GROUND WATER BACTERIAL INVESTIGATION IN THE MILFORD VALLEY

1998-1999

Prepared for the
Milford Valley Ground Water Steering Committee
by

Utah Department of Environmental Quality
Division of Water Quality

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Introduction

In the fall of 1998, the Department of Environmental Quality (DEQ) and the Southwest Public Health Department began receiving verbal and written reports from residents in the area referred to as Milford Flats, that bacteria was present in samples of water taken from residential drinking water wells. Milford Flats is an area south of the town of Milford in Beaver County, Utah. A Ground Water Steering Committee was formed in response to these reports. This committee is comprised of many state, federal and local agencies and area residents. This committee defined the objectives for this study and participated in the investigative effort. This document summarizes the DEQ lead effort to determine the cause of the problem. The primary investigative effort for DEQ has been coordinated by the Division of Water Quality, whose role it is to protect the Quality of Utah's water resources, which includes ground water. This document was prepared for and will be presented to the Ground Water Steering Committee for their review.

Recent Activities

Formation of a Local Ground Water Steering Committee

Subsequently to these reports a local Ground Water Steering Committee was formed with the objectives to “identify the sources and solve the bacteria and nitrate problem in our ground water resources” and “to have a comprehensive ground water study in the Milford Valley which would include ground water quality, velocity rates and flow directions”. The Committee has met since the fall of 1998, discussing items pertaining to these objectives. Identified potential sources of bacteria include: Hay Springs diversion; abandoned wells; poor well construction; septic tanks; fertilizer and land-use; livestock operations; Circle 4 Farm back-flow incident and lagoon leakage; and the effects of pumping irrigation wells. Presentations to the Committee have been made on Circle 4’s Drinking Water Systems and project proposal presentations have been made by the University of Utah and Brigham Young University.

Clean Water Act Funding, Section 319

The Non-Point Task Force is made up of representatives from the DEQ, Utah Department of Agriculture, USGS, NRSC, Farm Service, Utah State University, Bureau of Reclamation, Salt Lake County, Bureau of Land Management, Utah Association of Conservation Districts and several other state and federal agencies. In the fall of 1998 the Utah Non-Point Task Force approved $48,000 for studies on the above objectives in the Milford Valley. A minimum forty percent, 40%, match of non-federal funds is required to expend this 319 grant. This match requirement would consist of $32,000 of either State or local in-kind services or capital.

Monitoring Efforts and Data Analysis

The Department of Environmental Quality collected samples for analyses during the months of December 1998 and January, and February 1999 in the Milford Valley. Samples were collected from: twenty-five private wells; the Beaver River and associated canals; Circle 4 lagoons, shallow monitoring wells, and deep water supply wells. The State Health Laboratory provided the sample analyses for the detection of total nitrate plus nitrite, ammonia, total coliform, fecal coliform and fecal strep. Additionally, the following four analytical steps on cultured samples of the microorganisms were conducted.

1. The first type of analysis was to identify all of the organisms from samples submitted from wells, Circle 4 sewage lagoons, the Beaver River that flows through the Town of Minersville north through Milford Flats and the Trans River Canal and Low Line Canal, Table 1. The results of this analysis are:

   Twenty (20) of the twenty four (24) drinking water wells sampled in December 1998 were positive for total coliforms. The coliforms isolated from the wells included the following organisms: *Enterobacter cloacae, Citrobacter freundii, Enterobacter agglomerans, Klebsiella ozonea, Enterobacter amnigenus, Serratia plymuthica, Citrobacter farmeri, Serratia fonticola, Rahnella aquaticus, Citrobacter braakii, Hafnia alvei, Serratia liquefaciens, Enterobacter intermedius,* and *Enterobacter cancerogen*. None of these organisms are considered pathogenic in immunocompetent people. Only one well contained organisms considered to be a fecal coliform, *E. coli*. This organism is rarely pathogenic in humans, but is considered a possible indicator of fecal contamination of water. The drinking water wells tested positive for the presence of fecal streptococcus in nine (9) wells. The following streptococcus-like organisms were isolated from these tests*: Enterococcus gallinarium, durans, faecium,* and *faecalis*.

   The only organisms from the total coliform tests that were able to be isolated from the Circle 4 (four) sewage lagoon samples were *E. coli*. No Enterobacter, Citrobacter, Serratia, etc. species were found in the sewage lagoon. However, *Enterococcus durans* and *faecalis* were identified from the fecal streptococcus tests.

   The samples from the Beaver River/canal system were also analyzed. From the total coliform tests the following organisms were identified: *Serratia fonticola, Enterobacter amnigenus,* and *Rahnella aquaticus*. Additionally, in the fecal coliform test *E. coli* organisms were isolated and from the fecal streptococcus test *Enterococcus gallinarium, durans,* and *faecium* were isolated.

   The results of this analysis were inconclusive in determining the source of bacteria. The organisms of *E. coli* and the fecal streptococcus *Entercoccus durans* were found in common to the wells, sewage lagoons and Beaver River/canal system. Common organisms only to wells and the Beaver River/canal system included *Enterococcus gallinarium,,* and *faecium* from the fecal streptococcus test and from the total coliform identified common organisms of *Serratia fonticola, Enterobacter amnigenus,* and *Rahnella aquaticus*. Common organisms only to wells and the sewage lagoons included the fecal streptococcus organisms of *Enterococcus durans* and *faecalis*. **While this test identified the coliforms and fecal streptococcus-like organisms present, their variation in presence among the wells, sewage lagoons and Beaver River/canal system proved not sufficient in determining the source of bacteria.**

2. The second analysis was in retesting most of the drinking water wells following a sodium hypochlorite (Chlorox) decontamination of the wellheads. Twenty (20) previously positive wells were retested in January 1999. Of those twenty (20), eighteen (18) showed a significant decrease in total coliform and fecal streptococcus counts following the decontamination. Only five (5) residential wells still contained bacteria, and only two (2) of

them had significant numbers of bacteria. According to information provided to DEQ, only one (1) of those two (2) wells had been decontaminated. There was no residual chlorine in any of the samples.

This result is not consistent with what would be expected if ground water was contaminated with bacteria. Wellhead decontamination would only remove bacteria present as a biofilm in the pipes of the well. Had the ground water truly been contaminated, the number of wells showing bacteria present before and after wellhead decontamination would not have changed. This result is most consistent with wellheads being contaminated with organisms (notably Klebsiella, Citrobacter, and Enterobacter) which are known to persist in biofilms. **The combined results from step one (1), identified types of organisms present, and from step two (2), absence of organisms after decontamination, strongly suggest that the wells have a biofilm contamination problem. The results do not indicate that there is a ground water bacterium problem.**

3. The third step was to perform molecular fingerprinting analysis on the isolates obtained in step 1 above. Molecular fingerprints would show if two organisms are closely related. In this study, it was hoped to determine if the fecal streptococci or E. coli from the drinking water wells, the sewage lagoons, or the river/canal were related.

   All isolates of the following organisms were subjected to this third analysis: *Enterococcus faecium, durans, faecalis, gallinarium; Serratia fonticola, E. coli, Enterobacter amnigenus, Rahnella aquaticus.*

   Three isolates of *Enterococcus durans* matched; all three isolates were obtained from different sites in the canal/river. No other isolates of this organism matched each other. Two isolates of *Enterococcus gallinarium* matched; both were isolated from the same private well collected on different dates. **There were no isolates in the wells that matched any isolates in either the Beaver River/canal system or the lagoons.**

   The ability to identify matches from the same vicinity would seem to validate this procedure. **The inability to identify matches from the private wells and either the sewage lagoons or the Beaver River/canal system does not support the hypothesis that either of these sources contributed to the contamination found in the private wells.**

4. The fourth analysis was to perform the procedure for discriminant analysis of antibiotic resistance profiles of fecal streptococci as developed at James Madison University. In this procedure all isolates of enterococci were plated with several different antibiotics. Plates were scored for growth by marking the highest concentration of each antibiotic upon which the organisms could grow. The results were:

   For *Enterococcus durans*, the isolates from the Circle 4 sewage lagoons were significantly more resistant to the antibiotics than the organisms from the river or private wells.

   For *Enterococcus faecalis*, the isolates from the Circle 4 sewage lagoons were significantly more resistant to the antibiotics than the organisms from the river or private wells.

   For *Enterococcus faecalis* and *gallinarium,* as well as for *durans* and *faecalis*, there is no difference in the resistance patterns found from isolates in the wells versus the river/canal.

DATA SAMPLING ANALYSIS
TABLE 1

Well/Site 0 Number	Dec. 1 & 2, 98' T C	F C	F S	NC	Nitrate	Dec. 10 & 11, 98' T C	F C	F S	NC	January 12, 99' TC	FC	FS	Chlorinated	Surfactant (mg/L)	Caffeine (ug/L)	Nitrate (mg/L)	January 26, 99' Surfactant (mg/L)
1	<4	<4		<2	0.23	0	0	0		0	0	0	no			0.231	
2	36	<4	58	>200	<0.1	3.1	0	8		0	0	0	12/17/98	<0.015	<0.02	<0.1	
3	<4	<4	8		0.27	40.6	0	3		0	0	0	12/23/98	<0.015	<0.02	0.308	
4	<4	<4	<2	>200	1.45	0	0	0		0	0	0	12/5/98			1.33	
5	4	<4	<2		1.11	7.5	0	>200		0	0	0	12/5/98	0.064	<0.02	1.05	
6	4	<4	<2		<.01	0	0	0		0	0	0	unknown			<0.1	
7	<4	<4	<2		0.25	9.9	0	0		0	0	0	12/5/98			0.251	
8						201	0	0		27	0	0	no			0.897	
9	<4	<4	<2	>200	4.92	40.6	0	4		0	0	0	no	0.038	<0.02	5.51	
10	<4	<4	<2		1.33	201	0	>200		0	0	0	12/5/98	0.022	<0.02	3.78	
11						6.4	0	1		0	0	0	12/5/98			3.54	<0.015
12	<4	<4	<2		2.2	1	0	0		0	0	0	unknown			<0.1	
13	<4	<4	<2	>200	5.26	25.4	0	4		0	0	0	½/99	0.048	<0.02	4.77	
14	<4	<4	<2		0.99	3.1	0	0		0	0	0	12/12/98	<0.015		0.87	
15	<4	<4	2	>200	4.95	8.7	0	0		0	0	0	no		<0.02	5.94	<0.015
16	<4	<4	<2		0.01	0	0	0		0	0	0	no	<0.015	<0.02	<0.1	
17						1	0	0		0	0	0	no			5.84	
18	<4	<4	<2		2.84	11.1	0	5		2	0	0	12/2/98		<0.02	3.05	<0.015
19						17.8	0	0		0	0	0	no			0.232	
20	<4	<4	<2		0.21					0	0	0	no			1.37	
21	<4	<4	4		4.5	12.4	0	0		0	0	0	no	<0.015	<0.02	4.22	
22	100	<4	<2		0.38	201	0	0		201	0	0	no			0.225	
23	<4	<4	<2		0.43	1	0	0		0	0	0	no			0.471	
24	460	<4	2		2.72	165	6.4	3		12	0	2	12/23/98	<0.015	<0.02	2.84	
25	32	<4	<2	>200	0.29	201	0	0		201	0	0	12/23/98			0.202	

* see footnote for abbreviations on page 7

DATA SAMPLING ANALYSIS (Con't)

TABLE 1

Well/Site		Dec. 1 & 2, 98'					Dec. 11 & 12, 98'				January 12, 99'		
Number	Well Name	T C	F C	F S	NC	Nitrate	T C	F C	F S	NC	TC	FC	FS
36	Beaver River At Minersville						1100	10	20		112	INDT*	18
37	Lowline Canal						64000	14900	1080		90	4	640
38	Beaver River above landfill						1100	10	520		10	2	150
39	Trans Canal above Beaver												
41	Beaver River @ Rollins										40	<10	110
42	Beaver River at Milford Flats										20	<10	700
43	Beaver River North Walker										60	20	680
44	Beaver River @ U-130 Minersville										250	240	970
45	Beaver River @ Milford										60	<10	320
46	Beaver River below Landfill										<10	10	170
51	Skyline Ranch Well #4						0	0	0				
52	Skyline Ranch Well						0	0	0				
53	Skyline Ranch Well #3						40.6	0	2				
	CFF 102 MU						0	0	0				
	CFF 102 MD2						0	0	0				
	CFF203 MU						200.5	0	0				
	CFF 203 MD						200.5	0	0				
	CFF 103 MU						0	0	0				
	CFF 103MD2						0	0	0				
	CFF Lagoon 102p	1400000	840000	0									
	CFF Lagoon 102s	28000	12000	15000									
	CFF Lagoon 202p	930000	55000	1100000									
	CFF Lagoon 202s	<1000	<1000	13000									
	CFF Lagoon 302p	450000	43000	94000									

*TC = Total Coliform (counts per 100 ml.)

*FC = Fecal Coliform (counts per 100 ml.)

*FS = Fecal Strep (counts per 100 ml.)

*NC = Non Coliform Bacteria (counts per 100 ml.)

*CFF Circle Four Farm

Nitrate data given in mg/l

*INDT=Unable to quantitate

This data therefore does not support the theory that the organisms in the private wells originated at the Circle 4 sewage lagoons. This data does not differentiate the organisms from the river versus those from the private wells.

5. The fifth procedure was to perform analysis for caffeine and surfactants in the private wells. The analysis found no caffeine detected above the 0.02 ug/L detection level in any of the water samples, see Table 1. The GC/MS method used for the analysis had a detection level of 0.02 ug/L (20 parts per trillion). Caffeine is a chemical that has been used as a marker to determine if contamination of ground water is of human origin. The detection of caffeine in ground water may indicate contamination of the water from septic tank systems. Caffeine is a weakly basic alkaloid that may have a tendency to "stick" to finer grained and organic rich sediment. It is a nitrogen containing compound and may be subject to metabolism by bacteria in the anaerobic septic tank or aerobic leach field. Caffeine amounts in a cup of coffee or tea range from 40-100 mg, and in cola drink between 35-55 mg. The metabolism of caffeine in humans is extensive. Only about 1% is excreted unchanged. In one study of 85 coffee drinkers, it was found that urinary caffeine concentrations averaged about 5.8 mg/L. Considering the levels that are excreted and the dilution that would occur in the septic tank and ground water the amount of caffeine that could be present would be extremely low. The State Health Laboratory analyzed 2.5 liters of ground water from each of eleven wells in Milford Valley. The extraction process involved concentrating the samples 25,000 fold.

   Analysis of water samples for caffeine did not produce results that would suggest bacteria were from septic tank systems. However, the absence of caffeine above the detection level is not conclusive by itself in ruling out contamination of ground water from the septic tank systems.

   Surfactants such as alkylbenzene sulfonate type $[RSO_3]^- Na^+$ (LAS), the sulfate ester type $[ROSO_3]^- Na^+$, and sulfated nonionics $[REnOSO_3]^- Na^+$ are commonly found in detergent formulations. Some of these chemicals may pass through the septic tank system and enter ground water. The detection of surfactants in ground water might be an indicator for septic contamination of the aquifer. Surfactants are detected by conducting analysis that measure methylene blue active substance (MBAS). The minimum detection level for MBAS is 0.015 mg/L (15 parts per trillion).

   The analysis found four (4) of fourteen (14) water samples collected from Milford Flats wells during January 1999 had detectable levels of surfactant. The surfactant levels ranged from 0.022 to 0.064 mg/L (22 to 64 parts per trillion). **These concentrations are below expected levels that would indicate contamination from septic tanks and may actually be false positives that are within the practical quantization limit of the analysis method.**

6. Trend Analysis on Nitrate/TDS Data
   In the USGS Water-Resource Investigation Report 96-4057 reported total nitrogen values for the ground water in the Milford Valley ranged from 0.042 to 25.6 mg/L, with the Milford Flat area generally in the 3 to 6 mg/L range. In recent sampling efforts, see Table 1, total nitrogen values from residential wells ranged from 0.01 to 5.94 mg/L . Unlike the previous study, no samples exceeded the State standards for total nitrogen of 10 mg/L. This wide range of values

could be interpreted as demonstrating the vulnerability of this aquifer from present land-use practices.

Potential Bacterial Sources

The occurrence of bacterial contamination in as many as twenty (20) wells in the Milford Flats area was alarming enough to warrant a serious examination of the problem. The Division of Water Quality had never been involved in any similar situations. During the course of this project the Division has become aware of the fact that bacteria in rural wells in not an uncommon occurrence. Bacteria are generally not a good measure of aquifer contamination. Much like municipal systems, rural wells require maintenance to stay bacteria free. This maintenance is usually performed by periodic dosing of wells with chlorine. Municipal systems are required under Drinking Water Regulations to test their systems on a regular basis for bacteria and to take corrective actions when bacteria are found. Similarly residential wells should be tested periodically and treated when necessary.

The areal extent of the bacterial occurrence in residential wells stretches for about eight (8) miles in a north to south direction and about two (2) miles in a east to west direction. The southern most residential wells with bacterial occurrence are less than three (3) miles from the nearest Circle 4 lagoons and the location of the back siphoning incident. Based on previous hydrogeologic studies it is believed to be very unlikely that any Circle 4 activities could have impacted ground water nearly three miles from their activities in as little as five (5) years from the commencement of operation. It is considered a virtual impossibility that Circle 4 activities would have impacted wells as far as eleven (11) miles away in the same time frame.

The Beaver River/canal system and the Hay Springs diversion cut through and outline the area of impacted residential wells. The river and the canals are losing streams in the Milford Flats area and can be a significant source of recharge to the area's ground water. In the spring of 1998 significant water was diverted into the Beaver River channel and to the Hay Springs diversion due to high run off in the Beaver River Basin. The last time this had occurred was in 1985. Many of the impacted residential wells are within only a short distance of these water sources. Significant runoff has again been diverted into the Beaver River during the winter of 1998-99 and expected high spring runoff is also expected. The Beaver River and associated canals pass through agricultural areas near the town of Minersville where several cattle feeding operations are located. Based on the river/canal data collected, these operations appear to be the source of bacteria identified in the river/canal. **However, none of the microbiological analyses conducted were able to link these sources with bacteria found in residential wells.**

At one time the wells in the Milford Flats area flowed under artesian pressure and the area of Hay Springs was a wetland. Due to water development in the area the artesian pressure in the area has significantly declined and the wetlands in the area of Hay Springs have disappeared. Formerly flowing wells had to be replaced with deeper wells for continued agricultural activity. Because of this there are probably a number of improperly abandoned wells in the area that can serve as conduits for shallow ground water to flow into deeper portions of the aquifer. Further, it has been reported by a number of individuals that many of the large diameter irrigation wells in the area are screened across their entire depth. This would allow shallow ground water to flow into deeper portions of the aquifer. Shallow ground water may be impacted by irrigation seepage, local animal operations, septic tanks or other local activities. Although not well documented in Milford Flats these activities are potential sources of bacteria to ground water resources in the area.

Conclusions

1. There is no compelling data to support the contention that the ground water is contaminated with bacteria. Indeed, the data strongly suggests that the ground water is not contaminated, and that bacterium stems from the pipes of the well apparatus.
2. There is no data to support the contention that the bacteria in the private wells originated at the Circle 4 sewage lagoons or as a result of the back siphoning incident.
3. There is no data to support the contention that the Beaver River/canal system as the source of bacteria in the pipes of the private wells.
4. The limited caffeine and surfactant data collected do not indicate that the source of bacteria is from septic tank seepage.
5. Data are insufficient to rule out a transient or very low level of bacteria in ground water that led to the contamination of the pipes in the wells.

Recommendation To Well Owners

The Department of Environmental Quality (DEQ) and the Southwest Utah Public Health Department recommends that well owners test their well annually at a minimum. When the analysis has total coliform bacteria present, the water supply should be considered be at health risk. Water should not be consumed unless it is boiled first. Re-sampling should be done as soon as possible. If the results show the presence of coliform bacteria still exist, investigate the sources of contamination and disinfect the water system. Contact the Southwest Health Department on the latest procedures in well chlorination.

Chlorination has appeared to have a positive impact on water quality results, Table 1 . Of the twenty (20) wells that contained bacteria during the December 11-12, 1998 sampling event, only three wells still had indications of Total Coliform present (a 85% reduction) from the January 12, 1999 sampling following chlorination. Nine (9) residential wells tested positive for fecal strep previously with only one (1) testing positive following chlorination. No residual chlorine was detected in any of the wells during the January 12, 1999 sampling.

Watershed Protection

Although there has been much progress in the areas of water quality, the State programs are not comprehensive enough to cover all activities which can be sources of ground water contamination. There is continuing need for involvement at the community level, which also includes the individual citizens, to adequately respond to measures which can protect the ground water before contamination occurs. The local community groups and governmental entities need to join with the DEQ in a partnership to bridge gaps and build a comprehensive ground water protection program which will protect future beneficial use of ground water resources.

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