QUALITY of GROUND WATER in PRIVATE WELLS in the LOWER YAKIMA VALLEY, 2001-02

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ABSTRACT

In 2001-02, the non-profit Valley Institute for Research and Education (VIRE) tested 249 private wells of low-income residents of the lower Yakima Valley in Washington State. The primary objective of this project was to apprise participants of the quality of their drinking water; a secondary objective was to gather baseline data on the quality of the ground water in the area. A contract laboratory analyzed the samples for nitrate+nitrite-N, coliform and E. coli bacteria and arsenic, and VIRE analyzed samples for chloride, ammonia, pH, specific conductivity, temperature, dissolved oxygen and ferrous iron.

The study area comprises the portion of the lower Yakima Valley bounded on the north by Rattlesnake Ridge, the south by the Horse Heaven Hills, the east by the Yakima County line and the west by the Toppenish Creek Basin. The lower Yakima Valley is one of the most intensely irrigated and diverse agricultural areas in the United States. In addition, the southern portion of the study area includes over 60 dairies with approximately 100,000 animal units and many animal feeding operations (AFO).

A statistical analysis of the results of the chemical tests showed that the quality of ground water was significantly better ($p<0.05$) in the northern portion of the study area (Region 1) than in the southern portion (Region 2). The communities of Buena, Parker, Toppenish, Wapato and Zillah are located in Region 1 and the communities of Granger, Grandview, Outlook, Mabton and Sunnyside are located in Region 2. None of the wells sampled in Region 1 exceeded the U. S. Environmental Protection Agency's maximum contaminant level (MCL) for nitrate+nitrite-N of 10 milligrams per liter whereas 21% of the wells sampled in Region 2 exceeded this standard. Mean values for ammonia, chloride and specific conductivity were also significantly higher in Region 2. This study was not designed to identify sources of contaminants, but other studies have shown that overuse of nitrogen fertilizers is the primary cause of nitrate contamination of ground water in agricultural areas. An examination of well drillers' logs in Region 2 indicated that some wells were inadequately cased and sealed which facilitated contamination.

A higher percent of wells were contaminated with coliform bacteria in Region 1 (41%) than in Region 2 (22%). The proximity of contaminated wells in some areas suggests that the ground water may be contaminated although other causes may include poor construction or maintenance of wells. None of the 74 wells tested for arsenic exceeded the MCL of 50 micrograms per liter (μg/l), but eight will exceed the new MCL of 10 μg/l effective in January 2006.

This study has shown that the quality of ground water is impaired in some areas. To prevent further deterioration, it is recommended that area residents and agricultural interests form a Ground Water Management Area in the lower Yakima Valley with the goal of reducing contaminants. This organization could more extensively survey, characterize and monitor trends in ground water quality, identify areas with the highest contamination for in-depth study and determine the effects of agricultural practices and other human activities on contaminants. Through public outreach and educational efforts, this organization could also play a key role in making stakeholders aware of the value and the vulnerability of ground water.

INTRODUCTION

In 2001-02, the non-profit Valley Institute for Research and Education (VIRE) conducted free water testing for low-income residents of the lower Yakima Valley who obtain their drinking water from private wells. The primary objective of this research was to apprise participants of the quality of their drinking water relative to Washington State Drinking Water Standards for Public Systems. The secondary objective was to create a database of the quality of ground water in the lower Yakima Valley to serve as a baseline for determining future trends.

Wells were tested for nitrate+nitrite-N (nitrate), arsenic, coliform and E. coli bacteria, pH, temperature, specific conductivity, dissolved oxygen, ammonia-N (ammonia), ferrous iron and chloride. Nitrate and arsenic are designated as primary contaminants in drinking water by the U.S. Environmental Protection Agency (EPA) and all of these analytes are general indicators of ground water quality.

The lower Yakima Valley is located in south central Washington State and the primary population centers are Toppenish and Sunnyside. The study area encompasses the portion of the lower Yakima Valley bounded on the north by Rattlesnake Ridge, the south by the Horse Heaven Hills, the east by the Yakima County line and the west by the Toppenish Creek Basin (Map 1). Agriculture is the primary activity in this area and includes the growing of apples, grapes, silage corn, hops, alfalfa, cherries, asparagus, hay, pears, spearmint, wine grapes, spring wheat, grain and sweet corn and pasture for livestock. The majority of irrigated acreage is watered by permanent and portable sprinklers and rill irrigation (information provided by the South Yakima Conservation District). In addition, Yakima County has more than 70 dairies, 62,000 milk cows, leads the state in milk production and ranks 13th in the United States in pounds of milk produced (Washington State Dairy Federation web site). Over 90% of these dairies are located in the study area with the majority concentrated in the Sunnyside area[1]. The study area is also the location of many animal feeding operations (AFO).

The terrain of the study area is a broad plain that slopes to the south and is underlain by successive layers of loess, flood sediment, Ellensburg Formation and Columbia River basalt. Snipes Mountain, located immediately northeast of the Yakima River, is an eight-mile long basaltic outcropping that has a principal axis which runs from the northwest to the southeast. Ground water in this study area generally flows toward the south and southeast. Snipes Mountain, however, is a hydrologic barrier that diverts partial ground water flow around its eastern and western extremities (personal communication, Newell Campbell).

The effects of human activities on surface waters in the lower Yakima Valley are well documented[2]. There have also been several ground water studies conducted by the USGS in the Toppenish Creek Basin, including the most recent in 1989-91[3] which reported that the ground water quality was generally good. Only 2 of 487 wells (0.4%) sampled during one phase of that study had nitrate levels that exceeded the EPA maximum contaminant level (MCL) for drinking water of 10 milligrams per liter (mg/l). The MCL refers to the maximum permissible level of a contaminant in water delivered to any public water system user. The quality of the ground water in private wells in the lower Yakima Valley outside the Toppenish Creek Basin, however, has never been studied.

Many rural residents of the lower Yakima Valley rely on ground water from private wells as their source of potable water. Owners of private wells, however, are not required by law to have their water regularly tested and little information is currently available on the quality of this water. The Washington State Department of Health (WaDOH) recommends that private wells be tested on a yearly basis for coliforms and every three years for nitrates but, since over 48% of the residents of the lower Yakima Valley[4] are below poverty level, many cannot afford the tests. Without testing, users are unaware that they could be exposed to contaminants in their drinking water.

The lower Yakima Valley is one of the most intensely irrigated and diverse agricultural areas in the United States. Nitrate from chemical fertilizers, animal manures and septic systems is the most common contaminant of ground water in the United States and the highest nitrate concentrations occur where fertilizer use and irrigation are the greatest[5]. Nitrates are highly soluble and can easily move through soil into the ground water supply. The potential for nitrate to contaminate the ground water depends on several factors including the soil characteristics, time of year, location and characteristics of the underground aquifers and the depth and construction of wells. Shallow wells, poorly constructed or sealed wells and wells that draw water from unconfined aquifers are at greatest risk.

Concentrations of nitrate in excess of the MCL of 10 mg/l can pose a health risk to infants under one year of age, pregnant women, individuals with impaired immune systems and individuals with a hereditary lack of methemoglobin reductase[6]. High nitrate exposures have also been associated with intrauterine growth restriction and prematurity[7].

METHODS

Recruitment of Participants

The goal of the project was to sample 250 private wells of low income individuals in the study area. Techniques to reach the target population included presenting informational material in both English and Spanish on radio and television and in print media, conducting seminars for community organizations, staging advertising campaigns and distributing brochures. The uneven distribution of well sites reflects the difficulty of recruiting participants in all areas and accounts for the clustering of some well locations. Word-of-mouth referral was the most effective recruitment tool. Participant eligibility and demographic information were obtained through screening interviews. To qualify, the participant's income had to be less than or equal to 200% of the 2001 U.S. Department of Health and Human Services' Poverty Levels Guidelines, a standard used by government agencies for projects involving children's health issues. Participants were asked to sign a statement indicating their income was within the guidelines.

Original plans for the study excluded testing wells in the Toppenish Creek Basin which had previously been studied by the USGS[3]. Concerns of some residents in that area about the quality of their drinking water, however, led to including some wells from there. This also provided an opportunity to determine if ground water quality in that area had changed in the past decade.

Testing Well Water

As a preliminary to the study, VIRE prepared a Quality Assurance Project Plan (QAPP) and a Sampling and Analysis Plan which were approved by the Washington State Department of Ecology. College science students were trained as field technicians for the project and were responsible for performing chemical and physical tests on water samples on site, collecting samples for analyses off site and determining Global Positioning System (GPS) coordinates of the wellhead. Testing was primarily conducted on weekends because most participants worked and were unavailable on weekdays. Well identification numbers were designated as xxx (y), where xxx is a three-digit number based on the elapsed days since January 1, 2001, and (y) is a number indicating the numerical order in which the sites were sampled on day xxx. For example 321 (3) indicates the third well sampled on November 17, 2001.

On site testing included the measuring of pH, temperature, and specific conductivity using a Yellow Springs International (YSI) Model 63 meter. The pH meter was calibrated at the beginning of each sampling day and the calibration of the specific conductivity meter was periodically checked for accuracy using commercial standards (see Performance Standards Section). Most samples collected during the winter months were taken from an indoor faucet upstream from any water treatment such as softening or filtration and the aerator was removed. In most cases it was not possible to obtain the sample before the water had gone through a pressure tank. Before testing began, the line was purged for five minutes. If an outside faucet was used, a hose was attached during the purge to discharge the water away from the house and then removed before testing began. A metal bowl containing the YSI's detector was placed under the faucet and allowed to fill and overflow for one minute before the first reading was taken. The bowl was then emptied and allowed to overflow for another minute before the second reading was taken. Subsequent determinations were made in the same manner until three consecutive readings for pH, temperature and specific conductivity remained constant ($\pm$ 5%). The final readings were assumed to be the most accurate and are reported herein.

Water samples were then collected for off site testing for coliform and E. coli bacteria. To prevent contamination from external sources, inside faucets were first cleansed with alcohol pads and then flushed with water for one minute to remove residual alcohol. Outside faucets were immersed in a bleach solution for two minutes and then flushed with water to remove residual bleach. Water samples were then collected following procedures described in the project's Standard Operating Procedures. The qualitative presence-absence Colilert test was used to test all samples and was justified on the theory that no coliforms should be present in a 100 ml sample of drinking water. The WaDOH-certified Water Laboratory at Central Washington University, Ellensburg, WA, performed the tests and supplied the sterile containers which contained the preservative sodium thiosulfate.

Well water and appropriate quality assurance samples were then collected for nitrate, arsenic, chloride and ammonia for analysis off site. The WaDOH-certified Cascade Analytical Laboratory, Wenatchee, WA, analyzed samples for nitrate and arsenic, and occasionally performed confirmatory tests for chloride and ammonia. Sealed bottles for nitrate and arsenic were supplied by the contract laboratory and were used as provided. VIRE conducted the tests for chloride (Chemetrics P/N k-2010) and ammonia (Chemetrics P/N I-2004) at Alliance Analytical Laboratory, Yakima, WA. The sample bottles for chloride and ammonia were supplied by VIRE and were washed with soap and water, triple rinsed with distilled water, and allowed to air dry before use.

Dissolved oxygen (DO) was then determined on site using a direct and an indirect method. The direct method used a test kit from Chemetrics Inc. (0.0 to 15.0 mg/l range P/N V-7513, or 0.0 to 2.0 mg/l range P/N V-7503), and a colorimeter (V-1000). The lip of the faucet was submerged in the collection vessel to prevent the sample from becoming aerated while the vessel was purged with several volumes of water to remove residual oxygen. A 25-ml aliquot was then collected and immediately analyzed for DO using the 0.0 to 15.0 mg/l range kit. If the concentration was below 2.0 mg/l, a second sample was collected as before and analyzed using the 0.0 to 2.0 mg/l range kit. The low range kit was considered more accurate for samples below 2.0 mg/l and those results are reported herein.

Since direct measurement of DO could be unreliable, a test for ferrous iron was added later in the study as an indirect method for detecting DO. In the presence of DO, ferrous iron is oxidized to ferric iron which cannot be detected by the method. Therefore, finding ferrous iron in ground water indicates low or absent DO. This second method employed a Chemetrics' ferrous iron test kit (P/N K-6210). Water samples were collected for this test following the procedure outlined above.

All samples were transported in ice chests containing non-aqueous "Blue Ice". Temperature (average 4^0 C) was monitored and recorded during transit and storage and chain of custody documentation was maintained throughout. Bacteriological samples were collected and shipped to ensure that the maximum holding times were not exceeded. Samples for chemical analyses were preserved according to WaDOH procedures when holding times would have been exceeded. Documentation was maintained on collection and analyses times for all samples.

Participants were given their laboratory results and an interpretive summary in either English or Spanish, an educational packet explaining the tests and guidelines for protecting their wellhead. Participants whose wells were contaminated with either nitrate or bacteria were notified by phone and sent WaDOH information about the health effects of these contaminants and precautionary steps that should be followed. If a well was contaminated with bacteria, the participant was also given WaDOH's decontamination procedure and the opportunity to have the well retested to determine if the procedure was successful.

Quality Assurance

This section summarizes the field and laboratory procedures that were used to satisfy the requirements given in the QAPP and Sampling and Analysis Plan. To determine if the study met these requirements, a quality assurance officer (QAO) was designated by board members of VIRE to periodically inspect all phases of the project. The QAO reported directly to VIRE's board and copies of his reports were given to the project director and are included in Appendix 1.

Quality assurance (QA) procedures for determinations made with the YSI meter were done in the field. Readings for specific conductivity, pH, and temperature were replicated until the difference between the last two was less than $\pm$ 5%. A minimum of three readings was required and the last was the accepted value for the parameter.

Duplicate samples were collected to assess the precision of the analytical methods, water collection techniques, field and laboratory handling procedures and storage conditions. A "duplicate" consisted of having the same field technician collect two samples in sequence which were then analyzed for the same analyte at the same laboratory. The relative percent difference (RPD) between the two results was then calculated from the following equation:

$$RPD = abs[(C_1-C_2)*100/(C_1+C_2)/2]$$

where abs = absolute value
C_1 = concentration of analyte in the first sample of the duplicate pair
C_2 = concentration of analyte in the second sample of the duplicate pair

Duplicates were collected during most sampling events for nitrate and arsenic and were periodically collected for ammonia and chloride. Occasionally, one of a pair of duplicates was sent to an alternative laboratory for confirmative purposes. This sample was referred to as an interlaboratory split and was used to verify VIRE's and the contract laboratory's testing methods.

Other quality assurance samples included trip and field blanks, trip, field and laboratory spikes and performance standards. A trip blank was a sample in which a container was filled with distilled water at the laboratory and handled in the same manner as well water samples. The purpose of this sample was to evaluate the potential for contamination from containers and to assess storage and transportation protocols. A field blank was a container filled with distilled water in the field and treated in the same manner as the well samples and was used to assess contamination from handling during the collection process. Trip blanks were prepared for each sampling event and field blanks were periodically prepared.

Trip spikes for nitrate, ammonia, chloride, and arsenic were used to assess the precision of the analytical methods and the exposure impacts of field handling, storage and transportation. These samples were prepared by filling a container with a known concentration of one of these chemicals in distilled water at the commencement of each sampling event. These samples were taken into the field and handled and stored in the same manner as the field samples. The contract laboratory supplied spike solutions for nitrate and arsenic and VIRE supplied spike solutions for chloride and ammonia which were prepared using reagent grade chemicals.

Field spikes were prepared as needed by pouring a known concentration of nitrate, ammonia or chloride into a container in the field and were used to evaluate the potential for contamination from containers and from handling during the collection process. Arsenic field spikes were not prepared because of the hazards of handling this element in the field.

Laboratory spikes for nitrate and arsenic were prepared in-house and analyzed along with each batch of field samples run by the contract laboratory to access the precision of the analytical methods. Laboratory spikes for ammonia and chloride were usually prepared and analyzed by VIRE each time they performed these tests.

Performance standards, which contained accurately prepared solutions of nitrate, arsenic, pH, specific conductivity and chloride, were purchased from commercial vendors and submitted periodically for analyses. These standards were used to determine the accuracy of laboratory and field tests. When performance standards were submitted to Cascade Analytical Laboratory, they were identified as well water samples and therefore represented "blind" samples. VIRE's laboratory technicians were aware that they were testing performance standards, but they were unaware of the target values of the chemicals in the standards. The data quality objectives (DQO) for duplicate samples, interlaboratory splits, trip spikes, field spikes, laboratory spikes and performance standards are discussed in the Results section.

RESULTS

Field sampling began November 17, 2001 and was completed August 7, 2002. During that period 249 wells were tested and 38 were retested. Wells with coliform bacteria were retested after decontamination. Also, several wells were retested when an exceptional result was obtained for one of the analytes, for example the nitrate result from site 483 (6) or the ammonia results from sites 517 (1) and 517 (3). Data for field and laboratory test results are given in Table 1 (Appendix 1).

A ranking of mean concentrations of chemical contaminants based on locations of participants indicated that ground water quality was better in the northern portion of the study area than in the southern portion. To determine if there were statistical differences between the mean contamination levels, 95% confidence intervals were calculated for the mean concentrations of nitrate, ammonia, chloride, specific conductivity and arsenic based on the zip codes of participants (Table 2). The

Table 2. Maximum and minimum values, medians, means and confidence intervals (95%) for specific conductivity, nitrate, ammonia, chloride and arsenic based on region of study area.

Region	Groundwater Parameter	Maximum Value	Minimum Value	Median	Mean	95% Confidence Interval of Mean	
						Lower	Upper
1[1]	Sp. Cond.[3] (μS/cm)	845	120	271	322	277	367
2[2]	Sp. Cond. (μS/cm)	1995	261	593	621	590	652
1	Nitrate (mg/l)	9.41	<0.07	1.81	2.28	1.77	2.79
2	Nitrate (mg/l)	55.2	<0.07	3.75	5.93	4.98	6.88
1	Ammonia (mg/l)	0.2	<0.2	0	0.02	0.01	0.04
2	Ammonia (mg/l)	1.0	<0.2	0.05	0.12	0.09	0.15
1	Chloride (mg/l)	30	<15	0	5.87	3.26	8.48
2	Chloride (mg/l)	60	<15	19.5	18.7	16.26	21.14
1	Arsenic (μg/l)	11.4	<3.0	0	2.77	0.86	4.68
2	Arsenic (μg/l)	13.8	<3.0	3.69	4.24	3.25	5.23

1. Region 1 includes 54 wells around Buena, Parker, Toppenish, Wapato and Zillah.

2. Region 2 includes 195 wells around Grandview, Granger, Mabton, Outlook and Sunnyside.

3. Specific conductivity.

95% confidence interval is a statistical calculation which gives upper and lower confidence ranges for the means, and means are considered to be significantly different if the ranges do not overlap. The equation used to calculate the 95% confidence interval (I) follows:

$$I = \text{mean} \pm 1.96\,(S/(n)^{1/2})$$

where S = standard deviation of the mean
n = number of wells

These calculations showed that there were statistically significant differences between the contamination levels in the northern and southern portions of the study area and provided a basis for dividing the area into two regions (Map 1). In Region 1, which includes areas around Buena, Parker, Wapato, Toppenish, and Zillah, mean concentration levels of nitrate, ammonia, chloride and specific conductivity were significantly lower than in Region 2 which includes Grandview, Granger, Mabton, Outlook and Sunnyside. The mean values for arsenic, however, were not significantly different between the two regions. While the coliform test could not be statistically evaluated, a higher percentage of wells was contaminated in Region 1 than in Region 2. A total of 54 wells were tested in Region 1 and 195 in Region 2 and a summary of the results for individual analytes and microbiological tests follows. Also, a geohydrologic study focusing on surficial sediment type, well and aquifer characterization and surficial drainage considerations as related to nitrate contamination follows.

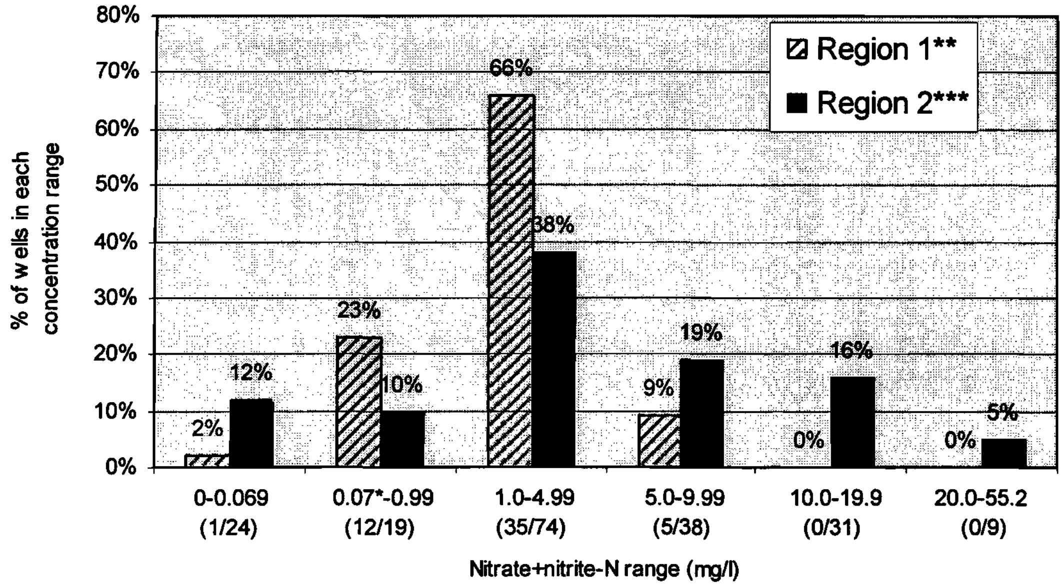
Well Water Test Results

Nitrate+nitrite-N and Ammonia-N

Nitrate, analyzed in this study as nitrate+nitrite-N, is a primary contaminant under the EPA drinking water standards[8] and has a MCL of 10.0 mg/l. The MCL for nitrate has a toxicological basis unlike the arbitrary "normal" (1 to <5.0 mg/l) and "elevated" (5 to <10.0 mg/l) concentration ranges which in this report are similar to the convention used by the USGS[9]. While the "elevated" range could be considered conservative, it prevents overestimating elevated nitrate levels. Synthetic and manure fertilizers, and septic wastes are the most common sources of excess nitrate in ground water.

A total of 248 wells were tested for nitrate and the results are shown on Maps 2 and 3 in four concentration levels: "subnormal", "normal", "elevated" and "above MCL". Maps 4 and 5 provide more detailed views of the wells with abnormal nitrate levels. In these maps, the "normal" concentration level has been omitted and the abnormal concentrations have been divided into five ranges: "subnormal" includes a "non-detectable" range which is below the limit of detection of the analytical method (<0.07mg/l), and "above MCL" ($\geq$10.0 mg/l) has been divided to include a $\geq$ 20 mg/l range to show where the highest levels of contamination were found. Figure 1 illustrates the percent of wells in each nitrate concentration range for Region 1 and Region 2. Nitrate

Figure 1. Percentage of wells in Nitrate+nitrite-N concentration ranges in Region 1 and Region 2 (total number of wells in each range is shown in parenthesis as follows: (Region1/Region2)).



*Minimum detection level
**Region 1 includes 53 wells tested for nitrate.
***Region 2 includes 195 wells tested for nitrate.

concentrations often fluctuate, however, so a single sample may not represent the average or peak concentration within the ground water.

The results showed that in Region 1 the median nitrate concentration was 1.8 mg/l, the mean concentration was 2.3 mg/l and none of the wells exceeded the EPA's MCL of 10.0 mg/l. In Region 2, the median concentration was 3.8 mg/l, the mean concentration was 5.9 mg/l and 40 wells (21%) exceeded the MCL; nine of these wells had concentrations above 20.0 mg/l. Twenty-five of the 40 wells that exceeded the MCL of 10.0 mg/l were located north of the I-82 freeway between Granger and the county line east of Sunnyside. An additional nine wells with nitrate concentrations above 10.0 mg/l were located south and east of Mabton. Wells with nitrate levels that exceeded 20.0 mg/l were located north of Outlook and Sunnyside and south and southeast of Mabton The well with the highest nitrate level (55.2 mg/l) was located north of Sunnyside.

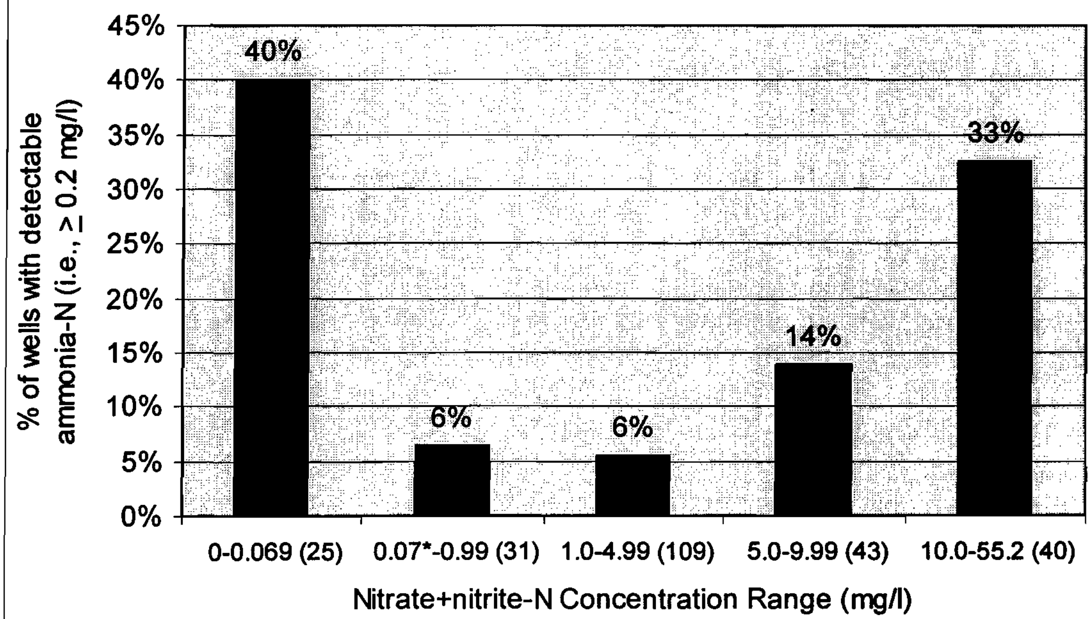
Most of the wells with non-detectable nitrate (<0.07 mg/l) also had low levels of dissolved oxygen and contained ferrous iron, indicative of the anaerobic conditions favorable to denitrification (see DO and Ferrous Iron Section). Non-detectable levels of nitrate were found in one well (2%) in Region 1 and in 24 wells (12%) in Region 2. Most of these wells were located in the vicinity of

Outlook and in the area between Sunnyside and Mabton. Wells with nitrate concentrations that were elevated or above MCL were frequently in close proximity to these wells.

The occurrence of ammonia in ground water suggests contamination from human and animal wastes. Since this cation does not readily move through soil into ground water, its presence indicates the source is nearby. Under aerobic conditions, bacteria oxidize ammonia to nitrate in a process called nitrification and utilize the energy released by the reaction. Under anaerobic conditions, however, the reaction is inhibited and ammonia can persist and leach into the ground water. Of the 243 wells tested for ammonia, it was detected in 2 wells (4%) in Region 1 and 35 wells (19%) in Region 2 (Maps 6 and 7), and was found in a higher percentage of wells with either above normal or below normal nitrate concentrations (Figure 2).

The contract laboratory's results for ammonia determinations from wells 517 (1) and 517 (3) were extraordinarily high and were suspect because they could not be replicated when these wells were retested 17 days later (Table 1). Since laboratory personnel were unable to explain this anomaly, these data were omitted.

Figure 2. Percentage of wells with detectable ammonia based on their nitrate+nitrite-N conc. (number of wells in each range for the entire study area are shown in parenthesis).

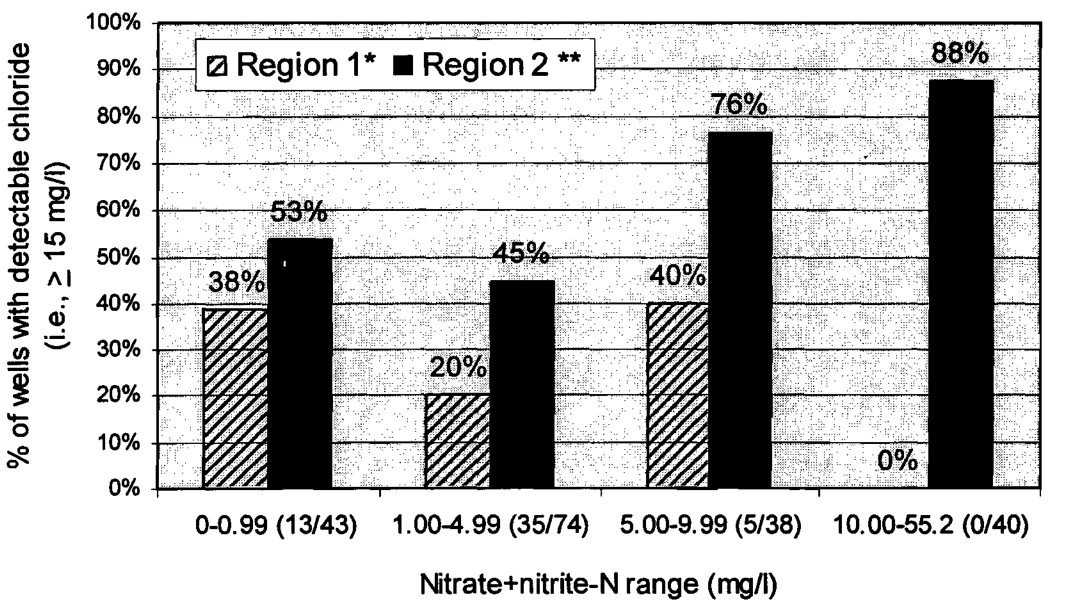


*Minimum detection level

Chloride

Chloride is a secondary drinking water constituent and has an MCL of 250 mg/l. Secondary drinking water standards apply to constituents that affect the aesthetic qualities of drinking water for such things as odor, taste and staining and are non-enforceable. Chloride occurs naturally in groundwater but is also present in human and animal wastes. Because it is highly soluble and diffuses more rapidly in water than other contaminants, temporal increases in chloride levels may portend a plume of contamination. Of the 244 wells tested for chloride, 134 had detectable levels ($\geq$ 15 mg/l) and concentrations varied from 15 to 60 mg/l (Maps 8 and 9). Chloride was found in 15 wells (27%) in Region 1 and 120 wells (62%) in Region 2. A higher percentage of wells contained chloride when the nitrate concentration was either above or below normal levels (Figure 3). Ammonia also was present in 22% of the wells that contained chloride as compared to 7% of the wells that did not. The high concentration (315 mg/l) obtained for well 329 (4) may have been the result of a lab error and that datum was disregarded.

Figure 3. Percentage of wells with detectable chloride in Regions 1 and 2 based on nitrate+nitrite-N ranges (total number of wells in each range is in parenthesis as follows: (Region 1/Region 2))



*Region 1 includes 53 wells tested for chloride.
**Region 2 includes 195 wells tested for chloride.

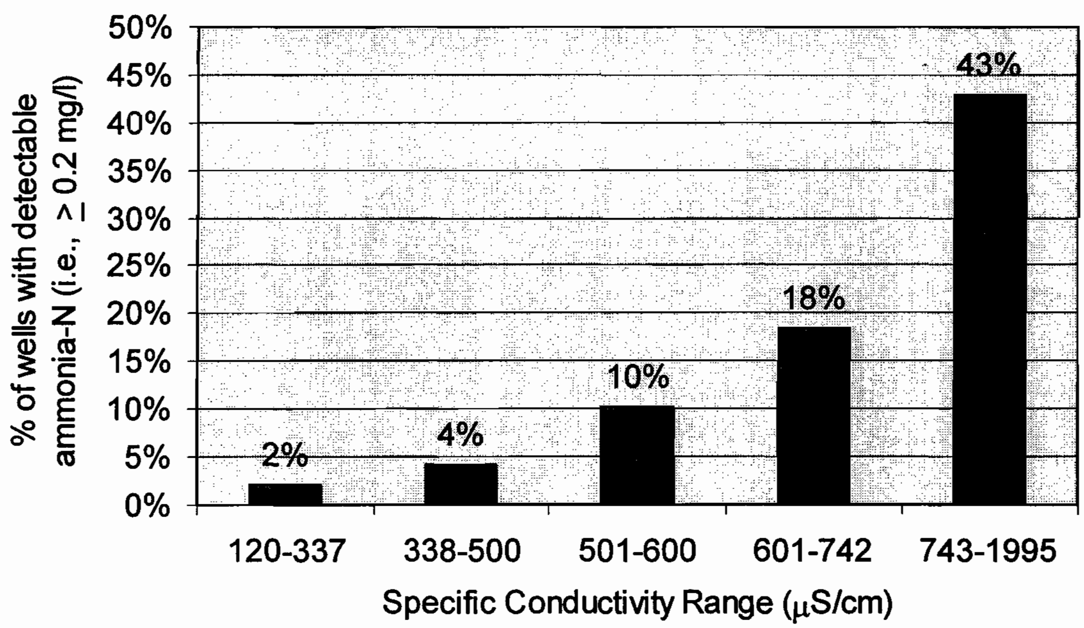
pH, Temperature and Specific Conductivity

The secondary MCL for pH is 6.5-8.5. In this study, the pH values ranged from 6.6 to 8.2 and the mean was 7.6. Acidic pHs (< 7.0) were found in low lying areas northwest of Toppenish and alkaline pHs ≥ 8.0 were found east of Granger (Maps 10 and 11).

Temperature and specific conductivity are unregulated. Water temperatures ranged from 6.5 °C to 22.0 °C (Table 1) and the mean was 13.9 °C. This wide range in temperatures is likely attributable to the effect of ambient temperature on plumbing and pressure tanks.

Specific conductivity, which measures the salt content of water, ranged from 120 to 1995 μS/cm (Maps 12 and 13) and the mean for the study area was 556. In Region 1, 6 wells (11%) exceeded the mean and in Region 2, 118 wells (61%) exceeded the mean. Wells that exceeded the MCL for nitrate had specific conductivities above 592 and six wells with non-detectable nitrate also had specific conductivities above that level. Higher ammonia levels were also associated with higher specific conductivities (Figure 4). The two wells in Region 1 which have ammonia fell into the lowest conductivity range in Figure 4. Other wells represented in this chart are in Region 2.

Figure 4. Percentage of wells containing detectable levels of ammonia based on specific conductivity ranges (each range represents 50 wells except the 743- 1995 range which represents 49 wells)



Dissolved Oxygen and Ferrous Iron

Dissolved oxygen determinations made downstream from a pump could be subject to error since oxygen can be introduced by the pump. Determinations of low DO were useful, however, for identifying anaerobic sites where conditions were favorable for denitrification. In this process, bacteria use nitrate and nitrite as an oxygen source and release gaseous forms of nitrogen into the environment as byproducts. There were 4 wells in Region 1 (7%) and 60 wells in Region 2 (31%) with DO less than 1.0 mg/l. (Maps 14 and 15 show results of DO tests.) The ferrous iron test was used as an indirect method of determining the presence of DO. Of the 149 wells tested for ferrous iron, 23 contained the compound and 15 of the 23 had no detectable nitrate (Maps 16 and 17). Ferrous iron was present in one well in Region 1 and 22 wells in Region 2.

Arsenic

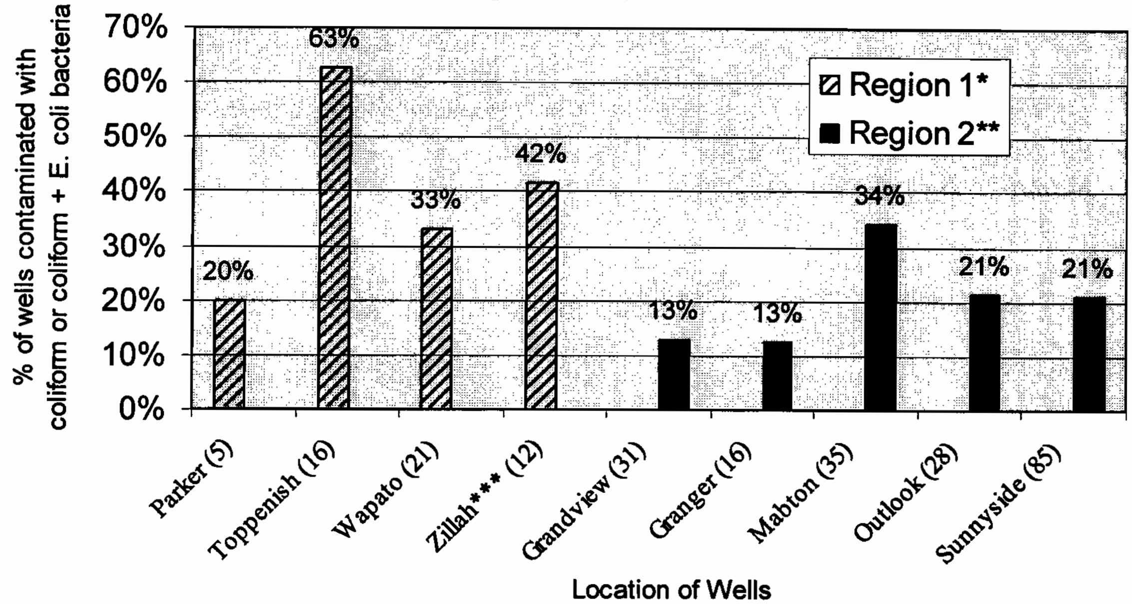
Because of the expense of the arsenic test, determinations were made on only 30% of the wells, 19 in Region 1 and 55 in Region 2. Wells were arbitrarily selected for testing to give a broad coverage of the study area but, when a well tested above 7 μg/l, nearby wells were also tested. In addition, wells in orchard areas were routinely tested because of potential contamination from lead arsenate. The EPA's present MCl for arsenic in drinking water for public systems is 50 μg/l but a change to the Clean Drinking Water Act, effective in January 2006, will reduce this to 10 μg/l. None of the wells tested exceeded the present MCL, but eight will exceed the new tolerance: two in Region 1, and six in Region 2 (Maps 18 and 19). In Region 1, arsenic concentrations ranged from <3.0 μg/l to 11.4 μg/l and in Region 2 concentrations ranged from <3.0 μg/l to 13.8 μg/l.

Coliform Bacteria

Coliform bacteria are normally found in the environment, but they should not be present in ground water. While these bacteria are not considered pathogenic, their presence is an indication that disease causing organisms could also be present. E. coli, a species of fecal coliform bacteria, indicates that the ground water could be contaminated with animal or human fecal waste and may carry other disease-causing bacteria associated with fecal contamination. Potential sources of contamination include septic tanks, barnyards and areas where warm-blooded animals and associated manure are present. A well that tests positive for E. coli always tests positive for total coliforms.

The locations of wells with coliform and E. coli bacteria are shown in Maps 20 and 21. Coliform bacteria were found in 22 (41%) of the wells in Region 1 and 42 (22%) of the wells in Region 2 (Figure 5). In addition, E. coli was identified in one well in Region 1 and three wells in Region 2. Participants whose wells tested positive for coliform bacteria were given a decontamination procedure from the WaDOH and their wells were retested if they performed the procedure. Of the 24 participants who attempted the procedure (37.5%), 13 were successful although one participant had to repeat the procedure three times.

Figure 5. Percentage of wells contaminated with bacteria (number of wells in each location is shown in parenthesis).



*Region 1 includes 54 wells tested for bacteria.
**Region 2 includes 195 wells tested for bacteria.
***Zillah statistic includes 1 contaminated well in Buena

Geohydrologic Analysis *(prepared by Newell Campbell, November 2002)*

Region 2, roughly centered on Sunnyside, encompasses about 200 square miles. There were 195 wells sampled in this area. While this region obviously contains many more wells, those sampled represent a variety of elevations, rock types and topographic expression. Results of the well tests show wide ranging nitrate concentrations throughout Region 2. While man-made activities may account for some (or all) of the elevated and high nitrate results, geologic conditions may be a factor of some wells. The geohydrologic study focused on three factors which may influence well contamination: surficial sediment type, well and aquifer characterization and surficial drainage considerations.

Surficial Sediments

Table 3 shows the wells grouped by the type of surficial material that the well was drilled into. One rationale is to see if fine-grained sediments (silt-sized) might hold abundant nitrates loosely where they might then be flushed downward to an unconfined aquifer or a recharge area for a confined aquifer. Flushing might occur from rapid snow melt, excess irrigation, flash flooding or other causes.

Table 3. Wells Grouped by Surficial Sediment Type				
Rock Type	Low-Normal NO_3	Elevated NO_3	High NO_3	Unknown
	(0.0-3.9 mg/l)	(4.0-9.9 mg/l)	($\geq$10.0 mg/l)	
A. Stream Alluvium (Qa)	29 wells	7 wells	3 wells	0 wells
Mostly unconsolidated gravel,				
sand and silt; on river and				
stream flood plains. Thickness				
to 30 m but usually thinner.				
B. Stream Terraces (Qt)	1	0	0	0
Older Yakima River alluvium				
(little in area). Thickness				
to 30 m.				
C. Alluvial Fans (Qaf, Qafo)	1	2	0	0
Mostly gravel and sand deposited				
by flash flooding; unconsolidated,				
in sheets (fans) and channels.				
Thickness 0-10 m.				
D. Loess (Ql)	14	12	10	9
Wind deposited silt and very				
fine sand; unconsolidated.				
Thickness 1-70 m; often found				
on top of Qfs.				
E. Slackwater Sediments (Qfs)	54	32	25	6
(Touchet beds) silt with fine				
sand lenses; unconsolidated;				
deposited by glacial flood				
waters in temporary lakes.				
Thickness 3-25 m.				
F. Ellensburg Formation (MC orTeu)	0	0	0	0
Poorly to moderately consolidated				
tuff, pumicite, and lahars; some				
lenses and layers of quartzite				
gravel often near top of unit.				
Thickness 0-300 m.				

Another possibility is that in coarse-grained high permeability deposits (sand and gravel), rapid downward movement of surface water -- or a rapid rise in water table-- might move nitrates into the unconfined aquifer. The unconfined aquifer in this area is almost always within coarse-gravel and sand deposits related to the Yakima River and almost never within the fine-grained sediments. Other coarse deposits are described in Figure 6.

Coarse deposits. Using the Toppenish 1:100,000 geologic map as a guide, only 38 wells drilled into high permeability sediments (stream alluvium stream terraces and alluvial fans) were sampled for nitrates. Only three of these wells had nitrate levels exceeding 10 mg/l (2 of the 3 actually cut thick surficial loess and silt indicated as Qa on the map). Most are on the Yakima River flood plain; not enough wells were sampled in terrace and fan gravels to be useful. Notably, only a small percentage of farmland in the Sunnyside area is on the flood plain. Large blocks of agricultural land on Yakima River terraces do occur upstream around Wapato and Toppenish; more well sampling there is needed.

Fine deposits. Low to medium permeability sediments in the study area include loess deposits, Touchet beds and the Ellensburg Formation. No well samples were obtained from wells drilled directly into surficial rocks of the Ellensburg Formation. Loess, composed almost entirely of windblown silt, often lies on top of Touchet beds in this area and seldom exceeds 3 m in thickness. Touchet beds, deposited in lakes caused by temporary damming of flood waters from Glacial Lake Missoula, are dominated by silt with occasional layers of fine sand. Touchet and loess deposits surround the majority of highly contaminated wells (Table 3). These sediments overlie either stream alluvium near the edge of the Yakima River flood plain or the Ellensburg Formation in higher elevations north and south of the river (Figure 6).

The unconfined aquifer in this area is nearly always within coarse stream gravels underneath fine-grained sediments, or in stream gravels at the top of the Ellensburg Formation (ancestral Columbia River gravels), or absent where silt rests on fine-grained, low permeability Ellensburg Formation tuffs. Studies at Hanford in unfarmed loess and silt show that evapotranspiration removes nearly all the vadose water so that little or no water is left to recharge an unconfined water table directly below.

Well and Aquifer Characterizations

Unconfined aquifer. Figure 6 shows the relationship between rock units and aquifers in the Sunnyside area. The unconfined aquifer lies almost entirely in coarse fluvial sand and gravel within the limits of the study area. Note that either slackwater sediment or loess cover stream deposits adjacent to the Yakima River flood plain. Here, downward percolating ground water could, under certain conditions, pass directly through silt deposits and into coarse sediments containing the unconfined aquifer.

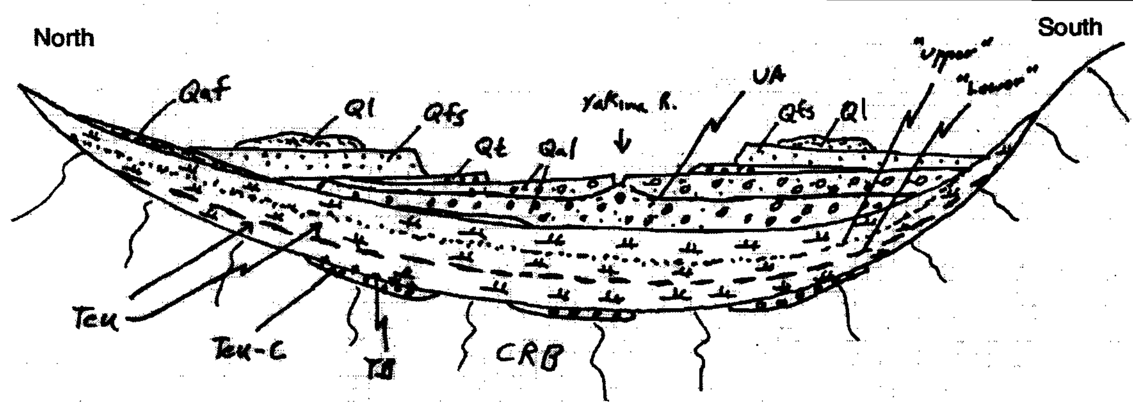


Figure 6. Part 1. Diagrammatic cross section through study area looking east (not to scale).

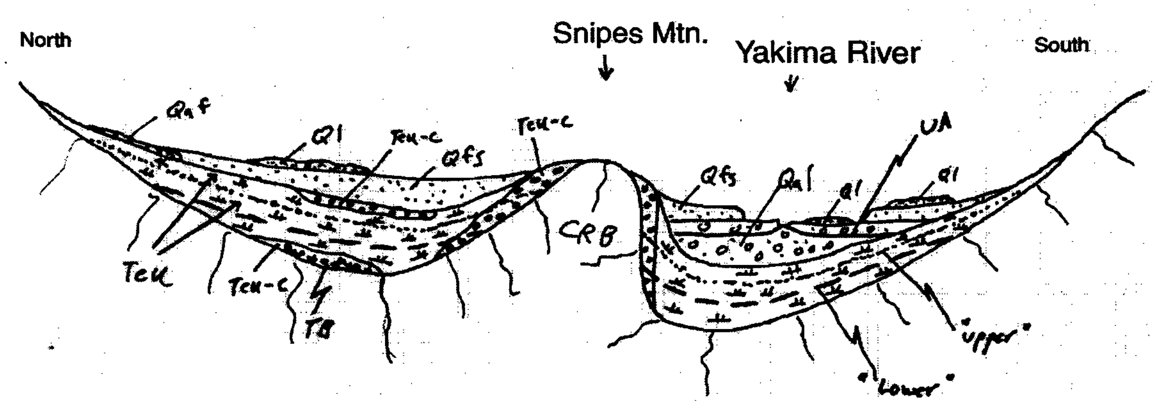


Figure 6. Part 2. Section through Snipes Mountain looking east.

Ql = loess	Qt = stream terraces	VA = unconfined aquifer
Qaf = alluvial fan gravels	Teu = fine-grained Ellensburg Form.	"upper" = upper aquifer in Teu
Qfs = Touchet beds	Teu-c = conglomerate	"lower" = lower aquifer in Teu
Qal = stream alluvium	CRB = Columbia River Basalt	TB = aquifer, top of basalt

Diagrams by N. Campbell, Nov. 2002

Elsewhere fine surficial sediments rest on the Ellensburg Formation. Much of the uppermost Ellensburg is composed of very low permeability tuff and tuffaceous clays. In some places stream activity on top of the tuff has created a thin gravel layer (1 or 2 meters thick) between the overlying Touchet silts and the tuffaceous beds. These are sometimes basalt-rich alluvial fan deposits, shed from flash flooding off of Rattlesnake Ridge and Horse Heaven Hills. In other places, notably around Snipes Mountain, layers of quartzite rich conglomerate related to the ancestral Columbia River lie atop the Ellensburg Formation. In the first case, silts over fan gravels, little or no water is found; here the unconfined aquifer is absent. Likewise where silt rests directly on tuff an unconfined aquifer is usually absent. In the second case, where continuous ancestral Columbia River channels — filled with rounded quartzite gravel — are cut into tuff, wells can produce high yields from a localized unconfined aquifer. One of these, at Barbee Orchards to the west of the study area, flowed at rates exceeding 3000 gpm.

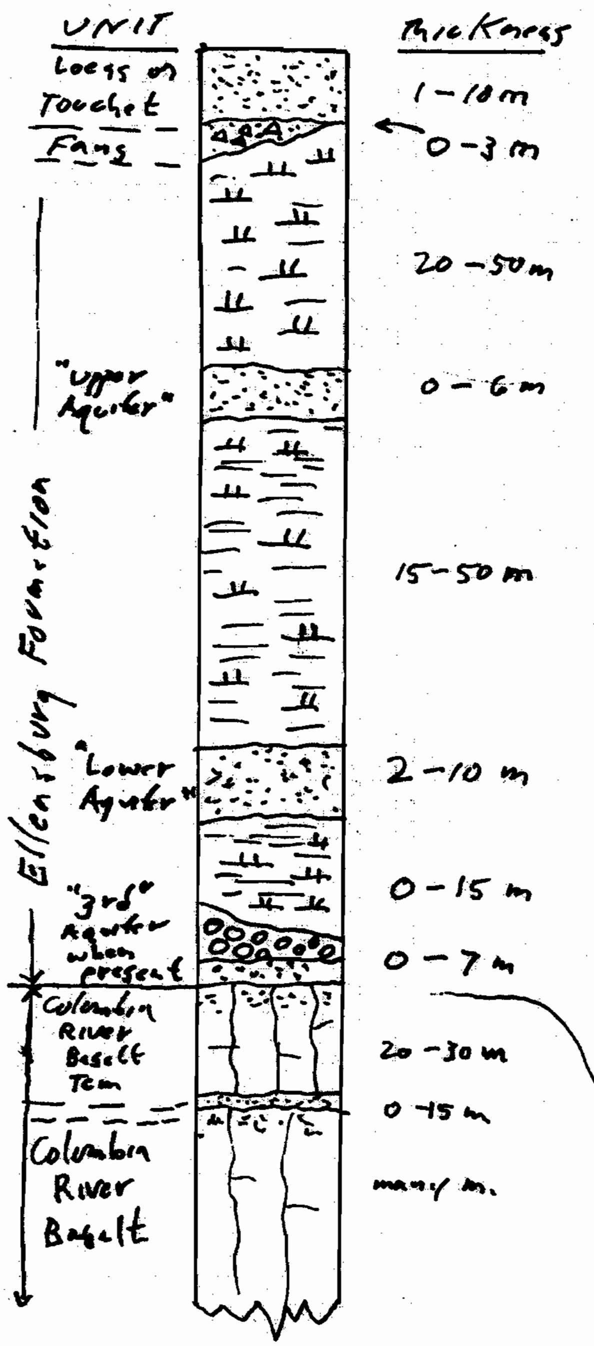
Figure 7 shows a diagrammatic profile of a typical well drilled where slackwater sediments or loess lie directly in Ellensburg Formation tuffs. An unconfined aquifer is usually absent unless Columbia River gravels exist. The lower valley's dry and hot climate means little surface water reaches the top of the Ellensburg Formation although excess irrigating may form a temporary aquifer. Where slackwater sediments (or loess) lie directly on fine-grained Ellensburg Formation, none of the well logs examined showed production from an unconfined aquifer. Normally this zone is sealed off in good well construction; the casing and grout extend a short distance into the tuff and clay part of the Ellensburg.

<u>Confined aquifers</u>. Only 23 of the 195 wells sampled in Region 2 have existing driller logs. Fortunately, there are well logs available from nearby wells and the stratigraphy and aquifer situation is well-known in Ellensburg rocks, thanks to an extensive study in nearby Toppenish Basin.

Both previous work and this study show that two main aquifers exist within the Ellensburg Formation, informally called "upper aquifer" and "lower aquifer". Both are confined within low permeability tuffs or lahars and consist of stream reworking of lahar tops. The aquifer consists mostly of dacite-rich sands and suggests two temporary halts to the massive influx of Cascadian volcanic detritus that make up this formation.

The "upper aquifer" is thinner, contains more clay and tuff and generally yields less water; it may also be breached by local tributary channels as it is sometimes contaminated from surface recharge. The "lower aquifer" is cleaner, thicker sand that is a major water source for local domestic wells. Confining layers are more clay-rich and less permeable than those up-section. Surface contamination is less likely than in the "upper aquifer". In some areas the lowermost confining

Figure 7. Typical well having surficial fine grained sediments (Touchet beds and loess) resting on Ellensburg Formation.



Description

Unconsolidated silt *1-10 m*

Gravel and sand from either side-stream alluvial fans or stream reworked Ellensburg Formation. Not usually an aquifer; rarely yields enough water for a well. *0-3 m*

Tuff, tuffaceous clay and lahars. Confined aquifer with low permeability. *20-50 m*

Stream-reworked sand, dacitic, aquifers with some domestic wells producing from only this horizon. *0-6 m*

Tuff, tuff altered to clay, lahars confining layers-low permeability. *15-50 m*

Sand and fine gravel, stream reworked, Aquifer, many domestic wells produce from this zone.
2-10 m

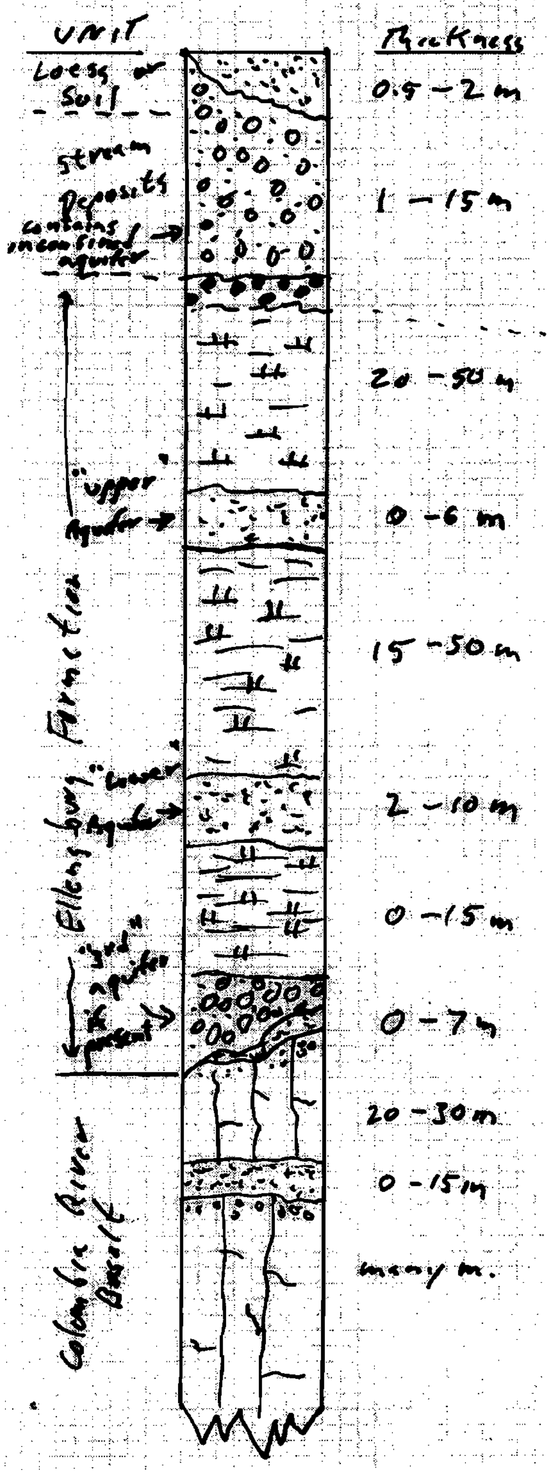
Tuff and clay, low permeability, sometimes absent, confining layer. *0-15 m*

Round quartzite, gravel and coarse sand from ancestral Columbia River channels; also some reworking of basalt flow top scattered patches and channels--scattered aquifer except where "lower" aquifer is part of unit. *0-7 m*

Columbia River Basalt (*20-30 m*)--upper flow here is Elephant Mountain Flow with Rattlesnake Ridge interbed (*0-15 m*); beneath multiple aquifers in CRB (*many meters*) but not part of this study

Diagrams and text by N. Campbell, Nov. 2002

Figure 8. Typical well drilled into coarse-grained sediments with unconfined aquifer (stream gravels).



Description

Mostly silt-sized material, sometime slackwater sediments (Touchet beds). *0.5-2 m*

Gravel and sand of mostly basalt origin; related to floodplain and terraces of the Yakima River; unconsolidated, contains unconfined aquifer; base can be quartzite related to ancestral Columbia River. *1-15 m*

Tuff and lahars, low permeability; confining layer except in old Columbia River channels.
20-50 m

Stream-reworked dacitic sand aquifer, some wells produce from this aquifer. *0-6 m*

Tuff and clay, some lahars, low permeability, confining layer.
15-50 m

Sand and fine gravel, stream reworking of Ellensburg lahars, many domestic wells produce from this zone.
2-10 m

Tuff and clay; sometimes absent; confining layer. *0-15 m*

Round quartzite rich gravel and coarse sand; in old Columbia River channels, very permeable, when present can have eroded flow top as part of aquifer. *0-7 m*

Columbia River Basalt flows and interbed's uppermost flow is Elephant Mountain basalt (*20-30 m*), and the upper interbed is Rattlesnake Ridge interbed (*0-15 m*); aquifers in Columbia River basalt are not discussed in this report.

Diagrams and text by N. Campbell, Nov. 2002 layer of clay and tuff is absent (Figure 7). Here the "lower aquifer" becomes part of a third discontinuous aquifer at the Columbia River Basalt-Ellensburg contact. Several wells near Snipes Mountain exhibit this kind of aquifer, caused sometimes by local reworking of the Elephant Mountain Basalt flow top, but usually by deposition of ancestral Columbia River gravels at the base of the Ellensburg section. Columbia River gravels are not continuous but in channels corresponding to the old river course. In the study area, they exist mostly in the vicinity of Snipes Mountain.

Beneath the Ellensburg Formation are multiple aquifers in the Columbia River Basalts. Flows with brecciated and rubbly flow tops, especially in Wanapum Basalt flows, produce water yields in hundreds to thousands of gpm. Most of these wells in the study area are used for irrigation and not domestic use. This report concentrates on shallow aquifers above the top of the Columbia River Basalt, here the Elephant Mountain flow.

Figure 8 shows a typical well drilled into coarse-grained surficial sediment either into flood plain gravels or similar gravels under slackwater sediment. On the floodplain proper, soil or loess often covers stream alluvium. The unconfined aquifer lies within the stream deposits, its position varying with the season, irrigation recharge and timed release of reservoir water from upstream.

If large amounts of water enter the flood plain (i.e., near end of irrigation season), the water table can rise to levels within the overlying soil. Stream flooding can cause water to cover agricultural and grazing lands on the active flood plain. In dry periods water levels may drop nearly to the top of the Ellensburg Formation. Aquifers beneath the stream alluvium are normally confined, can have recharge from the Yakima River or from sidestreams, and can be contaminated if drill holes are not cased and grouted into the top of the underlying Ellensburg Formation.

Drainage Considerations

Gullies. In and around the study area, numerous gullies and channels exist along both sides of the Yakima River. Although normally dry, they serve to channel excess water off the nearby ridges (Rattlesnake Hills and Horse Heaven Hills). Flash flooding from rapid snow melt or rainfall has incised some of the gullies deeply into surficial sediments, deposited alluvial fan gravels over parts of the Ellensburg Formation, exposed normally confined aquifers (i.e., "upper aquifer" and ancestral Columbia River channels), at times provided recharge to the Ellensburg Formation and underlying basalt, and provided a means to rapidly move nitrate-laden water both down stream and down to water basin zones. Some of the contaminated wells lie at or near the bottom of these small gullies; conversely others are far from any natural depression. All wells in gully bottoms do not exhibit increased nitrate levels.

Irrigation ditches. Several previous studies in the Yakima area have shown elevated water levels adjacent to ditches, especially unlined ones. Ditch seepage may provide enough excess water to the soil and underlying silt to carry nitrates down to the water table. Wells immediately down slope from ditches could potentially have elevated nitrate levels. In this study some wells near ditches displayed elevated nitrates while others did not.

In summary, while ditches and gullies have the potential to affect nitrate levels in wells, not every nearby well displayed high levels and not nearly enough wells were sampled (with driller's logs) to draw accurate conclusions. In the future, after a flash flood or large ditch break, wells downstream should immediately be tested for contamination.

Data Quality Assessment

Quality assurance data for trip, field and laboratory spikes, trip and field blanks, interlaboratory splits, duplicate samples and performance standards are included in Appendix 1. Summary data for duplicate samples and spike samples follow. Because microbiological analyses measure constantly changing living organisms, they are inherently variable which precludes normal QA procedures.

Wells retested for bacteria or for other reasons were also retested for pH, temperature, specific conductivity and DO and frequently for ferrous iron and nitrate (Table 1). The results of these replicates indicate the reproducibility of the field and laboratory tests over time and also reflect temporal changes in ground water. Usually the tests were highly reproducible if conducted within a few weeks of each other. Dissolved oxygen was the most variable and was probably influenced by air introduced by the action of the pump and the method of sample collection. Temperature variability may reflect the effect of ambient temperature on the pressurized holding tank and on the plumbing.

Specific conductivity and temperature determinations were replicated in the field until the last two readings agreed within ± 5% which was within the range of the DQO established for these parameters in the QAPP. The results of analyses of duplicate samples (Table 4, Appendix 1) for nitrate, ammonia and chloride are summarized in Table 5. Average RPD for these analytes were within their target range of the DQO.

Table 5. Summary of results of analyses of duplicate samples.

Analyte	# of duplicate pairs analyzed	Target* RPD**	Average RPD	Standard Deviation
Nitrate+nitrite-N	57	±20%	±3%	±4%
Ammonia-N	12	±30%	±14%	±7%
Chloride	13	±20%	±8%	±5%

* Target RPD were the maximum ranges established in the DQO.

** Relative Percent Difference

Percent recoveries for trip, field and laboratory spike samples (Table 6, Appendix 1) are summarized in Table 7. The most variable recoveries were obtained for low level nitrate spikes (0.10 mg/l) and for the ammonia spikes. Values that are outside the DQO ranges are flagged in bold in Table 6, Appendix 1.

Table 7. Summary of results of analyses of spiked samples.

Type of Spike	# of Spikes	Concentration of Spike	Average % Recovery	% Standard Deviation
Nitrate+nitrite-N				
Trip	30	10.0 mg/l	99	±5
Trip	4	0.10 mg/l	110	±14
Field	6	10.0 mg/l	99	±4
		Average=	103	±8
Ammonia-N				
Trip	31	0.82 mg/l	84	±11
Field	1	0.82 mg/l	79	-
Lab	32	0.41 mg/l	86	±14
		Average=	83	±13
Arsenic				
Trip	17	50.0 µg/l	103	±4
Trip	3	3.0 µg/l	103	
		Average=	103	±4
Chloride				
Trip	30	50 mg/l	95	±8
Field	6	50 mg/l	101	±6
Lab	27	25 mg/l	99	±11
		Average=	98	±8

The results of interlaboratory splits for chloride determinations showed that the overall RPD was satisfactory (20%) but unacceptably high variability (> 30%) was obtained for some sample pairs (Table 8, Appendix 1). These values are flagged in bold in the table. The chloride test kit was calibrated from 15-150 mg/l in 15 mg/l increments and interpolating between increments was inherently inaccurate. Also, it was easy to overshoot the endpoint giving low results if the titrant was added too rapidly.

Performance standards were submitted for analyses throughout the field testing phase of the project and the results are shown in Table 9, Appendix 1. All of the results were within the advisory range established by the manufacturer with the exception of chloride samples 342 (7) and 427 (7) as analyzed by VIRE. These samples are flagged in bold in the table.

Field and laboratory data for this project were compiled in an electronic database. To assure that the data were entered correctly, a comprehensive verification of field and laboratory data with the database was conducted upon the completion of field testing.

The Quality Assurance Officer inspected field and VIRE laboratory operations at his discretion and submitted reports of his findings to VIRE's board and to the project director. A summary of these reports is given in Appendix 1. The results showed satisfactory adherence to the quality assurance plan.

Demographics of Participants

Information obtained from the screening questionnaire and from interviews conducted during the field testing is summarized by location of the wells in Table 11 (Appendix 1). These data were gathered to determine eligibility for the study and to better serve the participants.

DISCUSSION

Ground water quality in Region 1 was generally good with respect to chemical contaminants. None of the wells in Region 1 exceeded the EPA's MCL of 10 mg/l for nitrate and only 9% had elevated nitrate levels (5.0-9.9 mg/l). Thirty-two wells in Region 1 were located in the Toppenish Creek Basin area which has been previously studied by the USGS and others. A comparison of the nitrate results for these wells with results obtained in the same area a decade ago[3] indicates that nitrate concentrations have changed little since then. It also appears that land use and population density have remained about the same. Nitrate concentrations for the 32 wells ranged from <0.07 mg/l to 5.88 mg/l with a median concentration of 1.88 mg/l and a mean concentration of 2.41 mg/l.

Significant impairment of ground water quality was evident in Region 2 where mean levels of nitrate, ammonia, chloride and specific conductivity were statistically higher than in Region 1 (Table 2). Nitrate results for Region 2 showed that 21% of the wells exceeded the MCL and 19% had elevated levels. These percentages are similar to those found in the 1998 Columbia Basin Ground Water Management Area (GWMA) survey of nitrate levels in wells in Adams, Franklin and Grant Counties east of Yakima County[10]. The GWMA survey found that 23% of the wells exceeded the MCL and cited this high incidence of contamination as one of the key factors in the formation of the organization. GWMA also identified 37% of the wells as having elevated nitrate levels defined as 3.0-9.9 mg/l. If the same "elevated" range definition was applied to this study, the percentage of wells with elevated nitrate levels in Region 2 would increase to 37%. A 1985 study conducted by the USGS[11] reported that a nitrate concentration of 3 mg/l or higher is likely attributable to anthropogenic sources (primarily fertilizers, manures and septic systems). A more recent national study in 1999 by the USGS[12] determined that naturally occurring nitrate is typically below 2.0 mg/l in wells less than 100 feet deep in undeveloped areas. A separate study in Washington State reported natural nitrate concentrations in ground water as low as 1 mg/l[13].

The identification of sources and of flow of contaminants was outside the scope of this study but, nationwide, excessive use of nitrogen fertilizers is the most common cause of nitrate contamination in ground water. Also, nitrate leaching under irrigation has become a major environmental concern[5]. Improperly constructed or maintained septic systems also contribute to nitrate pollution.

Arsenic was detected in 37 % of the wells tested in Region 1 and 75% of the wells in Region 2, but levels did not exceed current EPA standards of 50.0 μg/l. Under the new regulation effective in 2006, however, eight of the 74 wells tested (11%) will exceed the new limit of 10.0 μg/l.

Coliform bacteria, indicators of sanitary water quality, were detected in 64 wells. While these bacteria are not considered pathogens, their presence indicates that pathogenic organisms more difficult to test for could also be present and the well should be treated and/or repaired for safety health reasons. A high percentage of wells around Wapato and south of Buena and Toppenish (Region 1) tested positive for coliforms, but it was beyond the scope of this study to determine if the aquifer was contaminated. Other sources of bacterial contamination could be attributed to improperly constructed wells and leaks in the plumbing. In addition, many owners reported that their wells were old and that some were shallow.

While VIRE encouraged participants with contaminated wells to perform the decontamination procedure, many (64%) felt the process was too complicated for them to attempt. This includes a participant whose well also tested positive for E. coli. Of the 24 participants who performed the decontamination procedure, only 13 were successful. In addition, four participants made multiple unsuccessful attempts which suggest that the procedure was difficult for homeowners, or there were defects with the well or that the ground water was contaminated or any combination of these factors. Neither VIRE nor the WaDOH in Yakima County had sufficient funding to offer assistance with this procedure.

An attempt was made to relate nitrate contamination in Region 2 to the geohydrology of the area by examining well drillers' logs. Since logs were available for only 12% of the wells in Region 2, logs for nearby wells were also examined. (Drillers were not required to file well logs with the WaDOE until 1991, but logs for over 50% of the wells that owners reported drilled after 1991 could not be located.) Figures 9 and 10 show well contamination possibilities for wells drilled in stream alluvium and in slackwater sediments respectively. The results suggest that:

- The "upper aquifer" of the Ellensburg Formation is often contaminated, especially in the northern part of Region 2. This may be due to poor well construction, to well seals being too shallow, to water from unconfined aquifers traveling downward along the borehole, to contamination of recharge water or to a combination of the above.

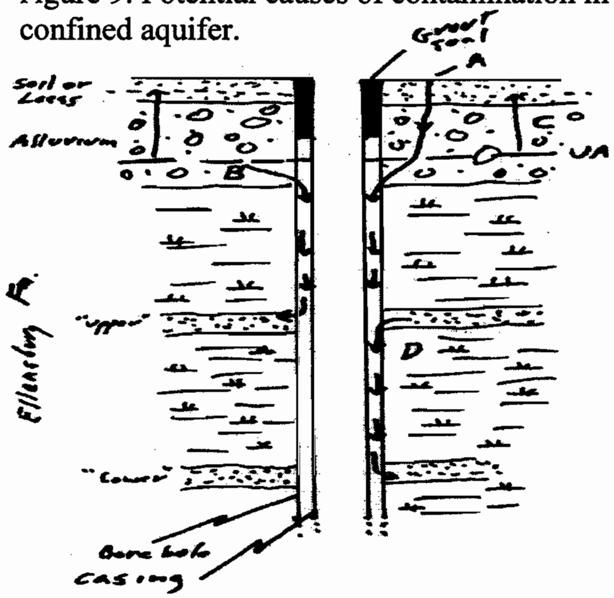
- Some wells appeared to have grout seals that are too shallow and don't extend down the borehole far enough to reach low permeability rocks, the clayey part of the Ellensburg Formation or basalt. Of these wells, about half have seals ending within slackwater sediments so that excess surface water can reach the borehole. In another group of wells drilled through gravels, the grout seal failed to adequately block off water from the unconfined aquifer.

- Some wells appeared to be producing water exclusively from the unconfined aquifer either under slackwater sediments, or from within the visible flood plain, or from alluvial fan gravels.

- Location of gullies and ditches may affect contamination but not enough well data were available for an adequate determination.

- About 20% of the wells showed no clear cut evidence of geohydrologic factors associated with the contamination.

Figure 9. Potential causes of contamination in wells drilled through stream alluvium and unconfined aquifer.



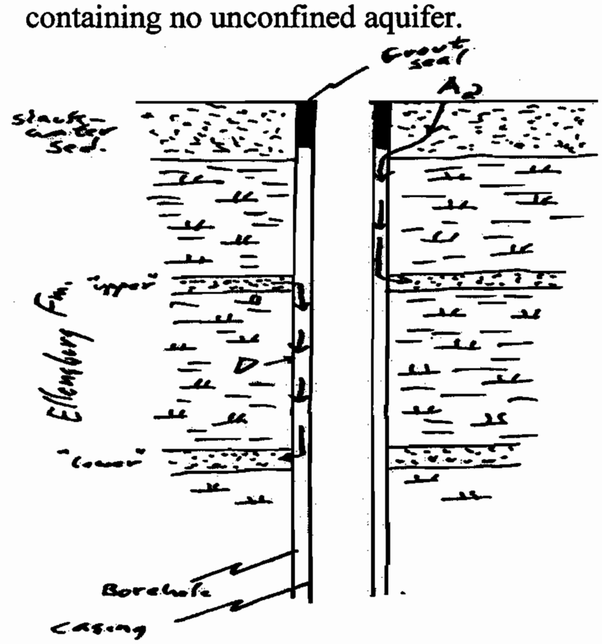
A. Surface water bypasses grout seal and enters well between well casing and borehole. Also unconfined aquifer bypasses are contaminated. Cause: shallow surface seal; heavy ppt.

B. Water from unconfined aquifer bypasses seal and enters borehole. Cause: shallow surface seal.

C. Water table rises into soil or loess cover flushing nitrates. Cause: flooding, heavy ppt., reservoir water release.

D. Upper aquifer--already contaminated and moves to lower aquifer via gap between casing and drill hole. Cause: depleted upper aquifer and/or dropping static water level.

Figure 10. Potential causes of contamination in wells drilled through slackwater sediments containing no unconfined aquifer.



A. Surface water bypasses grout seal and enters well between casing and borehole. Cause: shallow surface seal; heavy ppt.; flash flooding.

D. Upper aquifer already contaminated, water moves down to next aquifer between casing and well borehole. Cause: dropping static water level below upper aquifer.

Diagrams and by N. Campbell, Nov. 2002

RECOMMENDATIONS

- Findings from this study justify the creation of a Ground Water Management Area (GWMA) with the goal of reducing contaminant levels in ground water in the lower Yakima Valley. This organization should more extensively monitor and characterize ground water quality, identify areas of highest contamination for more in-depth studies, gather data on water quality trends, and determine the effects of agricultural practices and other human activities on ground water.

- There should be community outreach and education to make stakeholders aware of the value and the vulnerability of ground water. All information provided should be in bilingual form.

- Expand the sampling of wells for arsenic to better document the locations where wells will exceed the new drinking water standard of 10 µg/l effective in 2006.

- Provide bilingual information to all new well owners on how to inspect and maintain the integrity of their well head.

- Provide assistance to well owners in decontaminating wells with bacteria. This would afford an opportunity to measure static water levels and determine the directions of ground water flows to aide in identifying sources of contamination. These data would also provide a historical record of the level of the water table for managing this resource.

- Improve the quality and availability of well drillers' logs. The logs should identify well sites by GPS coordinates, have standardized terminology for strata, and be available in an electronic format for easy retrieval.

- New wells should be cased and grouted to exclude water from shallow, more contaminated aquifers.

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APPENDIX 1

Maps of field data, field and laboratory test results, quality assurance results, demographics and quality assurance summary reports.