Assessment of Chemical Contamination of Flooded Wells in Southeast Minnesota

Flooded Well Testing Project Report

Minnesota Department of Health

June 20, 2008

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Executive Summary

Following the record flooding in southeast Minnesota in August 2007, the Minnesota Legislature appropriated funds to conduct expanded testing of flooded wells found to be contaminated with bacteria. In response, the Minnesota Department of Health (MDH), with support from the Minnesota Department of Agriculture (MDA), initiated a special project to test flooded public and private wells in seven counties (Dodge, Fillmore, Houston, Olmsted, Steele, Wabasha, and Winona) for chemical contaminants. Eighty (80) wells were known to have been impacted by floodwater. All 65 wells that were available for testing, were tested for nitrate, chloride, disinfection by-products, volatile organic chemicals (VOCs), and selected pesticides and pesticide breakdown products.

Test results indicated that chemical contamination of wells that may have been due to floodwater was generally minimal and short-lived. Twenty-one of the 65 tested wells contained nitrate at more than 1 milligram per liter (mg/L) as nitrogen. Four wells (approximately 6 percent) exceeded the state Health Risk Limit (10 mg/L) for nitrate-nitrogen, which is consistent with statewide data on nitrate occurrence in groundwater. Chloride, a possible indicator of road salt, animal wastes, or septic systems, exceeded 20 mg/L in ten wells. No well exceeded 250 mg/L, the aesthetic limit for chloride in drinking water.

Thirty-one of the 65 tested wells contained at least one disinfection by-product, most commonly chloroform, with 21 of these 31 wells having levels less than 1 microgram per liter (µg/L). The ten wells having more than 1 µg/L were re-sampled within six weeks, and all the follow-up samples had significantly lower levels, ranging from not detected to 7.9 µg/L (the Health Risk Limit for chloroform is 60 µg/L). Ten of the 65 tested wells contained at least one volatile organic chemical (VOC), common components of fuels and cleaners, usually at levels less than 1 µg/L. Confirmation re-samples typically contained lower levels of VOCs than the initial samples.

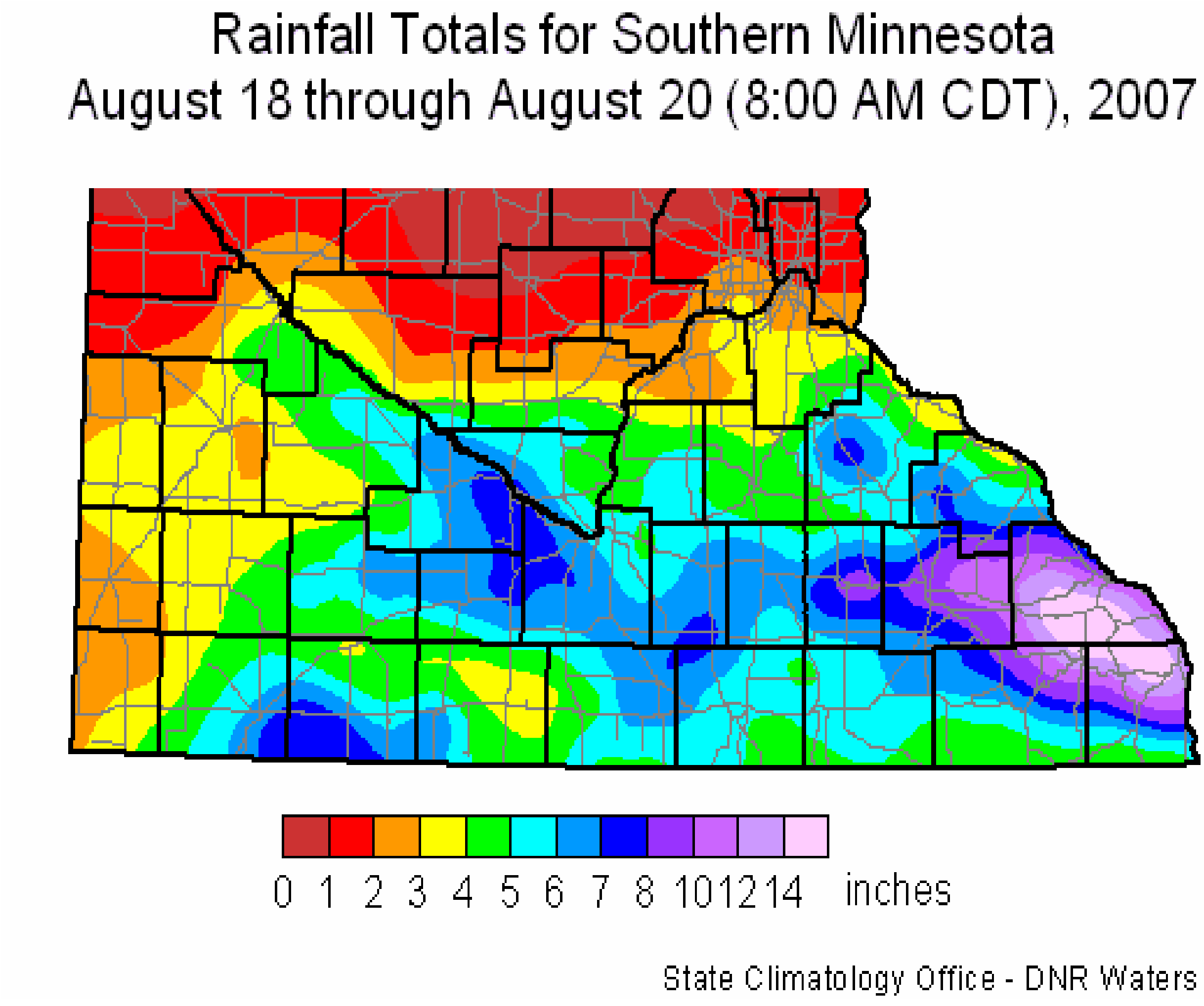
Twenty-one of the 65 tested wells contained at least one pesticide or pesticide breakdown product, most at levels below 1.0 µg/L. Re-samples collected within six to eight weeks confirmed most of these initial pesticide detections at similar levels, suggesting ongoing low-level pesticide contamination of the aquifer, rather than flood impacts.

All well owners were provided copies of their test results, and given individual consultations on the meaning of the test results and any further actions that might be recommended.

Introduction and Background

Following the record flooding that occurred in southeast Minnesota in August 2007 (see Figure 1), the MDH Well Management Program and the MDH Public Health Laboratory immediately implemented a prepared program to provide free well water testing to flood victims. Working closely with county and local responders, MDH ultimately tested over 1,900 wells for bacterial contamination. Each well owner was provided the test results and individual technical assistance when a well was found to be bacterially unsafe.

Figure 1



Also in response to the flooding, the Minnesota Legislature, in Minnesota Session Laws 2007, First Special Session, Chapter 2, Article 1, Section 9, Subdivision 3, appropriated $1,000,000 for capacity building grants, including, " . . . the costs of additional testing of wells where bacteria has been found." In response to this legislation, the MDH initiated a special project to test flooded public and private wells in the seven counties included in the Presidential Declaration of Major Disaster (Dodge, Fillmore, Houston, Olmsted, Steele, Wabasha, and Winona) for chemical contaminants most likely to occur in floodwaters.

Identification of Wells to be Sampled

As part of the MDH prepared program to test flooded wells for bacteria, MDH staff had contacted the owner of each well found to be bacterially contaminated, recorded whether the well had actually been flooded, and provided technical assistance to help the well owner take appropriate corrective actions. Working off this list, MDH offered additional chemical testing to the 70 owners of known flooded wells who could be reached (10 others could not be reached). Sixty-five private well owners ultimately agreed to additional testing of their wells. The locations of the sampled wells are shown in Figures 2 and 3.

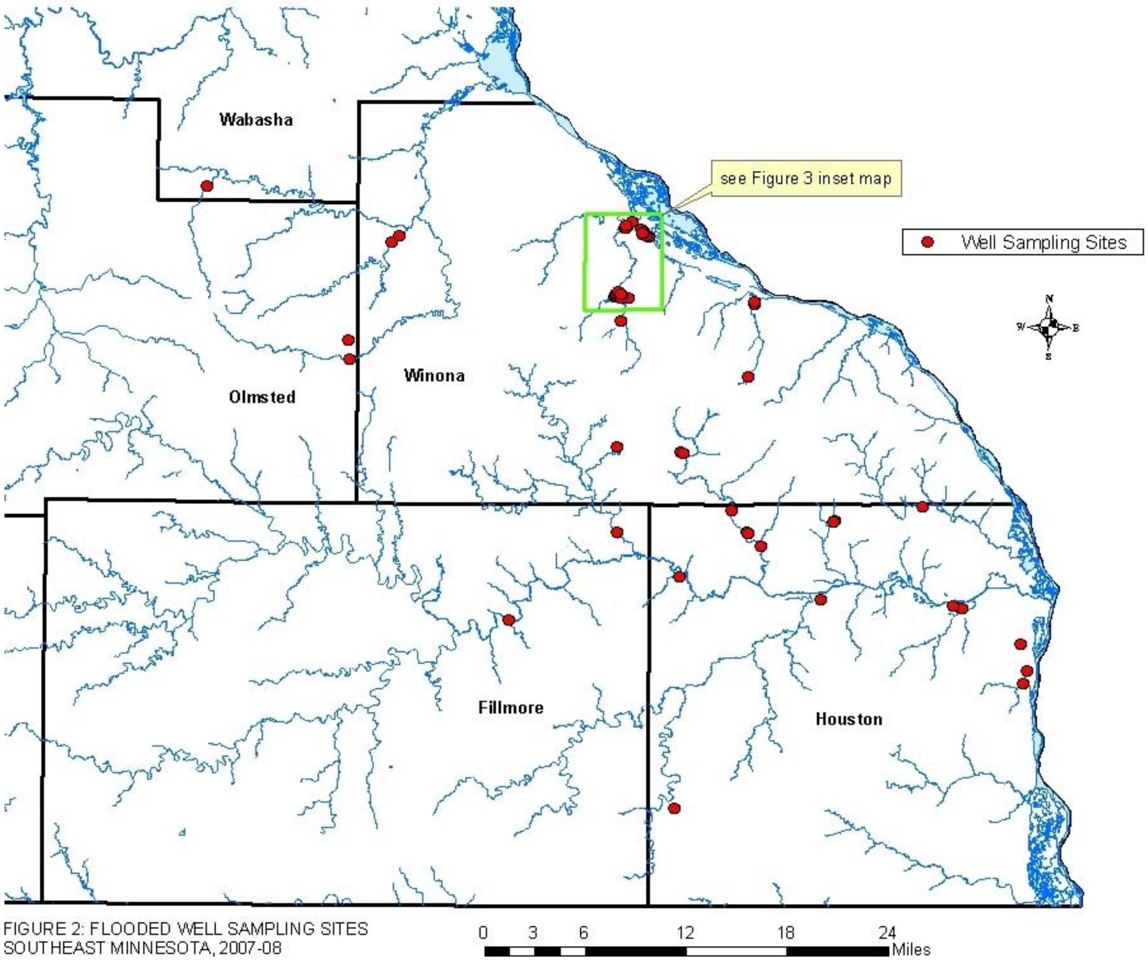


FIGURE 2: FLOODED WELL SAMPLING SITES
SOUTHEAST MINNESOTA, 2007-08

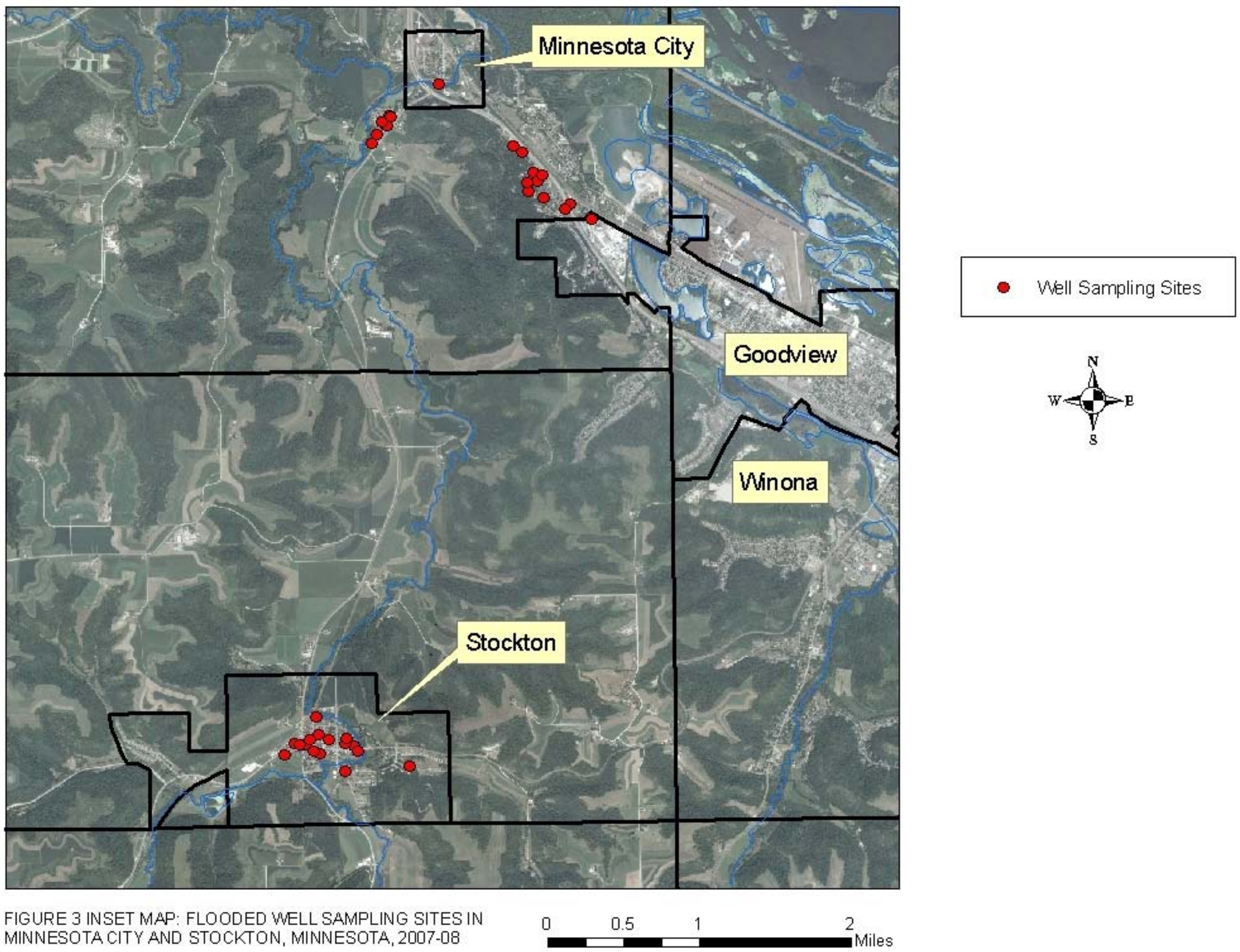


FIGURE 3 INSET MAP: FLOODED WELL SAMPLING SITES IN MINNESOTA CITY AND STOCKTON, MINNESOTA, 2007-08

It should be noted that the selection of the wells to be tested for this project was not based upon a scientifically-designed selection process, but was instead based solely on the unique set of conditions that caused each of the tested wells to become flooded. Therefore this project cannot be viewed as a scientific *study* of groundwater contamination, but rather as simply an *assessment* of the impacts of this specific flooding event upon the specific wells that were flooded.

Establishment of Chemicals to be Tested and Laboratories to Perform the Analyses

In September 2007, MDH convened an inter-agency workgroup of staff of MDH, MDA, and the Minnesota Pollution Control Agency (PCA) to develop a list of contaminants most likely to occur in floodwaters, and to divide the responsibilities for sample analysis between the MDH and the MDA laboratories. Where appropriate, the laboratories selected methods approved by the U.S. Environmental Protection Agency (EPA) for analyzing contaminants in drinking water samples. The following chemicals, methods, and laboratories were selected for analysis:

- Nitrate – EPA Method 353.2. MDH Public Health Laboratory.
- Chloride – EPA Method 325.2. MDH Public Health Laboratory.
- Volatile Organic Chemicals (VOCs) (69 analytes - EPA Method 524.2). MDH Public Health Laboratory.
- Pesticides, Base Neutral (30 analytes) – EAW Monitoring Neutrals. MDA Laboratory.
- Selected Pesticide Breakdown Products – EAW Chlorodegradates. MDA Laboratory, and the University of Wisconsin–Stevens Point Environmental Laboratory.

Sample Collection and Analysis

Well sampling began on November 19, 2007, and all sampling was completed by March 18, 2008. Staff of the MDH Rochester District Office scheduled appointments with well owners, completed a well information survey, collected and preserved the water samples according to established procedures, completed laboratory forms, and arranged for shipment of samples to the respective laboratories.

Samples were shipped on ice to the designated laboratories, preserved as specified by the standardized methods, and stored at 4 º C prior to analysis. The time from collection to laboratory receipt ranged from one to four days. All samples were analyzed within the method-specified maximum holding times between sample collection and sample extraction and sample analysis. The analytical work conformed to the quality assurance and quality control limits established for the specific instruments, methods, and analytical parameters. The laboratories established reporting levels for each chemical contaminant, which is an assessment of the lowest concentration of the chemical that can be reliably measured within specified limits of precision and accuracy. The reporting level for chloride was 1.0 milligram per liter (mg/L) and for nitrate was 0.05 mg/L (reported as nitrogen). The reporting levels for the other contaminants are listed in Tables 1 and 2.

Confirmation re-samples were collected, usually within six to eight weeks, from selected wells for nitrate and chloride, from all wells found to have disinfection by-products greater than 1.0 µg/L, and from all wells with detected VOCs, pesticides, or pesticide breakdown products.

All well owners were provided copies of their test results, and given individual consultations on the meaning of the test results and any further actions that might be recommended.

Results and Discussion

Floodwaters typically contain high numbers of bacteria and viruses, and may contain a variety of chemical contaminants at widely varying concentrations. The Minnesota Well Code (Minnesota Rules, Chapter 4725) requires all new wells to be “grouted,” that is, sealing the space between the well casing and the bore hole with an approved grout material such as cement or a slurry of special clay and water. The well casing (pipe) must be terminated at least 1 foot above grade (more if the well is in a floodplain), and the well casing must be fitted with a vermin-proof well cap or seal. All these requirements help to minimize the impacts of floodwater on the well, and will help to keep out large quantities of sediment and debris. Nevertheless, in order for wells to function properly, they must “breathe,” so even brand new, properly constructed wells are not airtight at the top. Therefore, if a wellhead is submerged under floodwater, the well is likely to become contaminated with bacteria and viruses.

In situations where there is time to prepare for an impending flood, well owners are often advised to take additional precautionary steps, such as turning off the power to the well and protecting the well head, including taping a sturdy plastic bag around the wellhead before leaving the property. This helps to further protect a properly constructed well from significant sediment intrusion, and makes disinfection of the well easier when it is ready to be returned to service.

It should be noted that the Minnesota Well Code (Minnesota Rules, Chapter 4725) was first enacted in 1974, and it is estimated that approximately one-third of all existing wells in the flooded area were constructed prior to 1974. Due to variability in original construction and deterioration over the years, many of these older wells are more vulnerable to flood impacts than newer wells that comply with the location and construction requirements of the Well Code. The flooded wells sampled for this project ranged from shallow “drive point” wells located in basements or “well pits” and completed in a shallow sand aquifer, to deep rock wells that are terminated above the ground surface with a vermin proof cap, and are cased and cement-grouted into a deep rock aquifer. Most of the wells sampled during this project, however, were less than 150 feet in depth, and completed in a surficial sand aquifer or a sandstone aquifer just below the surficial sands.

After a flood, wells and household plumbing systems are typically disinfected with a strong solution of chorine bleach prior to placing them back into service. If the well cap was broken or missing, or if the top of the well was damaged, the well will likely have some sediment or debris that will need to be removed (well pumps can be damaged if they are started before the sediment is removed). To do this, the well must be physically bailed out, or more commonly today, the well is “blown out” by a well contractor using a large air compressor. This cleaning activity also serves to remove significant amounts of any contaminants that may have entered the well with floodwater. After a well is cleaned out and disinfected, it is typically pumped for an extended period of time to remove excess chlorine and further clear the well of floodwater contaminants. After this process is completed, the well should be tested for bacteria and proven safe to drink before the water is again consumed.

Occurrence of Nitrate: Nitrate is a common indicator of impacts of fertilizers, animal wastes, or septic systems. Nitrate levels in Minnesota groundwater vary by location and aquifer, and are dependent upon a variety of factors, including local geology, hydrology, and land use. The natural background concentration of nitrate (as nitrogen) in Minnesota groundwater is usually 1 milligram per liter (mg/L) or less.

Twenty-one of the 65 tested wells contained more than 1 mg/L nitrate (as nitrogen), and four wells exceeded the state Health Risk Limit of 10 mg/L. One milligram per liter is the same as 1 part per million. Follow-up samples for nitrate were taken from the four wells that exceeded the state Health Risk Limit. All four results were still elevated, with one well remaining in the high teens (17-19 mg/L) and the other three wells between 7.1 and 8.5 mg/L. Nitrate levels in wells that had been flooded were similar to nitrate levels reported for wells in the area prior to the flood event. These findings all indicate that the observed nitrate levels in the flooded wells were largely due to ongoing contamination of the aquifer by nitrate, and not the flooding.

Occurrence of Chloride: Chloride is a common indicator of contamination by road salt, animal wastes, or septic systems. There is no health-based standard for chloride, but there is an aesthetic standard of 250 mg/L, based on the ability of chloride to impart a salty taste to water. According to reports by the Minnesota Pollution Control Agency, the median background level of chloride in Minnesota groundwater is 2.4 milligrams per liter (mg/L).

Ten of the 65 water samples contained chloride at levels greater than 20 mg/L. The highest level found in any sample was 150 mg/L. Eight of these ten wells were re-sampled, and chloride levels dropped considerably in five wells, remained similar to the initial result in two wells, and increased from 59 mg/L to 97 mg/L in one well.

The well that contained 150 mg/L chloride in the initial sample also contained 150 mg/L chloride in the follow-up sample. This well is a flowing well most likely constructed into the protected “Mount Simon” sandstone aquifer. Because it is unlikely that floodwater entered a flowing well that contains water under positive pressure, the chloride level in this well is likely representative of the level of chloride in the aquifer.

The well that increased from 59 mg/L in the initial sample to 97 mg/L in the follow-up sample is a well located along Highway 61, a four lane major highway. Because this well had no detectable pesticides, pesticide breakdown products, or VOCs, and has a reasonably low nitrate level of 2.6 mg/L, the source of chloride in this well is probably road salt.

Occurrence of Disinfection By-products: Disinfection by-products can be created by the reaction between a water disinfectant (usually chlorine) and organic matter in the water. The initial water samples collected from 31 of the 65 tested wells contained measurable disinfection by-products, most commonly chloroform, with 21 of these 31 wells having levels less than 1 microgram per liter (µg/L). One microgram per liter is the same as 1 part per billion. The occurrence of disinfection by-products in these wells was not unexpected, as they had all been recently disinfected with strong solutions of chlorine bleach. Since these wells are not continuously chlorinated, disinfection by-products should dissipate over time.

All ten wells with disinfection by-products exceeding 1 µg/L were re-sampled. Four of the ten wells no longer contained chloroform, five wells showed significant decreases in chloroform levels, and one well had similar chloroform levels in both samples (8.0, 7.9 µg/L). The only sample result (100 µg/L of chloroform) that initially exceeded a health limit (60 µg/L) for a disinfection by-product proved to be from an unused and un-flushed water line that still contained a strong residual of chlorine bleach. The chloroform level in the follow-up sample from this well was 0.4 µg/L.

Occurrence of VOCs: Volatile organic chemicals (VOCs) are common components of fuels, cleaners, and solvents, and they can occur in floodwater. Once wells are cleaned out and flushed, VOCs that were introduced with floodwater should be eliminated over time.

The initial samples from 10 of the 65 tested wells contained at least one VOC, usually at a low level of less than 1 µg/L. Follow-up samples were collected from nine wells, the tenth well having been sealed and replaced with a new well. Of these nine wells, four wells no longer contained any detectable VOCs, two wells still contained low levels of several VOCs, two wells still contained a low level of one VOC, and one well contained a low level of a different VOC, toluene (see Table 1). Toluene was found in a total of six wells throughout the project, in either the initial and/or follow-up sample. The source of the toluene may have been a cleaner used to clean the electrical connections on some replacement pumps installed after the flood, or the electrical tape used to secure the electric wire to the pump piping within the well.

The initial sample from one well contained ten VOCs, including carbon tetrachloride at 17.0 µg/L, which exceeds the corresponding Health Risk Limit of 3 µg/L. This sample was taken from the same un-flushed waterline discussed previously. The follow-up sample for this well showed no remaining VOCs, other than a trace of tetrahydrofuran.

The two wells that still contained low levels of several VOCs in the follow-up samples were completed in shallow sand aquifers, and located in or very near industrial areas. Thus, it is again likely that this contamination represents low-level background contamination of a shallow aquifer, rather than flood impacts.

Table 1. Occurrence of Volatile Organic Chemicals (VOCs)

Well	VOC	Minimum report level (µg/L)	Level in Sample 1 (µg/L)	Level in Sample 2 (µg/L)	Health-based limit (µg/L)
Well 1	Toluene	0.5	59.0	3.9	1000
Well 2	Methylene Chloride	0.5	0.7	Not detected	5
Well 3	Methylene Chloride	0.5	1.3	Not detected	5
Well 4	Trichloroethene (TCE)	0.1	0.4	Well Sealed	5
Well 5	Trichloroethene (TCE)	0.1	0.2	Not detected	5
Well 6	Methylene Chloride	0.5	1.3	Not detected	5
	Toluene	0.5	Not detected	2.1	1000
Well 7	Ethylbenzene	0.5	0.5	Not detected	700
	Toluene	0.5	0.3	Not detected	1000
	1,2,4-Trimethylbenzene	0.5	0.3	Not detected	300
	o-Xylene	0.2	0.5	Not detected	10,000
	p&m-Xylene	0.3	1.5	Not detected	10,000
Well 8	1,2-Dichlorobenzene	0.2	1.4	2.3	600
	1,3-Dichlorobenzene	0.2	0.1	1.0	600
	1,4-Dichlorobenzene	0.2	0.6	1.0	10
	Methylene Chloride	0.5	0.3	Not detected	5
	Trichloroethene (TCE)	0.1	1.8	0.6	5
Well 9	Carbon Tetrachloride	0.2	0.3	Not detected	3
	Methylene Chloride	0.5	0.3	Not detected	5
	Toluene	0.5	0.2	Not detected	1000
	o-Xylene	0.2	2.0	2.2	10,000
	p&m-Xylene	0.3	0.5	0.6	10,000
Well 10	Acetone	20	21	Not detected	700
	Benzene	0.2	0.8	Not detected	5
	Bromomethane	1.0	4.8	Not detected	10
	Carbon Tetrachloride	0.2	17	Not detected	3
	Chloromethane	1.0	49	Not detected	No value
	1,1-Dichloroethene	0.2	0.5	Not detected	6
	Methylene Chloride	0.5	0.49	Not detected	5
	Tetrachloroethene	0.2	0.9	Not detected	5
	Tetrahydrofuran	10	Not detected	0.5	100
	Trichloroethene (TCE)	0.2	0.7	Not detected	5

Occurrence of Pesticides and Pesticide Breakdown Products: In the initial samples, 21 of the 65 tested wells contained at least one pesticide or pesticide breakdown product, most at levels below 1 µg/L. The most common pesticides and pesticide breakdown products respectively were desethylatrazine, atrazine, alachlor ESA, and metolachlor ESA. The highest level of a single pesticide or breakdown product in any sample was 4.10 µg/L. No health limit was exceeded in any sample. Follow-up samples were collected from 20 of these 21 wells, one well having been sealed and replaced. Eighteen of those 20 re-tested wells still contained pesticides or pesticide breakdown products, at levels similar to the initial levels. Table 2 lists the pesticides and pesticide breakdown products that were confirmed in two successive samples.

The presence of low levels of pesticides in both the initial and follow-up samples suggests the presence of low levels of pesticides in some surficial and shallow rock aquifers in southeastern Minnesota, rather than flood impacts.

Table 2. Confirmed Detections of Pesticides in Two Successive Samples

Pesticide	Number of Wells With Confirmed Detection	Minimum Report Level (µg/L)	Highest Level Reported (µg/L)	Health-based Limit (µg/L)
Acetochlor Breakdown Product	2	0.07	0.82	50
Alachlor Breakdown Product	6	0.07	1.89	40
Atrazine and/or Atrazine Breakdown Product	17	0.05 - 0.2	0.39	3
Metolachlor Breakdown Product	6	0.07	4.10	1000-2000

Conclusions

1. Chemical contamination of wells that was likely caused by the intrusion of floodwater was generally minimal and short-lived. VOC levels in re-samples decreased dramatically in most wells, suggesting that the initial contamination, while low in most cases, was due either to floodwater intrusion or the use of solvent cleaners during pump replacement. Chloride levels in five wells decreased significantly in the re-samples, suggesting possible floodwater impacts on those five wells. The typical actions necessary to restore flooded wells to service, including bailing, blowing with compressed air, and extended pumping, remove of much of the chemical contamination that may have occurred. As wells are placed back into service and used regularly, contaminant levels due to flooding continue to decrease.

2. Contaminant levels that did not change significantly in the six to eight weeks between the initial and confirmation samples suggest background contamination of the aquifers supplying water to the wells, rather than direct contamination of the wells by floodwaters. When nitrate and/or pesticides were found in a well, the levels were usually similar in both the initial sample and the confirmation sample. Pesticide levels found in all wells were quite low, usually less than 1 µg/L, with the highest single reported level being 4.10 µg/L.

3. It is important that owners of flooded wells have their wells thoroughly flushed, or pumped for an extended period of time, prior to placing them back into service. Failure to adequately flush a flooded well and the connected household plumbing system can result in higher contaminant levels in the water. This was demonstrated by the contaminant levels found in the system that was not yet in use and had not been thoroughly flushed.