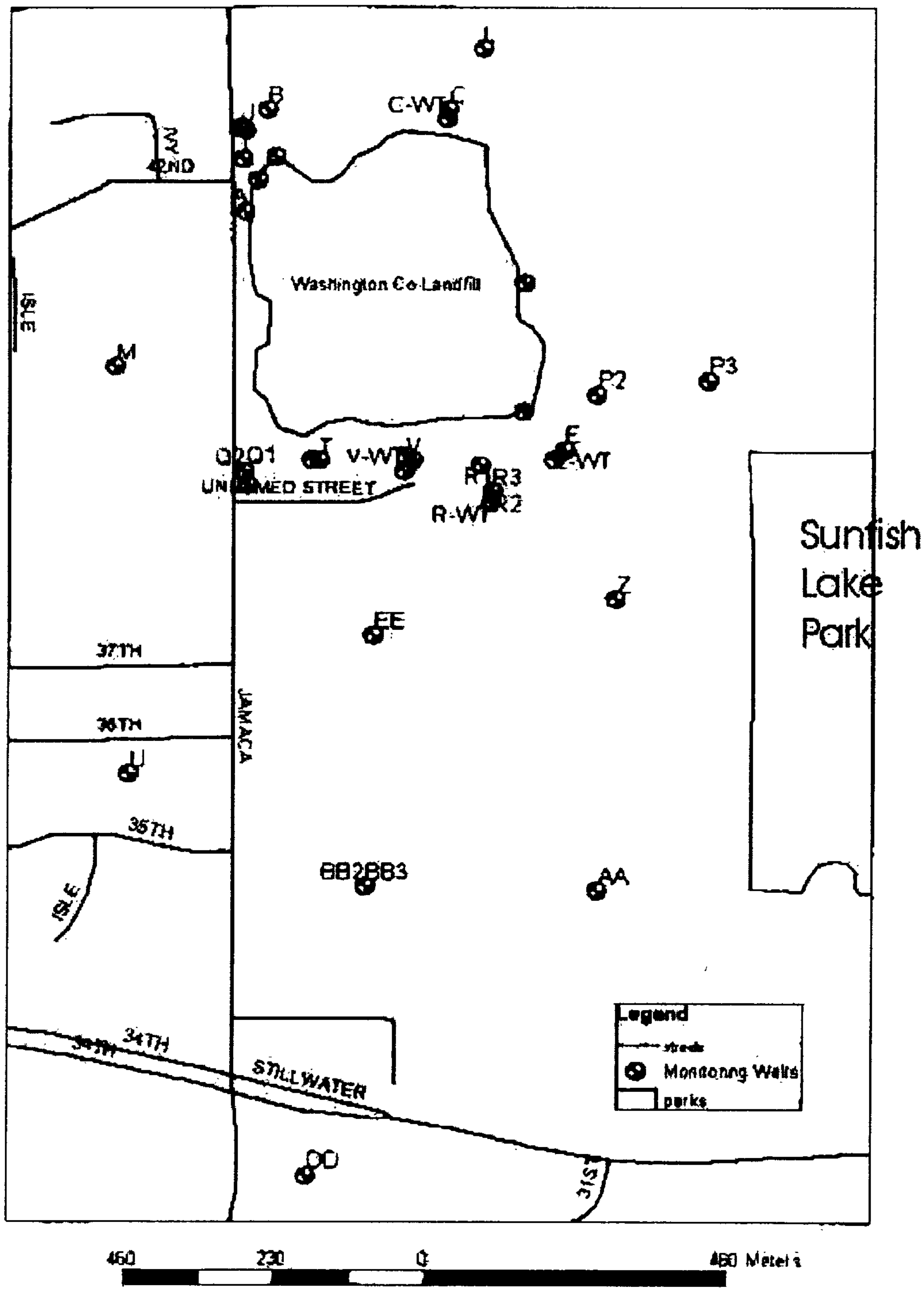
Office of Communications
National Center for Environmental Health/Agency for Toxic Substances and Disease Registry
1600 Clifton Road, N.E. (MS E-29)
Atlanta, GA 30333
Telephone: (404) 498-0080

# Appendix 1: Figures




# FIGURE 1: LOCATION OF PFC SITES IN WASHINGTON CO. MINNESOTA

Figure 2 Ground Water Monitoring Network around Washington County Landfill



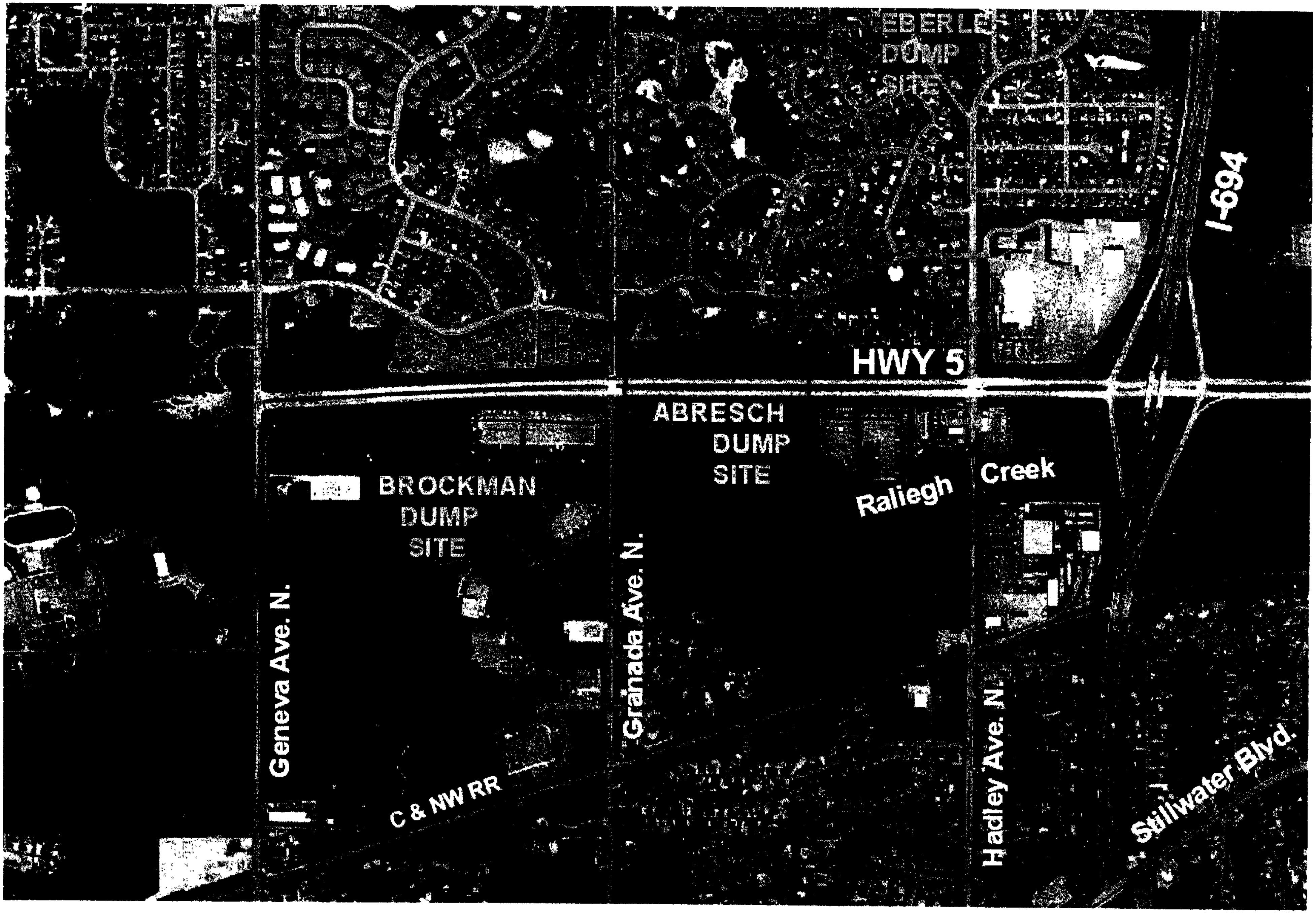



**Figure 3: 3M - Oakdale Dump Sites**

0.2 0 0.2 0.4 Miles

Location of 3M Groundwater Pumpout System

Prepared 6/22/05

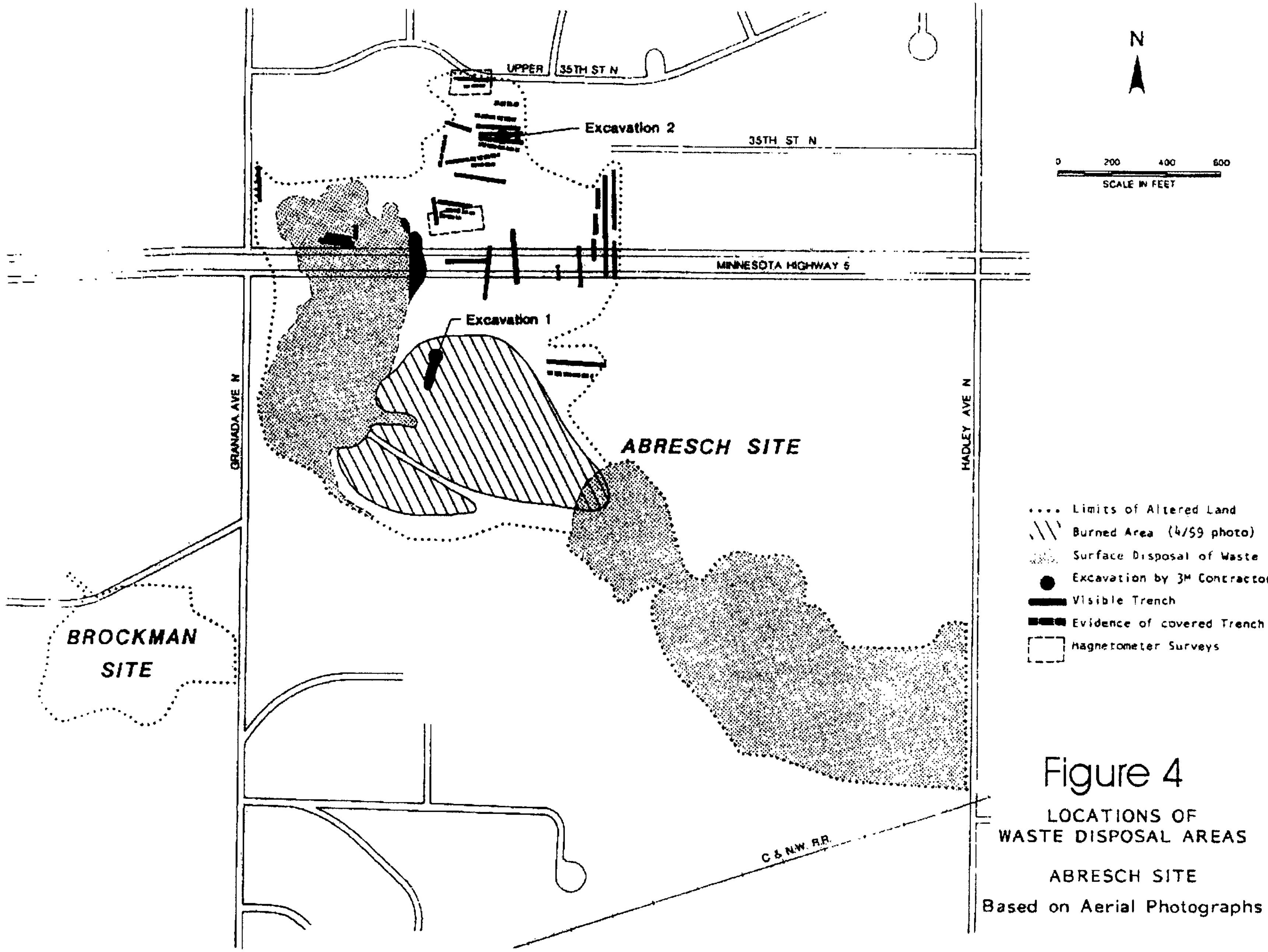


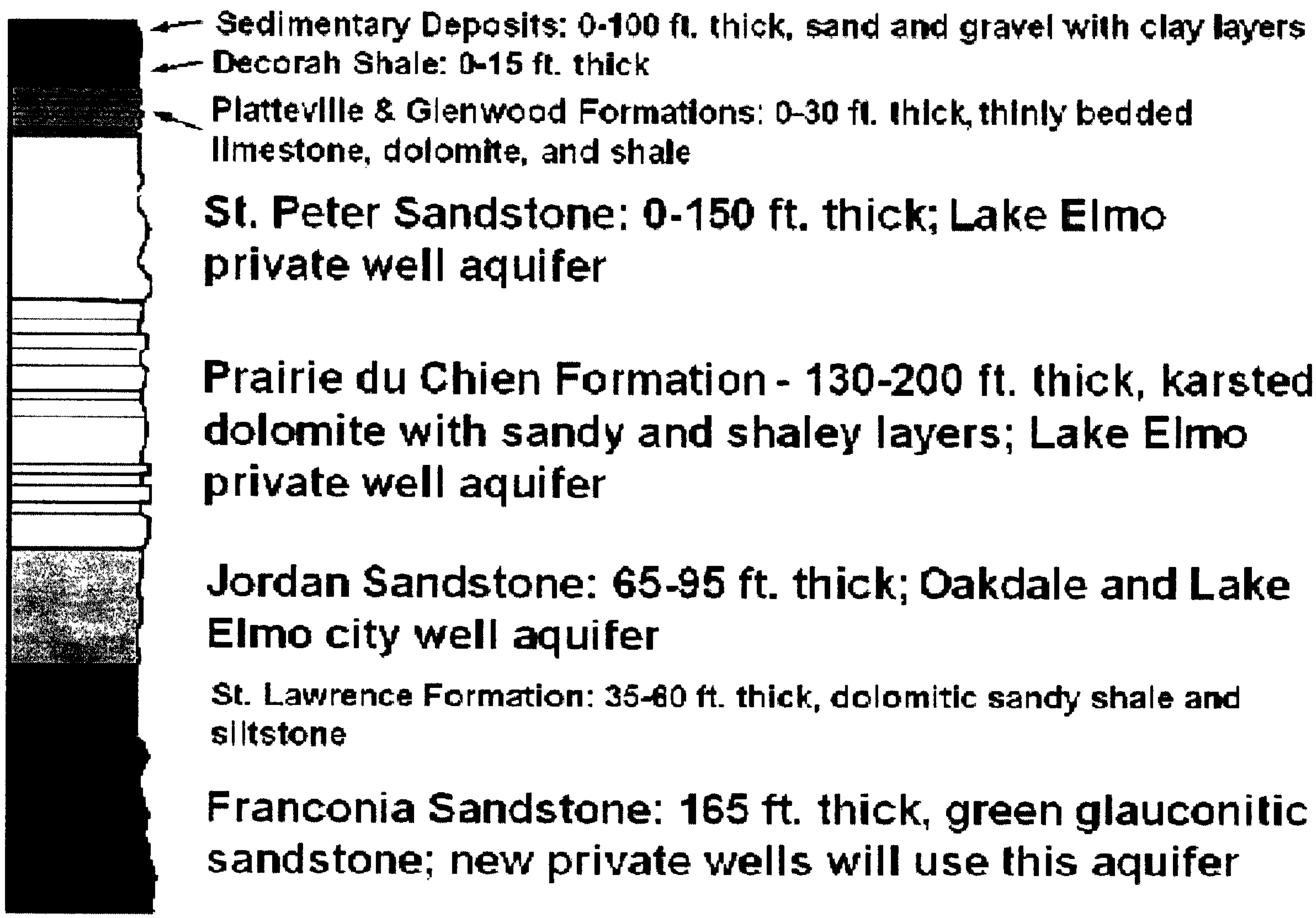

Figure 4

LOCATIONS OF
WASTE DISPOSAL AREAS

ABRESCH SITE

Based on Aerial Photographs

Figure 5: General Geologic Sequence, Lake Elmo - Oakdale Area



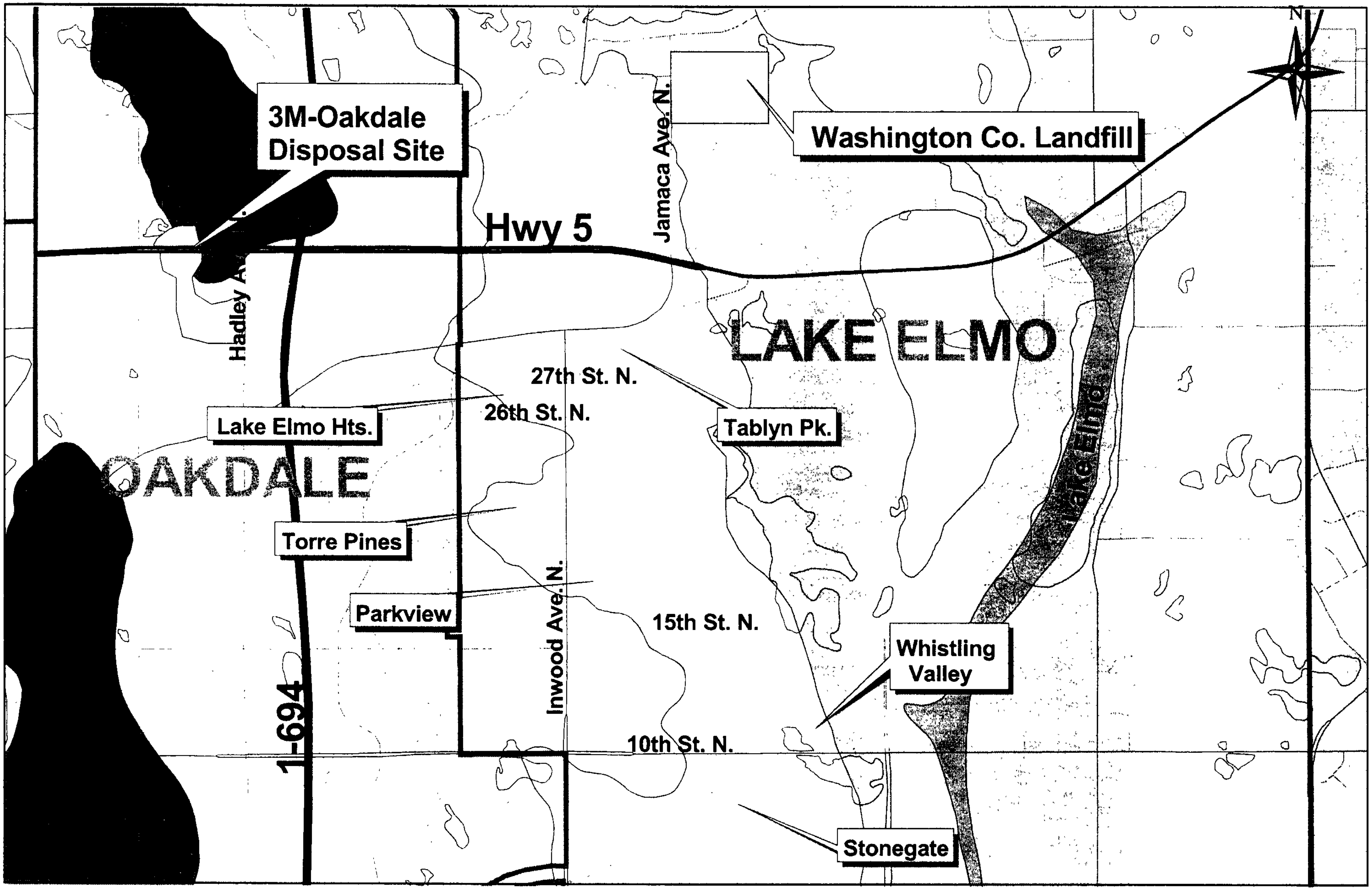
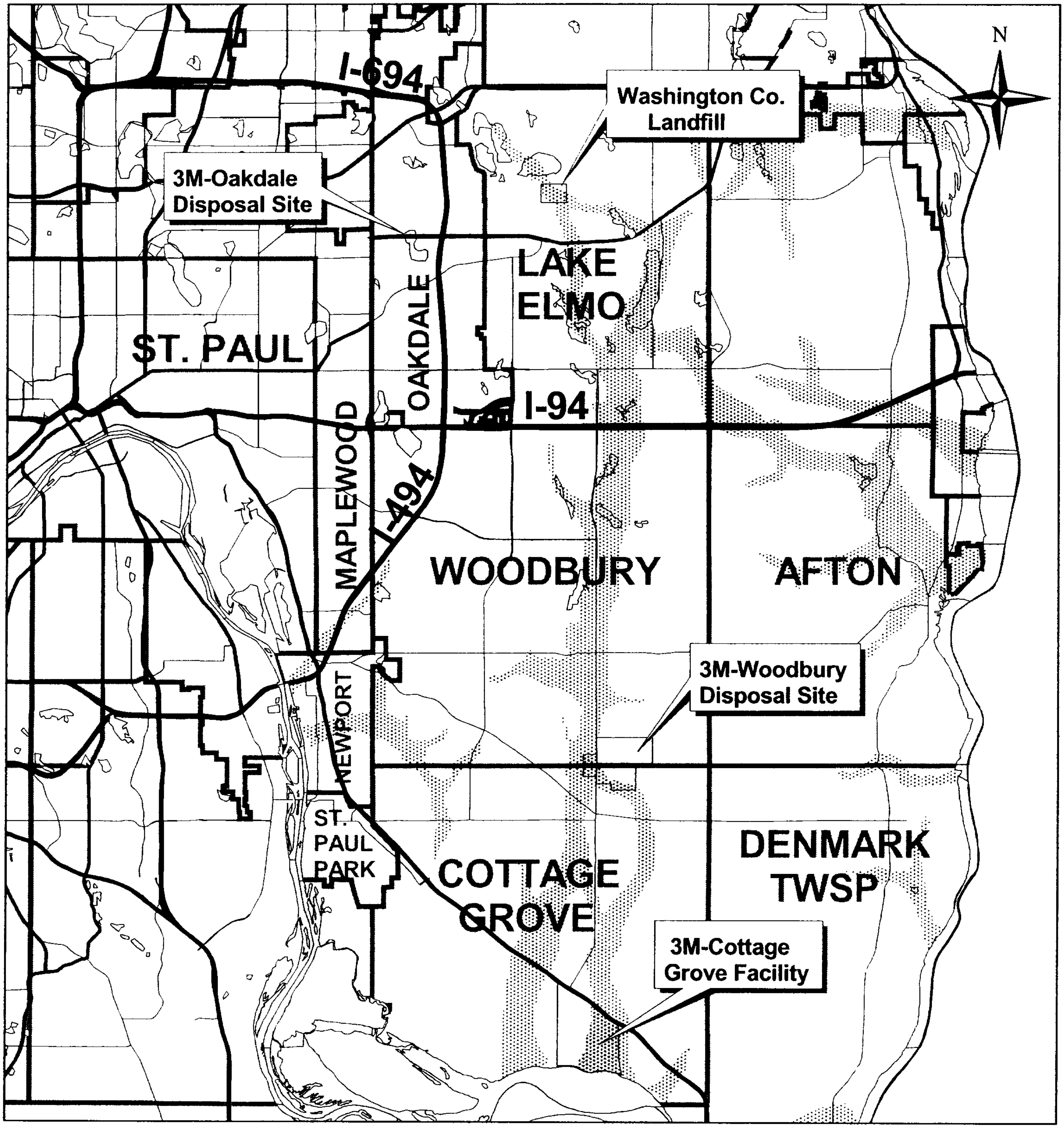


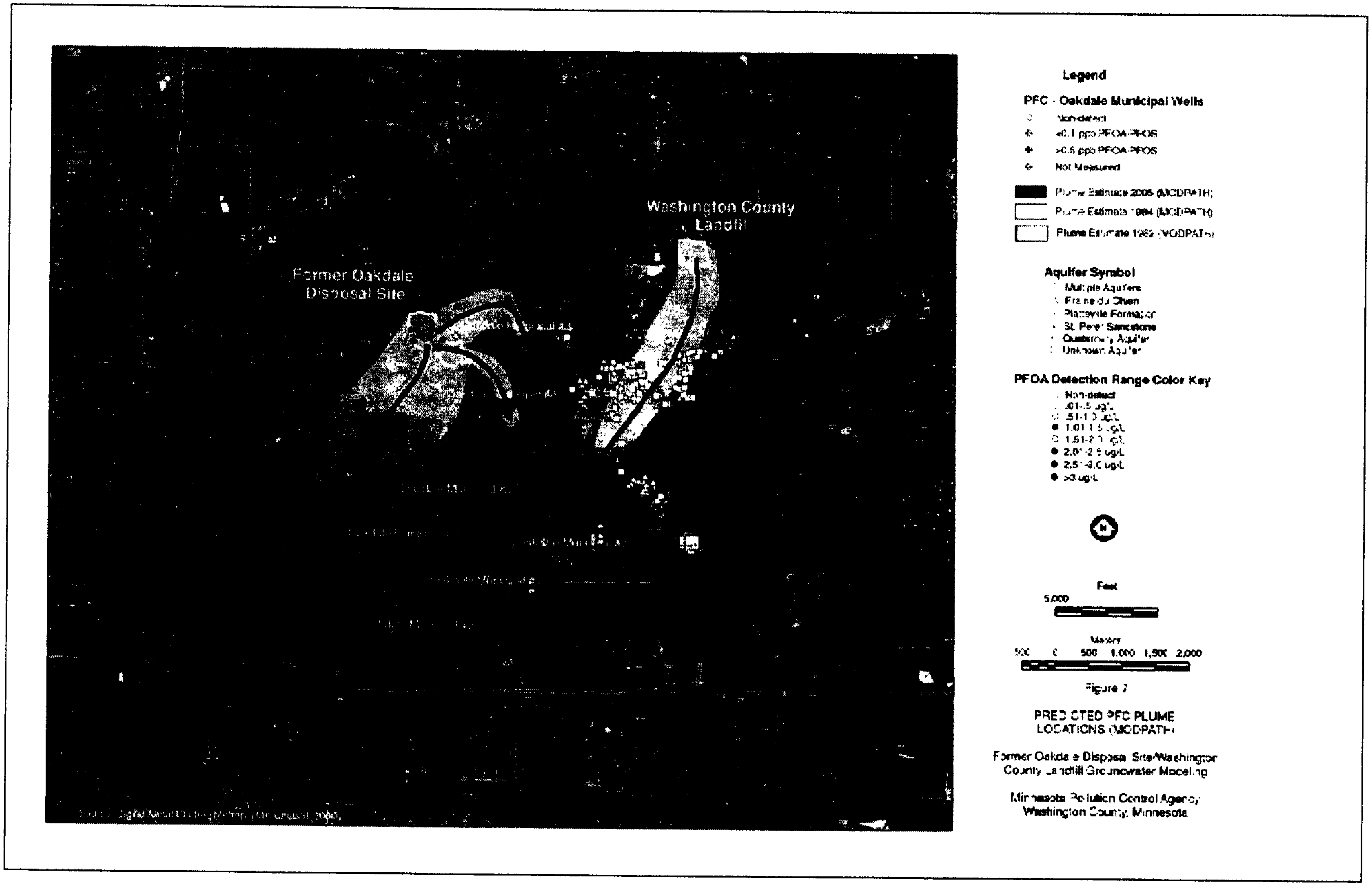

Figure 6: Map of Upper Bedrock Layers in Lake Elmo - Oakdale Area

| | | |
|---|---|---|
| Decorah Shale | St. Peter Sandstone | Jordan Sandstone |
| Platteville Limestone | Prairie du Chien Dolomite | lake or pond |




# Figure 7: Map of Bedrock Valleys in Washington County

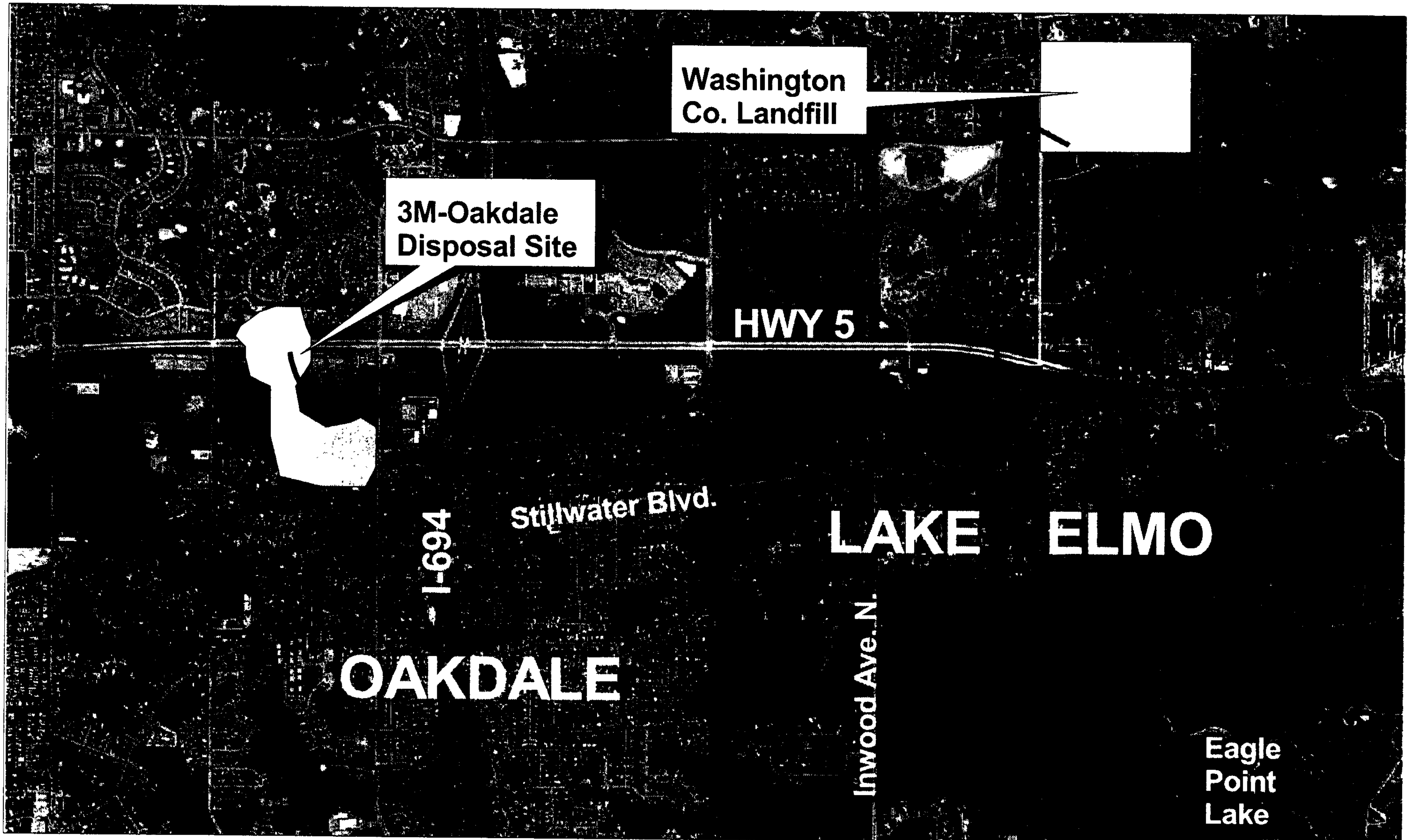
**Valleys cut into the bedrock by glacial meltwater and streams, and later filled with sand and gravel, are shown in the brown stipled pattern. Note that a major bedrock valley extends southward from beneath the Washington Co. Landfill in Lake Elmo, beneath the western edge of the 3M-Woodbury Disposal Site and then to the river near the 3M-Cottage Grove facility.**




# Figure 8: Regional Groundwater Flow in Lake Elmo-Oakdale Area

This figure illustrates groundwater flow pathways, based on modeling by Barr Engineering (2005). The colored areas are the estimated distance groundwater beneath the disposal sites at the time of waste disposal would have moved by 1982, 1984, and 2005. The black arrows have been added to highlight the effect that radial flow of groundwater off the top of the Decorah Shale has had on groundwater movement at the 3M-Oakdale Disposal Site.

Modified from Figure 7 of Barr (2005).

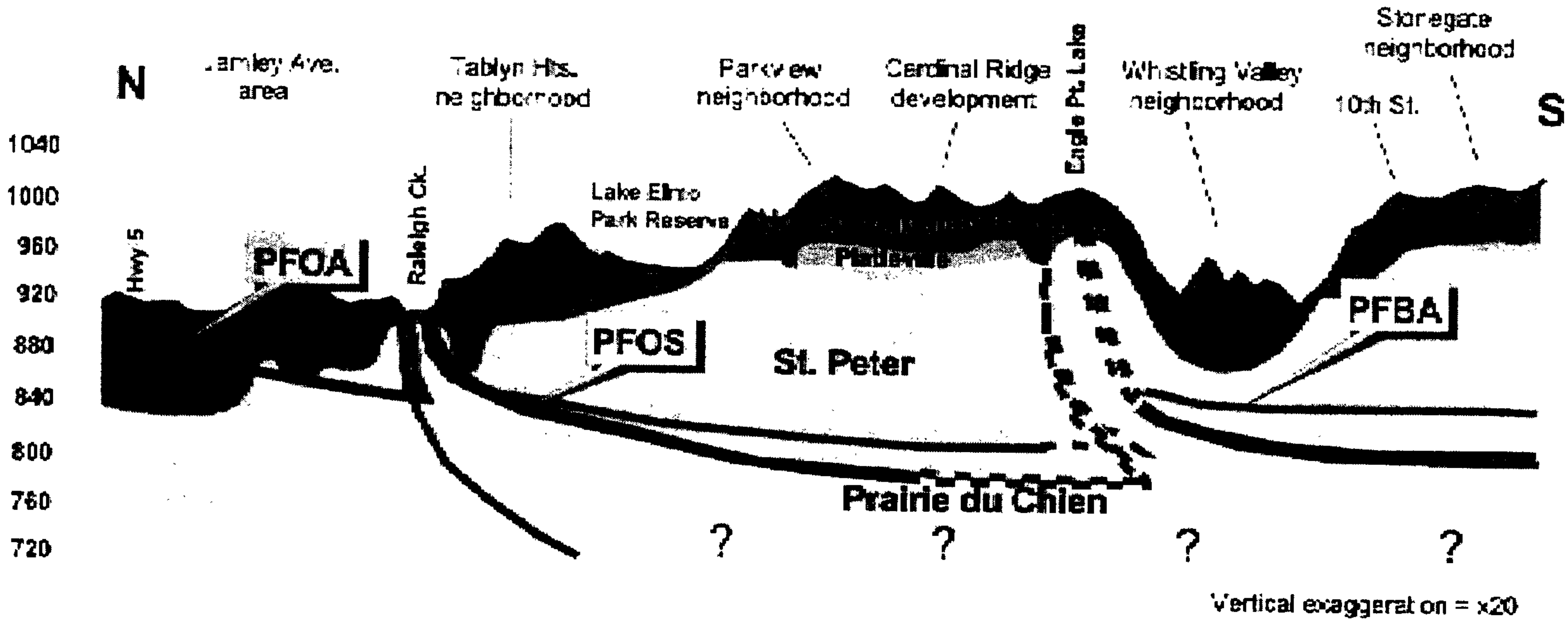



# Figure 9: Raleigh Creek

"Gaining" stream section of creek* — "Losing" stream section of creek*

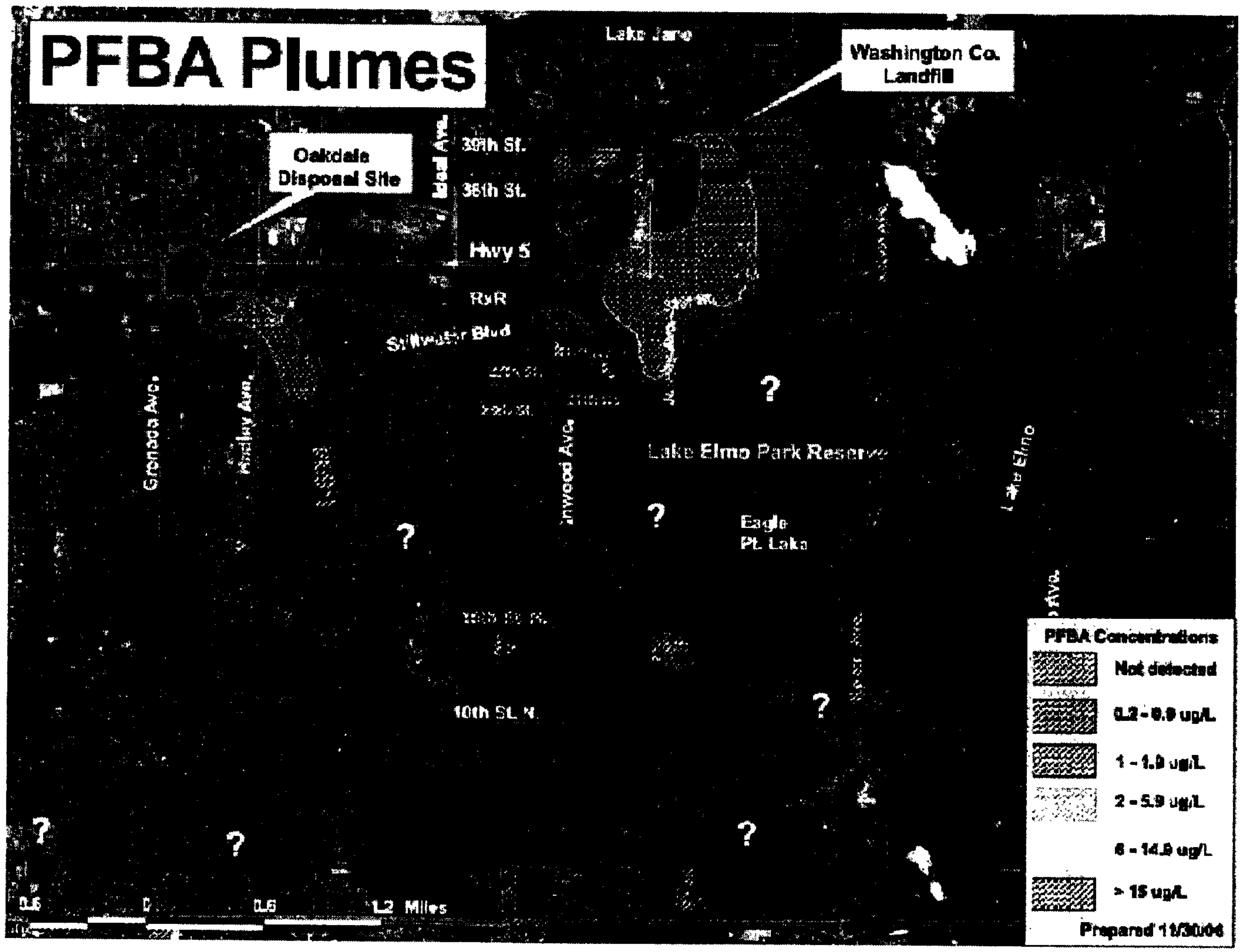
Route of 1988-1995 discharge from landfill to the creek

* see page 22 or glossary



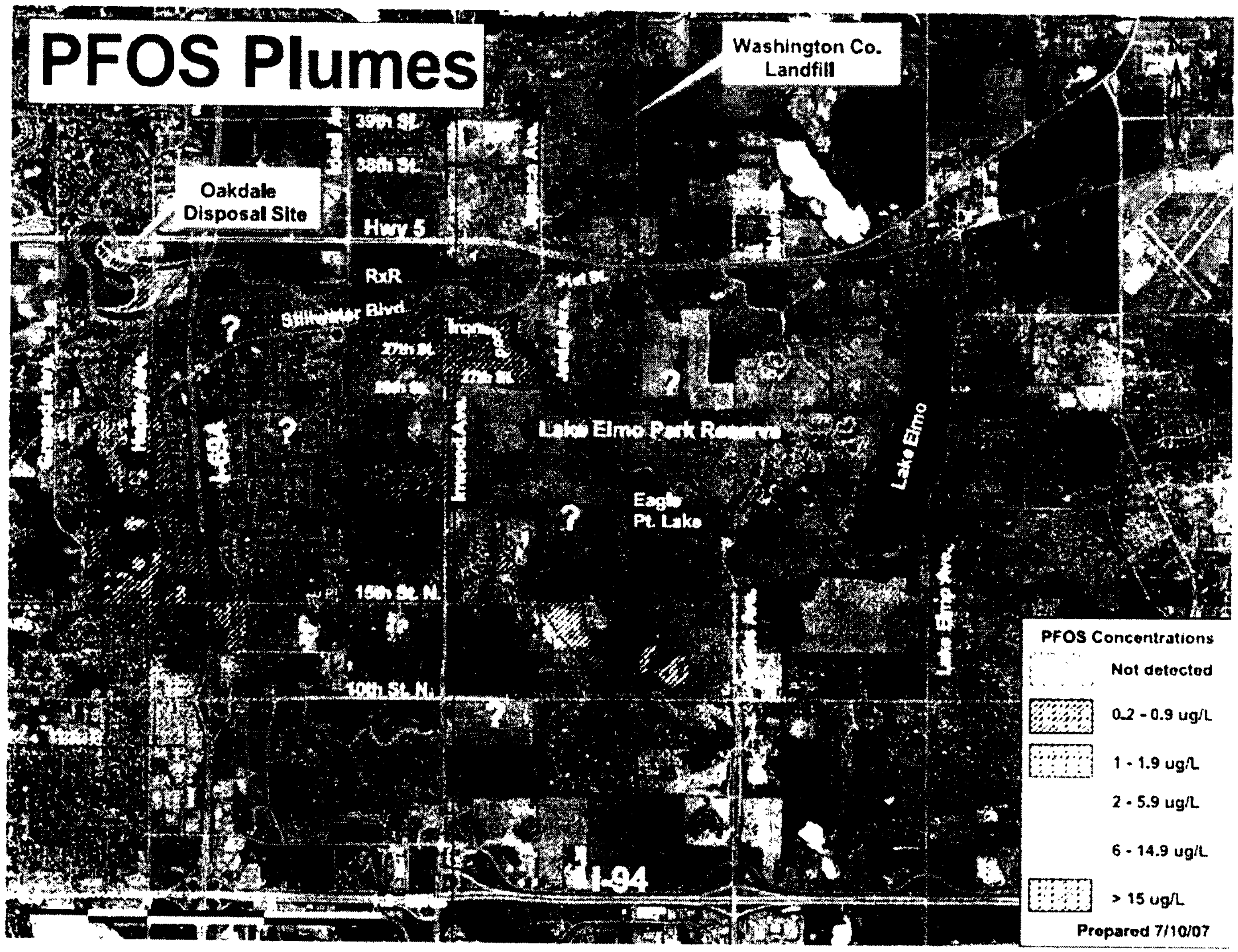

## Figure 10: Cross-section of PFC plumes in Lake Elmo/Oakdale area

**This north to south "section" through the bedrock in the Lake Elmo/Oakdale area illustrates how the PFC plumes (PFOA – red; PFOS – blue; PFBA – green) move downward with distance from their sources. The Washington County Landfill is located just to the left of the cross-section (north of Highway 5). PFOA and PFBA are present in the unconsolidated sediments (brown) and the St. Peter Sandstone (yellow) near the landfill, but south of Tablyn Park, are present only in the Prairie du Chien (blue). Note that PFOS is present only beneath and south of Raleigh Creek, and then moves downward into the Prairie du Chien. The dashed lines indicate where there is insufficient data to draw the plume boundary with certainty; however concentrations trends and site history strongly suggest that a second source is present north of Whistling Valley and Stonegate, and that source is likely a result of PFCs discharged to Eagle Point Lake. The question marks indicate there is insufficient data to determine how deep the contaminants have moved in those areas.**



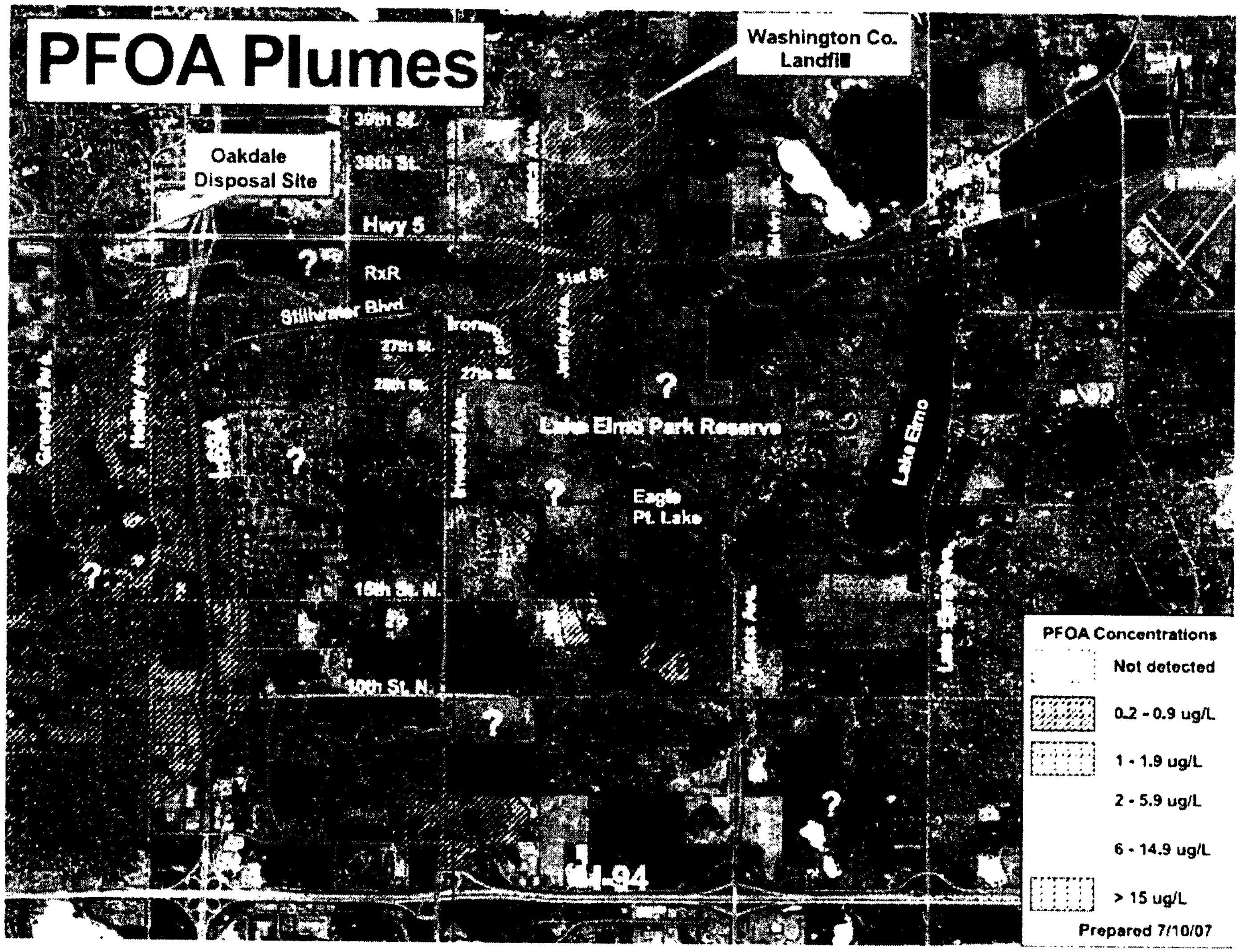

# Figure 11: Extent of PFBA in the St. Peter and Prairie du Chien Aquifers in Lake Elmo / Oakdale Area

(Note – this is a “placeholder” figure until the map can be revised to reflect most recent sample results)




# Figure 12: Extent of PFOS in the St. Peter and Prairie du Chien Aquifers in Lake Elmo / Oakdale Area

(Note – this is a "placeholder" figure until the map can be revised to reflect most recent sample results)

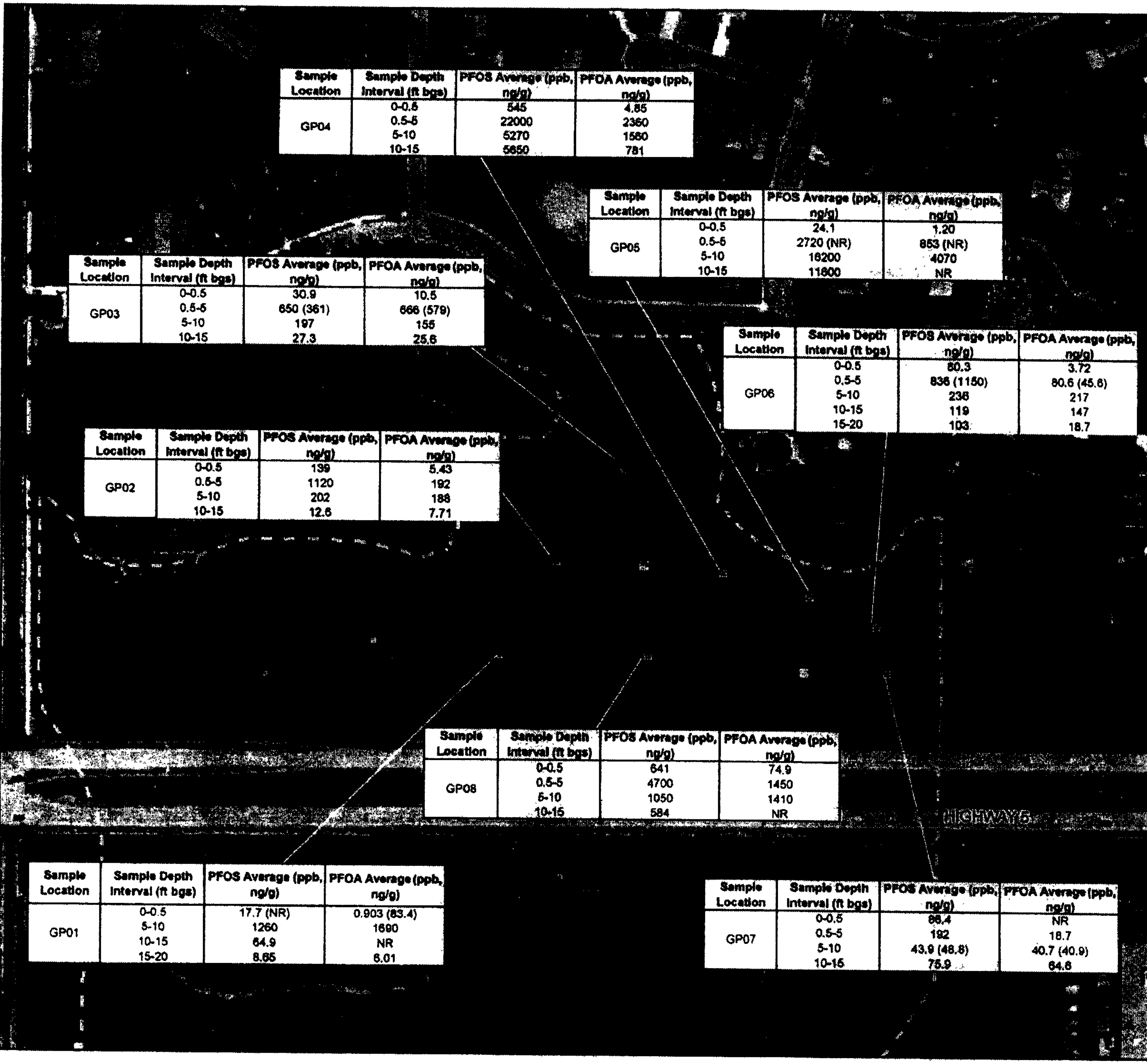



# Figure 13: Extent of PFOA in the St. Peter and Prairie du Chien Aquifers in Lake Elmo / Oakdale Area

(Note – this is a "placeholder" figure until the map can be revised to reflect most recent sample results)

Figure 14: Oakdale Water Treatment Plant

File: \\swc6\proj6\Oakdale\mxd\highway5_PFOS_PFOA_soil.mxd, 06-Sep-06 11:30, ricksc




| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP04 | 0-0.5 | 545 | 4.85 |
| | 0.5-5 | 22000 | 2360 |
| | 5-10 | 5270 | 1560 |
| | 10-15 | 5650 | 781 |

| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP05 | 0-0.5 | 24.1 | 1.20 |
| | 0.5-5 | 2720 (NR) | 853 (NR) |
| | 5-10 | 16200 | 4070 |
| | 10-15 | 11600 | NR |

| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP03 | 0-0.5 | 30.9 | 10.5 |
| | 0.5-5 | 650 (361) | 666 (579) |
| | 5-10 | 197 | 155 |
| | 10-15 | 27.3 | 25.6 |

| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP06 | 0-0.5 | 60.3 | 3.72 |
| | 0.5-5 | 836 (1150) | 80.6 (45.6) |
| | 5-10 | 236 | 217 |
| | 10-15 | 119 | 147 |
| | 15-20 | 103 | 18.7 |

| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP02 | 0-0.5 | 139 | 5.43 |
| | 0.5-5 | 1120 | 192 |
| | 5-10 | 202 | 188 |
| | 10-15 | 12.6 | 7.71 |

| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP08 | 0-0.5 | 641 | 74.9 |
| | 0.5-5 | 4700 | 1450 |
| | 5-10 | 1050 | 1410 |
| | 10-15 | 584 | NR |

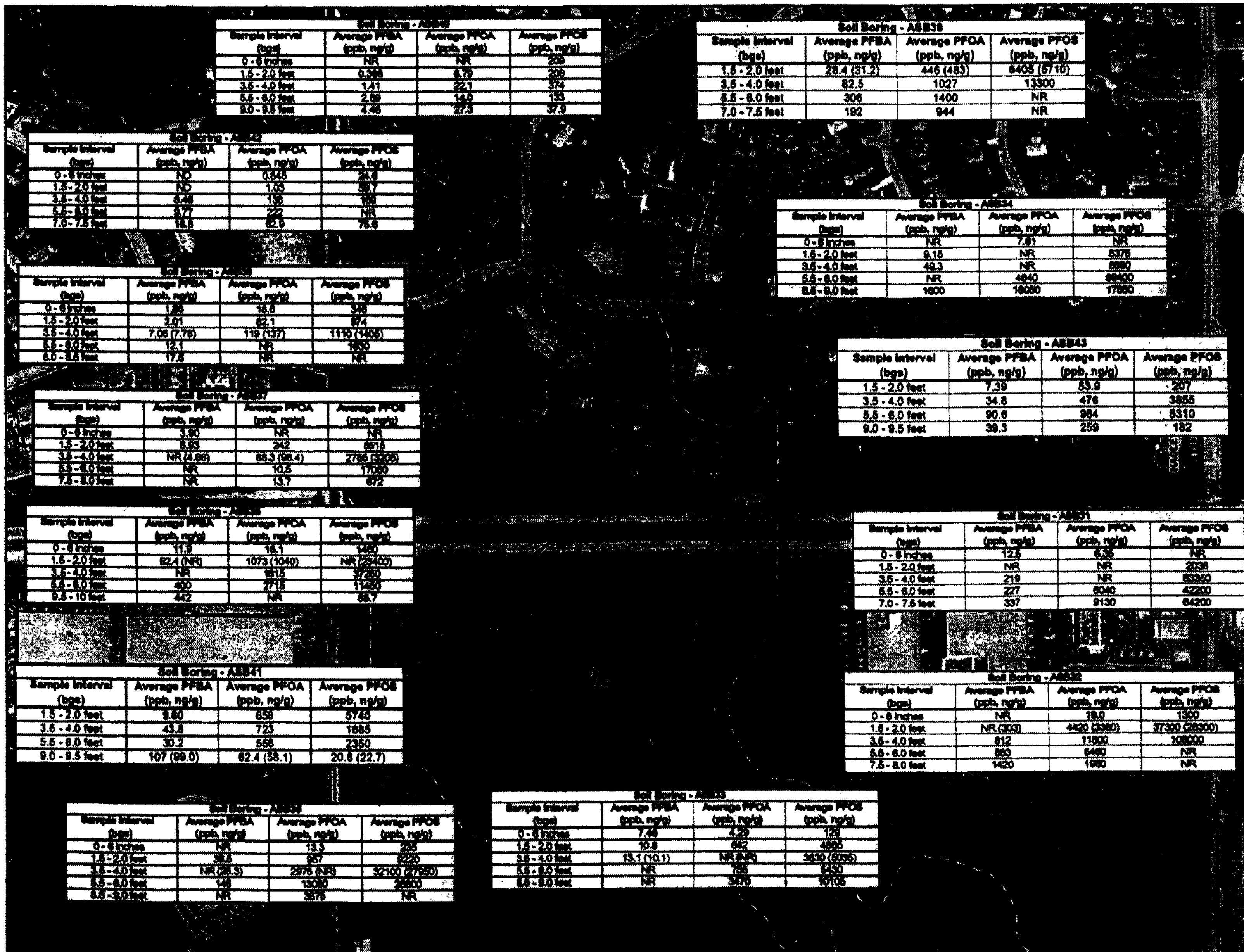
| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP01 | 0-0.5 | 17.7 (NR) | 0.903 (83.4) |
| | 5-10 | 1260 | 1690 |
| | 10-15 | 64.9 | NR |
| | 15-20 | 8.65 | 6.01 |

| Sample Location | Sample Depth Interval (ft bgs) | PFOS Average (ppb, ng/g) | PFOA Average (ppb, ng/g) |
|---|---|---|---|
| GP07 | 0-0.5 | 86.4 | NR |
| | 0.5-5 | 192 | 18.7 |
| | 5-10 | 43.9 (48.8) | 40.7 (40.9) |
| | 10-15 | 75.9 | 64.6 |

# Figure 15

Area of North of Highway 5-
Soil PFOS and PFOA Concentrations
November/December 2005

Oakdale Site
Oakdale, Minnesota



| Soil Boring - ASB[illegible] | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | NR | NR | 209 |
| 1.5 - 2.0 feet | 0.389 | 6.79 | 208 |
| 3.5 - 4.0 feet | 1.41 | 22.1 | 374 |
| 5.5 - 6.0 feet | 2.89 | 14.0 | 133 |
| 9.0 - 9.5 feet | 4.46 | 27.3 | 37.9 |

| Soil Boring - ASB[illegible] | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | ND | 0.845 | 24.6 |
| 1.5 - 2.0 feet | ND | 1.03 | 59.7 |
| 3.5 - 4.0 feet | 6.46 | 136 | 169 |
| 5.5 - 6.0 feet | 9.77 | 222 | NR |
| 7.0 - 7.5 feet | 16.6 | 62.9 | 76.6 |

| Soil Boring - ASB[illegible] | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | 1.89 | 16.6 | 348 |
| 1.5 - 2.0 feet | 2.01 | 82.1 | 974 |
| 3.5 - 4.0 feet | 7.06 (7.76) | 119 (137) | 1110 (1405) |
| 5.5 - 6.0 feet | 12.1 | NR | 1650 |
| 8.0 - 8.5 feet | 17.6 | NR | NR |

| Soil Boring - ASB37 | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | 3.90 | NR | NR |
| 1.5 - 2.0 feet | 6.93 | 242 | 8616 |
| 3.5 - 4.0 feet | NR (4.66) | 88.3 (96.4) | 2795 (3205) |
| 5.5 - 6.0 feet | NR | 10.5 | 17050 |
| 7.5 - 8.0 feet | NR | 13.7 | 672 |

| Soil Boring - ASB[illegible] | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | 11.9 | 16.1 | 1460 |
| 1.5 - 2.0 feet | 82.4 (NR) | 1073 (1040) | NR (23400) |
| 3.5 - 4.0 feet | NR | 1615 | 37260 |
| 5.5 - 6.0 feet | 400 | 2715 | 11460 |
| 9.5 - 10 feet | 442 | NR | 68.7 |

| Soil Boring - ASB41 | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 1.5 - 2.0 feet | 9.80 | 658 | 5740 |
| 3.5 - 4.0 feet | 43.8 | 723 | 1685 |
| 5.5 - 6.0 feet | 30.2 | 568 | 2350 |
| 9.0 - 9.5 feet | 107 (99.0) | 62.4 (58.1) | 20.6 (22.7) |

| Soil Boring - ASB[illegible] | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | NR | 13.3 | 235 |
| 1.5 - 2.0 feet | 38.5 | 957 | 3220 |
| 3.5 - 4.0 feet | NR (28.3) | 2976 (NR) | 32100 (27950) |
| 5.5 - 6.0 feet | 146 | 13050 | 26800 |
| 8.5 - 9.0 feet | NR | 3876 | NR |

| Soil Boring - ASB[illegible] | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | 7.49 | 4.29 | 129 |
| 1.5 - 2.0 feet | 10.8 | 662 | 4805 |
| 3.5 - 4.0 feet | 13.1 (10.1) | NR (NR) | 3630 (6035) |
| 5.5 - 6.0 feet | NR | 756 | 6430 |
| 8.5 - 9.0 feet | NR | 3470 | 10105 |

| Soil Boring - ASB39 | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 1.5 - 2.0 feet | 28.4 (31.2) | 446 (483) | 6405 (5710) |
| 3.5 - 4.0 feet | 82.5 | 1027 | 13300 |
| 5.5 - 6.0 feet | 306 | 1400 | NR |
| 7.0 - 7.5 feet | 192 | 944 | NR |

| Soil Boring - ASB34 | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | NR | 7.61 | NR |
| 1.5 - 2.0 feet | 9.15 | NR | 8375 |
| 3.5 - 4.0 feet | 49.3 | NR | 8880 |
| 5.5 - 6.0 feet | NR | 4840 | 69400 |
| 8.5 - 9.0 feet | 1600 | 18050 | 17650 |

| Soil Boring - ASB43 | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 1.5 - 2.0 feet | 7.39 | 53.9 | 207 |
| 3.5 - 4.0 feet | 34.8 | 476 | 3855 |
| 5.5 - 6.0 feet | 90.6 | 984 | 5310 |
| 9.0 - 9.5 feet | 39.3 | 259 | 182 |

| Soil Boring - ASB31 | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | 12.5 | 6.36 | NR |
| 1.5 - 2.0 feet | NR | NR | 2036 |
| 3.5 - 4.0 feet | 219 | NR | 63360 |
| 5.5 - 6.0 feet | 227 | 6040 | 42200 |
| 7.0 - 7.5 feet | 337 | 9130 | 64200 |

| Soil Boring - ASB32 | | | |
|---|---|---|---|
| Sample Interval (bgs) | Average PFBA (ppb, ng/g) | Average PFOA (ppb, ng/g) | Average PFOS (ppb, ng/g) |
| 0 - 6 inches | NR | 19.0 | 1300 |
| 1.5 - 2.0 feet | NR (303) | 4420 (3380) | 37300 (28300) |
| 3.5 - 4.0 feet | 812 | 11800 | 108000 |
| 5.5 - 6.0 feet | 853 | 6460 | NR |
| 7.5 - 8.0 feet | 1420 | 1960 | NR |

File \\Fswo6\proj8\Oakdale\mxd\ASB_wells_mxd, 08-May-07 10:04 rickso

WESTON

**Legend**

○ Soil Boring Location

□ Water Table Monitoring Well

---- Fenceline

Inferred Limits of the Former Abresch Disposal Site Area

ASB = Abresch site soil boring
bgs = below ground surface
ND = Not detected at, or above, Limit of Quantitation (LOQ) of 0.2 ng/g
NR = Not reported due to quality control failures

Note: Values in parentheses are results from duplicate samples collected in the field.

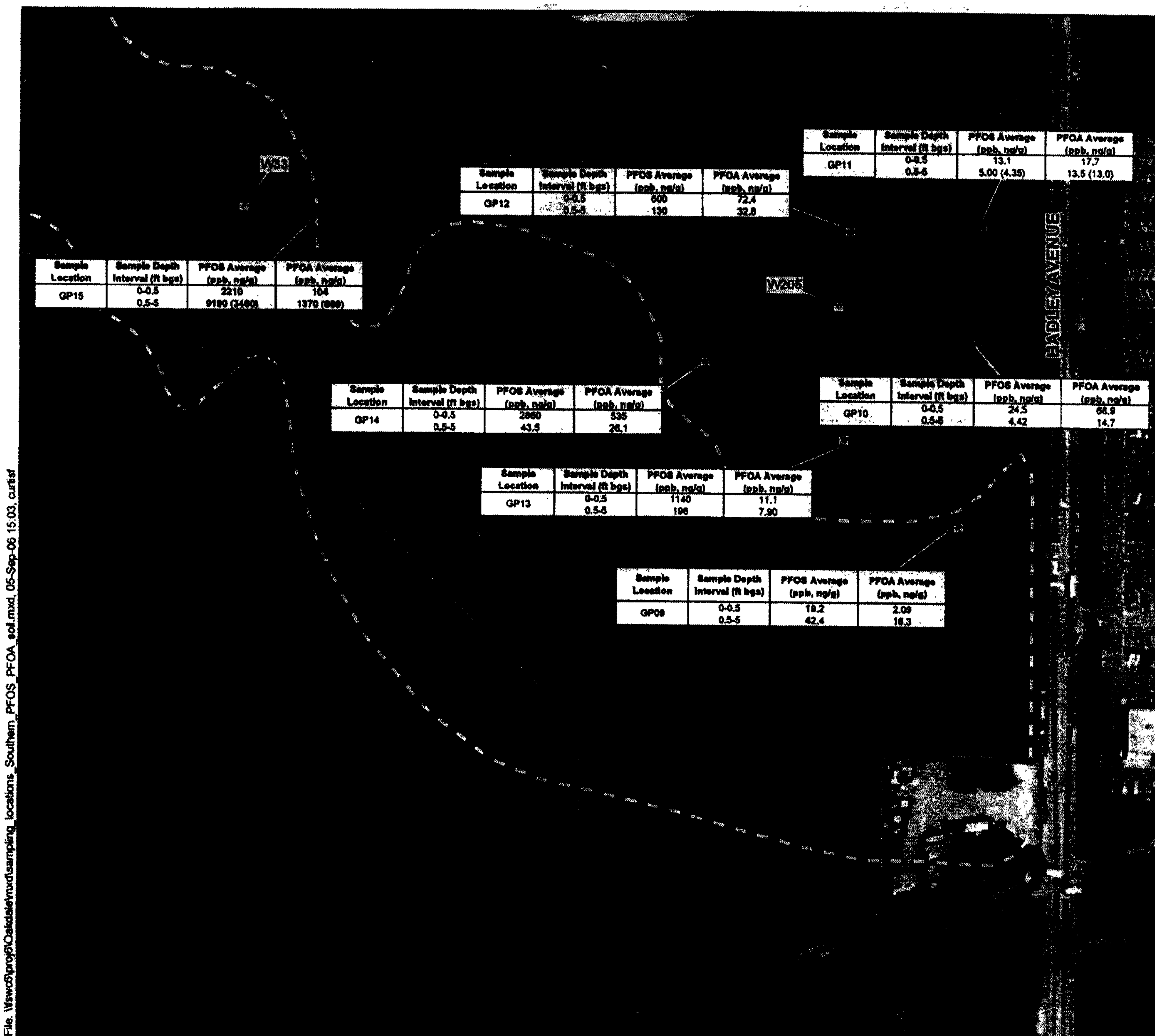
0 150 300 600
Feet

# Figure 16

PFBA, PFOA and PFOS Concentrations in Soil Borings
December 2006

Oakdale Site
Oakdale, Minnesota

File. \\swc6\proj6\Oakdale\mxd\sampling_locations_Southern_PFOS_PFOA_soil.mxd, 05-Sep-06 15:03, curtisf




WESTON

**Legend**

- Geoprobe Boring Location
- Sediment/Surface Water Sampling Location
- Water Table Monitoring Well
- Base of Surficial Alluvium Monitoring Well
- Platteville Monitoring Well
- Pump-out Well
- Fenceline
- Inferred Limits of the Former Abresch Disposal Site Area
- Area of Saturated Soil/Water

N W E S

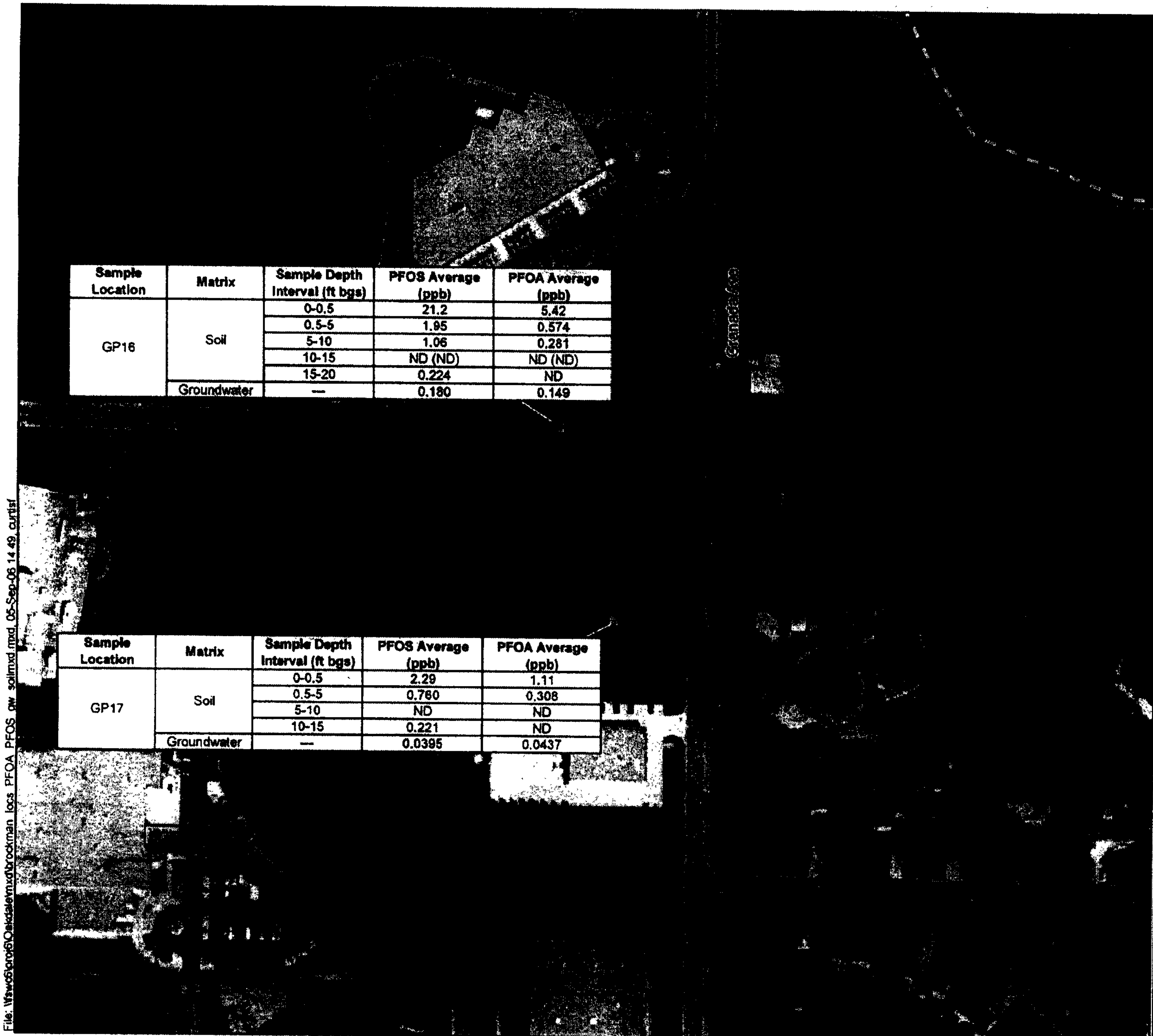
0 100 200
Feet

# Figure 17

Area of Monitoring Wells W205 and W33-
Soil PFOS and PFOA Concentrations
December2005/February 2006

Oakdale Site
Oakdale, Minnesota

File: \\fswc6\proj6\Oakdale\mxd\brockman_locs_PFOA_PFOS_gw_soilmxd.mxd, 05-Sep-06 14 49, curtisf




| Sample Location | Matrix | Sample Depth Interval (ft bgs) | PFOS Average (ppb) | PFOA Average (ppb) |
|---|---|---|---|---|
| GP16 | Soil | 0-0.5 | 21.2 | 5.42 |
| | | 0.5-5 | 1.95 | 0.574 |
| | | 5-10 | 1.06 | 0.281 |
| | | 10-15 | ND (ND) | ND (ND) |
| | | 15-20 | 0.224 | ND |
| | Groundwater | — | 0.180 | 0.149 |

| Sample Location | Matrix | Sample Depth Interval (ft bgs) | PFOS Average (ppb) | PFOA Average (ppb) |
|---|---|---|---|---|
| GP17 | Soil | 0-0.5 | 2.29 | 1.11 |
| | | 0.5-5 | 0.760 | 0.308 |
| | | 5-10 | ND | ND |
| | | 10-15 | 0.221 | ND |
| | Groundwater | — | 0.0395 | 0.0437 |

WESTON

**Legend**

- Geoprobe Boring Location
- Fenceline
- Inferred Limits of the Former Abresch Disposal Site Area

Note: Concentrations in parenthesis are duplicate samples
ND= Not Detected at or Above 0.2 ng/g (wet weight)

N S E W

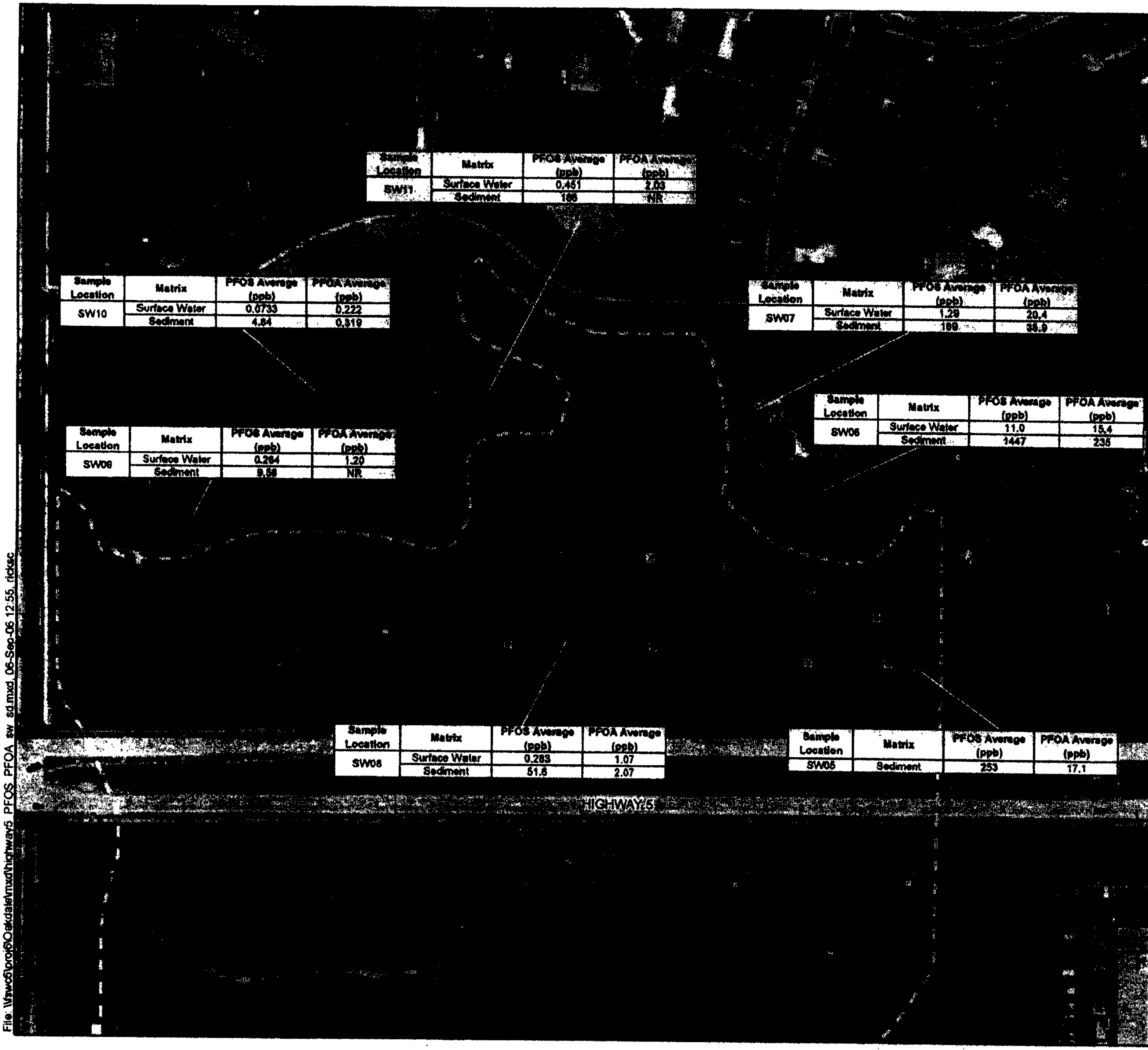
0 100 200
Feet

# Figure 18

Brockman Area-
Groundwater and Soil
PFOS and PFOA Concentrations
December 2005

Oakdale Site
Oakdale, Minnesota

File: \\fswc6\proj6\Oakdale\mxd\highway5_PFOS_PFOA_sw_sd.mxd, 06-Sep-06 12:55, ricksc




WESTON

**Legend**

- Water Table Monitoring Well
- Geoprobe Boring Location
- Sediment/Surface Water Sampling Location
- Abandoned
- Basal Alluvium Monitoring Well
- Base of Surficial Alluvium Monitoring Well
- Pump-out Well
- Eliminated Pumping at Well
- Walking Path
- Unpaved Access Road
- Drainage Features
- Fenceline
- Inferred Limits of the Former Abresch Disposal Site Area

N W E S

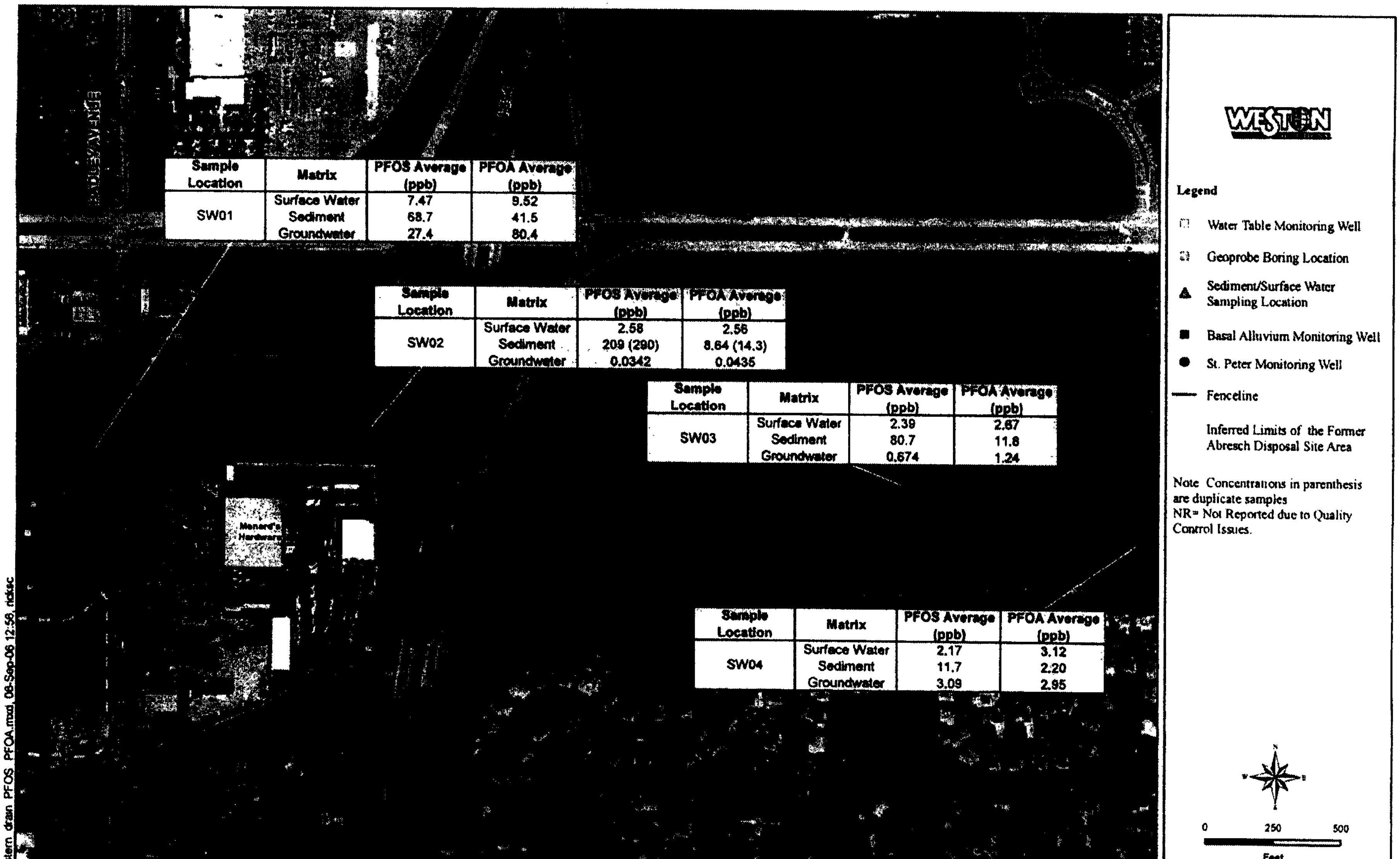
0 100 200
Feet

# Figure 19

Area of North of Highway 5-
Surface Water and Sediment
PFOS and PFOA Concentrations
February 2006

Oakdale Site
Oakdale, Minnesota

File: \\swo6\proj6\Oakdale\mxd\eastern_drain_PFOS_PFOA.mxd, 08-Sep-06 12:56, rickc




| Sample Location | Matrix | PFOS Average (ppb) | PFOA Average (ppb) |
|---|---|---|---|
| SW01 | Surface Water | 7.47 | 9.52 |
| | Sediment | 68.7 | 41.5 |
| | Groundwater | 27.4 | 80.4 |

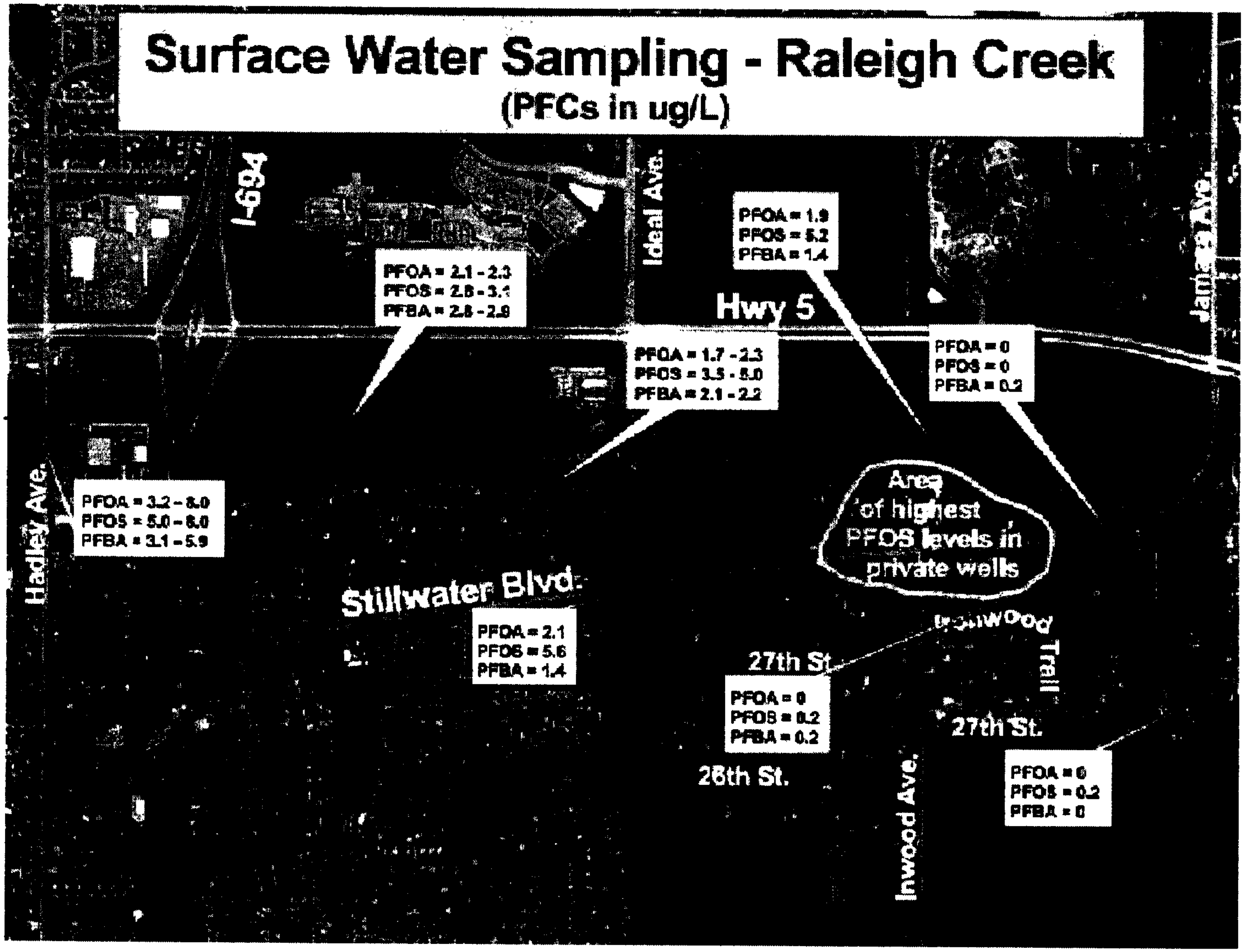
| Sample Location | Matrix | PFOS Average (ppb) | PFOA Average (ppb) |
|---|---|---|---|
| SW02 | Surface Water | 2.58 | 2.56 |
| | Sediment | 209 (290) | 8.64 (14.3) |
| | Groundwater | 0.0342 | 0.0435 |

| Sample Location | Matrix | PFOS Average (ppb) | PFOA Average (ppb) |
|---|---|---|---|
| SW03 | Surface Water | 2.39 | 2.67 |
| | Sediment | 80.7 | 11.8 |
| | Groundwater | 0.674 | 1.24 |

| Sample Location | Matrix | PFOS Average (ppb) | PFOA Average (ppb) |
|---|---|---|---|
| SW04 | Surface Water | 2.17 | 3.12 |
| | Sediment | 11.7 | 2.20 |
| | Groundwater | 3.09 | 2.95 |

Figure 20
Eastern Drainagway-
Surface Water, Sediment and
Groundwater PFOS and PFOA
Concentrations
February 2006

Oakdale Site
Oakdale, Minnesota




# Figure 21: PFC Sample Results in Raleigh Creek

# Appendix 2: 2007 MDH HBVs for PFOS and PFOA

# Memo

MINNESOTA MDH DEPARTMENT OF HEALTH

**Date:** February 26, 2007

**To:** John Stine, Environmental Health Division Director

**Via:** Larry Gust, Environemental Surveillance and Assessment Section Manager
Pamela Shubat, Health Risk Assessment Unit Supervisor

**From:** Helen Goeden, Health Risk Assessment Unit staff

**Subject:** Health Based Values for Perfluorooctane Sulfonate (PFOS)

---

In 2002 the Minnesota Department of Health (MDH) developed a HBV of 1 ppb for PFOS. Since 2002 additional toxicity data, toxicokinetic data, and reviews of preexisting data have been produced. After a careful review of this information the Health Risk Assessment Unit staff recommends that the HBV for PFOS be lowered to 0.3 ug/L (ppb).

The following information was utilized in generating the revised HBV:

| Chemical | CAS # | Endpoint | RfD (mg/kg-d) | HBV (ug/L) | Source |
|---|---|---|---|---|---|
| PFOS | 1763-23-1 | hepatic (liver) system and thyroid | 0.000075 | 0.3 | MDH 2007 |

More detailed information, supporting the development of the HBV, is attached. Please be advised that, although we believe that this number will provide an adequate level of protection, there is a degree of uncertainty associated with all HBVs, and they should be considered provisional. Professional judgment should be used in implementing this HBV. MDH will review this HBV if and when additional studies have been conducted.

The MDH's authority to promulgate health risk limits under the Groundwater Protection Act is limited to situations where degradation has already occurred. Similarly, health-based values, which are un-promulgated exposure values, serve as interim advice issued for specific sites where a contaminant has been detected. As such, neither health risk limits nor health-based values are developed for the purpose of providing an upper limit for degradation.

cc: Larry Gust, MDH
Pam Shubat, MDH
Rita Messing, MDH
Cathy Villas-Horns, MDA
Shelley Burman, MPCA
Paul Hoff, MPCA
Doug Wetzstein, MPCA

# ATTACHMENT

*(Corrected March 9, 2007)*

## DATA FOR DERIVATION OF GROUND WATER HEALTH BASED VALUE (HBV)

**Chemical Name: Perfluorooctane Sulfonate (PFOS)**
**CAS: 1763-23-1 (acid)**
**29081-56-9 (ammonium salt)**
**70225-14-8 (diethanolamine salt)**
**2795-39-3 (potassium salt)**
**29457-72-5 (lithium salt)**

**Non-Cancer Health Based Value (HBV) = 0.3 ug/L**

$$= \frac{\text{(toxicity value, mg/kg/d) x (relative source contribution) x (1000 ug/mg)}}{\text{(intake rate, L/kg-d)}}$$

$$= \frac{\text{(0.000075 mg/kg/d) x (0.2) x (1000 ug/mg)}}{\text{(0.048 L/kg/day)}}$$

= **0.3 ug/L**

| | |
|---|---|
| Toxicity value: | 0.000075 mg/kg-d (Cynomolgus monkeys) |
| Source of toxicity value: | MDH 2007 (RfD derived by MDH) |
| Point of Departure: | minimal LOAEL, 0.15 mg/kg-d |
| Dose Metric Adjustment: | 20 (to adjust for half-life duration of 5.4 years in humans versus 110 - 132 days in Cynomolgus monkeys) |
| Total uncertainty factor: | 100 |
| UF allocation: | 3 interspecies toxicodynamic differences, 10 intraspecies variability; and 3 LOAEL-to-NOAEL (a value of 3 was applied to the study LOAEL rather than using the NOAEL or the default UF of 10 because the effect observed at the LOAEL was considered to be of minimal severity) |
| Critical effect(s)*: | Decreased HDL and T3 |
| Co-critical effect(s)*: | None |
| Additivity endpoint(s): | Hepatic (liver) system, Thyroid (E) |
| Secondary effect(s)*: | Developmental (decreased body weight/weight gain, decreased total T4), decreased gestation length, immune system alterations |

* for explanation of terms see Glossary located at: http://www.health.state.mn.us/divs/eh/groundwater/hrlgw/glossary.html

**Cancer Health Risk Limit (HRL) = N/A**

**Volatile: No**

**Summary of changes since 2002 HBV:**
Toxicity Value (RfD):
Improved toxicokinetic (e.g., half-life) information allowed for the incorporation of a 20-fold dose-metric adjustment based on half-life differences between humans and monkeys and a 10-fold decrease in the total UF. In 2002 a 30-fold factor (3 interspecies extrapolation + 10 subchronic-to-chronic) was used to address uncertainties around toxicokinetics.

Intake rate:
PFOS, unlike most ground water contaminants, has a long half-life and therefore will accumulate in the body if repeated exposure occurs over long-periods of time. Eventually the internal concentration of PFOS will reach a plateau (steady-state). The length of time to reach steady state conditions is equivalent to approximately 5 half-lives. In the case of PFOS the time to steady-state would be approximately 27 years (5 x human half-life of 5.4 years). The intake rate selected for the revised HBV was a time-weighted average intake of an upper-end consumer over the first 27 years of life (0.048 L/kg-d). This intake rate incorporates the higher intake rates early in life (i.e., infants and children) as well as the accumulation of the chemical over time.

**Consideration of Sensitive Populations:**
Growth deficits, alterations in thyroid hormone levels (T4 and T3), increased liver weights, and delays in development have been reported in offspring exposed during development. These effects were observed at doses approximately 3 to 7 times higher than the critical study minimal LOAEL. Potential health-based values based on protection of a pregnant woman and her fetus were evaluated. Two scenarios were evaluated: 1) a long-term exposure – exposure to the mother from birth to age 27 years, and 2) a short-term exposure – exposure to an infant. The long-term exposure scenario incorporated accumulation over time and utilized a time-weighted intake rate 0.048 L/kg-d. The short-term exposure scenario did not incorporate accumulation over time but did utilize a young infant intake rate of 0.221 L/kg-d. The resulting potential HBVs for both scenarios were not lower (i.e., more restrictive) than the HBV based on the selected critical study in monkeys.

**Summary of toxicity testing for health effects identified in the Health Standards Statute:**

| | Endocrine | Immunotoxicity | Development | Reproductive | Neurotoxicity |
|---|---|---|---|---|---|
| Tested? | Sec. Observations[1] | Yes | Yes | Yes | Yes |
| Effects? | Yes | Yes[2] | Yes[3] | Yes[4] | Yes[5] |

Note: Even if testing for a specific health effect was not conducted for this chemical, information about that effect may be available from studies conducted for other purposes. Most chemicals have been subject to multiple studies in which researchers identify a dose where no effects were observed, and the lowest dose that caused one or more effects. A toxicity value based on the effect observed at the lowest dose across all available studies is considered protective of all other effects that occur at higher doses.

**Comments on extent of testing or effects:**
[1] Thyroid hormonal perturbations have been observed in laboratory animals at dose levels similar to the critical study LOAEL. Alterations in thyroid hormone levels have been identified as critical effect.
[2] Short-term immunotoxicity studies have shown that PFOS exposure alters several immunologic parameters (suppression of SRBC-specific IgM production and T-cell proliferation, increased natural killer cell activity) at levels below the critical study LOAEL. The biological significance of these effects

is not entirely clear. Further study is needed to determine whether PFOS poses potential health risks to humans as a result of alterations in immune function, however, the MDH will include immune system as a secondary effect at this time.

[3] Lower body weight in offspring, decreased T4, increased sternal defects and decreased gestation length have been reported at levels approximately 3-fold higher than the critical study LOAEL. These effects have been identified at secondary effects. At doses approximately 10-fold higher than the LOAEL additional developmental effects (decreased pup viability, developmental delays) are observed.

[4] A male reproductive study reported decreases in sperm count and increases in sperm deformities at levels 10-fold higher than the critical study LOAEL.

[5] Hypoactive responses to nicotine has been observed in neonatal mice acutely exposed to levels 75-fold higher than the critical study LOAEL but these effects were not observed at levels 5-fold higher. Convulsions, severe rigidity and body trembling have been observed in Rhesus monkeys subchronically exposed to levels approximately 30-fold higher than the critical study LOAEL.

**The following sources were reviewed in the preparation of the HBV:**

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# Appendix 3: MDH Special Well Construction Area, March 8, 2007

MINNESOTA MDH DEPARTMENT OF HEALTH

*Protecting, maintaining and improving the health of all Minnesotans*

**DATE:** March 8, 2007

**TO:** Licensed and Registered Well Contractors
Cindy Weckwerth, Washington County
Susan Hoyt, City of Lake Elmo
Brian Bachmeier, City of Oakdale
Advisory Council on Wells and Borings

**FROM:** John Linc Stine, Director
Environmental Health Division
P.O. Box 64975
St. Paul, Minnesota 55164-0975

**PHONE:** 651/201-4675

**SUBJECT: Notice of Designation of Special Well Construction Area, Lake Elmo-Oakdale, Washington County, Minnesota**

The Minnesota Department of Health (MDH) is designating a SPECIAL WELL CONSTRUCTION AREA (SWCA), which includes portions of Lake Elmo and Oakdale in Washington County, Minnesota (see Figure 1). The SWCA designation is effective March 15, 2007, and applies to the construction repair, modification, and sealing of wells and borings. The SWCA designation remains effective until further notice. This designation is an expansion and renaming of the existing Washington County Landfill SWCA, originally established in 1982. This expansion includes the Oakdale disposal site. The SWCA addresses the finding of more extensive groundwater contamination by perfluorochemicals in Lake Elmo and Oakdale.

## AUTHORITY

Minnesota Statutes, section 103I, subdivision 5, clause 7 grants the commissioner of health the authority to establish standards for the construction, maintenance, sealing, and water-quality monitoring of wells in areas of known or suspected contamination. Minnesota Rules, part 4725.3650, details the requirements for construction, repair, and sealing of wells within a designated SWCA, including plan review and approval, water-quality monitoring, and other measures to protect public health and prevent degradation of groundwater.

## SITE HISTORIES

The Washington County Landfill is located approximately one-quarter mile south of Lake Jane in Lake Elmo, Minnesota. It was initially permitted as a solid waste landfill by the Minnesota Pollution Control Agency (MPCA) in 1969 and operated until 1975. The landfill received approximately 2.5 million cubic yards of municipal and industrial wastes (MPCA 2004). In 1981, sampling of on-site monitoring wells and off-site private wells to the south and southwest indicated the presence of volatile organic chemicals (VOCs), including trichloroethylene and tetrachloroethylene, and metals in groundwater. A "Well Advisory," of approximately 1 square mile, was established on July 19, 1982. The advisory covered an area from the landfill south to Highway 5. The advisory boundaries were revised in 1983 and, in 1993, the advisory became a SWCA. Due to the presence of VOC contamination, the SWCA required persons proposing to construct or seal wells within the SWCA to obtain written plan approval from the MDH prior to beginning work. This SWCA has been in effect to the present.

In 1983, Ramsey and Washington Counties installed a groundwater remediation system, including a gradient control well system with spray irrigation to remove VOCs. In 1996, the site entered the MPCA-administered Closed Landfill Program and the MPCA has taken additional steps to improve the landfill cover and the groundwater remediation system. Municipal water service, provided by the Oakdale municipal system, was extended into the SWCA in 1986, and private wells were sealed.

The Oakdale disposal site (actually three sites - Abresch, Brockman, and Eberle) was used in the 1940's through 1960's for disposal of commercial, industrial, and residential wastes. Disposal was via burying containers and solid materials in trenches, dumping liquids on the ground or in pits, and burning materials in pits. The site investigation began in 1980. Contaminants detected at the site include methyl ethyl ketone, acetone, toluene, isopropyl ether, and other VOCs. A number of remedial actions were taken, including excavation and disposal/incineration of wastes and contaminated soils, sealing 39 multiaquifer (Platteville limestone – St. Peter sandstone) wells and connecting potentially affected well owners to the Oakdale municipal water supply, installation and operation of a groundwater remediation system (12 extraction wells) in the unconsolidated aquifers, and installation of a groundwater monitoring system (Minnesota Department of Health, 1993).

## PERFLUOROCHEMICALS

In 2003, the MPCA began investigating a family of chemicals called "perfluorochemicals" (PFCs) that were used in products resistant to heat, oil, grease, and water, and which appear to be persistent in the environment. These compounds were used in a wide array of products and materials, including nonstick cookware, stain- and water-resistant fabrics, fire-suppression foams, film coatings and other consumer and commercial products.

PFCs were produced by the 3M Company (3M) at its Cottage Grove facility. Wastes from this production were disposed at the Washington County Landfill and at the Oakdale disposal site. The initial investigations focused on two specific PFCs in groundwater – perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Testing of monitoring wells in 2003 at the Washington County Landfill and the Oakdale disposal site identified the presence of PFOA and PFOS. In 2004, 32 private wells near the Washington County Landfill were tested for PFCs. PFOA was detected at low levels in seven wells.

In December 2004, initial sampling of the Oakdale municipal wells identified five wells showing the presence of PFOA and PFOS. Testing expanded in early 2005 to investigate private wells in Lake Elmo, south and southwest of the Washington County Landfill. Findings indicated that PFOA and PFOS had migrated far beyond the distribution of the VOC contaminant plume and the boundaries of the original SWCA.

In the Spring 2006, testing was expanded to include five additional perfluorochemicals:

- perfluorobutane sulfonate (PFBS),
- perfluorobutanoic acid (PFBA),
- perfluoropentanoic acid (PFPeA),
- perfluorohexane sulfonate (PFHxS), and
- perfluorohexanoic acid (PFHxA).

Three of the chemicals (PFPeA, PFHxS, and PFHxA) were found in private wells that had previous detections of PFOA and PFOS. However, PFBA was detected in 204 wells that show the presence of no other PFCs. To date, 425 private wells and noncommunity public water-supply wells have been sampled and tested for PFCs. The testing results showed 92 wells with no detection of PFCs, 129 wells with multiple PFCs present, and 204 with only PFBA present. MDH advised that 151 wells should not be used for consumptive uses because of PFOS/PFOA/PFBA exceedances of the Health-Based Values (HBVs) or well advisory guidelines or a combination of PFCs exceeding a health index of greater than or equal to one. Some of the areas impacted include the Lake Elmo Heights, Tablyn Park, Torre Pines, and Parkview neighborhoods of Lake Elmo, extending south-southwest of the Washington County Landfill. PFBAs were also detected in a sixth Oakdale municipal well and in a recently-constructed municipal well in Lake Elmo that has not been put into service, and at very low levels in 16 Woodbury municipal wells, south of Interstate 94.

Additional testing in January-February 2007 indicated that PFBA contamination is found throughout much of southwest Washington County and part of northern Dakota County, affecting wells and public water-supply systems in Cottage Grove, Hastings, Newport, South St. Paul, and St. Paul Park. Investigations and well testing are continuing to better determine the extent and magnitude of contamination, assess source areas, and address remedial options. These findings south of Interstate 94 are not the subject of this SWCA, but may be addressed in a future SWCA designation.

**RESPONSE ACTIONS**

3M provided the city of Lake Elmo with a $3.3 million grant to extend the municipal water supply to service the Lake Elmo Heights and Tablyn Park neighborhoods. The grant is expected to cover the extension of watermains, connection of 214 homes to municipal service, and permanent sealing of the wells serving those homes. The extension of municipal water service is scheduled for completion in early 2007, at which time sealing of the private wells will occur.

In 2005, the MPCA began providing granular activated carbon (GAC) treatment for wells that exceeded the HBVs, well advisory guidelines, or had a hazard index of greater than or equal to one. Existing wells outside the area of the proposed municipal water-supply expansion are eligible for GAC treatment. The MPCA is providing bottled water until GAC treatment or an alternate water supply can be provided to these wells. New or replacement wells must meet the requirements of this SWCA.

In October 2006, the city of Oakdale began operation of a GAC filtration plant, designed to remove PFCs from water supplied by the two public water-supply wells having PFOA/PFOS concentrations exceeding HBVs. The design, construction, and operation costs were covered by 3M. During periods of high water demand, the city attempts to minimize PFC levels by careful management of use of the municipal wells.

**SWCA HYDROGEOLOGY**

The surficial geology of the Lake Elmo/Oakdale area consists of 50-150 feet of unconsolidated materials, comprised of glacial till deposits associated with the St. Croix Moraine. Lacustrine and wetland deposits are predominant in Oakdale, and glacial outwash is more widespread in Lake Elmo (Minnesota Geological Survey, Plate 3, 1990).

These materials are underlain by Paleozoic-era sedimentary rocks of interbedded dolostone/limestone, sandstone, and shale units (see Figure 2). These bedrock units have a slight southwesterly dip, reflecting the fact that this area is on the eastern flank of the Twin Cities Basin (Barr Engineering Company, 2005). In the northwestern corner of the SWCA, a remnant of the Decorah shale is present, and, in fact, directly underlies the Abresch disposal site in Oakdale. The first bedrock unit underlying most of Oakdale is the Platteville limestone/Glenwood shale. Further east, these units are eroded and, progressively eastward, the St. Peter sandstone, or the Prairie du Chien group, is the first bedrock encountered beneath the surficial materials. The first bedrock underlying the Washington County Landfill is the Prairie du Chien group.

A major groundwater divide bisects Washington County from north to south, with groundwater east of the divide moving eastward and discharging to the St. Croix River and groundwater west of the divide moving west-southwest towards the Mississippi River (Minnesota Geological Survey, Plate 5, 1990). The eastern boundary of the SWCA is located just east of this divide. Within the SWCA, groundwater flow within the drift and outwash deposits can be variable. Flow is controlled by local discharge/recharge points, the presence of confining layers, groundwater withdrawals, and land use. For instance, the groundwater remediation system at the Washington County Landfill and the presence of bedrock with low permeability at the Oakdale disposal site create mounding conditions that produce radial flow in the local groundwater. Groundwater levels and flow directions are also influenced by recharge from losing streams (i.e., Raleigh Creek) and by natural discharge to local lakes and streams.

Regional groundwater flow in the bedrock, particularly the St. Peter sandstone and the Prairie du Chien group, is generally to the southwest. The distribution and migration of PFCs to the south – southwest reflect this groundwater flow direction. The contaminant plume is also gradually "sinking" into deeper formations and dispersing along the transport path. PFC contamination tends to be limited to the drift and St. Peter sandstone in the northern third of the SWCA and is found in the Prairie du Chien dolomite and Jordan sandstone in the southern two-thirds of the SWCA.

## ENVIRONMENTAL AND PUBLIC HEALTH CONCERNS

PFCs are synthetic chemicals that are not natural to the environment. They are found both as an ingredient in manufacturing processes and as part of some finished products. Unlike most organic compounds that tend to degrade in the environment or are adsorbed onto natural materials, PFCs are very stable compounds and appear to be resistant to environmental degradation. In addition, these compounds can be transported widely in the environment, in general, and in groundwater, in particular. Some PFCs (primarily PFOA and PFOS) have been found to bioaccumulate (Minnesota Department of Health, 2005). Because of these characteristics, uses of groundwater for purposes other than drinking, such as irrigation and other nonconsumptive uses, may also be of concern.

PFCs are a relatively new family of environmental contaminants and there are limited numbers of studies of health effects in people. In animal studies, high concentrations of PFCs harm the liver and thyroid. Developmental problems have been seen in the offspring of rats and mice exposed to PFCs while pregnant. Studies of 3M workers exposed to PFOS and PFOA during manufacturing show no apparent impacts to their health. There is no similar health study information for the general population. However, the U.S. Environmental Protection Agency and other researchers are investigating the potential health effects on the general population and on other populations who are exposed to PFCs in their drinking water.

On March 1, 2007, the MDH issued revised HBVs, which are 0.5 micrograms/liter (μg/l) for PFOA and 0.3 μg/l for PFOS. A HBV is the concentration of a groundwater contaminant, or mixture of contaminants, that poses little or no risk to health, even if consumed over a lifetime. The MDH also recommends that consumers limit or reduce their intake of water that has a concentration of PFBA exceeding 1 μg/l. The MDH continues to evaluate toxicity data in order to calculate a HBV for PFBA in the future.

**BOUNDARIES OF THE SPECIAL WELL CONSTRUCTION AREA**

The boundaries of the existing SWCA, last revised in 1983, were as follows:

- Northern boundary of Lake Jane Hills Park, and west following an irregular boundary of Ivy Court North to Isle Avenue North.
- The alignment of Isle Avenue North to approximately 37th Avenue north, then west to the alignment of Irvin Circle North, then south to Highway 5.
- Highway 5 on the south, between Iris Avenue North and the midpoint of Section 15 (immediately east of intersection with 31st Street North.
- The north-south centerline of Section 15 and that part of Section 10 to the north boundary of Lake Jane Hills Park.

The location of the revised SWCA is shown on the attached map (Figure 1). Encompassing the area described above, the revised SWCA includes the following:

- Ramsey-Washington County line on the west (County Road 120, also known as Century Avenue or Geneva Avenue).
- Interstate 94 on the south, from county line to Lake Elmo Avenue.
- Lake Elmo Avenue on the east, extending from Interstate 94 to Highway 5 (Stillwater Boulevard North in Lake Elmo, 34th Street North in Oakdale) and, then, to 47th Street North.
- 47th Street North-Lake Jane Trail to Ideal Avenue North on the north, then southward to Highway 5, then westward to Ramsey-Washington County line.
- The area between Granada Avenue North and Hadley Avenue North, north of Highway 5 and south of 35th Street North.

The SWCA includes all of sections 14-16, 19-23 and 26-35 and portions of sections 9-11, 13, 17-18, and 24 of Township 29 North and Range 21 West.

**REQUIREMENTS OF THE SPECIAL WELL CONSTRUCTION AREA**

1. All wells and borings regulated by the MDH are subject to the requirements of this SWCA. Wells include water-supply wells (domestic, public irrigation, commercial/industrial, cooling/heating, remedial, monitoring wells, and dewatering wells). Borings include environmental bore holes, elevator borings, and vertical heat exchangers. Notifications and permit applications, and their respective fees, must be submitted to the MDH.

2. Construction of a new well or boring, or modification of an existing well or boring, may not occur until plans have been reviewed and approved in writing by MDH. In addition to the normally required notification or permit application and fee, the plan must include the following information: street address; well or boring depth; casing type(s), diameter(s), and depth(s) for each casing; construction method(s), including grout materials and grouting methods; anticipated pumping rate; and use.

3. As a condition of the well construction plan approval, the well owner must agree to pay for a PFC analysis of the water, to be performed by the MDH Public Health Laboratory. Copies of analytical results will be forwarded to the well owner, the MPCA, Washington County Department of Public Health and Environment, and the city of Lake Elmo (or Oakdale). The MDH will review the analytical results and determine if the well can be completed, if the well must be drilled deeper, or if the well must be permanently sealed.

4. Special well construction and/or monitoring requirements may be imposed on a well/boring completion, location and use in order to protect the public health and groundwater quality and to prevent contaminant migration. These requirements will be based on available knowledge of groundwater contaminant movement near the well location and the proposed use and pumping rate of the well.

5. No potable water-supply wells may be completed in areas served by a community public water-supply system. The city of Lake Elmo has indicated that future new developments must be served by a community public water-supply system. For areas not served by a community system, potable water-supply wells may be allowed serving individual lots within already existing developments or replacing existing wells that go out of service. Potable water-supply wells may not be completed within the Platteville limestone, St. Peter sandstone, Prairie du Chien group, or Jordan sandstone without approval on a site-specific basis. For purposes of this SWCA, "potable use" includes any consumptive or other uses involving human contact, including drinking, cooking, bathing, recreation, manufacturing or processing of food, drink, or pharmaceuticals, or to supply water to fixtures accessible to humans.

6. Potable wells completed in the Franconia sandstone or Ironton-Galesville sandstones will be permitted throughout the SWCA. However, these wells must be cased and grouted through the full thickness of the St. Lawrence formation. Casing and grout must extend from at least 20 feet below the St. Lawrence formation to the surface.

7. Approval of plans and specifications for construction of a community public water-supply well and of the well site is required by Minnesota Rules, part 4725.5850. The MDH may approve completion of a public water-supply well within the designated SWCA if the system owner/operator can demonstrate that the water delivered to the distribution system meets Maximum Contaminant Levels (MCLs) established by the U.S. Environmental Protection Agency or other health guidelines referenced by the MDH, either through treatment, blending with other sources, monitoring, or other mechanisms.

8. A well completed in one of the geologic formations named in item 5 and used for a nonpotable purpose, such as groundwater quality monitoring or construction

dewatering, may be allowed, provided that the MDH and the MPCA determine that the well will not interfere with remediation efforts, cause further spread of contamination, or result in environmental or human exposures in excess of public health and environmental standards.

9. No well or boring in bedrock may be permanently sealed until the MDH has reviewed and approved the plans for the proposed sealing. In addition to the required notification and fee, the plan must include the following information: street address; original well/boring depth; current well/boring depth (if different); casing type(s), diameter(s), and depth(s); methods of identifying and sealing any open annular space(s); methods for identifying and removing any obstruction(s); grout materials and placement methods.

10. All other provisions of Minnesota Rules, Chapter 4725, are in effect.

**WELL DISCLOSURE IN WASHINGTON COUNTY**

Before signing an agreement to sell or transfer real property in Washington County that is not served by a municipal water system or is served by a municipal water system but has an unsealed well, Minnesota Statutes, section 103I.236, requires the seller to state in writing to the buyer whether, to the seller's knowledge, the property is located within a SWCA. Figure 1, details the Lake Elmo – Oakdale SWCA. This disclosure is in addition to the disclosure of the number, location, and status (in use, not in use, or sealed) of all wells on a property as required for all property transfers in Minnesota, as required under Minnesota Statutes, section 103I.235.

**PERSONS TO CONTACT**

For additional information regarding this SWCA, please contact Mr. Michael Convery of the MDH at 651/201-4586 or Michael.Convery@state.mn.us.

Plans for construction, repair, or sealing of wells and borings within the SWCA must be submitted to:

Mr. Patrick Sarafolean
Minnesota Department of Health
Well Management Section – Metro District
P.O. Box 64975
St. Paul, Minnesota 55164-0975
651/643-2110
Patrick.Sarafolean@state.mn.us

Notifications/permit applications for either construction or sealing of wells and borings must still be mailed or faxed to the MDH Central Office at:

Minnesota Department of Health
Well Management Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975
651/201-4599

For information regarding public health concerns, please contact:

James Kelly/Virginia Yingling
Minnesota Department of Health
Site Assessment and Consultation Unit
P.O. Box 64975
St. Paul, Minnesota 55164-0975
(651)201-4910/(651)201-4930
James.Kelly@state.mn.us/Virginia.Yingling@state.mn.us

For information regarding the investigation, monitoring, and remediation of the ground water contamination, please contact:

Ms. Ingrid Verhagen/Mr. Shawn Ruotsinoja
Minnesota Pollution Control Agency
(651)296-7266/(651)282-2382
Ingrid.Verhagen@state.mn.us/Shawn.Ruotsinoja@state.mn.us

**REFERENCES**

Barr Engineering Company 2005, Washington County Landfill and Oakdale Disposal Site Groundwater Flow and Contaminant Transport Modeling, 23p.

Minnesota Department of Health, 1993, Site Review and Update – Oakdale Dump Site, CERCLIS Number MND980609515, 12p.

Minnesota Department of Health, 2005, Environmental Health Information – Perfluorochemicals and Health, 2p.

Minnesota Department of Health, 2006, Update: Perfluorochemicals and Private Drinking Water Wells in Lake Elmo, 2p.

Minnesota Geological Survey, 1990, *Hydrogeology* in Geologic Atlas – Washington County, Minnesota. County Atlas Series C-5, University of Minnesota – Plate 5.

Minnesota Pollution Control Agency, 2005, Minnesota Pollution Control Agency's Closed Landfill Program, Annual Report 2004, Washington County Sanitary Landfill SW-001.

JLS:MPC:jmw

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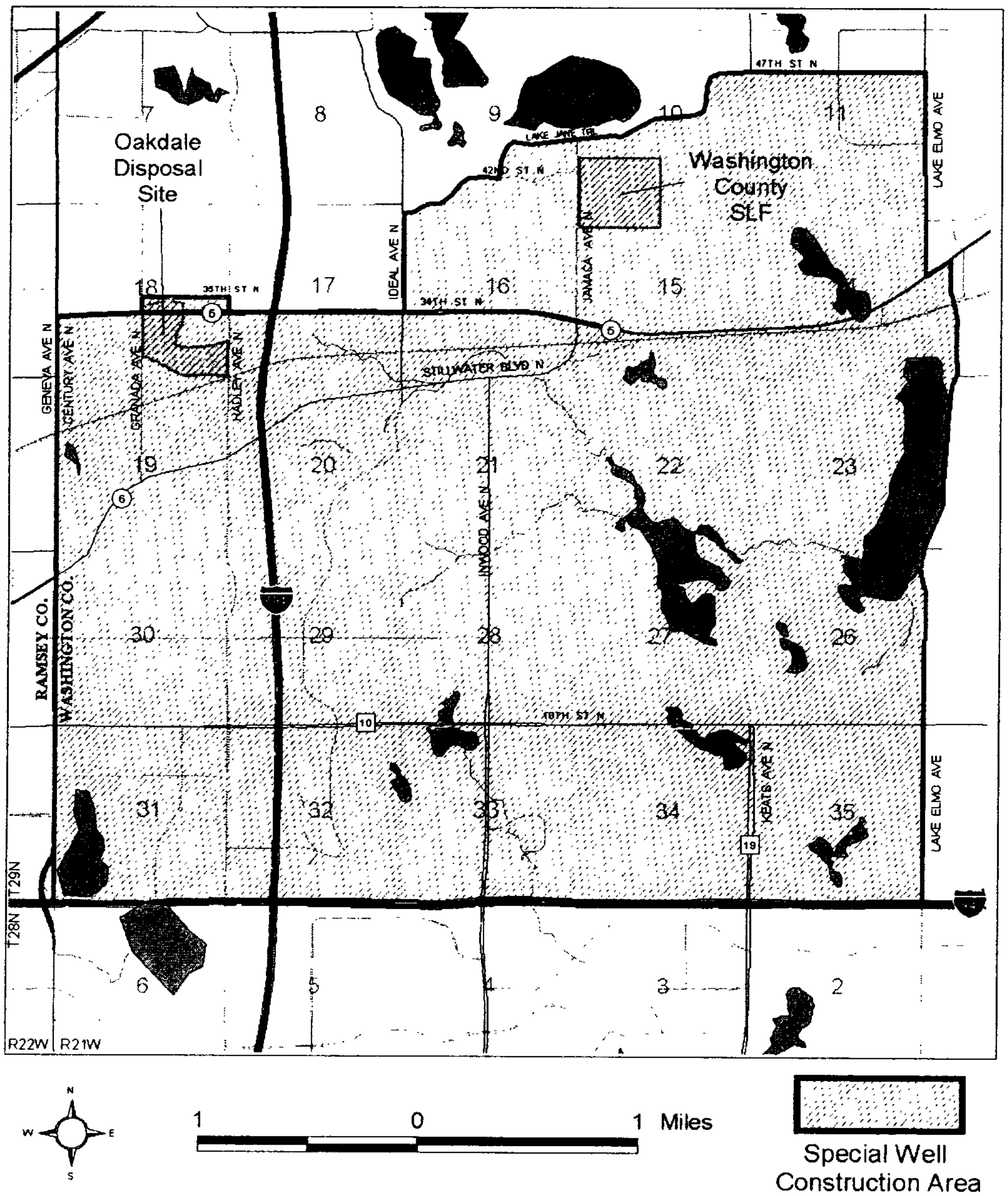
**Figure 1**

Special Well Construction Area
Lake Elmo - Oakdale
Washington County

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## Figure 2

## Lake Elmo / Oakdale Stratigraphy