

Ground Water Quality Technical Report No. 8

**An Evaluation of Bacteria in
Ground Water in Prairie, Elmore
County, Idaho**



**Idaho Division of Environmental Quality
Boise Regional Office
August 1997**

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**Idaho Division of Environmental Quality
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Table of Contents

| | |
|---|-----|
| List of Figures and Tables | ii |
| Abstract | iii |
| Introduction | 1 |
| Purpose and Objectives | 2 |
| Literature Review | 2 |
| Sample Location Numbering System | 4 |
| Study Area | 6 |
| Climate | 6 |
| Soils | 6 |
| Geology and Hydrogeology | 9 |
| Land Use | 11 |
| Water Use | 11 |
| Materials and Methods | 12 |
| Ground Water and Surface Water Sampling | 12 |
| | 12 |
| Central District Health Department Sampling | 13 |
| Microscopic Particulate Analysis | 15 |
| Dye Tracer Test | 16 |
| Statistical Analysis | 17 |
| Results and Discussion | 19 |
| Conclusion and Recommendations | 34 |
| Acknowledgments | 36 |
| Literature Cited | 37 |

List of Figures and Tables

Figures

| | |
|---|----|
| Figure 1. Sample Station Numbering System | 5 |
| Figure 2. Study Area | 8 |
| Figure 3. Basalt Features | 10 |
| Figure 4. Trilinear Diagram | 25 |
| Figure 5. X-Y Plot of Major Cations Versus Total Dissolved Ions | 27 |
| Figure 6. X-Y Plot of Major Anions Versus Total Dissolved Ions | 28 |
| Figure 7. Fingerprint Diagram | 29 |

Tables

| | |
|---|----|
| Table 1. Sample Location Numbering Systems | 7 |
| Table 2. Chemical Constituents Evaluated in Water Samples | 14 |
| Table 3. Cation-Anion Balance Errors | 15 |
| Table 4. DEQ Inorganic Chemistry Analytical Results | 20 |
| Table 5. DEQ Microorganism Analytical Results | 21 |
| Table 6. EPA Microorganism Analytical Results | 22 |
| Table 7. CDHD Inorganic Chemistry Analytical Results | 23 |
| Table 8. CDHD Microorganism Analytical Results | 24 |
| Table 9. MPA Results | 30 |
| Table 10. Summary Statistics | 32 |
| Table 11. Statistical Analysis | 33 |

Abstract

During the summer and fall of 1993, the Central District Health Department (CDHD) investigated several occurrences of gastrointestinal illness in residents and visitors of the small town of Prairie, Idaho. The CDHD conducted an epidemiological investigation during September 1993 which focused on residents of a temporary recreational vehicle park served by a single public water supply well. CDHD's epidemiological investigation report concluded that the disease outbreak was water-borne with 60 people exposed and 38 people experiencing symptoms. Less than 10 other residents of Prairie who obtain drinking water from different wells also reported similar disease symptoms to CDHD. A specific pathogen responsible for the illnesses was not identified although fecal coliform bacteria, used as a contamination indicator, was detected in the public water supply well.

The Division of Environmental Quality conducted an investigation that included collection of three surface water samples; collection of 13 ground water samples; and performance of a dye tracer test, microscopic particulate analyses, and a simple statistical analysis of water chemistry data. Both ground water and surface water data indicated the presence of total coliform and fecal coliform bacteria.

The objective of the investigation was to assess bacteria contamination in Prairie's ground water supply and to evaluate potential contaminant sources. Specifically, the investigation attempted to determine:

- (1) whether the bacteria contamination was a result of surface water entering ground water wells through bedrock fractures or faulty well casings, or
- (2) whether subsurface sewage disposal was the source of bacteria contamination.

The results of this investigation indicate that surface water is not negatively influencing the quality of ground water extracted by most of the wells in Prairie with respect to microbial contaminants, common inorganic ions, or nutrients. In addition, there was no positive correlation between those wells with more potential to be influenced by surface water and reports of illnesses from the respective users. The most likely cause of bacteria contamination in Prairie's ground water is the influence from subsurface sewage disposal systems. However, a dye tracer test was unable to confirm this hypothesis.

Introduction

During the summer and fall of 1993, the Central District Health Department (CDHD) investigated several occurrences of gastrointestinal illness in residents and visitors of the small town of Prairie, Idaho (Bob Fox, personal communication, 1993). The CDHD conducted an epidemiological investigation during September 1993 which focused on residents of a temporary recreational vehicle park served by a single public water supply well. CDHD's epidemiological investigation report concluded that the disease outbreak was water-borne with 60 people exposed and 38 people experiencing symptoms. Less than 10 other residents of Prairie who obtain drinking water from different wells also reported similar disease symptoms to CDHD. A specific pathogen responsible for the illnesses was not identified although fecal coliform (FC) bacteria, used as a contamination indicator, was detected in the public water supply well.

A temporary population boom occurred in Prairie in the summer of 1993 as a result of an active firefighting season in the area. Firefighters set up a temporary camp near the State landing strip east of town. Additional firefighters and forest salvage and restoration crews occupied the recreational vehicle park next to the Prairie Store. Many people living in the recreational vehicle park obtained drinking water from the store's well. Gastrointestinal illnesses were reported by 38 of these people.

Water samples collected from different distribution points from the Prairie Store public water system in August, 1993 indicated the presence of total coliform (TC) and FC bacteria. Follow-up sampling conducted by CDHD during August and September, 1993 indicated that some of the previously contaminated distribution points contained no TC or FC bacteria while others still contained these organisms. This pattern of intermittent occurrences of bacteria contamination in ground water has been observed in other parts of southwest Idaho and is documented for the Prairie area in following sections of this report. After implementing a chlorination treatment program for the Prairie Store public water system, the CDHD asked the Boise Regional Office of the Division of Environmental Quality (DEQ) to investigate the ground water conditions in the area.

The town of Prairie does not use paved streets or city utilities such as sewer and municipal drinking water systems. Therefore, storm water disposal systems and leaking municipal sewer lines can be discounted as potential sources of contamination. The remaining potential sources of bacteria contamination are septic tanks and drainfields and the infiltration of contaminated surface water into the ground water system. Livestock feeding and holding areas also exist in the area surrounding Prairie. It is expected that flood irrigation with surface water or intense precipitation would provide the hydraulic driving force to convey contaminants from livestock-inhabited areas to the ground water. Therefore, this potential contaminant source, and any other source resulting in bacteria contamination to surface water, was evaluated by comparing ground water and surface water chemical characteristics.

DEQ's investigation included surface and ground water sampling and laboratory chemical analyses, microscopic particulate analyses of ground water samples, simple dye tracer tests, and a statistical evaluation of water chemistry data. Each of these investigation activities was intended to evaluate potential sources of bacteria contamination in the ground water.

DEQ also developed a contract with the CDHD for follow-up well sampling that included late summer and springtime sampling events. The intent was to evaluate seasonal variations in bacteria, nitrate, ammonia, and chloride concentrations; all are indicators of human or animal wastes.

Purpose and Objectives

The purpose of this report is to present the results of DEQ's investigation and to summarize the findings of the follow-up CDHD sampling. The objective of the investigation was to assess the bacteria contamination in Prairie's ground water and to evaluate the potential contaminant sources. Specifically, the investigation attempted to determine:

- (1) whether the bacteria contamination was a result of surface water entering ground water wells through bedrock fractures or faulty well casings, or
- (2) whether subsurface sewage disposal was the source of bacteria contamination.

In addition, recommendations for potentially useful future investigation activities are provided.

Literature Review

Published information related to ground water conditions and geology in the Prairie area is sparse. The Geologic Map of Idaho (1:500,000 scale; Bond, 1978) indicates that the area is occupied by upper Pleistocene Snake Plain basaltic lava flows.

Abundant literature describing the physical/chemical characteristics, persistence, fate, and transport of microbial contamination exists. A quarterly report published by the National Governors' Association (1995) summarized a survey of wells performed in nine midwestern states. The survey included an evaluation of bacteria, nitrate, and the pesticide atrazine.

Samples were collected from 6,500 wells in Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin. Approximately 41% of the samples were found to be contaminated with TC bacteria. In addition 14% of the samples contained nitrate above the Safe Drinking Water Act maximum contaminant level (MCL) of 10 milligrams per liter (mg/l). A much smaller percentage of samples, 0.25%, contained atrazine

Introduction

at concentrations greater than the Safe Drinking Water Act MCL of 0.003 mg/l. The report concluded that the cause of the TC bacteria contamination and a means of preventing it will be difficult to discern, even with the large data set. The investigators did find that older wells are more likely to be contaminated than newer wells. The average age of the wells in the midwestern survey was 30 to 35 years. It is surmised that older well construction standards may not be as adequate as newer standards in preventing ground water contamination.

Key investigation results or characteristics of microbial contamination reported in the literature are summarized as follows:

- ! The average volume of liquid-transported wastes received by a typical subsurface sewage disposal system is approximately 42 gallons per person per day (Wilhelm et al., 1994).
- ! Under conditions of inadequate design, construction, siting, operation, and maintenance, subsurface sewage disposal systems are the most frequently reported source of ground water contamination (Bicki et al., 1984).
- ! From 1946 to 1977, there were 264 disease outbreaks and 62,273 cases of illness related to contaminated ground water in the United States. Subsurface sewage disposal systems were implicated in 42% of the outbreaks and 71% of the illnesses (Bicki et al., 1984).
- ! Bacteria range in size from 0.2 to five microns and viruses from 0.005 to 0.1 microns; the pore entrance size of aquifer materials is 0.7 to seven microns for fine- to coarse-grained silts, 24 to 240 microns for fine- to coarse-grained sands, and 720 to 7,200 microns for fine- to coarse-grained gravels (Vance, 1995).
- ! Bacteria removal from wastewater percolating through soil is inversely proportional to the particle size of the soil (Bicki et al., 1984).
- ! The use of indicator organisms such as TC or FC bacteria may be inaccurate in some cases because pathogens are not always present in feces. Therefore, the presence of fecal organisms (like FC and TC bacteria) in water does not necessarily indicate the presence of pathogens (Bicki et al., 1984).
- ! Bacteria migration is impeded by unsaturated soil conditions and enhanced by saturated conditions (Bicki et al., 1984).

- ! Factors affecting bacteria survival include soil moisture content, temperature, pH, and organic matter content. Conditions favorable to survival are high moisture content, low temperature, alkaline pH, and high organic matter content.
- ! Bacteria seldom survive longer than 10 days under adverse conditions. Survival may extend beyond 100 days under favorable conditions.
- ! Factors affecting bacteria transport include (Vance, 1995):
 - (1) **mechanical processes** such as filtration in the aquifer matrix.
 - (2) **adsorption processes**; bacteria have an overall negative charge on the surface of their cell wall; increasing the ionic strength of ground water increases bacterial capability to adhere to soil surfaces.
 - (3) **biological processes**; adhesion to an attachment surface is initially reversible given adequate shearing from ground water flow; irreversible binding takes place through the cellular production of exopolymers that anchor the cell to a binding surface.
- ! In fractured bedrock environments, the following conclusions are supported (Allen and Morrison, 1973):
 - (1) Percolating sewage effluent was observed to traverse a horizontal distance exceeding 100 feet; it is suspected that distances may exceed several hundred feet, and
 - (2) microbial filtration in or along fractures and joints is insufficient to prevent ground water contamination.

Sample Location Numbering System

The numbering system for identifying locations of wells and surface water sampling sites in this report is based on the common subdivision of land into townships, ranges, and sections (Figure 1). This subdivision of lands is called the public land survey system (PLSS). The location based on the PLSS is referenced to the Boise baseline and meridian. The first segment represents the township north of the Boise baseline, the second segment represents the range east of the Boise meridian, and the third is the section number. The three letters following the section number indicate the quarter-quarter-quarter section (10-acre tract) within the section.

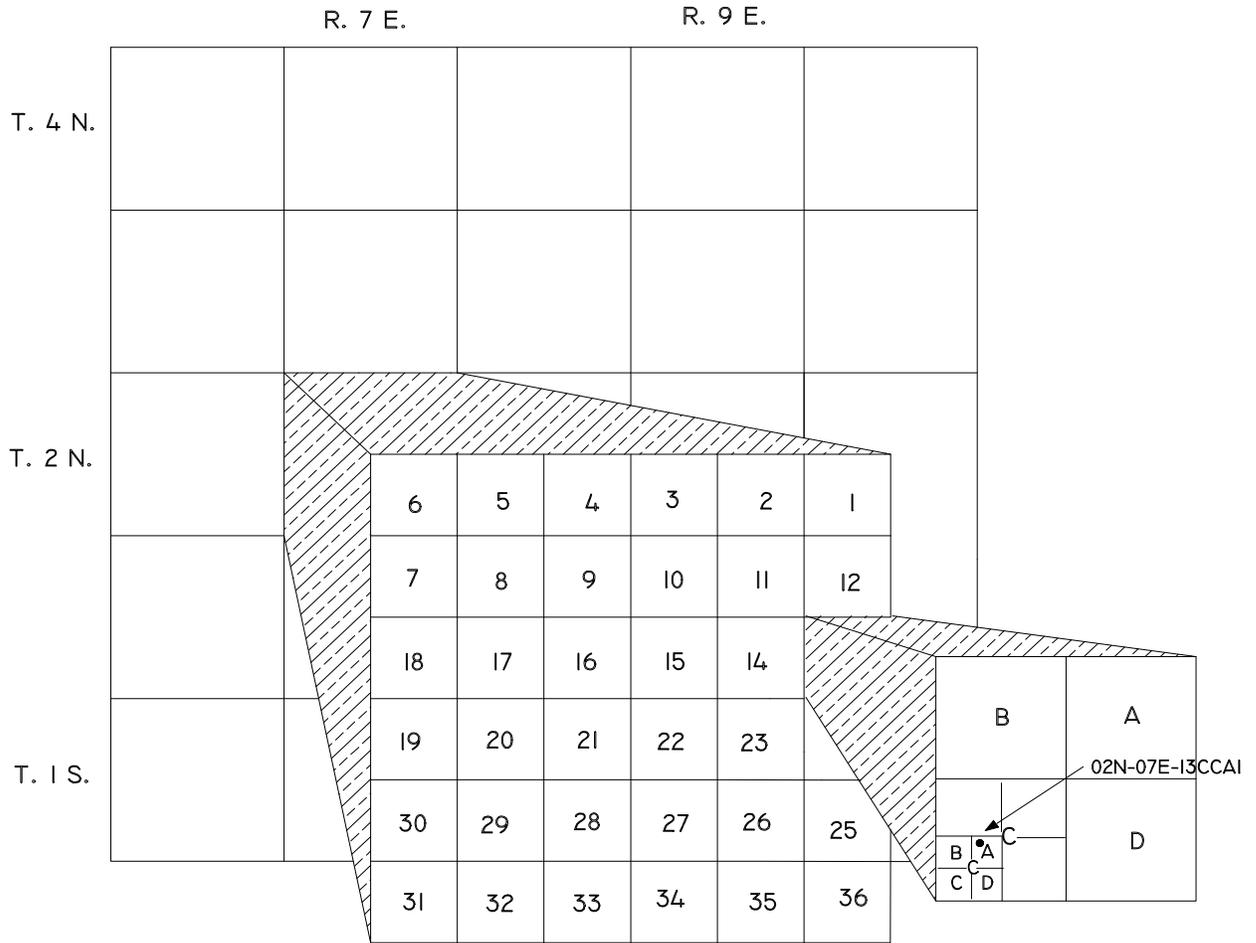


Figure 1. Sample Station Numbering System (modified from the USGS)

Quarter sections are labeled A,B,C, and D in counterclockwise order starting with the northeast quarter of the section. A number following the letters indicates the order in which wells within the 10-acre tract were sampled. An "S" following the number indicates that the sampling location is a surface water body rather than a well.

In addition to the formal numbering system described above, a simplified sample location identification number was correlated to each sampled well or surface water sampling station. The identification numbers are labeled P-01 through P-21 on the maps and tables in this report. The sample location identification numbers provide a concise local reference, whereas the more formal PLSS numbering system provides a broader, generally accepted locational reference. Table 1 shows the correlation between the PLSS numbering system and the simplified location identification numbering system.

Study Area

The town of Prairie lies on a gently-sloping basalt plateau near the southern reach of Cretaceous granitic rocks of the central Idaho mountains. The southwest-sloping plateau is known as Smith Prairie. The elevation of Prairie is approximately 4800 feet above mean sea level. Smith Creek, the main surface water feature, flows southwesterly through town. Water diverted from Smith Creek is used to irrigate surrounding pasture land. Near Prairie, Smith Creek flows throughout the year although no record of its measured volume is known to exist.

This investigation encompassed the area of concentrated domestic wells in the town of Prairie with additional surface water sampling taking place in Smith Creek up to approximately three miles north of town (Figure 2).

Climate

Climatological data are not available for Prairie. The most representative station, Hill City, lies southeast of Prairie in Camas County at a similar elevation to Prairie. Average annual precipitation is approximately 15 inches. Average snowfall is 104 inches. Average winter and summer temperatures are 26.1E and 57E F, respectively (USDA Soil Conservation Service, 1991).

Soils

The soils found in the area of investigation are described in the *Soil Survey of Elmore County Area, Idaho, Parts of Elmore, Owyhee, and Ada Counties* (USDA Soil Conservation Service, 1991). The general soil unit mapped near Prairie is the Simonton-Baib-Harahill. This general unit classification is based on a distinctive pattern of soils, relief, and drainage. The unit is

Table 1. Sample Location Numbering Systems

| Sample Location Identification Number | Sample Location Based on the Public Land Survey System |
|--|---|
| P-01 | 02N07E13CAB1 |
| P-02 | 02N07E13CAB1S |
| P-03 | 02N08E06ADC1S |
| P-04 | 02N07E24BAA1 |
| P-05 | 02N07E13CCB1 |
| P-06 | 02N07E13CCB2 |
| P-07 | 02N07E13CCA1 |
| P-08 | 02N07E13CCA2 |
| P-09 | 02N08E06CDA1S |
| P-10 | 02N07E13CCA3 |
| P-11 | 02N07E13CCA4 |
| P-12 | 02N07E13CCA5 |
| P-13 | 02N07E24BBB1 |
| P-14 | 02N07E13CCA6 |
| P-15 | 02N07E13CCD1 |
| P-16 | 02N07E13CCA7 |
| P-17 | 02N07E13CCA8 |
| P-18 | 02N07E13CCB3 |
| P-19 | 02N07E13CCB4 |
| P-20 | 02N07E13CDB1 |
| P-21 | 02N07E23AAB1 |

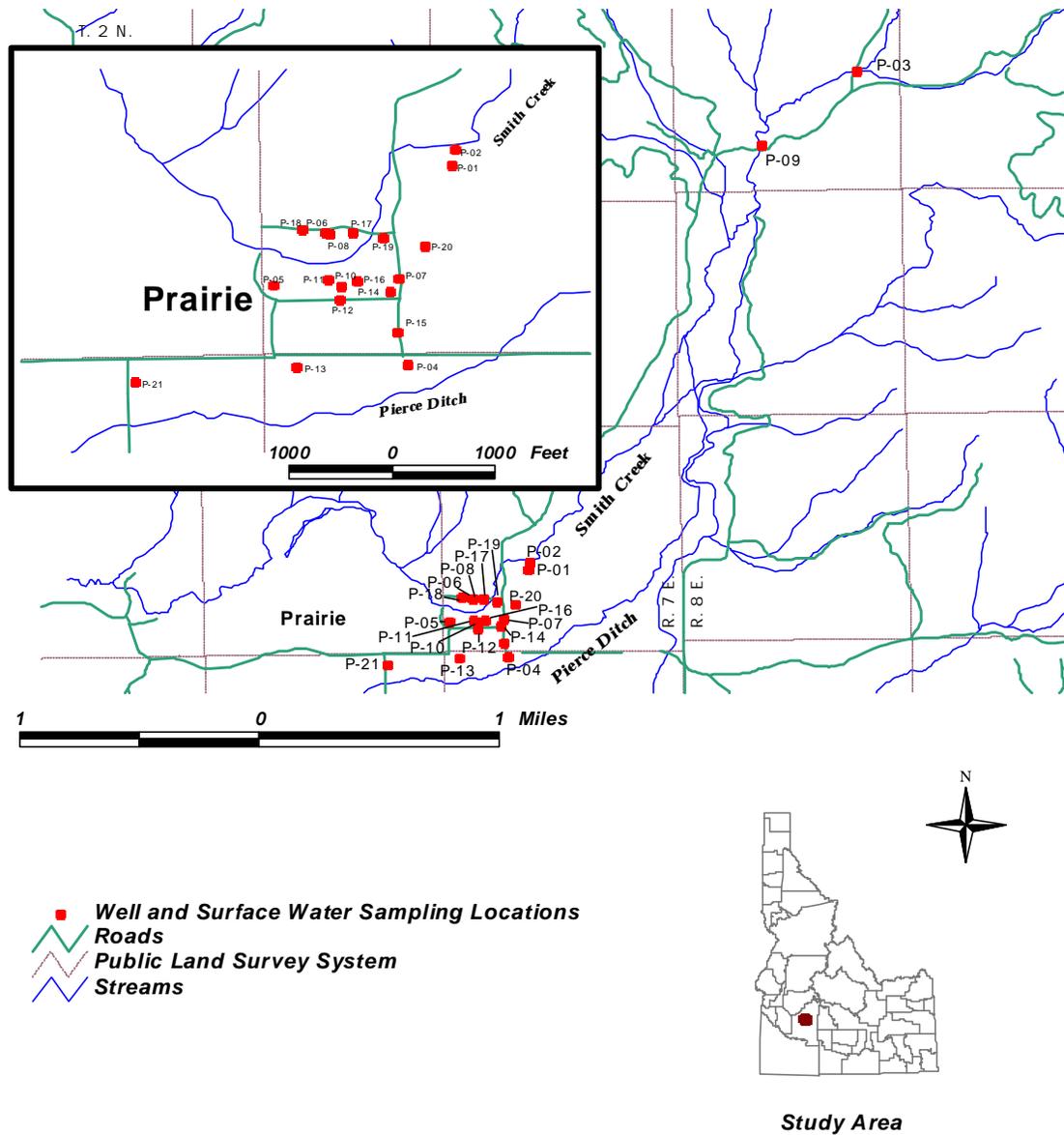


Figure 2. Study Area

Introduction

described as gently sloping to steep, shallow, moderately deep, and very deep, well drained soil on basalt plains and canyon sides. Land use includes rangeland, pasture, hayland, and irrigated cropland. The soil unit's main limitations are the depth to bedrock (shallow) in some areas, stones on the surface, the slope in some areas, and the limited frost-free season.

Typical soils found in the area include:

- ! Haplaquolls-Xerofluvents complex, 0-2% slopes; very deep soils found on flood plains. Management factors include available water capacity, pebbles and cobbles on the surface, depth to gravelly material, flooding, risk of seepage, and wetness.
- ! Simonton-Bauscher loams, 2-20% slopes; very deep soils found on foothills, granitic hills, and alluvial terraces. Management factors include hazard of water erosion and slope.
- ! Gaib-Elkreek-Rock outcrop association, 2-20% slopes; found on foothills; can include unweathered bedrock outcrops. Management factors include available water capacity, stones on the surface, depth to bedrock, hazard of water erosion, and slope.

These soils are described as limiting the effectiveness of septic tank absorption (drain) fields due to a shallow depth to bedrock or excessive soil wetness. These factors can lead to sewage emerging at the land surface or rapid percolation of poorly-treated sewage effluent to the ground water.

Geology and Hydrogeology

Detailed published information on geologic and ground water conditions on Smith Prairie could not be found. The Geologic Map of Idaho (Bond, 1978) indicates the presence of Pleistocene Snake Plain basalt. The basalt forms the steep canyon walls of the South Fork of the Boise River south of Prairie. Much of Smith Prairie is covered with basalt flows with little or no soil cover. Several collapsed flow features (lava tubes) are visible from roadways transecting Smith Prairie. The porous nature of the basalt is apparent in the fractured and vesiculated outcrops throughout the area (Figure 3).

A review of 20 well drillers' reports revealed that most of the domestic wells in Prairie are completed in basalt or cinder zones within basalt. A few wells are reportedly completed in sand or gravel. All wells are less than 200 feet deep. Static water level typically ranges from 50 to 80 feet below ground surface. However, certain drillers' reports list water levels as shallow as eight feet and as deep as 109 feet.



Figure 3. Basalt Features

Introduction

Water level measurements in wells were not taken. Ground water flow direction, therefore, is not known. The flow direction of surface water features and topography indicate that regional ground water flow should be to the west or southwest. It is also expected that local ground water flow directions are dominated by fracture flow conditions within the basalt and that local flow conditions would be difficult to predict. The variability in static water levels listed on the drillers' reports support the idea that many individual flow systems exist. The amount and depth of ground water encountered is highly dependent on the location of connected fractures or sedimentary zones.

Land Use

The buildings in Prairie consist of a few vacation homes and permanent residences, a school, the Prairie Store, a community hall, and a highway district shop. Cattle ranching constitutes the main source of commerce. Cattle are raised on both irrigated pasture land and on surrounding rangeland.

Water Use

The town of Prairie does not utilize a municipal drinking water supply. Most of the dwellings receive domestic water from an accompanying single well. At least two public water systems tapping ground water exist in Prairie (the school and the store). The percentage of ground water versus surface water used for irrigation is not known. Field observations indicate a predominance of surface water irrigation.

Materials and Methods

This investigation included the collection and analysis of ground water and surface water samples. The analytical results of these samples allow some simple hydrochemical and statistical evaluations to be made and provide a foundation from which to base more detailed studies. Even though this investigation focused on bacteria contamination, several of the samples were also analyzed for common inorganic constituents to help characterize and differentiate surface water and ground water samples on a chemical basis.

In addition to standard water analysis procedures, two other investigative tools were employed. A tracer test was conducted using fluorescein dye in an attempt to directly observe a hydraulic connection between a septic tank drainfield and nearby wells. A newly developed microscopic particulate analysis (MPA) protocol was also used at two well sites to evaluate potential surface water hydraulic connection to the wells.

Ground Water and Surface Water Sampling

DEQ collected water samples from 13 wells. Some of the wells were sampled multiple times for TC and FC bacteria analyses. Samples for inorganic chemical analyses were collected one time from five of the wells.

Separate samples were collected from two public water supply wells (the Prairie Store and the school) for detailed microbiological analysis at the Environmental Protection Agency Ground Water and Drinking Water Technical Support laboratory in Cincinnati, Ohio (Lieberman, 1993). These samples were evaluated for the presence of TC bacteria (including *E. coli*), Fecal Enterococci, *Clostridium perfringens*, and somatic coliphage. The Cincinnati laboratory states that “These organisms are either highly feces-specific (*E. coli* and enterococci) or very stable due to formation of spores (*Clostridium perfringens*). None are unique to humans.”

Three surface water samples from Smith Creek were collected and analyzed for TC and FC bacteria. Two of the samples were also analyzed for inorganic chemical constituents.

Each well was purged a minimum of 15 minutes before the samples were collected. Surface water samples (grab samples) were collected from flowing stretches of Smith Creek. Field measurements of temperature, pH, specific conductance, and dissolved oxygen were recorded at each sampling location. Dissolved oxygen measurements were subsequently deemed invalid due to unacceptable variability in the equipment calibration. Therefore, the dissolved oxygen measurements are not reported.

Materials and Methods

Field quality control samples for inorganic analyses were not collected. All analyses for samples collected by DEQ were performed by the State of Idaho, Bureau of Laboratories (State lab) except for the specialty microbiological analyses described above. Internal laboratory quality control checks were performed by the State lab in accordance with their standard operating protocols. The State lab has verified that the accuracy goals prescribed by the analytical methods have been achieved. The analytes, corresponding laboratory analytical methods, and sample preservation methods are listed in Table 2.

A cursory evaluation of analytical accuracy is accomplished by calculating cation-anion balances for each sample (Table 3). The balance errors ranged from zero to 5.6 percent. The average balance error for the seven inorganic analyses is 2.0 percent. The suggested allowable balance error is considered variable depending on the ionic concentration of the samples. Total dissolved solids (TDS) concentration is considered a measure of the ionic concentration. As the ionic concentration increases, the allowable balance error decreases. TDS concentrations were not analyzed for the samples in this study. However, TDS can be estimated based on specific conductance measurements which range from 50 to 100 micromhos per centimeter ($\mu\text{mhos/cm}$). According to Hem (1985), specific conductance values multiplied by a factor of approximately 0.59 provide a reasonable estimate of TDS values in mg/l. Therefore, TDS is estimated to range from 30 to 59 mg/l. Acceptable balance errors given this range of TDS concentrations is seven to 15 percent indicating that the acceptance criteria are met.

Central District Health Department Sampling

Under contract to DEQ, the CDHD performed additional sampling of wells in Prairie for bacteria (TC and FC), chloride, nitrate, and ammonia analyses. Twelve wells were sampled on August 31, 1994. Eight of these 12 wells were the same wells included in DEQ's investigation. To assess seasonal variability in the water quality parameters, three of the wells were sampled again on February 28, 1995. One additional sample was collected from a previously unsampled well on February 28, 1995.

DEQ developed a quality assurance project plan to assist CDHD field staff as part of this contract. The sampling protocol was similar for both the DEQ and CDHD projects. The only area of deviation was in regard to the measurement of field parameters. The CDHD sampling project did not include the field measurement of temperature, pH, conductivity, and dissolved oxygen. Laboratory analyses were performed by Analytical Laboratories, Inc. in Boise, Idaho.

Table 2. Chemical Constituents Evaluated in Water Samples

| Parameter | Method | Container | Preservation | Holding Time |
|--------------------|-----------------|-----------|--|--------------|
| Calcium | EPA 215.1 | Plastic | Cool, 4E C | 60 days |
| Magnesium | EPA 242.2 | Plastic | Cool, 4E C | 60 days |
| Sodium | EPA 273.1 | Plastic | Cool, 4E C | 60 days |
| Potassium | EPA 258.1 | Plastic | Cool, 4E C | 60 days |
| Chloride | EPA 325.3 | Plastic | Cool, 4E C | 28 days |
| Alkalinity | EPA 310.1 | Plastic | Cool, 4E C | 14 days |
| Carbonate | EPA 310.1 | Plastic | Cool, 4E C | 14 days |
| Bicarbonate | EPA 310.1 | Plastic | Cool, 4E C | 14 days |
| Sulfate | EPA 375.4 | Plastic | Cool, 4E C | 28 days |
| Nitrate | EPA 353.2 | Plastic | 2 ml/l conc. H ₂ SO ₄ | 28 days |
| Nitrite | EPA 353.2 | Plastic | 2 ml/l conc. H ₂ SO ₄ | 28 days |
| Ammonia | EPA 350.1 | Plastic | 2 ml/l conc. H ₂ SO ₄ | 28 days |
| Phosphorus, Total | EPA 365.4 | Plastic | 2 ml/l conc. H ₂ SO ₄ | 28 days |
| Silica | EPA 370.1 | Plastic | Cool, 4E C | 28 days |
| Hardness | EPA 130.2 | Plastic | Cool, 4E C | 28 days |
| Arsenic | EPA 200.9 | Plastic | 3 ml/l 1:1 dil. HNO ₃ | 60 days |
| Manganese | EPA 243.1 | Plastic | 3 ml/l 1:1 dil. HNO ₃ | 60 days |
| Iron | EPA 236.1 | Plastic | 3 ml/l 1:1 dil. HNO ₃ | 60 days |
| Total Coliform | Membrane Filter | Plastic | Cool, 4E C | 24 hours |
| Fecal Coliform | Membrane Filter | Plastic | Cool, 4E C | 24 hours |
| <i>E. coli</i> | | Plastic | Cool, 4E C | 24 hours |
| Fecal Streptococci | Membrane Filter | Plastic | Cool, 4E C | 24 hours |

Table 3. Cation-Anion Balance Errors

| Sample Identification | Total Cations (meq/l) | Total Anions (meq/l) | Cation-Anion Balance Error (%) |
|------------------------------|------------------------------|-----------------------------|---------------------------------------|
| P-01 | 0.888 | 0.888 | 0 |
| P-02 | 0.810 | 0.907 | 5.6 |
| P-03 | 0.801 | 0.830 | 1.7 |
| P-04 | 1.224 | 1.125 | 4.2 |
| P-05 | 1.150 | 1.150 | 0 |
| P-06 | 1.524 | 1.572 | 1.6 |
| P-07 | 0.930 | 0.940 | 0.5 |

Microscopic Particulate Analysis

Microscopic Particulate Analysis (MPA) is a tool used to identify ground water supplies suspected of being in direct hydraulic connection with surface water (EPA, 1992). This tool has been developed for regulatory evaluations of public water systems under the Safe Drinking Water Act.

MPA sampling involves running well water through a one micron, wound polypropylene yarn cartridge filter over a period of eight to 24 hours. Pressure and flow rate are regulated in an attempt to filter a minimum volume of 500 gallons of water over the sampling period.

Sediment and particles captured by the filter are then evaluated according to prescribed laboratory protocol in order to determine a quantitative “relative risk” of the ground water being directly influenced by surface water. Indicator material that can be found in water samples and used in the development of relative risk factors include, *Giardia* cysts, algae, rotifers, pollen, insect parts, and plant debris.

MPA sampling was performed on two wells in Prairie over a 12-hour period on July 7 and July 8, 1994. The evaluation was performed on the Prairie School well (P-07) and on well P-13. Two hundred and sixty-three gallons and 519 gallons of water were filtered from these two wells, respectively. The low volume of water filtered from the Prairie School well was a result of partial plugging of the filter from what was later determined to be amorphous iron phosphate particles.

After the filtering process was completed, the filters were sealed in plastic bags and transported on ice to the State lab. Here, the filters were processed according the EPA consensus method for the microscopic particulate analysis of drinking water.

Dye Tracer Test

A dye tracer test utilizing fluorescein dye was performed in an attempt to document whether septic tank effluent could be the cause of TC and FC contamination in certain wells. The test was carried out by introducing about 200 grams of powdered fluorescein dye (water soluble sodium fluorescein) into the Prairie School septic tank (through the restroom sink). The dye was flushed into the septic system with about 480 gallons of water. It was assumed that the school septic tank volume was approximately 1,000 gallons. This, however, could not be confirmed. Two hundred grams of dye added to 1,000 gallons of water would result in a concentration of approximately 50 mg/l of fluorescein in the septic tank.

The school septic tank was selected for the test based on the apparent vulnerability of the school well and the adjacent well, P-16, to TC and FC contamination. The combination of well location, well depth, local geology (i.e., shallow depth to basalt), and well contamination history indicated that this “system” of septic tank/drainfield and two adjacent wells was appropriate for this dye tracer test.

Analysis of fluorescein in the suspected receptor wells involved methodology described by the Missouri Speleological Survey (1976). Packets of adsorbent carbon constructed of fine-mesh screen containing about 12 grams of granular activated carbon placed in toilet tanks have been shown to facilitate fluorescein detection in the water supply. Fluorescein adsorbed to the carbon is extracted by immersing the carbon in a five percent solution of potassium hydroxide in 70% isopropyl alcohol. If fluorescein is present in the sample, it will appear as a distinctive green haze in the liquid solution. An ultraviolet light causing fluorescence of the dye can also be used to help detect the presence of fluorescein in the sample. The methodology described above was used in the performance of the tracer test at Prairie.

This fluorescein detection methodology was used successfully in Minidoka County, Idaho in a 1985 nitrate study (Laumann, 1985). An investigation of 10 septic systems injected with fluorescein and 10 associated domestic wells yielded 10 positive dye detections after two weeks of carbon packet placement.

Prior to introducing dye to the school septic tank, carbon packets were placed in toilet tanks in the school and the home served by well P-16 to determine whether interfering natural organic material was present. The “background” packets were placed on April 13, 1994. One week later, on April 20, 1994, the carbon packets were collected and replaced and dye was

introduced into the school septic tank. Analysis of the background carbon packets did not indicate the presence of interfering organic material.

Carbon packet replacement at both Prairie sites continued through a period of time that was expected to allow fluorescein to travel from the school septic tank to either of the two receptor wells under a fracture flow situation. Packet replacement and analysis occurred on May 4, 1994. On May 18, 1994, the packet from well P-16 was collected and replaced. The packet from the school was collected and not replaced since school was adjourning for the summer and the restroom would not be used until fall. Carbon packet replacement continued on well P-16 on June 8, 1994 and was finally removed for the last time on June 30, 1994.

During the carbon packet replacement on May 4, 1994, water samples were collected from both well sites for evaluation by high performance liquid chromatography. The detection limit for fluorescein using this technology is 0.01 micrograms per liter ($\mu\text{g/l}$).

Statistical Analysis

A simple statistical procedure was used to investigate the possibility that chemical differences exist between surface water and ground water samples. Helsel and Hirsch (1992) promote the idea nonparametric statistical procedures be used when evaluating water resources data. Nonparametric procedures are not limited by the assumption that the data are normally distributed. Helsel and Hirsch (1992) characterize water resources data as:

- (1) containing a lower bound of zero (i.e., no negative values),
- (2) exhibiting the presence of "outliers", or observations considerably higher or lower than most of the data, and
- (3) exhibiting positive skewness due to items one and two above.

The propensity for these characteristics results in a non-normal data distribution which supports the use of nonparametric procedures.

The Prairie data were analyzed using a modification of the Wilcoxon Rank-Sum test, the Mann-Whitney Rank-Sum test (NCASI, 1986). Hypothesis testing was performed on those parameters that appeared to have the most significant differences in their central tendencies (median or mean) using the Mann-Whitney Rank-Sum test. A statement of the null (H_0) and alternative hypothesis (H_1) is as follows:

H_0 : monitored concentrations (surface water) equal background concentrations (ground water);

H_1 : monitored concentrations are less than background concentrations (one-sided test).

A significance level (i.e., acceptable error rate or ") of 0.05 was chosen. The significance level represents the probability of incorrectly rejecting the null hypothesis (H_0) when it is in fact true.

Mathematically, the Mann-Whitney Rank-Sum test is as follows:

$$T = W - [N_A(N_A + 1)/2]$$

where W = the sum of ranks of the surface water samples and

N_A = the number of surface water samples and

N_B = the number ground water samples.

The calculated test statistic, T , is then compared to a table of critical values corresponding with the chosen significance level to determine whether or not to reject H_0 . Note that N_B is not found in the formula above. However, it is used to obtain the critical value of the test statistic within a table of values.

Results and Discussion

Inorganic chemistry and microorganism analyses results for DEQ's surface water and ground water samples are provided in Tables 4 and 5, respectively. The results of the detailed microbiological analysis conducted at the Environmental Protection Agency Ground Water and Drinking Water Technical Support laboratory in Cincinnati are provided in Table 6. Results of the CDHD sampling are found in Tables 7 and 8.

Hydrogeochemical data evaluation techniques were applied to the analytical results of seven samples collected for general chemical parameters (i.e., cations, anions, and nutrients). These techniques were used in an attempt to characterize the interaction of surface water and ground water in the study area and to determine whether surface water infiltration into individual wells could account for the bacterial contamination. The following evaluation tools were employed:

- ! Trilinear plot
- ! Composition plots (x-y scatter plots)
- ! Fingerprint (Schoeller) diagram

Each of these methods was used to help identify trends or compositional variations in the water quality data. The small sample population results in inherent uncertainty when attempting to evaluate the analyses by graphical means. However, these tools still provide useful insights into the hydrogeochemistry of the ground water system as long as the limitations associated with the small data set are recognized.

Under natural conditions, the major ion composition of ground water is controlled by soluble minerals in the aquifer and the residence time of water in the aquifer. A general relationship between the mineral composition of the natural water and the solid minerals with which the water has been in contact is expected. This simple relationship can be complicated by the mixing of water from interconnected aquifers with different compositions. The system may also be affected by chemical reactions such as cation exchange, adsorption of dissolved ions, and biological influences (Hem, 1985).

Table 4. DEQ Inorganic Chemistry Analytical Results

| Parameter | P-01 | P-02 | P-03 | P-04 | P-05 | P-06 | P-07 |
|--|----------|----------|----------|----------|----------|----------|----------|
| Sample Date | 10/08/93 | 10/08/93 | 10/08/93 | 09/30/93 | 09/30/93 | 10/08/93 | 09/30/93 |
| Calcium [†] | 9.2 | 9.4 | 9.6 | 8.2 | 11.6 | 15.0 | 8.4 |
| Magnesium | 2.3 | 1.7 | 1.7 | 3.7 | 3.7 | 5.5 | 3.2 |
| Sodium | 4.2 | 3.8 | 3.7 | 11 | 5.7 | 6.9 | 5 |
| Potassium | 2.2 | 0.9 | 0.7 | 1.2 | 0.7 | 0.8 | 1 |
| Iron (total) | 0.02 | 0.24 | 0.06 | 0.02 | 0.02 | 0.04 | 0.07 |
| Manganese (total) | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 0.01 |
| Bicarbonate (as CaCO ₃) | 39 | 39 | 39 | 49 | 55 | 73 | 41 |
| Carbonate | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| Sulphate | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| Chloride | < 0.9 | 2.0 | < 0.9 | 2.0 | < 0.9 | 2.0 | 2.0 |
| Nitrate (as N) | 0.95 | 0.04 | 0.102 | 2.71 | 0.622 | 0.975 | 1.37 |
| Nitrite (as N) | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 |
| Ammonia (as N) | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 |
| Phosphorus (total) | 0.800 | 0.033 | 0.013 | 0.026 | 0.048 | 0.092 | 0.027 |
| Hardness (as CaCO ₃) | 32 | 32 | 30 | 40 | 38 | 62 | 36 |
| Silica | 19 | 15 | 16 | 24 | 22 | 32 | 21 |
| Alkalinity (as CaCO ₃) | 39 | 39 | 39 | 49 | 55 | 73 | 41 |
| Arsenic | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| *Conductivity (Fmhos/cm) | 65 | 55 | 50 | 85 | 75 | 100 | 75 |
| *pH (standard units) | 6.65 | 6.90 | 7.62 | 7.37 | 7.20 | 6.95 | 7.14 |
| *Temperature (°C) | 12 | 11 | 5 | 10 | 13 | 10 | 13 |

[†]All results in milligrams per liter unless otherwise indicated; *Represents field measurements.

Table 5. DEQ Microorganism Analytical Results

| Sample Location | Sample Date | †Total Coliform (CFU/100 ml) | †Fecal Coliform (CFU/100 ml) | † <i>E. coli</i> (CFU/100 ml) | †Fecal Streptococci (CFU/100 ml) | Well Depth (feet) |
|-----------------|-------------|------------------------------|------------------------------|-------------------------------|----------------------------------|-------------------|
| P-01 | 10/08/93 | P | NA | NA | NA | ? |
| P-02 | 10/08/93 | P | P | P | NA | SW* |
| P-03 | 10/08/93 | P | P | P | NA | SW* |
| P-04 | 09/30/93 | A | A | NA | NA | 195 |
| P-05 | 09/30/93 | A | NA | NA | NA | 150 |
| P-06 | 10/08/93 | A | NA | NA | NA | 100 |
| P-07 | 09/30/93 | P | P | P | NA | 66 |
| | 10/08/93 | P | P | P | NA | |
| | 04/13/94 | < 1 | NA | NA | NA | |
| | 05/04/94 | P | NA | P | NA | |
| | 06/30/94 | A | NA | NA | NA | |
| | 07/08/94 | 10 | 2 | NA | 20 | |
| | 10/25/94 | 5 | 3 | P | NA | |
| | 09/07/95 | P | < 1 | A | NA | |
| P-08 | 10/08/93 | P | NA | NA | NA | 120 |
| P-09 | 10/08/93 | P | P | P | NA | SW* |
| P-10 | 09/30/93 | P | P | P | NA | 100 |
| P-11 | 09/30/93 | P | A | NA | NA | 140 |
| | 04/20/94 | 14 | 1 | P | NA | |
| P-12 | 09/30/93 | P | P | P | NA | 75 |
| | 04/13/94 | 1 | 1 | NA | NA | |
| P-13 | 09/30/93 | P | P | NA | NA | 175 |
| | 07/08/94 | 14 | < 2 | NA | NA | |
| P-14 | 10/25/94 | A | NA | NA | NA | 55 |
| P-15 | 06/30/94 | P | P | NA | NA | ? |
| P-16 | 04/13/94 | 110 | < 1 | NA | NA | 100 |
| | 06/30/94 | P | A | NA | NA | |

†Numbers represent colony forming units per 100 milliliters; P or A represents “presence” or “absence” without quantification; NA means parameter was not analyzed; * Indicates surface water; ? = unknown.

Table 6. EPA Microorganism Analytical Results

| Public Water System | Sample Date | Microbial Contaminant | Counts per 100 ml |
|----------------------------|--------------------|------------------------------|--------------------------|
| Prairie School (P-07) | 11/16/93 | Total Coliform | 3.5 |
| | | <i>E. coli</i> | 3.5 |
| | | Fecal Enterococci | 1.0 |
| | | <i>C. perfringens</i> | Not Detected |
| | | Somatic Coliphage | Not Detected |
| Prairie Store (P-21) | 11/16/93 | Total Coliform | Not Detected |
| | | <i>E. coli</i> | Not Detected |
| | | Fecal Enterococci | Not Detected |
| | | <i>C. perfringens</i> | Not Detected |
| | | Somatic Coliphage | Not Detected |

Table 7. CDHD Inorganic Chemistry Analytical Results

| Sample Location | Sample Date | Chloride (mg/l) | Nitrate (mg/l as N) | Ammonia (mg/l) |
|------------------------|----------------------|----------------------------|--------------------------------|---------------------------|
| P-05 | 08/31/94 | 2 | 0.59 | < 0.04 |
| P-06 | 08/31/94 | 1 | 1.03 | < 0.04 |
| P-07 | 08/31/94 | 1 | 0.35 | < 0.04 |
| P-08 | 08/31/94 | 1 | 1.6 | < 0.04 |
| P-11 | 08/31/94 | 2 | 1.16 | < 0.04 |
| P-12 | 08/31/94 | 1 | 0.62 | < 0.04 |
| P-13 | 08/31/94 02/28/95 | 2 1 | 1.10 1.23 | < 0.04 < 0.04 |
| P-14 | 08/31/94 | 1 | 0.45 | < 0.04 |
| P-16 | 08/31/94 02/28/95 | 2 1 | 1.31 2.16 | < 0.04 < 0.04 |
| P-17 | 08/31/94 | 1 | 1.18 | < 0.04 |
| P-18 | 08/31/94 | < 1 | 0.59 | < 0.04 |
| P-19 | 08/31/94 | 1 | 0.34 | < 0.04 |
| P-20 | 02/28/95 | 2 | 3.54 | < 0.04 |

Table 8. CDHD Microorganism Analytical Results

| Sample Location | Sample Date | †Total Coliform (CFU/100 ml) | †Fecal Coliform (CFU/100 ml) | Well Depth (feet) |
|-----------------|----------------------|------------------------------|------------------------------|-------------------|
| P-05 | 08/31/94 | 47 | 20 | 150 |
| P-06 | 08/31/94 | < 1 | < 1 | 100 |
| P-07 | 08/31/94 02/28/95 | 4 A | < 1 A | 66 |
| P-08 | 08/31/94 | < 1 | < 1 | 120 |
| P-11 | 08/31/94 | 1 | 1 | 140 |
| P-12 | 08/31/94 | 2 | < 1 | 75 |
| P-13 | 08/31/94 02/28/95 | 60 A | < 1 A | 175 |
| P-14 | 08/31/94 | 25 | 2 | 55 |
| P-16 | 08/31/94 02/28/95 | 2 P | < 1 P | 100 |
| P-17 | 08/31/94 | < 1 | < 1 | 100 |
| P-18 | 08/31/94 | < 1 | < 1 | 70 |
| P-19 | 08/31/94 | 360 | 13 | 50 |
| P-20 | 02/28/95 | A | A | 140 |

†Numbers represent colony forming units per 100 milliliters; P or A represents “presence” or “absence” without quantification.

Figure 4 is a trilinear plot used to display major ion water chemistry (Piper, 1944). The diagram shows concentrations in percent milliequivalents per liter (meq/l) of the major cations and anions for each water sample. The major cations of each water sample (calcium, magnesium, sodium, and potassium) are plotted on the left triangle. The major anions of each water sample (carbonate, bicarbonate, chloride, and sulfate) are plotted on the right triangle. The plotted points for each water sample are then projected to the upper diamond-shaped area to show cation and anion groups as a percentage of the sample. Water samples with similar chemistry plot in the same area on the diagram.

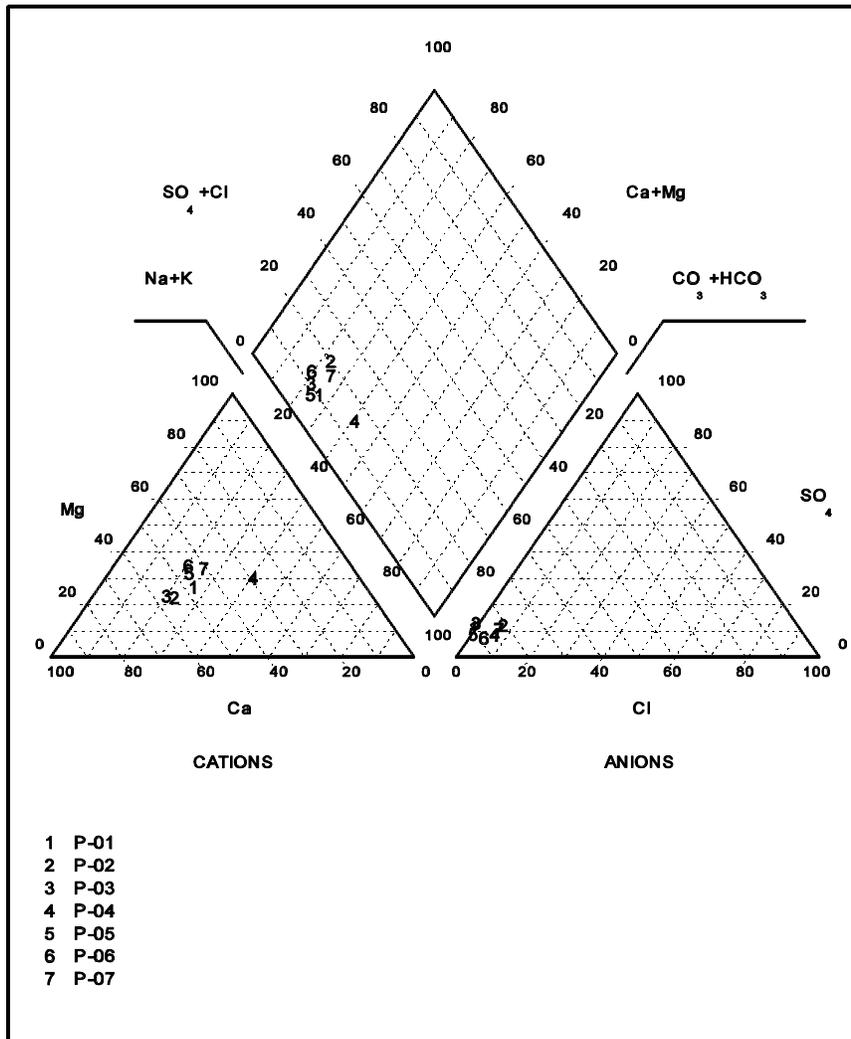


Figure 4. Trilinear Diagram

The trilinear diagram indicates some variability in the compositions of the water samples. The two surface water samples, P-02 and P-03, plot at unexpectedly different locations on the diagram owing mainly to presence of chloride in sample P-02. Sample location P-02 lies down stream from location P-03 in Smith Creek. Livestock grazing activities potentially account for the increased chloride content in the down stream sample. The other notable feature on the trilinear diagram is that well sample P-04 plots in a distinctively different location than the remainder of the samples. The physical location of this well is removed from the other ground water sample locations and may result in the well receiving water from a different ground water flow path or set of interconnected fractures. Other inferences based on the trilinear diagram are not readily apparent.

Figures 5 and 6 are compositional diagrams of the major ions plotted against the total dissolved ions (TDI; the sum of major cations and anions). Figure 5 displays graphs of common cations versus TDI. Figure 6 displays graphs of common anions versus TDI. Both axes represent concentrations in meq/l. Each symbol on the diagrams represents an individual water sample. This type of diagram is used to determine whether there are compositional differences (water types) in the sample set. Data that plot in diagonal linear trends represent mixing of water with low dissolved ion concentrations and water with higher dissolved ion concentrations. Data that plot as more than one cluster indicate separate types of water that are not mixed. A random distribution of data indicates that many individual, unrelated water types exist or that the analytical quality of the data is poor (Mazor, 1991).

Only weak linear trends are visible on certain graphs within Figures 5 and 6 (i.e., sodium, magnesium, and bicarbonate versus TDI). The linear trends may indicate that water with low solute concentrations is mixing in varying percentages with water of higher solute concentrations. Overall, however, both the surface water and ground water samples are low in dissolved ion content reflecting the fact that the ground water recharge source and the headwaters of Smith Creek are located near the sampling locations. Ground water flow primarily through fractured rock also provides minimal opportunity for dissolution of aquifer minerals. The lack of distinct sample clusters indicates that surface water and ground water in the area are: (1) not significantly different in their chemistry or (2) are mixing together in varying degrees. The small sample set makes either hypothesis difficult to support. However, the lack of clear linear trends in the plots indicates that surface water and ground water mixing may not be a dominant occurrence in Prairie. Review of the analytical results indicates very little difference in the ionic chemistry between the surface water and ground water.

Figure 7 is a fingerprint diagram of seven ground water and surface water samples. Each line on the diagram is a graphical representation of the concentration of the major ionic species of each sample. Water samples containing higher concentrations of ions plot higher on the diagram than those containing lower concentrations. Parallel lines indicate various dilutions of a similar water type. Lines with a fan shape indicate mixing of two distinct water types

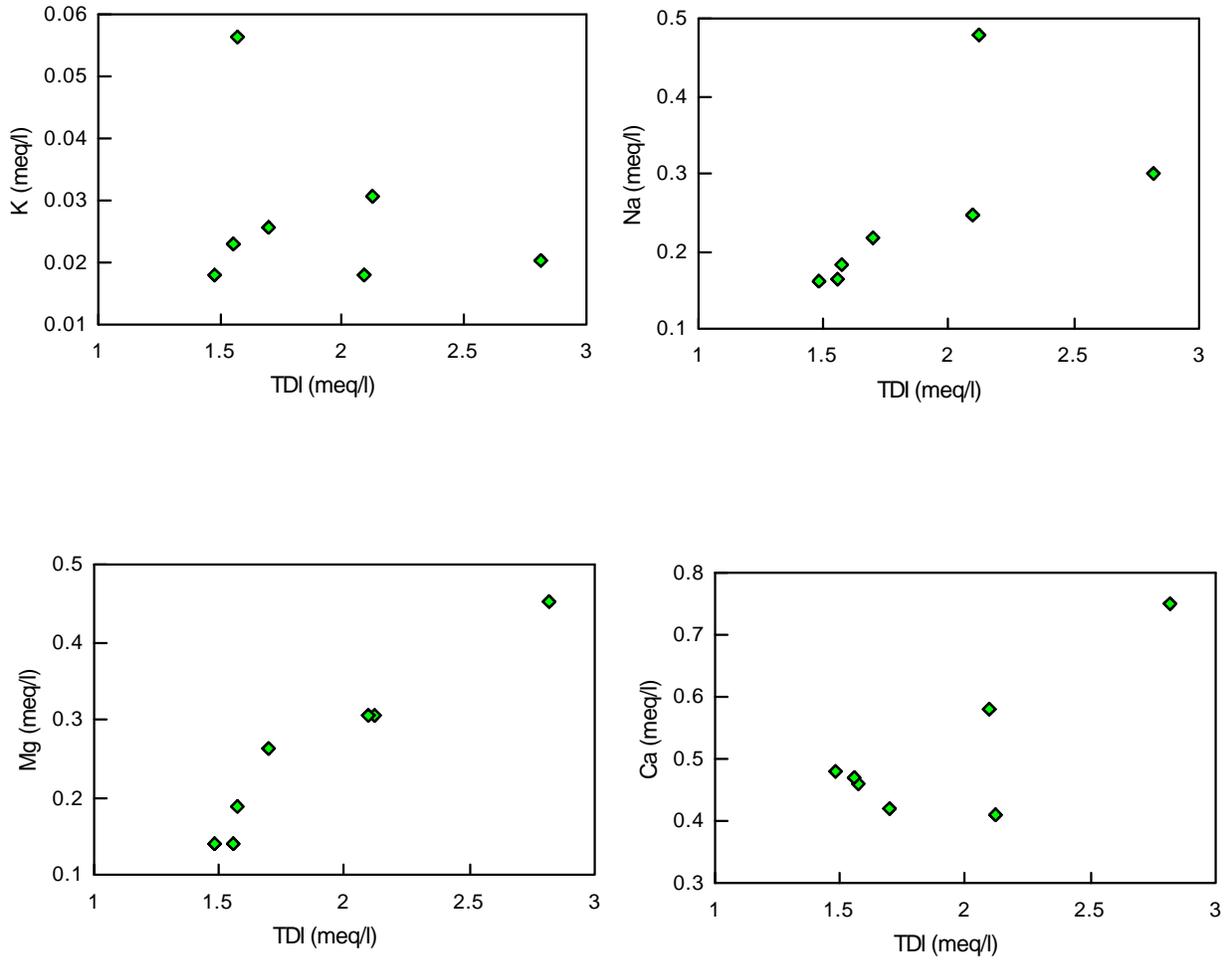


Figure 5. X-Y Plot of Major Cations Versus Total Dissolved Ions

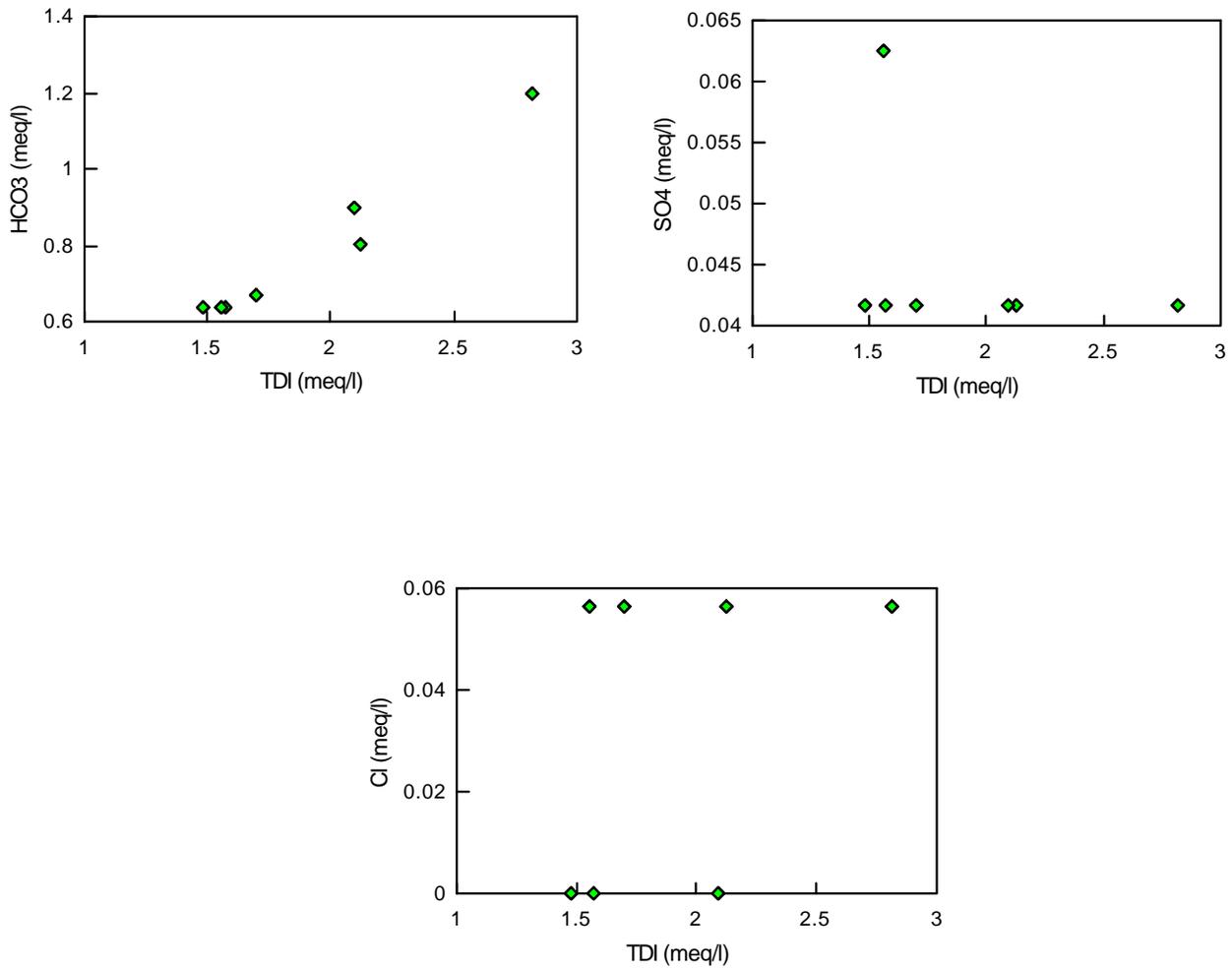


Figure 6. X-Y Plots of Major Anions Versus Total Dissolved Ions

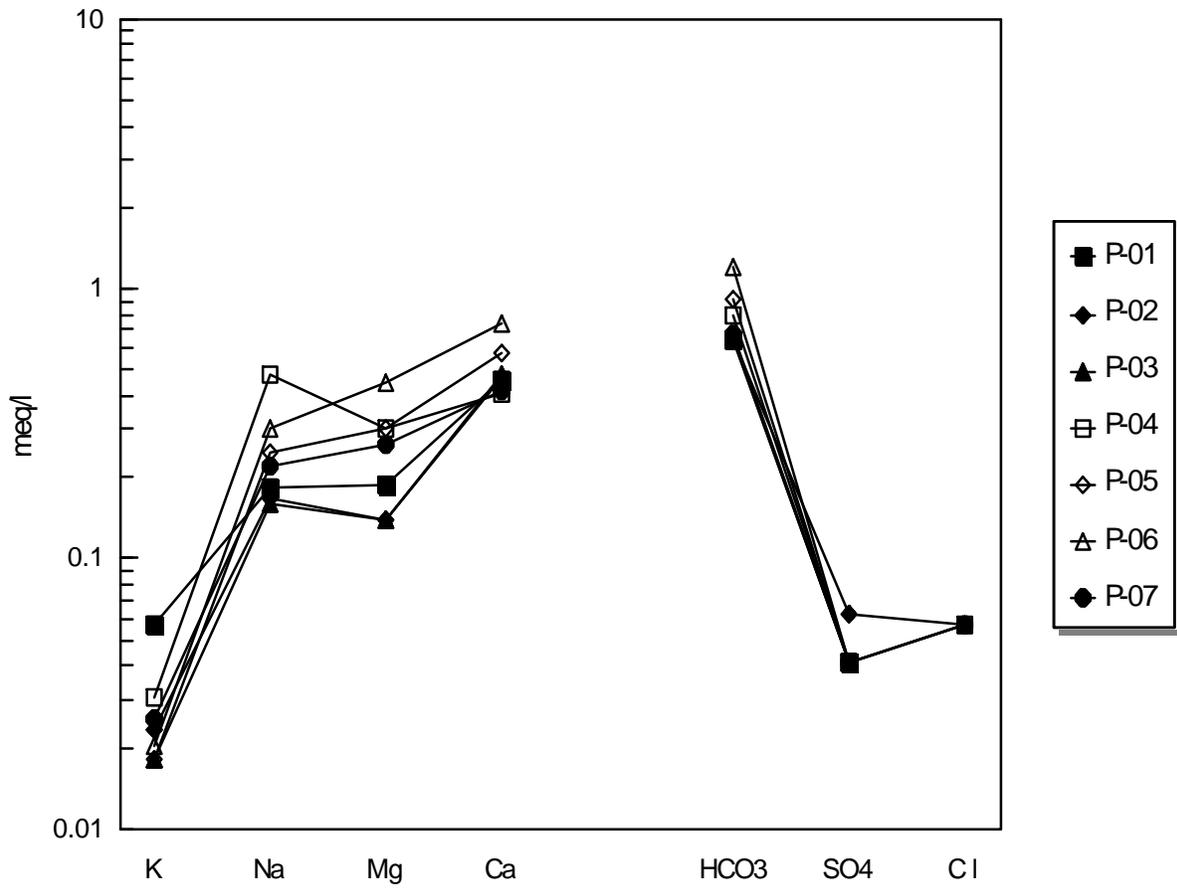


Figure 7. Fingerprint Diagram

(Mazor, 1991). The fingerprint diagram shows that all sample locations exhibit similar ionic compositions. Samples from sites P-01 and P-04 exhibit slightly different characteristics than the other samples as reflected by portions of their plotted lines crossing other lines. Significant features that would allow identification of distinct sample groups are not apparent on the diagram.

Results of the MPA are provided below in Table 9. The MPA results alone cannot determine surface water influence. The results must be used in conjunction with other pertinent data.

Table 9. MPA Results

| Parameter | P-07 (7/8/94) | P-13 (7/8/94) |
|--|---|------------------|
| Presumptive <i>Giardia</i> Cysts | < 0.26/liter | < 1/liter |
| Confirmed <i>Giardia</i> Cysts | < 0.26/liter | < 1/liter |
| Presumptive Oocysts | < 0.26/liter | < 1/liter |
| Confirmed Oocysts | < 0.26/liter | < 1/liter |
| Notes on bioindicators | one rotifer and three pollen grains per 100 gal. | None found |
| Relative Risk of Surface Contamination | Low | None |

Visual analysis of dye samples performed in accordance with methodology described in the Materials and Methods section of this report did not reveal the presence of fluorescein in any of the samples collected from the school well (P-07) or well P-16. The last carbon packet was removed on June 30, 1994, over ten weeks after the introduction of fluorescein dye into the school's septic system. High performance liquid chromatography analyses of water samples collected from the two wells on May 4, 1994 also failed to reveal fluorescein at a detection limit of 0.01 µg/l.

The duration of the tracer test should have been long enough for dye to migrate from the school's septic tank drainfield to either the school's well or well P-16 in the presence of adequate hydraulic connection. The fact that dye was not detected in either well is not conclusive evidence that septic tanks are not the source of Prairie's ground water contamination. It is not known whether the volume of dye introduced to the school's septic

Results and Discussion

system was sufficient to result in a detectable quantity of dye a few hundred feet away under the effects of dilution with ground water and adsorption onto subsurface materials. The complex nature of fracture-dominated ground water flow also makes the performance of a successful dye tracer test difficult to achieve. The school's septic system may not be hydraulically connected to nearby wells, whereas another single septic system or group of septic systems may be located in an area that does recharge zones of ground water withdrawal.

Table 10 provides summary statistics for surface water and ground water samples for which inorganic chemical parameters were analyzed. Note that median values are not provided for the surface water results since only two analyses were performed. Instead, the mean of the two surface water samples is reported.

The data resulting from the inorganic laboratory analyses and field parameter measurements were analyzed using the Mann-Whitney Rank-Sum test. Water quality parameters for which any possible differences between the surface water and ground water groups could exist were evaluated. Typically, graphical representations such as box plots would be useful for presenting the grouped data. However, the surface water group consisted only of two samples making box plots meaningless. The seven records (i.e., surface water and ground water sample results) from P-02 through P-07 represent seven sets of independent individual observations for each parameter. A statement of the null (H_0) and alternative hypothesis (H_1) is as follows:

H_0 : monitored concentrations (surface water) equal background concentrations (ground water);

H_1 : monitored concentrations are less than background concentrations (one-sided test).

A significance level (i.e., acceptable error rate or α) of 0.05 was chosen. For this one-sided test, H_0 is rejected when the calculated value of T is less than the critical value of T (tabulated value) at the chosen significance level, $T_{0.05}$. The results of the statistical analysis are presented in Table 11.

Based on concentrations of magnesium, sodium, nitrate, and silica and on the field measurement of specific conductance, the Mann-Whitney Rank-Sum test indicates that statistically significant chemical differences exist between the ground water and surface water samples. Clearly, the power of this test and the resulting statistical outcome are limited by the extremely small sample set. Reliance on this evaluation alone in formulating conclusions would be erroneous.

Table 10. Summary Statistics

| Parameter | Ground Water | | | Surface Water | | |
|-------------------------------------|----------------|----------------|---------------|----------------|----------------|-------------|
| | Minimum (mg/l) | Maximum (mg/l) | Median (mg/l) | Minimum (mg/l) | Maximum (mg/l) | Mean (mg/l) |
| Calcium | 8.2 | 15.0 | 9.2 | 9.4 | 9.6 | 9.5 |
| Magnesium | 2.3 | 5.5 | 3.7 | 1.7 | 1.7 | 1.7 |
| Sodium | 4.2 | 11.0 | 5.7 | 3.7 | 3.8 | 3.75 |
| Potassium | 0.7 | 2.2 | 1.0 | 0.7 | 0.9 | 0.8 |
| Iron (total) | 0.02 | 0.07 | 0.02 | 0.06 | 0.24 | 0.15 |
| Manganese (total) | < 0.01 | 0.01 | < 0.01 | < 0.01 | 0.01 | NA |
| Bicarbonate (as CaCO ₃) | 39 | 73 | 49 | 39 | 39 | 39 |
| Carbonate | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Sulphate | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.5 |
| Chloride | < 0.9 | 2 | 2 | < 0.9 | 2 | NA |
| Nitrate (as N) | 0.62 | 2.71 | 0.98 | 0.04 | 0.10 | 0.07 |
| Nitrite (as N) | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 |
| Ammonia (as N) | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 |
| Phosphorus (total) | 0.026 | 0.800 | 0.048 | 0.013 | 0.033 | 0.023 |
| Hardness (as CaCO ₃) | 32 | 62 | 38 | 30 | 32 | 31 |
| Silica | 19 | 32 | 22 | 15 | 16 | 15.5 |
| Alkalinity (as CaCO ₃) | 39 | 73 | 49 | 39 | 39 | 39 |
| Arsenic | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| Conductivity (Fmhos/cm) | 65 | 100 | 75 | 50 | 55 | 53 |
| pH (standard units) | 6.65 | 7.37 | 7.14 | 6.90 | 7.62 | 7.26 |
| Temperature (°C) | 10 | 13 | 12 | 5 | 11 | 8 |

Table 11. Statistical Analysis

| Parameter | N_A | N_B | T | T_{0.05} | Outcome |
|----------------------|----------------------|----------------------|----------|-------------------------|------------------------------|
| Calcium | 2 | 5 | 6 | 1 | Cannot reject H ₀ |
| Magnesium | 2 | 5 | 0 | 1 | Reject H ₀ |
| Sodium | 2 | 5 | 0 | 1 | Reject H ₀ |
| Potassium | 2 | 5 | 2.5 | 1 | Cannot reject H ₀ |
| Bicarbonate | 2 | 5 | 1 | 1 | Cannot reject H ₀ |
| Phosphorus | 2 | 5 | 2 | 1 | Cannot Reject H ₀ |
| Nitrate | 2 | 5 | 0 | 1 | Reject H ₀ |
| Silica | 2 | 5 | 0 | 1 | Reject H ₀ |
| Specific Conductance | 2 | 5 | 0 | 1 | Reject H ₀ |
| Temperature | 2 | 5 | 1 | 1 | Cannot Reject H ₀ |

N_A= number of surface water samples; N_B= number of ground water samples; T= calculated test statistic; T_{0.05}= critical value of the test statistic (tabulated) at the chosen error rate, " , of 0.05.

Conclusion and Recommendations

An integration of several data evaluation techniques and sampling methodologies was used to evaluate data collected for this investigation. None of the evaluation tools alone could provide conclusive evidence regarding the source of bacteria in Prairie's ground water. Taken together though, the tools allow some inferences to be made about potential contamination sources.

Infiltration of bacteria-contaminated surface water represents one of several potential sources of contamination to underground drinking water supplies. A comparison of general surface water and ground water chemistry indicates the presence of subtle differences. Although some mixing of surface water (e.g., Smith Creek) with ground water may be taking place, a widespread and dominant influence from Smith Creek is not readily apparent based on the results of this investigation. The chemical evaluations reveal a good-quality ground water with low levels of dissolved minerals and nitrate indicating that ground water beneath Prairie has traveled a relatively short distance from the source of recharge. The fractured basalt subsurface environment probably results in relatively rapid water movement through interconnected fractured zones or other open volcanic features.

The geologic conditions near Prairie make the aquifer system vulnerable to contamination. Areas with very little soil cover are particularly vulnerable since soil can provide some filtering and treatment capacity for contaminants introduced at the land surface. The results of this investigation along with consideration of the occurrence of fractured volcanic rock at or near the surface indicate that subsurface sewage disposal systems (septic tanks and drainfields) are a likely source of bacteria contamination. Below-standard or unapproved sewage disposal systems such as seepage pits, cesspools, or injection wells could be particularly harmful in this setting. No such systems were discovered during this investigation, but the relative remoteness of Prairie and the potential difficulty in installing a standard septic tank and drainfield in the presence of near-surface rock increases the likelihood of their existence.

Shallow wells drawing water from fractured basalt appear to be the most vulnerable to bacteria contamination. Wells less than 100 feet deep in this environment should be considered "shallow" and most vulnerable to contamination. Deeper wells, with proper seals, provide a greater level of assurance that natural subsurface features, such as sedimentary interbeds or deeper fracture sets, can provide protection from near surface contamination.

Based on the results of this investigation, the following recommendations are provided:

- ! Use shallow drainfields or sand mounds in areas with a shallow depth to basalt.
- ! Replace old septic systems that do not have an effective soil depth to provide proper contaminant treatment (e.g., cesspools and seepage pits).

Conclusion and Recommendations

- ! Request that IDWR thoroughly review well abandonment and construction practices in the vicinity of Prairie.
- ! Residents of Prairie should periodically (e.g., twice per year) test their wells for the biological contaminant indicator parameters, total coliform and fecal coliform bacteria.
- ! Owners of wells that are persistently contaminated should consider modifying or replacing the well using protective well construction techniques (contact IDWR for guidance). Alternatively, water treatment methods such as ozone treatment, chlorination with contact time, or boiling may render the water safe for consumption.
- ! Residents affected by suspected water-borne illnesses should report their symptoms immediately to CDHD or DEQ. These agencies should seek appropriate assistance in assessing the illnesses with the Idaho Department of Health and Welfare, Division of Health.

This investigation was limited in its scope and has not provided all of the necessary answers to questions regarding the source or sources of bacteria contamination in Prairie's ground water. It does form a foundation from which to base further studies as resources allow. Depending upon the availability of personnel and financial resources, DEQ or other agencies may choose to undertake further investigations. Virus studies, broader-scale MPA analyses, isotope studies, and ground water tracer tests using appropriate analytical techniques (e.g., fluorescein dye test with field fluorometer analysis) are worthy of consideration.

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